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Peri-Urbanization and Rurbanization in Leiria City: the Importance of a Planning Framework

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Abstract: The objective of this study is to evaluate the spatial and temporal dynamics of land use in the city of Leiria, which is located in central Portugal, and its relation to the planning framework. The analysis is based on land-use change recognition in the period 1958–2011, calculation of the stability grade indicator, the losses and gains between classes, and the rate of artificialization. The results show an increase of the artificial areas, namely in continuous and discontinuous urban fabric, contrasting with a continuous decrease of the agricultural land-use classes, giving origin to peri-urbanization and rurbanization processes. We can also observe a large fragmentation of the landscape in the city of Leiria, representing rapid urban expansion that is fundamentally related to the increase of residential and industrial areas, and afterwards, tertiary growth. This study also demonstrated the relation of a land-use and planning framework that works as a driving force for land-use changes. This underlines the importance of strategic regional planning instruments in managing urban sprawl and the artificialization processes of medium-sized cities.

Keywords: medium-sized cities; land-use change; stability grade; land artificialization; planning framework

1. Introduction

The territories are characterized by their constant mutation in land use and occupation, contributing to a constant alteration of the landscape [1–4]. Several factors, including demographic, socio-economic, biophysical, cultural, or environmental factors, contribute to these soil change dynamics [5–8].

Small and medium-sized cities (SMESTO) have been characterized in recent decades, in general, by deep changes in terms of land use, as well as by a complex and heterogeneous occupation [9]. The European Territorial Strategy and the Territorial Agenda of the European Union [10,11] consider these cities to be the backbone of a territory. At the European level, the last decades have been marked by an increase in the complexity with regard to the processes of urban expansion and the different dynamics of land use. European cities are increasingly presenting polycentric urban development where different territorial expression dimensions intersect [12]. The growth of the small and medium-sized cities and their changes in land use and occupation are generally a good reflection of public planning policies, but also the conflict with other uses, as well as social and cultural values. In the last five decades, the Portuguese urban system has undergone profound changes that have

deeply modified the relations between urban and rural areas. The process of late industrialization, coupled with the progressive loss of profitability and importance of agriculture, the aging of the population, and the scarcity of employment opportunities in rural areas have led to an intense exodus of the population toward urban spaces, especially to coastal areas [13]. The progressive tertiarization of the economy triggered changes between urban and rural space, giving rise to the emergence of new centralities, where the medium-sized cities assume a more prominent place [13,14].

Also, the demographic progress of the last decade, which has been associated with the improvement of living conditions, the densification of transport networks, and social, economic, and professional issues, has led to a redefinition of the boundaries of urban spaces, with an emphasis on medium-sized cities [15,16]. Thus, there is an intense process of reorganization and alteration of the peripheral spaces of urban centers, giving rise to new processes of spatial use and occupation with dynamics and distinctive forms that give rise to different rhythms and intensities of land use and occupation [15]. These processes include peri-urbanization and rurbanization. In the present article, peri-urbanization is understood as consisting of the physical expansion of cities, but also of the dissemination of social, economic, and cultural patterns that are inherent to the urban phenomenon [17]. According to Vidal Rojas, [18] the peri-urban space is characterized by the discontinuity of built spaces, a strong dynamism in land uses, strong pendular mobility, and functional dependence in relation to the city. The rurbanization process is understood as a process of exodus of people from the city to the rural environment, which in most cases is related to the search for new and better conditions of life originated by the degradation of the quality of the urban spaces. This process is characterized by the emergence of large and discontinuous spaces in functional and spatial terms [19]. These types of processes are especially visible in small and medium-sized cities, where transformation dynamics can be followed over time, but also because there are no hotspots that determine formal or informal breakdowns in use and occupation.

The study of the evolution of land use and occupation over time can be carried out using different methods and documented sources [20,21], namely through photo-interpretation techniques [22,23]. The use of satellite images allows the integration of territorial characteristics from different time periods. Several authors have characterized the analysis and reconstitution of the transformation of the land use and land change, according to defined criteria of validation and through fieldwork validation [24–28]. The analysis and characterization of the land use and change trajectories in small and medium-sized cities is an important condition for the application and development of territorial planning and cohesion strategies [29–32].

These cities are characterized by large transformations in land use, resulting in complex interactions between social, economic, environmental, and biophysical factors [33–35]. In Portugal, several authors have studied this theme [4,7,16,36,37]. The constant and profound changes that the peri-urban areas are subject to stress the importance of analyzing the different driving forces that contribute to the different dynamics of change.

On the other hand, several authors have emphasized the relevance of analyzing the contribution of the planning framework in the definition of the dynamics of change [16,38–40]. The same authors defend the importance of incorporating the analysis of land cover and land change over time in the definition and application of territorial planning strategies.

The main objective of this work is to evaluate and compare the spatial and temporal trajectories of land use–land cover (LULC) between 1958–2011 for the city of Leiria. The research questions we want to answer are: what are the changes in the land use in the period 1958–2011 in the three moments of analysis (1958–1984; 1985–1994; 1995–2011)? What are the principal spatial and temporal trajectories related to land use in terms of aggregated land-use classes? What are the principal dynamics over time in the city center and its surroundings divided into four sections? What is the relation between land-use dynamics and a planning framework?

The city of Leiria, in the central region of Portugal, was chosen to carry out the present study This particular city, being a historical town with a medieval nucleus around the castle, was during

the 20th century structured as an administrative city surrounded by some industrial spaces and wide rural spaces (supporting agriculture and some forest exploitation). Its growth and urban expansion, coupled with its privileged location in the national context, have reinforced its role as a driving force in regional terms, and also explain the choice of this city as a case study. The last decades have shown an industrial growth and the prevalence of agricultural spaces supported by legal regimes of protection. On the other hand, Leiria presents some specificities regarding its process of growth and urban development that are important to analyze. The city grew as a pole of attraction; it was structured from new neighborhoods and commercial centralities, and new roadways were defined, but essentially, a specific plan of urban planning was established in the flooded marginal areas of the river. The intense population growth since the 1970s is particularly noteworthy, which included a growing tertiarization of its urban agglomeration and an industrial relocation to its peripheral areas.

The present study analyzes its temporal and spatial trajectories using different satellite imagery and aerial photographs collected over about five decades (1958–2011). Different indicators—namely, the rate of artificialization and the stability grade—support the evaluation of the spatial dynamics, namely the peri-urbanization and rurbanization processes. The division of the study area into sections allows us to meet this objective, since in this way the dispersion of the different processes along the territories analyzed becomes more perceptible, as already evidenced by Tagliagambe (2008) [41].

2. Materials and Methods

2.1. Study Area

The study area is a part of the municipality of Leiria (Figure 1). The municipality of Leiria is a district capital and center of the Nomenclature of Territorial Units for Statistics, level III (NUT III Oeste).

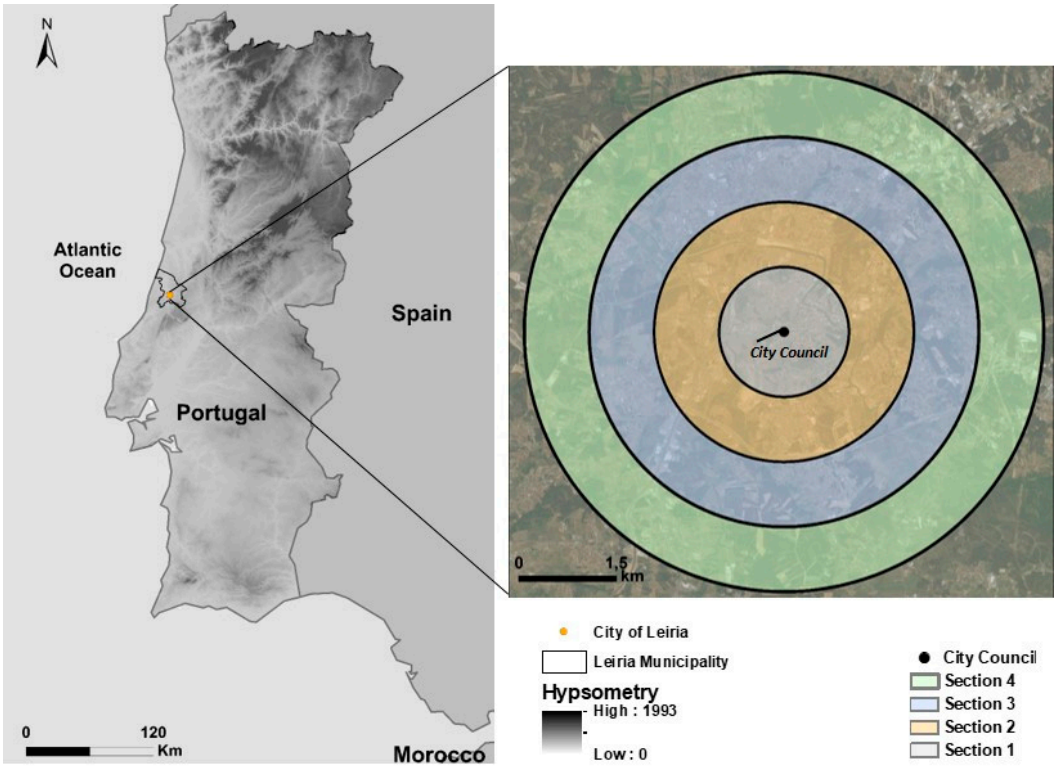

Figure 1. Location of the study area.

In terms of geology and morphology, the area of Leiria is marked by the sedimentary formations that are correspondent to alluvial and bottom valley deposits, fluvial terraces, sand and Pliocene sandstones, clays/silts, and the Jurassic marl. The formations of magmatic origin correspond to the domes and rock seams of predominantly magmatic dolerites [42,43] with altitudes ranging from approximately 7 m to 440 m. Regarding hydrology, the study area is crossed by the Lis River and its tributary the Lena, which manifests a torrential character, registering a great variability in quantitative annual flows. The city of Leira presents historical records of flooding that are associated with human and material losses. This impelled the development of flood mitigation structures and the implementation of spatial plans that have applied restrictions on land occupation over the last 25 years.

In terms of demography, the municipality of Leiria has 126,897 inhabitants [44], with a marked increase from 1970 onwards. We also observe a continuous growth in the number of family households since 1950.

For this study, the area under analysis is centered on the City Council, and has a circular shape with a 4-km radius and an area of 50.26 km^2 (Figure 1). This area includes the urban core and peri-urban areas, which have a total of 54,191 inhabitants and are covered by four civil parishes, namely: the Parish Union of Marrazes and Barosa; the Parish Union of Santa Eufémia and Boa Vista; the Parish Union of Leiria, Pousos Barreira, and Cortes; the Parish Union of Parceiros and Azoia.

2.2. Methodology

In the present study, the analysis of the LULC change was carried out by a set of four photographic mosaics between 1958–2011 (Table 1). The images were analyzed and processed using the ArcGIS 10.2 software (ESRI®, Redlands, CA, USA, 2013), according to the procedures presented by Tavares et al. (2012) [7]. For the adjustment of the different imagery scales, the following procedures were carried out: (1) single operator, (2) minimum unit of area, and (3) reverse analysis. The need for integration of images from different sources made a supervised analysis necessary, which was performed using fieldwork.

Table 1. General characteristics of data sources.

Date	Format	Type Image	Scale	Source
1958	Print	Black and white	1:26,000	IgeoE (Army Geographic Institute)
1985	Digital	Black and white	1:15,000	IGP (Portuguese Geographic Institute)
1995	Digital	False color	1:10,000	CNIG (National Center of Geographical Information)
2011	Digital	Color	1:10,000	IGP

Based on the categories defined by the European Environment Agency [45], a classification system was established and organized according to numerical codes [46]. In another phase, a geographic information system was developed where the classification of polygons of land use from each group of images was carried out, applying the previously defined classes [7,47]. The analysis was performed according to a minimum unit of analysis of one hectare, and supported on a 1:10,000 scale. In the present study, two different analyses were realized based on the classes present in Table 2. First, an analysis for the entire study area was conducted, where the classification of land use was made based on the 24 identified classes. Afterwards, another analysis for each of the sections identified in the study area was performed. For this evaluation, the classification of land use was based on the six aggregated classes.

Table 2. Classes applied in the classification system and the analysis.

Codes	Dessagregated Classes	Abbreviation	Aggregated Classes
111	Continuous urban fabric	**CUF**	Artificial areas
112	Discontinuous urban fabric	**DUF**	
121	Industrial or commercial units	**ICU**	
122	Road and rail networks	**RRN**	
131	Mineral extraction areas	**MEA**	
133	Construction sites	**CS**	
141	Green urban áreas	**GUA**	
142	Sport and leisure facilities	**SLF**	
211	Arable land	**AL**	Agricultural areas
221	Vineyards	**V**	
222	Fruit trees and olive groves	**FT/OL**	
231	Pastures	**P**	
241	Annual crops associated with permanent crops	**AC**	
242	Complex cultivation patterns	**CCP**	
243	Agriculture with natural spaces and agroforestry areas	**ANS/AF**	
311	Broad-leaved forest	**BF**	Forest areas
312	Coniferous forest	**CF**	
313	Mixed forest	**MF**	
322	Woods	**W**	Shrub vegetation areas
324	Degraded forest areas	**DFA**	
333	Sparsely vegetated areas	**SVA**	Sparsely vegetated areas
334	Burnt areas	**BA**	
511	Watercourses	**WC**	Inland waters
512	Water bodies	**WB**	

With the objective of understanding and evaluating where the major land-use changes occurred in the central urban core and the peripheral areas, the study area was divided into four sections as performed by other authors [48,49]. For this purpose, annular radii of 1 km, 2 km, 3 km, and 4 km were defined, centered on the City Council point, as shown in Figure 1. The objective of this analysis was to establish a model of land-use change dynamics according to the spatial planning framework that presents different scales and spatial enforcements.

For the identification and analysis of the dynamics of land use between 1958–2011 in the selected area belonging to Leiria city, four different indicators were used (Table 3), which had also been applied in previous studies [16,50,51]. For this purpose, a map was used to chart the comparison method, involving a set of successive images, with cross-references to define the transitions of land use and land cover. The maps that resulted from the analysis were used to produce matrices for all 24 identified classes and for the six aggregated classes for the periods 1958–1985; 1985–1995; 1995–2011; and 1958–2011.

Equation (1) was used, as in other studies [7,50,52,53], to express the land-use transition dynamics between two periods. For the evaluation of the conversion areas relative to gains and losses for a given year, themselves relative to the year under comparison, calculations were made in relation to the total land-use type using Equation (2). Equation (3) presents the stability grade (SG) that expresses the total area that has not experienced a possible transition to a different category of LULC. Finally, Equation (4) presents the annual rate of artificialization (AS) that expresses the increase in urbanization that is specifically related to peri-urban processes.

For the analysis between the land-use change and planning processes in the city of Leiria, a set of planning instruments were analyzed relative to a period between 1947–2012 (Table 4). The process of analysis of the planning documents consisted of content analysis supported by different methods [53,54].

Table 3. Equations used to evaluate the dynamics in land use and occupation.

Indicatour	Equation		Description
Change in land cover	$CHi = (pi. - p.i)/p.i$	(1)	***CHi***—change for the period in column *i* ***pi.***—the column total for the grid cells ***p.i***—row total for the grid cells in the same category *i*
Conversion areas matching to gains and losses for a given year	$P(i).j = (p_{j,i} - p_{i,j})/(p_j - p_i) \times 100\ i \neq j$	(2)	$P_{(i),j}$—percentage by type *j* in the total conversion of category row *i* $p_{j,i}$ and $p_{i,j}$—individual entry in the change matrix
Stability grade	$SG = [(C_{ix}A_{2\ldots4} - C_{ix}A_1)/TA] \times 100$	(3)	**SG**—global stability of the group of classes of land use in the year *A1* for the year $A_{2\ldots4}$ $C_{ix}A_{2\ldots4}$—sum of the areas of the different group of classes (*ix*) at the subsequent time point $C_{ix}A_1$—sum of the areas of the different group of classes (*ix*) at time point 1 ***TA***—total area studied (km^2)
Annual rate of artificialization of surfaces	$AS = [UA_{n+i} - UA_i/nTA_{n+i}] \times 100\%$	(4)	**AS**—speed of urbanization in the study area TA_{n+i}—total study area to be calculated at the time point $i + n$ UA_{n+i} **and** UA_i—surfaces with urban fabric and infrastructures in the target unit at time $i + n$ and *i* ***n***—number of years in each period

In the present study, changes in land use will be related to the approval and application of different planning frameworks. A survey was carried out regarding the different plans approved and applied between 1958–2011, with different enforcement areas (city, local, municipal, and special plans). The analysis between land-use changes and the planning framework is carried out based on the evaluation of the evolution of the rate of the artificialization and stability grade, with the entry into force of the different spatial planning framework. This analysis enables understanding the different dynamics of land-use change in the analyzed area, as well as understanding the influence of the different analyzed plans.

Table 4. Planning framework for the city of Leiria.

Date of Approval	Planning Framework Description	Enforcement Area
1947	Urbanization General Plan with proposals for historical area intervention, new residential expansion areas, and industrial areas	City
1965	Hidroprojecto City Master Plan with regulation of the residential areas, conditioning urban sprawl and defining the urban contour	City
1983	General City Plan—M3P, projecting new residential neighborhoods and encircling road consolidation	City
1992	One layout plan with local occupation proposals and infrastructures implementation rules.	Local
1993	RAN—Agricultural Protection Regime, for soils with agricultural potential.	Special plans
1995	Municipal Master Plan, establishing a development strategy and a spatial plan model, and defining urban policies and regulatory guidelines for the municipal territory.	Municipal
1996	REN—Ecologic Regime Protection, for sensitive ecological areas and areas susceptible to natural risk	Special plans
2000	POLIS Program—Urban Infrastructures Planning and Urban Rehabilitation, providing urban interventions in disqualified areas and developing green urban areas and leisure facilities.	Local
2002 to 2012	Five layout plans with local occupation proposals and infrastructure implementation rules.	Local

3. Results

3.1. Analysis of the Disaggregated Land-Use Classes

During the analysis, a total of 24 land-use classes were identified in the circular area defined for the city of Leiria. Figure 2 allows one to conclude, in a generic way, the existence of systematic changes in land use manifested in the increase of urban areas, namely on the discontinuous urban

fabric and industrial or commercial units. We also observe a considerable decrease in agricultural areas, namely fruit trees and olive groves, pastures, and annual crops associated with permanent crops (Figure 2). In the opposite direction, an increase was identified in areas of complex cultivation patterns. We also identify transformations in forest areas, where the increase in mixed forest and degraded forest areas stand out, along with a decrease in coniferous forest.

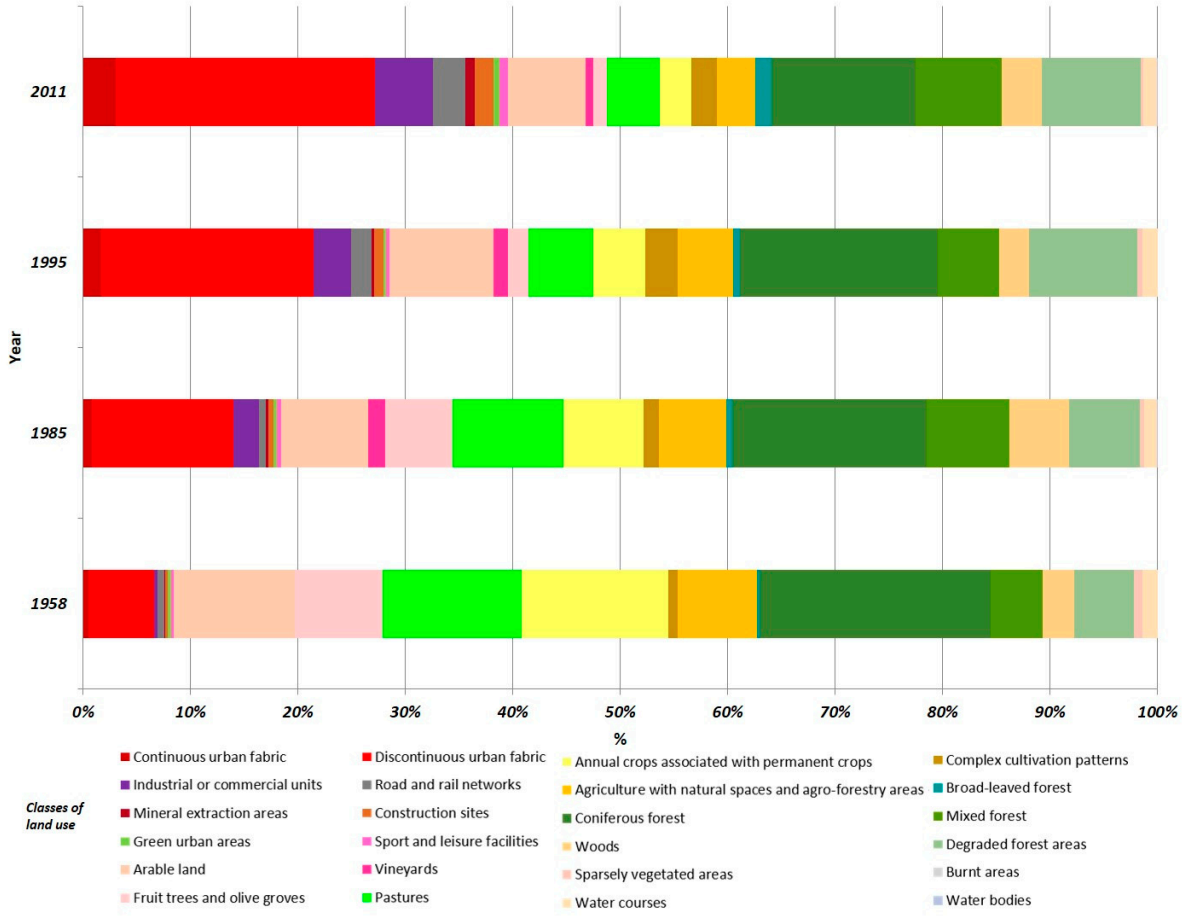

Figure 2. Representations of classes of land use from 1958 to 2011 for the study area.

Figure 3 presents the cartographic output for the 24 disaggregated land use classes, where we can see a set of differentiated changes in the different sectors of the area with a variety of trajectories between 1958–2011. We also observe the growth of pattern complexity over time, which is connected with peri-urbanization and rurbanization processes. This is verified by the general increase of the artificial areas from the center of the study area to the periphery, and a decrease in the agricultural areas and transformations in the forest areas. The analysis also reveals a great fragmentation of the landscape of the study area as a result of fast urban growth. This is attested to by the increase of more than 50% in the number of polygons between 1958–2011 (Table 5), highlighting the classes belonging to artificial areas, forest areas, and shrub vegetation areas.

During the analysis, conversion matrices were created for the following periods: 1958–1985, 1985–1995, 1995–2011, and the global period of 1958–2011, allowing one to discover and evaluate the dynamics of land use and calculate the stability grade (SG). The analysis of Table 6 allows us to conclude that the SG presents a continuous increase between 1958–2011. We also observe that the SG for the period 1958–2011 is low (27.32%), indicating a strong land-use change dynamic for the study area that is linked to peri-urbanization and rurbanization processes. The SG also highlights the emergence of new residential neighborhoods, the creation of green and leisure zones related to urban

requalification projects, the creation and development of new commercial and industrial zones, as well as the increasing density of the road network. We observe that we are in the presence of a continuous, cumulative expansion, with incidence in distinct spatial areas, from the center to the periphery.

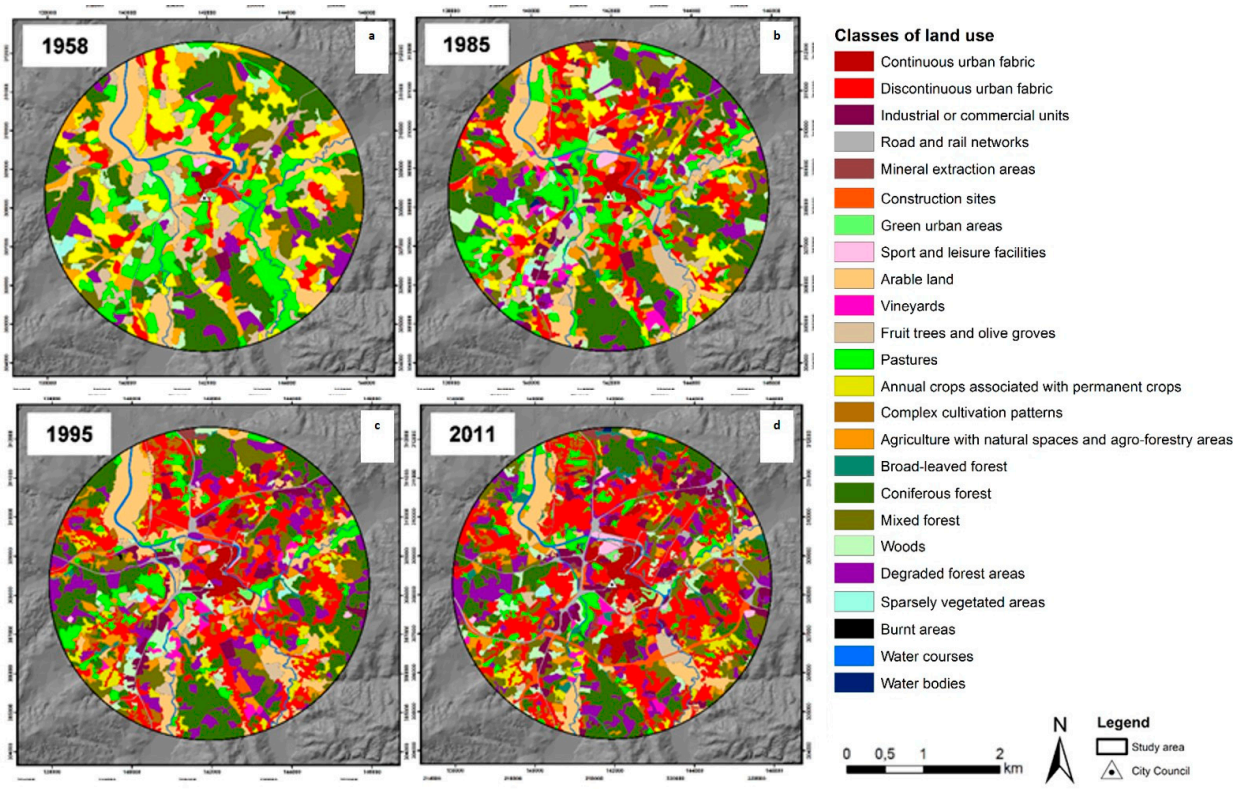

Figure 3. Land use and occupation for the study area based on image classifications by year.

Table 5. Number of patches and areas for each class of land use, according to the Corine Land Cover classification.

Classes Applied	Patch (nº)				Area (ha)			
	Year				Year			
	1958	1985	1995	2011	1958	1985	1995	2011
Continuous urban fabric	1	1	3	6	26.59	40.32	83.84	151.63
Discontinuous urban fabric	27	63	68	78	304.72	664.19	994.72	1213.80
Industrial or commercial units	2	25	26	52	17.65	118.38	176.63	269.89
Road and rail networks	3	2	1	1	30.59	33.69	92.68	152.62
Mineral extraction areas	1	2	1	10	4.18	11.83	13.48	45.58
Construction sites	2	6	9	11	13.26	24.06	45.18	86.43
Green urban areas	2	2	2	7	14.26	13.36	10.22	26.72
Sport and leisure facilities	3	4	7	12	11.58	21.96	17.16	43.06
Arable land	26	26	44	38	569.42	405.32	487.51	362.47
Vineyards		16	13	10		78.79	65.04	36.36
Fruit trees and olive groves	45	54	18	8	407.65	316.83	98.56	63.58
Pastures	43	60	45	61	650.56	519.92	301.66	247.08
Annual crops associated with permanent crops	43	48	47	34	688.14	373.77	244.16	146.09
Complex cultivation patterns	9	27	50	56	44.36	70.29	152.51	120.94
Agriculture with natural spaces and agroforestry areas	43	67	59	52	370.14	315.90	258.64	177.77
Broad-leaved forest	2	7	8	23	10.97	27.42	30.95	78.10
Coniferous forest	35	37	62	68	1082.56	910.72	924.01	671.63
Mixed forest	19	53	31	64	242.14	388.16	289.79	404.13
Woods	19	48	25	52	148.73	277.39	138.69	187.65
Degraded forest areas	30	65	77	95	280.11	332.04	505.64	463.98
Sparsely vegetated areas	3	5	4	1	37.59	21.64	23.79	9.85
Burnt areas			1				1.32	
Watercourses	3	4	8	13	71.18	57.13	70.20	64.53
Water bodies		1		1		3.27		2.49
Total	**361**	**623**	**609**	**753**	**5026.38**	**5026.38**	**5026.38**	**5026.38**

Table 6. Stability grade using land-use disaggregated classes.

Stability Grade (%)	1958–1985	1985–1995	1995–2011	1958–2011
	Land-Use Disaggregated Classes	Land-Use Disaggregated Classes	Land-Use Disaggregated Classes	Land-Use Disaggregated Classes
Leiria	37.96	43.16	48.47	27.32

As previously mentioned, during the period under analysis, there is a growing fragmentation of the landscape and a consequent increase in the complexity of the landscape. However, it is important to analyze and understand the evolution and the different transformations and transfers between the different classes of land use. Table 7 shows the individual evolution between 1958–2011 of the 24 classes identified in the study area. From the outset, it is possible to observe that all of the classes related to artificial areas show gains in area. The discontinuous urban fabric class stands out as the one that, among the 24 classes, presents the highest percentage of area increase (18%). Regarding the classes related to agricultural areas, one can observe that the general trend is a decrease between 1958–2011. However, standing out in the opposite direction are the vineyards and the complex cultivation patterns that, despite some oscillations, show growth. It is also worth mentioning the decrease in annual crops, which is associated with permanent crops as the class with the greatest area loss between 1958–2011 (10.8%). Regarding forest areas, we observed a continuous and marked decrease, with an emphasis on coniferous forest, in contrast to the global growth of broad-leaved forest and mixed forest areas. In terms of the classes belonging to shrub vegetation, there is an increase with a clear emphasis on the degraded forest areas, which almost doubled their area. In regard to the sparsely vegetated areas, there is a tendency of loss over the period under analysis and maintenance for the burnt areas. Finally, in terms of inland area classes, there is a decrease in the watercourse areas, which is related to the application of protection and mitigation measures for the flood risk in the Lis River and its tributary, the Lena.

Table 7. Evolution of the land-use classes over the time.

Land Use Classes	Evolution of Land Use Classes over the Time				
Legend	*Decrease*		*Maintenance*		*Increase*
	1958	1985	1995	2011	1958–2011
Continuous urban fabric					
Discontinuous urban fabric					
Industrial or commercial units					
Road and rail networks					
Mineral extraction areas					
Construction sites					
Green urban areas					
Sport and leisure facilities					
Arable land					
Vineyards					
Fruit trees and olive groves					
Pastures					
Annual crops associated with permanent crops					
Complex cultivation patterns					
Agriculture with natural spaces and agroforestry areas					
Broad-leaved forest					
Coniferous forest					
Mixed forest					
Woods					
Degraded forest areas					
Sparsely vegetated areas					
Burnt areas					
Watercourses					
Water bodies					

With the objective of analyzing the percentage of conversions in relation to the total land cover type, an internal transition matrix was created for the period between 1958–2011. Table 8 shows the gains and losses for the 24 classes of land use and occupation. This matrix was obtained by

cross-referencing the maps of 1958 and 2011, and the results show the units of change for each land-use class and indicate the rate of change in %. In general terms, the results show a considerable soil artificialization that was supported, in most cases, by annual crops associated with permanent crops, pastures, coniferous forest, arable land, mixed forest, fruit trees and olive groves, agriculture with natural spaces and agroforestry, and woods. In agricultural areas, the highlight goes to the increase in complex cultivation patterns (172.73%), and the decrease in the other classes. The gains in the complex cultivation patterns classes are mainly supported by gains in classes belonging to agricultural areas, highlighting the annual crops associated with permanent crops, fruit trees and olive groves, arable land, and agriculture with natural spaces and agroforestry areas. Gains in broad-leaved, mixed forest, and woods should also be noted, since the gains come essentially from the following classes: arable land, coniferous forest, pastures, fruit trees and olive groves, and agriculture with natural spaces and agroforestry. The results also reflect the decrease in coniferous forest, degraded forest areas, and sparsely vegetated areas.

Table 8. Transformations in land use and occupation in the city of Leiria (%).

Land Cover	Loss or Gain in 2011	Type (1)	%	Type (2)	%	Type (3)	%	Type (4)	%	Type (5)	%	Type (6)	%	Type (7)	%	Type (8)	%	Type (9)	%
CUF	484.62	DUF	22.32	P	15.87	CF	13.46	FT/OL	11.95	AL	8.82	CCP	8.03	ANS/AF	5.90	AC	5.54	GUA	2.60
DUF	295.44	AC	28.94	CF	15.07	P	13.79	FT/OL	14.47	ANS/AF	9.80	MF	7.69	DFA	5.48	AL	4.49	W	2.35
ICU	1400.00	P	23.51	CF	22.68	AC	13.06	AL	9.10	FT/OL	7.80	ANS/AF	6.44	W	4.60	MF	4.19	CS	2.69
RRN	406.67	CF	19.82	P	19.29	AL	12.72	AC	11.98	FT/OL	9.76	W	8.38	MF	5.39	DFA	4.91	ANS/AF	4.93
MEA		W	34.95	CF	28.93	FT/OL	13.84	AL	12.54	P	10.70	ANS/AF	4.11	DUF	2.81	AC	1.16	DFA	0.75
CS	600.00	CF	39.84	P	17.59	AC	11.60	ANS/AF	9.93	W	9.33	FT/OL	8.49	MF	6.52	SVA	4.44	AL	4.37
GUA	115.38	P	50.79	FT/OL	31.19	AC	20.17	SLF	13.31	WC	3.67	DUF	6.56	CUF	−26.07	AL	2.37	DFA	1.10
SLF	281.82	AL	42.04	CF	40.00	P	13.49	DUF	3.95	BF	4.08	DFA	0.50	WC	0.82	SVA	0.38	AC	0.01
AL	−36.03	P	2.49	AC	−8.39	ANS/AF	7.47	FT/OL	−0.43	WC	1.12	CF	0.20	W	4.68	DUF	19.75	RRN	7.50
V		P	47.74	DFA	20.89	AC	10.54	ANS/AF	7.02	SVA	6.64	FT/OL	4.01	MF	1.21	WC	1.16	CF	0.67
FT/OL	−84.56	P	−2.62	AL	0.26	ANS/AF	0.69	CF	7.20	WC	−0.16	AC	5.41	DUF	38.23	SVA	0.00		
P	−62.15	AL	−1.28	AC	−7.02	FT/OL	−1.39	ANS/AF	1.09	DUF	31.07	CF	3.82	CCP	1.15	WC	0.88	SVA	−0.57
AC	−78.60	P	5.23	FT/OL	−3.43	AL	3.20	ANS/AF	4.09	CF	3.30	DFA	4.70	MF	8.18	DUF	48.54	WC	0.05
CCP	172.73	AC	49.19	FT/OL	28.57	AL	17.28	ANS/AF	16.09	DUF	−11.92	P	6.07	MF	5.07	CF	6.07	WC	1.13
ANS/AF	−52.03	AC	−11.51	AL	−8.04	P	−2.30	CF	4.91	MF	25.23	FT/OL	−1.24	DFA	14.95	W	2.20	DUF	46.31
BF	566.67	AL	42.93	CF	18.80	P	14.41	ANS/AF	9.56	AC	7.57	MF	−0.75	W	5.63	FT/OL	4.91	DFA	1.42
CF	−37.95	DFA	27.97	FT/OL	−6.03	AC	−4.36	P	−3.75	ANS/AF	−2.30	W	−1.24	MF	16.07	AL	−0.10	SVA	−0.84
MF	66.67	CF	40.76	ANS/AF	29.97	AC	27.37	FT/OL	25.74	P	19.58	DFA	−1.89	AL	10.02	W	5.25	BF	0.31
W	25.33	P	181.54	AC	73.00	CF	−13.07	FT/OL	35.63	AL	24.87	ANS/AF	10.87	SVA	16.93	DFA	−37.38	MF	−21.85
DFA	65.84	CF	62.51	ANS/AF	15.64	FT/OL	16.82	AC	13.87	MF	1.66	AL	11.73	W	7.91	P	7.83	DUF	−27.11
SVA	−73.68	AC	−2.53	CF	12.40	MF	7.21	FT/OL	−0.01										
WC	−9.86	AL	−34.71	P	−53.39	AC	−4.34	DUF	52.85	ANS/AF	−5.18	BF	−1.09	GUA	6.87	RRN	30.30	FT/OL	8.38
WB		P	100.00																

Land Cover	Loss or gain in 2011	Type (10)	%	Type (11)	%	Type (12)	%	Type (13)	%	Type (14)	%	Type (15)	%	Type (16)	%	Type (17)	%	Type (18)	%
CUF	484.62	DFA	2.61	WC	1.40	ICU	0.65	RRN	0.31	MF	0.51	W	0.03						
DUF	295.44	CCP	1.00	RRN	0.17	WC	0.39	BF	0.18	CUF	−3.07	CS	0.14	SVA	0.11	SLF	−0.14		
ICU	1400.00	DUF	2.32	DFA	2.12	RRN	0.93	MEA	0.77	WC	0.11	CUF	−0.32	CCP	0.02				
RRN	406.67	DUF	−1.24	CS	1.55	CCP	1.36	WC	1.65	SVA	1.00	BF	0.42	CUF	−0.32	GUA	0.33	SLF	0.00
MEA		WC	0.21																
CS	600.00	DFA	1.93	RRN	−2.59	WC	0.12												
GUA	115.38	ICU	0.11																
SLF	281.82																		
AL	−36.03	MF	7.85	GUA	0.14	CCP	6.39												
V		AL	0.11																
FT/OL	−84.56																		
P	−62.15	DFA	3.57	MF	7.86	RRN	5.83	CS	3.19	W	17.51	CUF	4.92						
AC	−78.60	CCP	6.95																
CCP	172.73	RRN	−2.17	CS	0.56	CUF	−13.11	DFA	−2.08	W	0.00								
ANS/AF	−52.03	SVA	−1.83	CCP	6.40	WC	0.18	RRN	3.13	CS	3.78								
BF	566.67	WC	−0.11	CCP	0.76	DUF	−2.44												
CF	−37.95	ICU	13.92	DUF	33.33	RRN	5.89	CCP	1.13	CS	7.09	WC	0.00						
MF	66.67	MEA	1.36	SVA	1.24	DUF	−43.16	CCP	−2.39	RRN	−4.06	CS	−2.94	WC	0.04				
W	25.33	DUF	−54.78	WC	4.84	CS	−17.54	RRN	−26.27	BF	−9.71	MEA	−37.18	CCP	0.00				
DFA	65.84	SVA	1.43	CCP	0.87	CS	−0.77	WC	−1.03	BF	−0.52	RRN	−3.26	SLF	−0.09	ICU	−2.90		
SVA	−73.68																		
WC	−9.86																		
WB		P	100.00																

3.2. Analysis of Aggregated Land-Use Classes

In another phase of the study, the 24 classes were aggregated into six different classes, expressing the land-use change dynamics in the study area. For this analysis, an internal transition matrix was also created for the period between 1958–2011 (Table 9). The results show gains in artificial areas (371.97) and shrub vegetation areas (51.74), and a decrease in the rest of the aggregated classes with a focus on agricultural areas (−57.76) and sparsely vegetated areas (−73.68). It is also evidenced that the large gains in artificial areas come mainly from agricultural and forest areas. It is also worth noting the dynamics of transformations in land use related with innumerable interventions in the river margins in the flooded areas.

Table 9. Transformations in land use and occupation in the study area (%).

Leiria											
Land Cover	**Loss or Gain in 2011**	**Type 1**	**%**	**Type 2**	**%**	**Type 3**	**%**	**Type 4**	**%**	**Type 5**	**%**
Artificial areas	371.97	Agricultural areas	66.35	Forest areas	24.52	Shrub vegetation areas	8.30	Inland waters	0.51	Sparsely vegetated areas	0.32
Agricultural areas	−57.76	Forest areas	18.79	Shrub vegetation areas	15.30	Artificial areas	65.97	Inland waters	0.38	Sparsely vegetated areas	−0.44
Forest areas	−13.53	Agricultural areas	−163.54	Shrub vegetation areas	54.70	Artificial areas	212.15	Sparsely vegetated areas	−3.31	Inland waters	0.00
Shrub vegetation areas	51.74	Agricultural areas	108.07	Forest areas	44.39	Sparsely vegetated areas	4.48	Artificial areas	−58.30	Inland waters	1.35
Sparsely vegetated areas	−73.68	Agricultural areas	25.00								
Inland waters	−7.04	Agricultural areas	−120.00	Forest areas	0.01	Artificial areas	160.00				

The dynamics of land use, throughout the period under analysis, do not present a uniform behavior over time or along the different sections analyzed. With the objective of analyzing the evolution of land use over the four sections defined in the study area, a different output for each section was created that identifies the percentage of each of the six aggregated classes between 1958–2011. We can see that the artificial areas are the only class that presents a constant growth over time in the four defined sections (Figures 4–7) with emphasis on growth in Section 1 (Figure 4) and Section 2 (Figure 5) with a growth of 37.8% and 45.1% between 1958–2011, respectively. It should also be noted that in 1958, the agricultural areas had the highest percentage of area occupied in the four sections analyzed. However, this importance has dissipated over time, and it has also shifted from the center to the outer sections. It is also noted that the artificialization process of the agricultural areas has decreased from the center to the periphery.

It is possible to identify in Section 1, which coincides with the central urban center, the poles dynamizing the landscape of the study area. Although it began as an historical urban area with a strong presence of areas linked to agriculture in 1958, it became a mainly urban section in which the agricultural areas decreased by 39.9%.

Section 2 (Figure 5) moves from a predominantly agricultural area (65.6%) in 1958 to a predominantly artificial area (54.8%) in 2011. This evolution is related to processes of urban expansion, soil transformation dynamics related to economic forces, and processes of peri-urbanization and rurbanization; these processes are also identified in Sections 3 and 4. It should also be noted that in Section 2, there is an increase in shrub vegetation areas and forest areas between 1958–2011, which is often associated with the abandonment of agricultural land and the loss of the importance of the primary sector over time as an economic activity and in relation to employment.

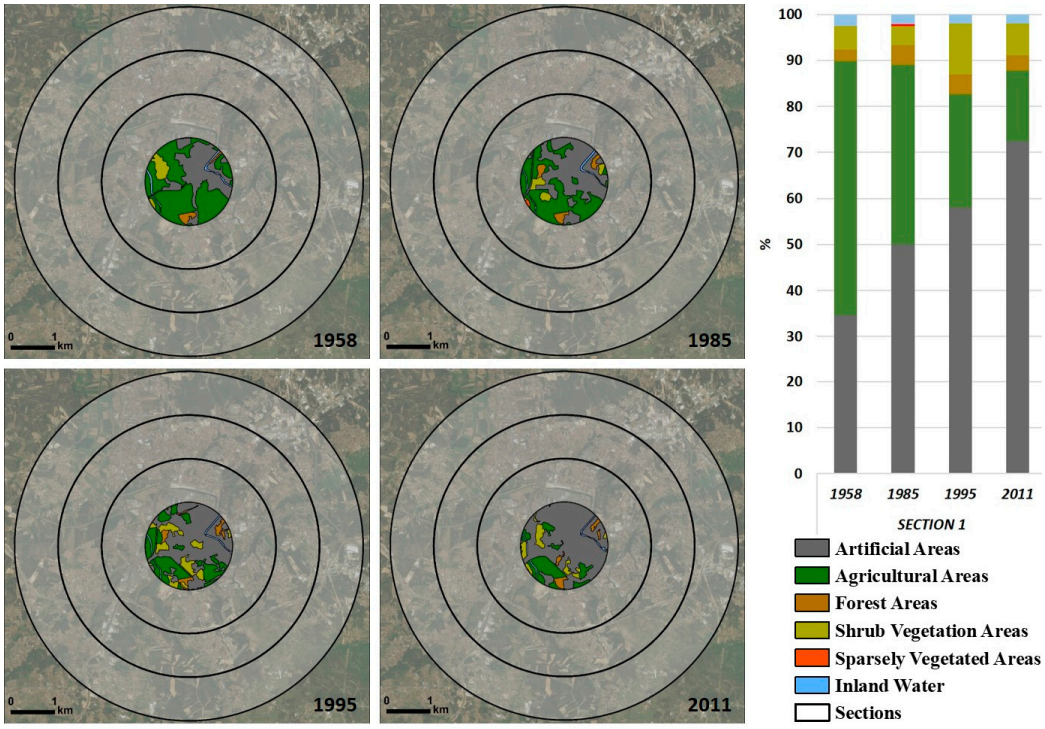

Figure 4. Evolution of aggregated land-use classes in Section 1 for the city of Leiria.

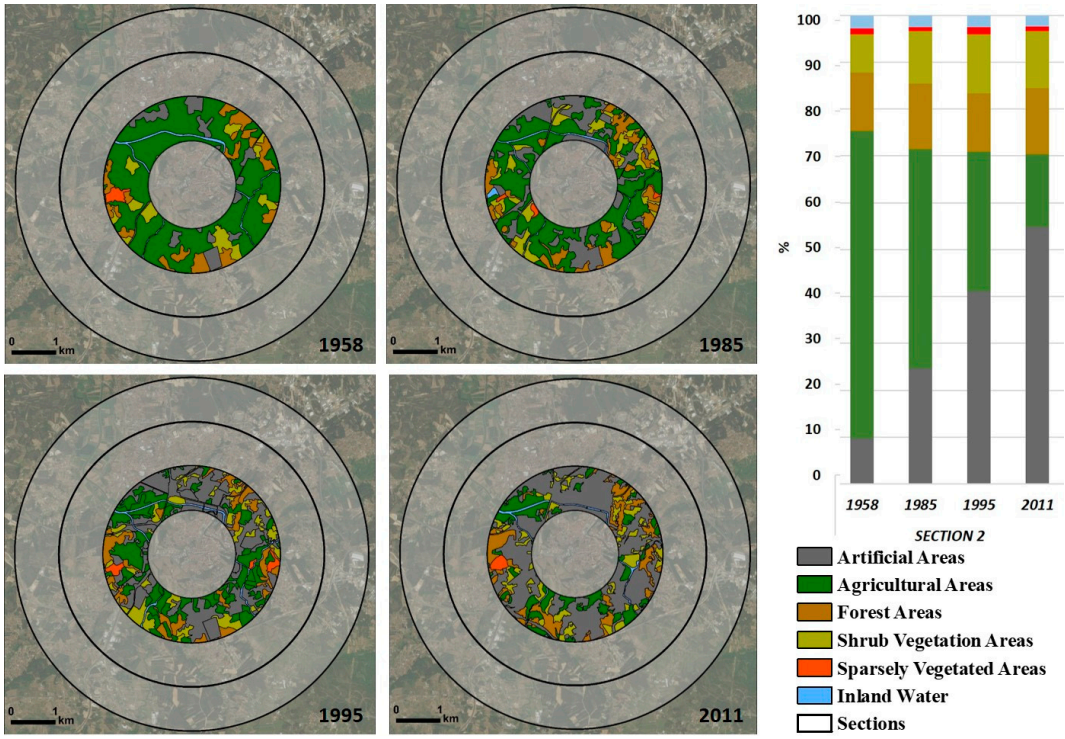

Figure 5. Evolution of aggregated land-use classes in Section 2 for the city of Leiria.

Section 3 (Figure 6) shows similar behavior to Section 2 with respect to artificial areas (31.2%), agricultural areas (29.7%), and shrub vegetation areas (6.5%). However, there is a decrease in forest areas (7.8%) between 1958–2011.

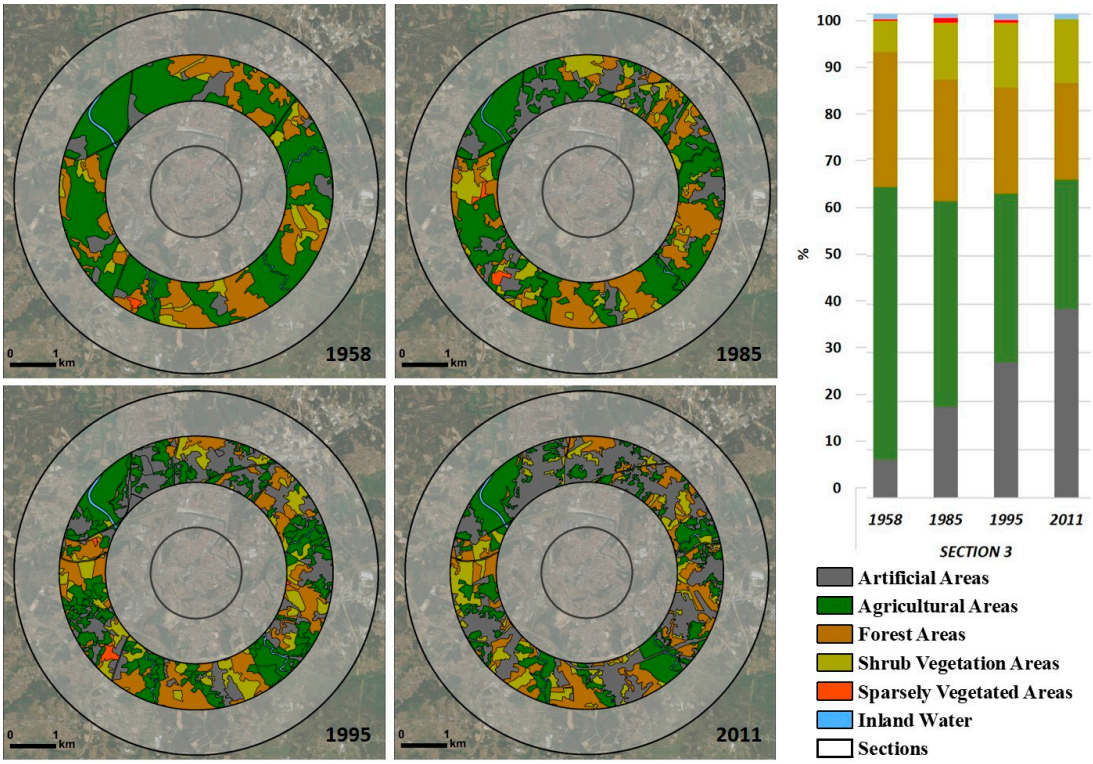

Figure 6. Evolution of aggregated land-use classes in Section 3 for the city of Leiria.

In Section 4 (Figure 7), as mentioned before in the remaining sections, gains in the artificial areas between 1958–2011 (24.2%) and shrub vegetation areas (3.4%) are observed. In the opposite direction, the agricultural areas surge with losses of 23.2% of area, and the forest areas show losses of 3.5%. In 1958, we were in the presence of a predominantly rural landscape that mostly consisted of agricultural area (47.8%) and forestry (35.2%), and artificial spaces had a residual representation (4.5%). However, the evolution over the period under analysis reveals that Section 4 shows a different evolution from the remaining sections. Although there is a considerable increase in artificial areas, which account for 28.7% of the area in 2011 and losses in agricultural and forestry areas, the land use in Section 4 remains mostly agricultural (24.6%) and forestry (31.7%).

With the exception of Section 4 (Figure 7), in which the most representative class is no longer agricultural areas and becomes forest areas from 1995, in all of the other sections, this domain passes from the agricultural to the artificial areas. The growth of forest areas in Sections 1 and 2 between 1958–2011 and their decrease in Sections 3 (Figure 6) and 4 can be seen for the same period. However, it should be noted that in the first two sections, this behavior is marked by oscillations, since growth is observed between 1958–1985, and a decrease between 1995–2011. In Sections 3 and 4, there is a constant loss between 1958–2011 in favor of the artificial areas and shrub vegetation areas.

In terms of shrub vegetation areas, as already identified for the artificial areas, there is growth in all of the sections between 1958–2011, but it is an irregular growth over time, showing losses in certain periods and gains in others. For the less representative classes, namely the sparsely vegetated areas and inland waters, it is verified that in relation to the former, the evolution between 1958–2011 moves in the sense of its decrease and residual representation throughout the four sections, being more represented in Section 2. In terms of the inland waters, there is maintenance of their associated areas, with a residual loss dynamic between 1958–2011 in Sections 1 and 2, which is derived from the implementation of flood mitigation measures carried out over time.

Figure 8 presents the stability grade for the four sections between 1958–2011. The principal conclusion is the increase of SG in all of the sections along the period under analysis. However, it is

possible to identify differences between the different sections. First of all, if we analyze the period between 1958–1985, we find that Section 4 is the one with the highest SG (39.79%), in contrast to Section 2, which has the lowest value (32.59), and consequently, the section that presents greater changes in land use and occupation. This can be explained by the intensification of urban expansion and suburbanization processes as a way of responding to the urban pressure exerted by the central part of the city due to the population increase that has been verified since 1970.

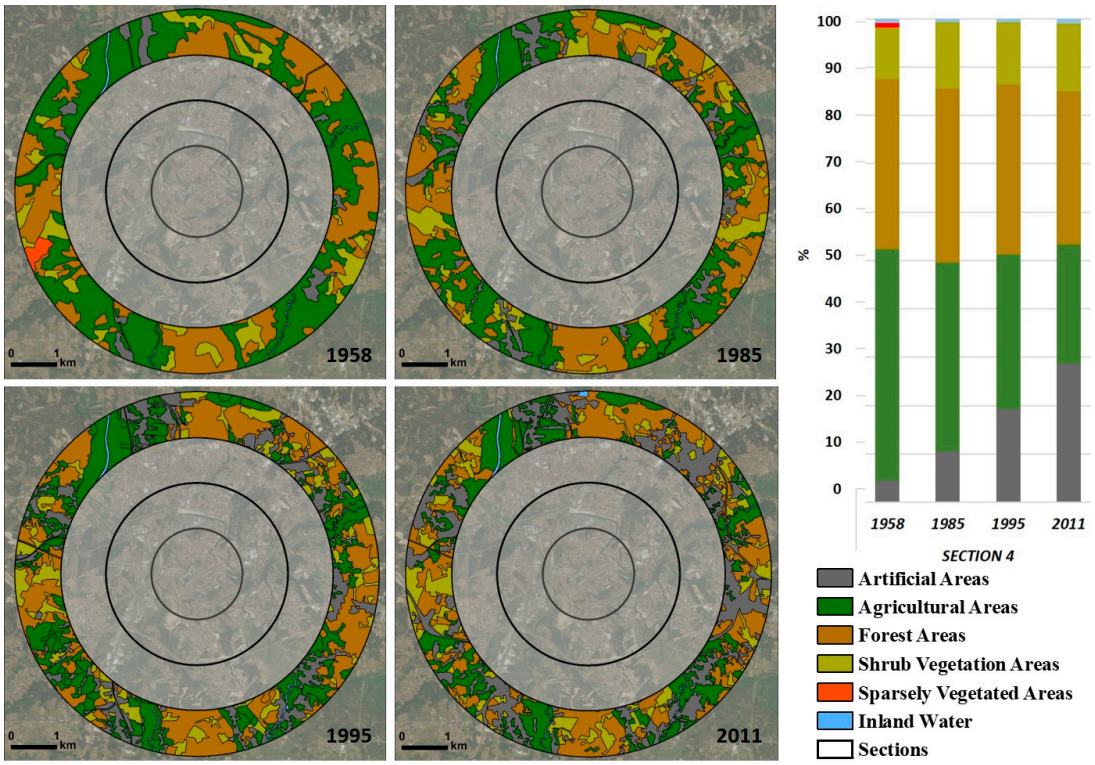

Figure 7. Evolution of aggregated land-use classes in Section 4 for the city of Leiria.

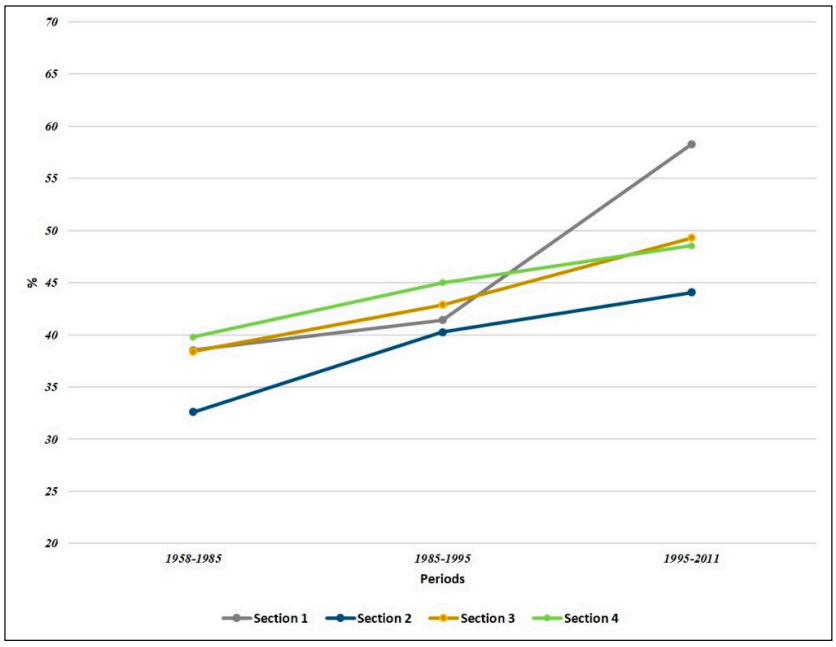

Figure 8. Stability grade for the four sections of the study area between 1958–2011.

3.3. Land Use Planning Framework

The planning framework acts as an activator of land-use transformation processes. The results for the rate of artificialization can still be considered more as clarifiers of the influence of planning on land-use trajectories. If we evaluate the impact of the various plans, it is possible to verify important changes from the beginning of the 1990s, with the implementation of municipal master plans. With the regulatory environmental and agricultural protection regimes (REN and RAN, respectively), artificialization fell sharply in the period 1995–2011 for the city of Leiria (Figure 9). This means that the land-use change processes in Leiria go beyond artificialization, with changes in agroforestry spaces and processes of landscape fragmentation explaining the rurbanization, forest rotation, and emergence of complex cultivation patterns, as pointed out by Tavares et al. [51] and Turcu [55]. These protection regimes were created in the early 1980s with the aim of safeguarding soils with greater agricultural suitability and the biophysical structure in certain areas, respectively. These regimes present a set of actions and uses that are interdicted with an emphasis on operations of land subdivision, urbanization works, construction or expansion works, interventions, or uses that cause soil degradation, in relation to the RAN regime; and land subdivision operations, urbanization works, construction and expansion works, communication routes, excavations, landfills and destruction of the plant cover, in terms of REN. According to Pinhal [32], these interdictions compromise the urban expansion process in the REN and RAN areas, giving rise to a diffuse occupation in areas integrated in the RAN and REN, promoting difficulties in the consolidation of built-up areas.

Figure 9 shows the relation between the planning framework and the annual rate of artificialization (AS) for Leiria. We can observe that AS remains practically unchanged until the mid-1980s, when an increase is noted. This is related to the intensification of different city plans, namely the implementation of the General City Plan of Leiria in 1983, outlining design plans that project new residential neighborhoods, health and educational equipment, and encircling road consolidation. The decrease on the AS that can be observed in the mid-1990s can be explained by the approval of a new Master Plan, which was approved in 1994 for Leiria with municipal scope, and involved restrictions for urban sprawl and the imposition of a set of conditions for land management related to legislation to protect ecological and agricultural areas. However, this planning instrument, with municipal-scale impact, promoted changes on the fringes of the urban areas, communicating a dynamic of transformation with peri-urbanization and rurbanization characteristics. The implementation of special legal restrictions, such as RAN and REN, also explains the decrease in the annual rate of artificialization in the 1990s. It is also worth mentioning the implementation of local plans (POLIS) in the early 2000s with the aim of rehabilitating degraded areas and promoting the environmental improvement of the same.

It can be summarized that the city-centered plans, until the early 1980s, have led to high land-use change and artificialization processes. It is with the municipal plans, which were complemented by protection regimes from the 1990s, that the dynamics of land-use transformation were regulated. The management of artificialization and infrastructures is now supervised by local plans that have been approved in the last two decades, some for rehabilitation purposes, and others for the construction of new neighborhoods.

In addition to these transformations, the planning framework, more specifically, the approval and implementation of the Hidroprojecto City Master Plan (1965) and the Macroplan Urban Plan (1983), promoted the artificialization and consequently increased the urban expansion to new outer urban areas, leading to peri-urbanization and rurbanization processes.

In the period 1985–1995, there was an increase in the SG in all of the analyzed sections, with Section 2 standing out with the highest growth, but nevertheless remaining the section that presented the lowest SG value when compared to the other sections. It is also observed that Sections 3 and 4 are the ones with the highest stability grade percentage, which means that the peri-urbanization process reaches a greater dynamic in Section 2, giving continuity to the process of urban expansion and the search for new areas for the emergence of new activities related to housing, services, industry, and commerce. In the last period (1995–2011), the trend of increasing SG remains in all of the sections,

with a clear highlight for Section 1 that shows a marked increase. This generalized increase is related to the approval and application of a set of planning instruments, namely the RAN legal regime (1993) for agriculture conservation, the Municipal Master Plan (1995), the REN legal regime (1996) for ecological conservation, and the POLIS program (2000) for urban requalification (Table 4).

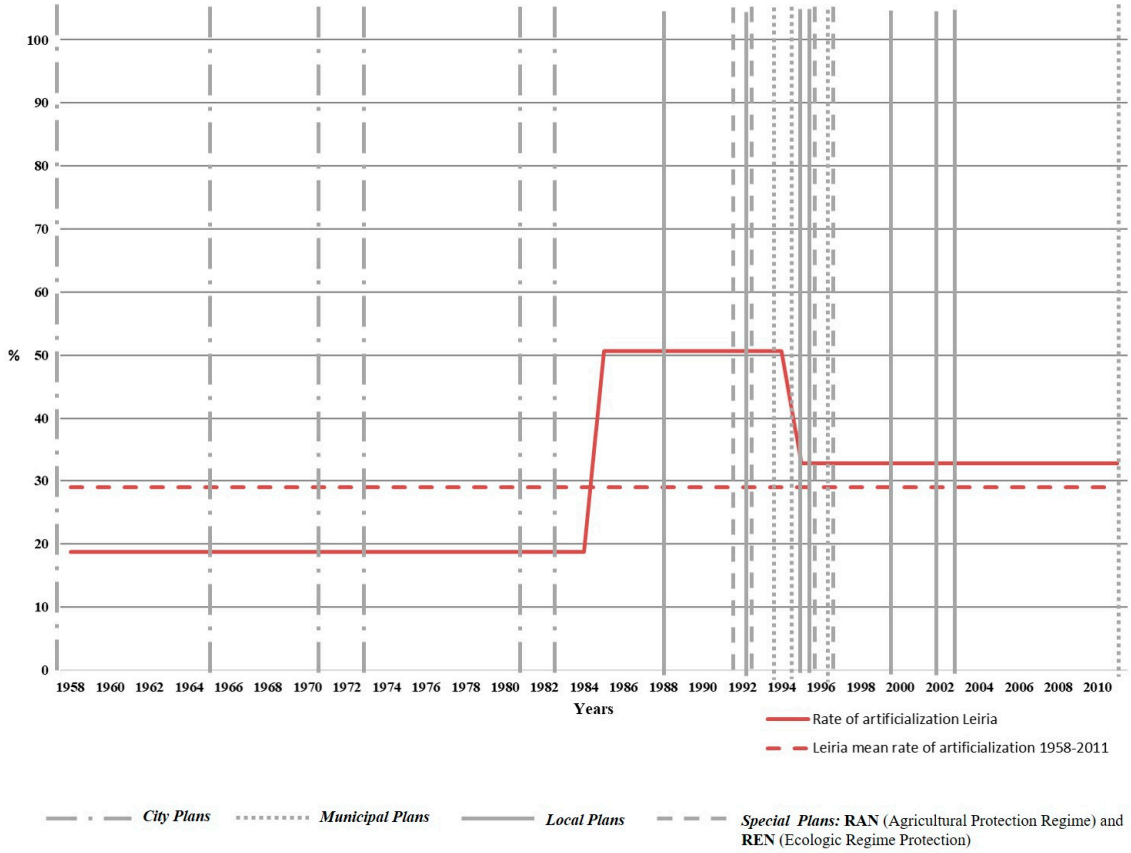

Figure 9. Annual rate of artificialization (%) and respective mean for the period 1958–2011 and the relation with the planning framework in the city of Leiria.

The definition and application of REN and RAN and the Municipal Master Plan led to a deceleration of the alteration of the soil transformation, as well as to a greater regulation of the municipal space, which has also impacted the potential inundated areas from the Lis River, which is an object of mitigation in the POLIS program.

4. Discussion and Conclusions

The analysis of land use and occupation between 1958–2011 for the study area belonging to the city of Leiria makes it possible to emphasize the consistent increase of the artificial areas during the period under analysis, and the sharp decrease of the agricultural areas. This increase is mainly related to the conversion of agricultural and forestry areas into artificial areas, and these results are in accordance with studies previously carried out for other areas [7,56–59].

In general terms, with regard to the disaggregated analysis of land-use classes, it is possible to observe a general increase in the areas occupied by the land-use classes related to artificial areas, with a clear highlight for the discontinuous urban fabric (18.1%), which quadrupled its area between 1958–2011 and the urban continuous (2.5%) section. Also noteworthy is the positive evolution of areas related to industrial or commercial units (5%) and road and rail networks (2.4%), which also registered a considerable increase that was related to economic, industrial, and planning framework forces, as well as the improvement of well-being [60]. These results are in line with the processes of

peri-urbanization and rurbanization that involve the dispersion of people, activities, and flows across the territory, resulting not only in the transformation of the peripheral areas, but also the consolidated urban centers themselves [32]. The peripheral areas of Leira are characterized since the 1940s by an intense process of industrial and population relocation, stimulated by a growing development of a network of road infrastructure that contributes to the development of new fronts of urban expansion toward the periphery. In this sense, it begins to develop housing centers linked to industry and services, with an emphasis on the peripheral areas in the north of the city and the development and creation of low-density landscapes based on typologies of isolated construction organized in a dispersed way throughout the territory [61] in the south of the city. It is also worth mentioning another peculiarity of the peripheral areas of the city of Leiria, which is based on the nodal and linear artificialization along the various road infrastructures built in the last 70 years. On the other hand, we find that we are facing a very fragmented landscape that presents an increase of complexity between 1958–2011, translating the outer urban processes or rurbanization. This is verified by the duplication of paths throughout the period in analysis, meeting what Pinhal [32] classified for the city of Leiria as an extensive and diffuse urban growth throughout the territory, with a clear intensification from the 1970s that is derived not only from the demographic explosion verified, but also by an intensification of a process of tertiarization of the urban agglomeration of Leiria, giving rise to what the author called the "urban explosion".

Also noteworthy within the positive evolution is the areas related to complex cultivation patterns (1.5%), mixed forest areas (3.2%), and degraded forest areas (3.7%). On the other hand, it is worth noting that almost all of the classes related to agricultural areas (with the exception of complex cultivation complex areas) show a decrease between 1958–2011. This is particularly visible in arable land (−4.1%), fruit trees and olive groves (6.9%), and pasture areas (−8%).

Finally, it should be noted that the land-use classes in the forest show increases in area with the exception of the coniferous forest class (mostly pine trees), which despite maintaining a considerable percentage of the area in 2011 (the second most representative class with 13.4% of the total area), is the one that between 1958–2011 shows the largest area decrease (8.2%).

In terms of the aggregated classes, the analysis points to what was previously held for disaggregated classes. We observe a steady and consolidated growth of artificial areas between 1958–2011, with an increase of 31.2%. The other class that presents gains is the shrub vegetation areas, which show a growth of 4.5%, and are often associated to the abandonment and degradation of spaces previously designated for agriculture [57,62,63]. The agricultural areas appear as the class that presents the greatest percentage of loss of area: more concretely, a decrease of 31.3%. Regarding forest areas, there is also a decrease of 3.6% between 1958–2011, but even with this decrease, the forest areas appear as the second most representative class, along with the agricultural areas in 2011.

These transformations of rural areas with loss in agricultural and forest degradation are in accordance with the urban sprawl that is typical in a small and medium-sized city.

The analysis of the stability grade identifies a low value (27.34%) for the period 1958–2011 for the 24 classes, which reflects an intensive dynamic of the changing classes in the area.

One of the conclusions of the present study is the increase in the fragmentation of the landscape, which is reflected by the increase in the number of polygons in the analyzed areas, from a total of 361 in 1958 to 753 in 2011. This is in line with previous studies carried out by Sherestha et al. [6], Tavares et al. [7], and Monteiro and Tavares [16], all of whom pointed this out as a main characteristic of change in small/medium-sized cities. The evidence shows a clear transformation over time, from peripheral rural areas to the old urban perimeters, and these dynamics are associated with processes of peri-urbanization and rurbanization. The overall results obtained are in line with similar changes identified in other contexts at the national level [16,36,64].

The city of Leiria presents a continuous increase in the percentage of the stability grade, which may be associated with driver factors such as the importance of agricultural areas in the alluvial watercourse banks and the subsequent application of environmental and agricultural protection

regimes, as referenced in Tavares and Monteiro [16] and Pato et al. [37]. However, if we consider the SG for the entire period under analysis (1958–2011), it presents a low value (27.32%), meaning intense dynamics processes of changing classes in the study area.

The planning frameworks act for the study area as activators of land-use transformation processes. At the beginning of the 20th century, a set of urbanization plans appeared for the city of Leiria in order to respond to the new challenges that the city faces in particular in terms of the search for new urbanization spaces. In this sense, the Urbanization General Plan in 1947 stands out, and it is possible to observe in Figure 10 that in this time, the city had well-defined limits and was concentrated in the central part of the study area, coinciding in the majority with Section 1, as defined in the present study. This plan presented as major concerns the search for new expansion areas to the south of the city, the location of equipment and construction of new areas, and also the resolution of traffic problems [32]. However, as mentioned by Salgueiro [65], the urban population of Leiria presented a weak growth until the end of the decade of 1960, and presenting from there a great demographic and industrial growth towards the peripheral spaces. This growing results in urban pressure and unprecedented growth for the peripheral areas of the city, diluting the boundaries between urban and rural. The different plans approved during the 1960s, 1970s, and 1980s present a broader area of action; this is visible in Figure 10, where we can verify the enormous growth of the limits of the city in the period between 1972–1995. This results in a greater fragmentation of the landscape, which is accompanied by a clear increase of the artificialized areas, showing a clear increase in the rate of artificialization that is highlighted for the period between 1983–1994 (Figure 10). Until the 1990s, the city of Leiria presented a growth in the majority of the cases, sprawling the urbanization in processes of peri-urbanization and rural and decharacterization, which was mostly because of the rigidity and the lack of operability of the majority of the plans that had been approved up until then. In 1995, the Master Plan (which was revised in 2015) for the city of Leiria was approved, which presented a less comprehensive resizing of the urban boundary with the aim of limiting urban expansion, as can be seen in Figure 9. Coupled with the incorporation of the constraints arising from REN and RAN in the Master Plan, this resulted in a clear limitation to the disorderly and diffuse urban expansion that existed until then. On the other hand, the identification and zoning of areas belonging to these protection regimes allowed, despite the loss of area between 1958–2011, the maintenance of considerable areas related to agriculture and forests areas, namely in Sections 3 and 4 of the study area.

The results obtained in the present study demonstrate the processes of transformation of land use and occupation that are characteristic of small and medium-sized cities, as recognized by other authors [31,66–70].

In the majority of cases, the complexity that characterizes the process of urban expansion in medium-sized cities through their extensive and diffuse polycentric development, justifies the approach that was used, since this way it is possible to conduct both a partial and an overall analysis of the study area, enabling the hypothesis to evaluate the different dynamics and different trajectories in terms of the land use present in the territory. On the other hand, the present methodology makes it possible to perceive in a more coherent way the urban expansion toward the peripheral and rural areas of the city during the different periods analyzed. In this way, it is possible to distinguish land-use dynamics, land occupation differences, and occupancy trends over the period analyzed.

The realization of studies of this nature are extremely important, because they allow knowledge of the past and present of cities' dynamics, helping to understand land-use and occupation changes over time. On the other hand, this type of analysis could be an important tool for improving the spatial planning in the future.

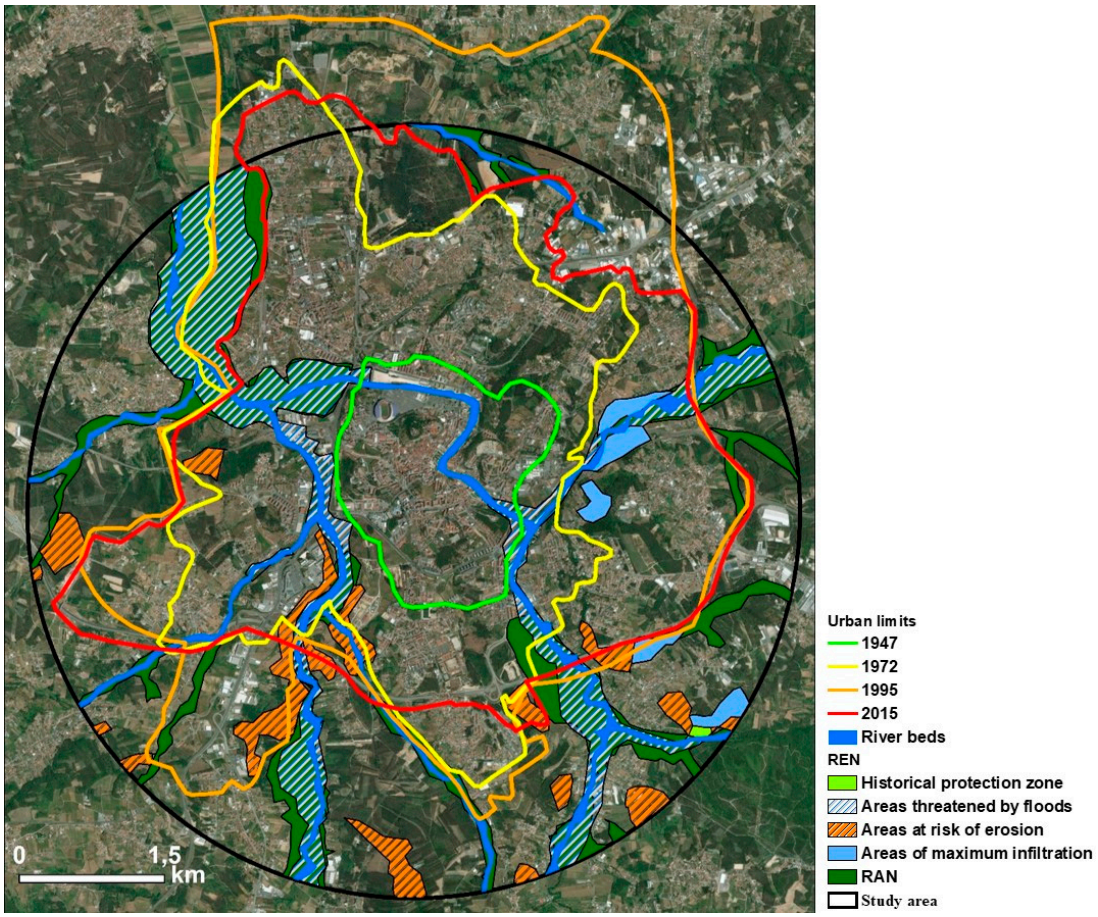

Figure 10. Urban limits and the regulatory environmental and agricultural protection regimes (REN and RAN) of the city of Leiria. The limit was defined within scope of Urbanization General Plan of 1947; within the scope of Hidroprojecto City Master Plan in 1972; within the scope of Municipal Master Plan in 1995; and within the scope of the revision of Municipal Master Plan in 2015. (Own elaboration based on Pinhal, 2016 and the Municipal Master Plan of Leiria).

Author Contributions: J.L.B. worked on the LULC mapping and analyses, performed the experiment work and the statistical analysis, and wrote the paper. A.O.T. designed the research, analyzed the data and wrote the paper. M.M. worked in the methodology for LULC mapping, made fieldwork, worked in the statistical analysis. P.P.S. contributed for the data analysis, read and made improvements to the paper.

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Conflicts of Interest: The authors declare no conflict of interest.

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