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Land-Use Changes in Insular Urban Territories: A Retrospective Analysis from 1990 to 2018. The Case of Madeira Island—Ribeira Brava

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Abstract: As the main island of the Madeira Archipelago, Madeira is faced with a clear demand for more precise and specific planning policies, in order to respond to regional requests. Bearing in mind the urgency of this issue linked to the concept of sustainability, planning strategies must be based on and strengthened by several studies, with the most varied themes, as a way of incisively understanding the problem at hand. Based on tools such as GIS (geographic information systems), this study allows the analysis of variations and patterns of land use and occupancy in the municipality of Ribeira Brava, located on Madeira Island. In a comprehensive manner, the study allows us to highlight the stagnation of the urban fabric of the region and, on the other hand, the change in the dynamics of agricultural cultivation present in the county. In addition, this study highlights the change in the predominant native vegetation in the municipality between the years 1990 and 2018. It is still necessary to emphasize the worrying scenario with the loss of native vegetation due to human activity, which requires more emphatic monitoring by regional government actors to protect, preserve and conserve these landscapes, environments and ecosystems.

Keywords: CORINE Land Cover (CLC); geographic information systems (GIS); land use and occupancy; planning and territorial management; territorial planning

1. Introduction

The development of multiple global land datasets, which enable the acquisition of land-cover data collected from Earth observation through satellites, has been prompted by the growing need for thorough and reliable information on land cover, land uses, and their dynamics and trends [1]. Numerous initiatives and programs at the national and international levels drove this development. It should also be mentioned that several sets of global or continental land-cover data from satellite Earth observation have promoted and produced a range of mapping patterns [2–10].

In fewer words, land use cover maps are incredibly helpful data due to their wide diffusion of use and their interdisciplinary character. These maps give us access to data on the land cover and biophysics cover of the Earth's surface [11], making their use crucial for the research and modeling of territorial dynamics [12].

In addition, land-use and land-cover maps can play an important role in balancing economic, political, cultural and environmental factors in a given territory [13], as they allow the analysis of significant changes in landscapes, study cycles and trends. In this context, Initial Operations of the Land Monitoring Service (GIO-Land) is an operational project of the European Copernicus Program that aims to provide several sets of land-cover data, employing satellite images that are updated every six years in almost all European nations, as already portrayed by different authors [14,15]. In addition, geographic information systems (GIS) give users access to a variety of data sources and enable the tracking of land changes, supported by fine-grain analyses of the land cover and assessments of changes, particularly in urbanized regions [16–19]. Urbanization is a process that creates and leaves an impact on the economic and social development of developing countries [20]. These issues globally depend on the unsolved conflict between anthropic systems and environmental components [21]. The need for tools to support policymaking oriented to sustainable planning arises at several levels of governance. In this regard, the fast progress of geographic information systems (GIS) during the last few decades provided researchers with powerful tools with which to conduct spatial analyses and modelling [22,23]. Additionally, this system is capable of tracking changes in human activity and the ecological condition of metropolitan areas [24,25].

Following the previous section, the Urban Atlas (UA) includes many other more detailed data, that is, it classifies resolution satellite images (SPOT 2.5 m, ALOS 2.5 m; RapidEye 5 m), which promotes the separation of significant coverage classes. The smallest mapping unit is 0.25 hectares and has an estimated accuracy of 5 m, supporting the production of land-cover maps for just 305 large European cities with a population of over 100,000. However, the UA comprises only 20 land-cover classifications, a number that is considerably lower than CORINE Land Cover (CLC or 'Corine') [7]. Together, terrestrial systems incorporate all processes and activities related to the human use of territories, including technological and organizational advances, as well as classifications, land profits and unintended cultural and environmental factors, from social activities [26–28].

As a result, an extra effort was made across Europe to monitor land-cover change in a consistent manner. This was achieved through the creation of the so-called inventory (CLC), which was carried out using satellite pictures. The European Environment Agency (EEA) has processed this shared database, which is utilized by several organizations throughout Europe and is co-financed by the European Commission and member states [7]. With regard to map characteristics, land-cover heterogeneity is brought about by the application of multiple techniques and underlying patterns, including varied layouts, syntactic issues, schematic heterogeneity, and semantic factors [25]. Therefore, since these changes are the result of a distinct strategy employed in the development of the map, it becomes challenging to differentiate land use when using alternative mapping methodologies [1]. Created in 1985, Information on the Environment Coordination CORINE Land Cover (CLC) results from the combined effort of the nations that form the European Community (EC). Its main purpose lies in collecting and interpreting geospatial data in a more accurate and coordinated way, since it aims to achieve the following goals: (a) collect and coordinate interdisciplinary data regarding the state of the environment; (b) mainly focus on areas that are viewed as priorities within each EU state; (c) manage and organize these data, not only from an international perspective, but also locally; and (d) assure that all the data are compatible [7]. Thus, this database can be understood as an important tool when undertaking more complex geographical analyses, especially if they consider multiple categories regarding land use. Consequently, CLC's hierarchical structure can be divided into three levels. The first one covers the following five primary types of land use and land cover: artificial areas, agricultural areas, forest and semi-natural areas, wetlands, and water bodies. On the other hand, the second level has fifteen components, while the third one accounts for forty-four components. Additionally, the third level's components arise with the clear definition of these three classes' methodological scope as their main goal [7,26]. Within Europe, a joint effort, in terms of establishing certain standardized parameters in order to keep track of land-cover changes, has been accomplished. As a consequence, this database plays a decisive role in the integration of the EEA's information system and is currently considered a significant addition in terms of information availability on the topic of major land-cover variations [29,30]. Even though the CLC's data collection process has traditionally been based on the interpretation of images from satellites, multiple countries, namely Germany, Austria, Finland, Ireland, Iceland, Norway, United Kingdom, Sweden, and Switzerland, mostly since 2006, have been gathering these data from detailed national maps, through generalization techniques [31]. In contrast, nations such as Slovakia, Hungary and Poland turn to CLC intending to get more detailed information, scale 1:50,000 maps, with a minimum map unit (MMU) from 4 in addition to an adapted legend, which considers the geographical specificities of the territory [31]. Identical methods have also been applied to estimate information before the 1990 CLC data [30]. Hence, it is possible to verify that there are many ways of obtaining CLC data. Nonetheless, it is important to mention that nations such as Germany and Ireland have modified the methods used to obtain CORINE land-use maps—as for the generally used photo interpretation—while, for instance, in the Netherlands, the government determined that CLC data should be produced autonomously [31,32]. Overall, despite these administrative and technical issues, CORINE's maps regarding land use continue to be an important tool for soil application-related analyses. In fact, the directive INSPIRE 2007-2-EC [33] considers CLC as a superlative dataset that stands out from the remaining European datasets due to its level of standardization; furthermore, this standardization encompasses both the semantic and technical fields, since CLC is based on a generic land-cover classification that is applied throughout Europe [34,35]. In fact, other sources of information have only compatibility and comparability between different maps sources of land cover and their legends' theme, since it is necessary to consider that they are independent datasets [1]. Typically, different methodologies can cause a significant level of heterogeneity within multiple land-cover maps, due to, for instance, multiple layouts, syntactic problems, schematic heterogeneity and semantic aspects [36]. Therefore, in a scenario where different mapping methodologies have been used, it is hard to effectively analyze land-use changes, since some of these changes may be a result of the methodological heterogeneity [1]. However, despite the rate of change in land uses in the European landscape, there is only a small amount of research that examines the pattern of periods of change in land use at a pan-European level. In this regard, several studies and research papers have focused on the change in the landscape of European territories, pointing to a significant change [37–39]. Agriculture is one of the most significant land uses in Europe, which has a diverse range of regional traits and well-defined dynamics [40]. More than 35% of European territory is used for agriculture, which equates to roughly 10 times more land than is used for urban purposes [41,42].

Similar to other territories, island territories suffer unique challenges and are particularly vulnerable to change due to their geographic situation, which results in a high degree of isolation and their limited size (spatial constraints) [43]. This type of territory is regarded as a coastal territory, since it is both directly and indirectly impacted by the presence of the water [44–46]. Territorial planning, in this sense, serves as a crucial tool for ensuring that the circumstances of prosperity are passed down to present and future generations, supporting the reduction in social inequities and geographical imbalances, and acting as a catalyst for growth.

In contemporary society, regional planning must, inevitably, take into account the future and be developed in an orderly way to meet public needs and not be ordered by casuistic and uncontrolled progression from the political and individual point of view regarding investments. Therefore, sustainable development and growth are, undoubtedly, the main concerns and objectives of the territories [47–52].

Through a practical experience approach to a case study that involves the Ribeira Brava municipality, Madeira Island, Portugal, the major goal of this study is to assess and evaluate the changes in land use in the peripheral or "ultraperipheral" and insular areas, that is, the islands. In addition, impediments and possibilities for sustainable growth and development can be examined and handled by comprehending the land, using changes and, consequently, territorial dynamics and trends. The aim of the current study is to map and explain the land-use changes in the Ribeira Brava municipality, Madeira Island, Portugal, between 1990 and 2018. In this regard, we emphasize that the current study will contribute to science by enabling the collection of big data connected to land-use changes, as well as by providing an overview of how they have evolved in the Ribeira Brava municipality, over the last three decades. The data must be used to avoid or minimize flood events that have become increasingly intolerable over time, bringing constant risks of human loss and economic damage, as has already occurred in the recent past in the Ribeira Brava municipality, which mostly develop along its main water line.

In the first decades of the current century, the Ribeira Brava municipality experienced strong territorial growth, a development that occurred along the length of its main water line (river). Therefore, this development results in clear land-use changes, which has a relevant importance in terms of hydrological management issues, namely episodes of extreme rainfall. That is, the land-use changes over the years have contributed to a clear increase in the area of waterproofing, and thus a consequent increase in surface runoff, which inevitably causes floods. The level of water on the floor derives not only from the origin of the water, but also from the characteristics of the surrounding vegetation. In addition, processes such as underground infiltration, which can be influenced by soil characteristics, and underground water leaking are commonly associated with the occurrence of floods. Furthermore, floods are partly worsened by incorrect urban planning, which often leads to inappropriate land uses—for example, uncontrolled growth of urban areas—and infrastructures on stream beds, such as levees, embankments, or dams. Moreover, when this flawed urbanization phenomenon starts to also affect rural areas, planning and territorial management decision makers have to create structural and non-structural mitigation measures to prevent or at least mitigate flood impacts.

The study of the land-use changes in the Ribeira Brava municipality reveals that this area has an innovative character, based on some unique characteristics, such as developed at the bottom of a very narrow valley (with large drifts and steep slopes) with large numbers of water evacuation vessels completely sealed by infrastructure; the short course of the water line, which is approximately 15 km, so there is little warning in cases of flood disasters; as also observed in the highlands, the replacement of the type of vegetation in this area (land-use changes), which contributed to the increase in surface runoff due to unevenness and slopes, will contribute to an increase in flow, as well as the speed of flow (this must be avoided in case of the occurrence of an episode of extreme rainfall).

However, the correct management of land-use changes helps to alleviate the geomorphological and hydrological problem of this municipality, which has been growing due to anthropic pressure. Consequently, there is a need for high-impact measures to further mitigate the impact of floods and not just redirect the problem from one area to another, from the land management area to the hydraulic area.

Finally, we discuss the spatial patterns observed, and provide some principles and recommendations for future regional planning and management strategies and policies that could be developed and implemented throughout the Ribeira Brava municipality.

2. Methodology

2.1. Study Area

The Madeira Archipelago is located in the North Atlantic, more precisely in the region called Macaronesia, between the parallels 30° 01′ N and 33° 08′ N and the meridians 15° 51′ W and 17° 30′ W of Greenwich [53]. With a total of 796.77 km^2, the archipelago consists of Madeira Island, the largest and most important island in the group, with an area of 736.75 km^2; Porto Santo, with an area of 42.17 km^2; the Desertas Islands, with an area of 14.23 km^2 and the Selvagens, with an area of 3.62 km^2 [54].

Specifically, the municipality of Ribeira Brava, located on the south coast of Madeira Island, covers an area of approximately 65 km^2 and comprises the following four civil parishes: Campanário, Ribeira Brava, Serra de Água and Tabua. In addition, it is situated in the Atlantic Ocean and borders the municipalities of Câmara de Lobos (east), Ponta do Sol (west) and São Vicente (north) [55], as shown in Figure 1.

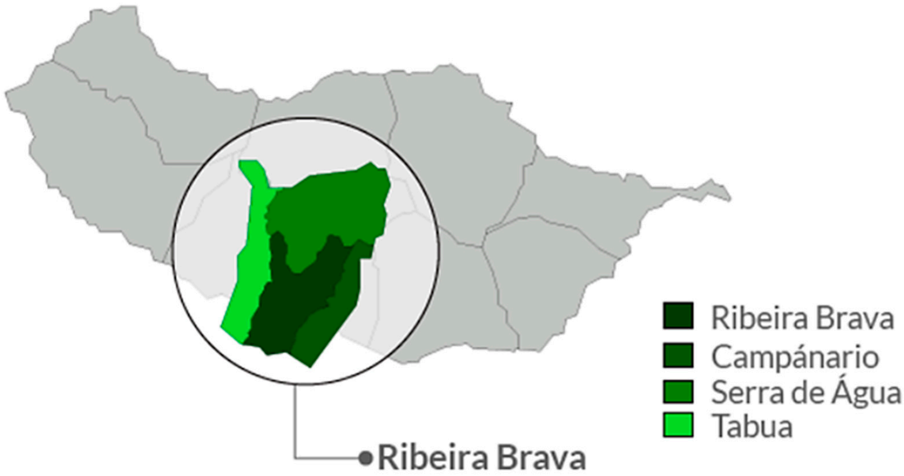

Figure 1. Location of the study area—municipality of Ribeira Brava (source: [55]).

The relief of the city of Ribera Brava is very rugged, with deep valleys and steep slopes, while almost vertical and plateau areas are rarely observed. Its highest points are Pico Grande and Pico do Cerco, with heights of 1675 m and 1586 m, respectively, as shown in Figure 2.

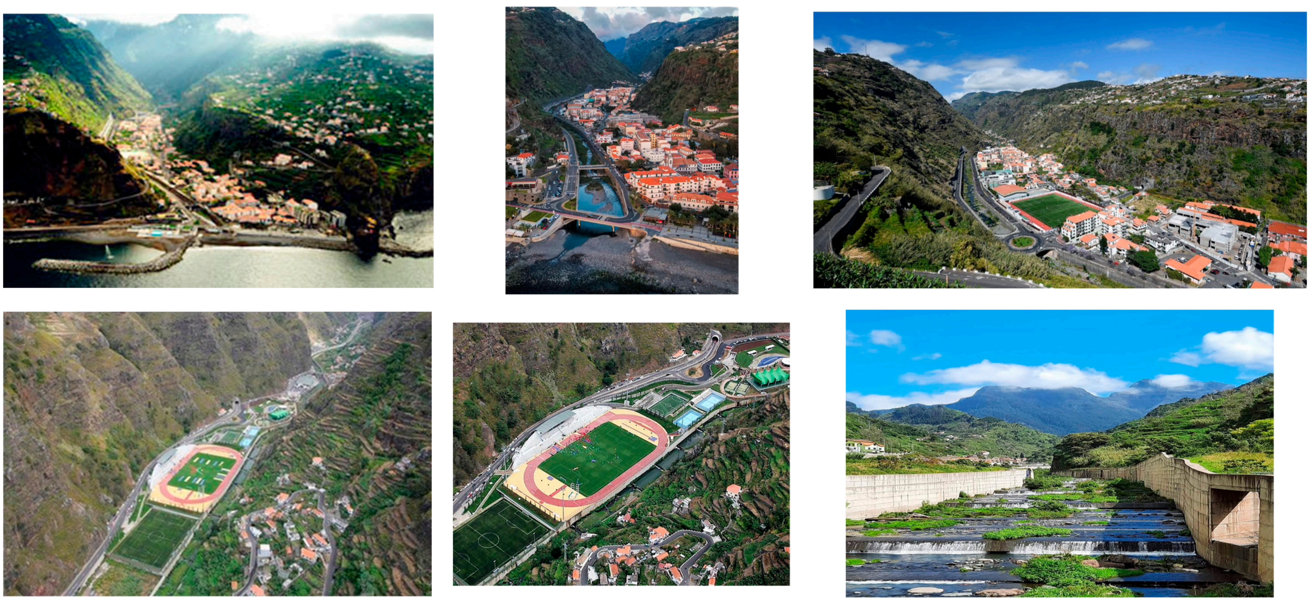

Figure 2. Observation of the study area—municipality of Ribeira Brava (from river mouth to east) (source: authors).

It has a mild Mediterranean climate, with average summer temperatures of 27 °C and winter temperatures around 16 °C. Regarding the population, the municipality of Ribeira Brava follows the trend of population reduction, from 14,132 inhabitants in 1920 to 13,375 in 2011, and to 12,411 in the last census carried out in 2021 [55].

2.2. Applied Methodology

There were two layers of information in the data used. These can be utilized to duplicate this work in another work area because they are public and open. The municipality of Ribeira Brava on Madeira Island is the subject of the analysis.

Data on land use were first gathered. The European Space Agency (EEA) provides a geodatabase that employs polygonal graphic characteristics that indicate land use throughout the European Union for the years 1990, 2000, 2006, 2012, and 2018 through the CORINE Land Cover (Coordination of Information, CLC) project [56]. Regarding the use of remote sensing data, the information was supplied by means of shapefiles. These files were managed by using ArcGis 10.5. A project was generated and subsequentially, the shapefiles were added as layers, that is, vectorial information.

The mapping system used was the Universal Transverse Mercator (UTM), and the scale was 1:100,000 in the Geodesic Reference System, which corresponds to the European Terrestrial Reference System 1989 (ETRS89), with the minimal cartographic unit (MCU) being equivalent to 25 hectares. The precision attained has improved over time, rising from less than 50 m in 1990 to less than 25 m in 2000, 2006, and 2012, and eventually, less than 10 m in 2018. Additionally, the polygons' information was organized hierarchically into three layers (Table 1).

Table 1. CORINE Land Cover nomenclature (source: [56] *).

Level 1	Level 2	Level 3
1. Artificial surfaces	1.1. Urban fabric	1.1.1. Continuous urban fabric
		1.1.2. Discontinuous urban fabric
	1.2. Industrial, commercial and transport	1.2.1. Industrial or commercial units
		1.2.2. Road and rail networks and associated land
		1.2.3. Port areas
		1.2.4. Airports
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites
		1.3.2. Dump sites
		1.3.3. Construction sites
	1.4. Artificial, non-agricultural vegetated areas	1.4.1. Green urban areas
		1.4.2. Sport and leisure facilities
2. Agricultural areas	2.1. Arable land	2.1.1. Non-irrigated arable land
		2.1.2. Permanently irrigated land
		2.1.3. Rice fields
	2.2. Permanent crops	2.2.1. Vineyards
		2.2.2. Fruit trees and berry plantations
		2.2.3. Olive groves
	2.3. Pastures	2.3.1. Pastures
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops
		2.4.2. Complex cultivation
		2.4.3. Land occupied by agriculture

Table 1. *Cont.*

Level 1	Level 2	Level 3
3. Forests and semi-natural areas	3.1. Forests	3.1.1. Broad-leaved forest
		3.1.2. Coniferous forest
		3.1.3. Mixed forest
	3.2. Shrub and/or herbaceous vegetation association	3.2.1. Natural grassland
		3.2.2. Moors and heathland
		3.2.3. Scierophyllous vegetation
		3.2.4. Transitional woodland shrub
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes, and plains
		3.3.2. Bare rock
		3.3.3. Sparsely vegetated areas
		3.3.4. Burnt areas
		3.3.5. Glaciers and perpetual snow
4. Wetlands	4.1. Inland wetlands	4.1.1. Inland marshes
		4.1.2. Peatbogs
	4.2. Coastal wetlands	4.2.1. Salt marshes
		4.2.2. Saline
		4.2.3. Intertidal flats
5. Water bodies	5.1. Inland waters	5.1.1. Water courses
		5.1.2. Water bodies
	5.2. Marine waters	5.2.1. Coastal lagoons
		5.2.2. Estuaries
		5.2.3. Sea and ocean

* The authors suggest visiting www.eea.europa.eu/publications/COR0-landcover, accessed on 30 November 2021, for comprehensive information regarding the CLC codes.

The administrative delineation of the municipality of Ribeira Brava is represented by the second layer of information. The Official Administrative Charter of Portugal (CAOP2020) for the Autonomous Region of Madeira was retrieved from the National Geographic Information System of Portugal (SNIG), as depicted in Figure 3.

ArcGIS 10.5 geographic information systems (GIS) management software was then used to process both levels of data. When Lambert-2001's ETRS-LAEA was first adopted as the official coordinate reference system, all layers of information were converted to this system by means of designation of projection in the project [57], due to the fact that they are the inputs, the projection of equivalent regions within the territory, on which ETRS-LAEA is based. In this way, it acts as a standard for homogeneous units across all of Europe. Thus, the representation of analytical and statistical data uses this coordinate system.

After performing a selection query using alphanumeric data, the municipality of Ribeira Brava was chosen for the layer that refers to the administrative divisions of the Autonomous Region of Madeira. This particular municipality was then maintained in a single layer of information. The scope of action for this study was limited to this layer of information. The boundary of Ribeira Brava was then utilized as the reference layer for the clip tool. For each of the years under consideration, this process was used (1990, 2000, 2006, 2012 and 2018). Land uses were acquired in this way, but only those that were a part of the municipality. The area of each polygon was then geometrically measured and converted to hectares by means of the command geometry. As a result, each polygon's total hectares, which correspond to the CLC nomenclature's representation of land uses, were determined.

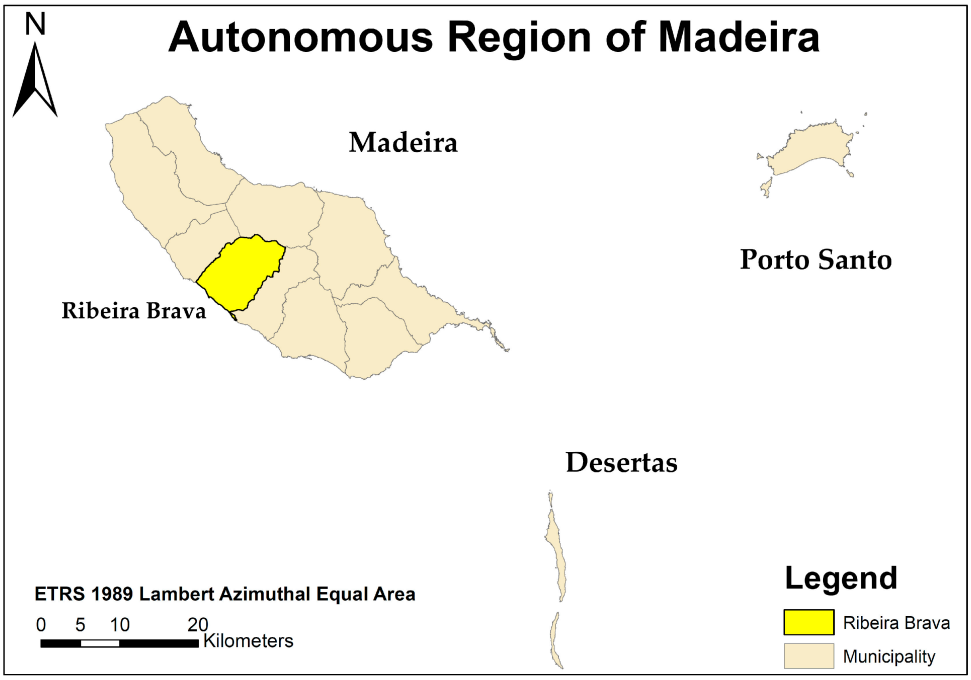

Figure 3. Municipality of Ribeira Brava's delineation of the study's geographic scope (source: authors by ESRI ArcGIS, 2020).

The alphanumeric data stored in each of the tables for the years under analysis were then exported by means of the command export and imported into a database that was maintained by the Microsoft Access database management program, a component of the Microsoft Office 365 suite of applications.

Using Structured Query Language (SQL), selection queries were created for the database to be selected in accordance with the CLC nomenclature, and then another grouping query was appended to the original query. Finally, for the years 1990, 2000, 2006, 2012, and 2018, the number of hectares for each type of land use was determined.

Thematic maps were also obtained for each year in order to take into consideration both the numerical and geographic outcomes. This made it possible to pinpoint both the areas with the highest variety in land uses and those with predominant land uses. The data flow described in the previous paragraphs can be observed in Figure 4.

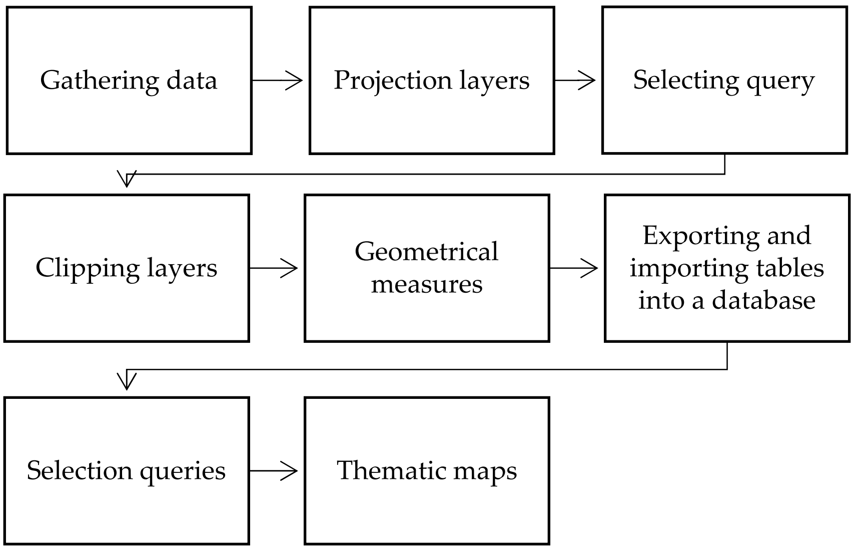

Figure 4. Data flow used to perform the analysis (source: authors).

A system was designed to obtain a better understanding of the technique utilized and the criteria for selecting case studies (Figure 5).

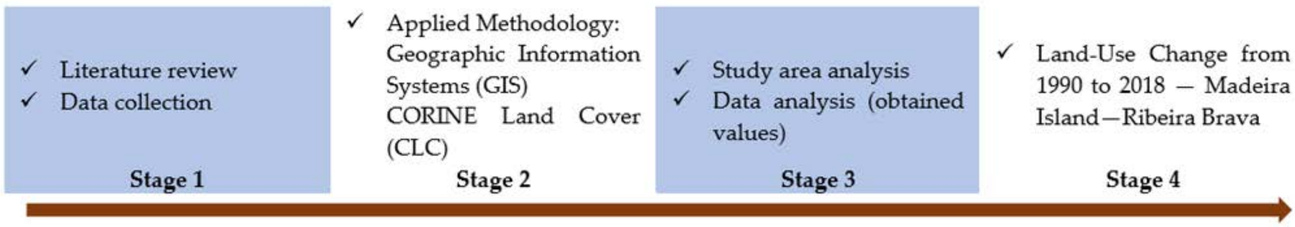

Figure 5. Summary of the methodology's selection criteria and case study selection process (source: authors).

3. Results

The results are based on an examination of the land-use changes in the municipality of Ribeira Brava between 1990 and 2018, as well as between 1990 and 2000, 2006, and 2012. The graphs, tables, and themed mapping are used to display the results. This disclosed results typology enables the most pertinent information to be extracted and characterizes the progression of land use based on the 44 soil uses identified by CLC. The data are organized as percentages and are shown in Table 2.

Table 2. Percentage of level 3 CLC nomenclature land uses in the municipality of Ribeira Brava (source: authors).

CLC Nomenclature\Year	1990	2000	2006	2012	2018
112	10.32%	11.64%	**11.79%**	11.40%	11.40%
121	0.00%	0.00%	0.00%	**0.39%**	**0.39%**
212	**0.39%**	**0.39%**	0.00%	0.00%	0.00%
221	0.00%	0.00%	**0.08%**	**0.08%**	0.03%
222	**1.06%**	**1.06%**	1.05%	1.05%	1.05%
241	**2.43%**	**2.43%**	1.02%	1.02%	0.00%
242	3.54%	3.33%	4.97%	4.97%	**4.99%**
243	**14.24%**	13.42%	12.70%	12.78%	13.15%
311	**6.88%**	**6.88%**	6.19%	3.42%	6.44%
312	4.25%	4.39%	4.08%	3.98%	**4.46%**
313	**21.43%**	**21.43%**	20.81%	18.03%	16.68%
321	10.33%	10.33%	11.14%	11.60%	**13.45%**
322	16.55%	16.22%	16.22%	14.84%	**20.12%**
324	6.07%	5.97%	**7.46%**	5.37%	6.57%
333	**2.33%**	**2.33%**	**2.33%**	**2.33%**	1.11%
334	0.00%	0.00%	0.00%	**8.58%**	0.00%
523	**0.17%**	**0.17%**	0.16%	0.16%	0.16%

Note: The highest values found are in bold.

In order to obtain a better visualization of the area variation by CLC classification, the graph in Figure 6 was drawn up using percentages.

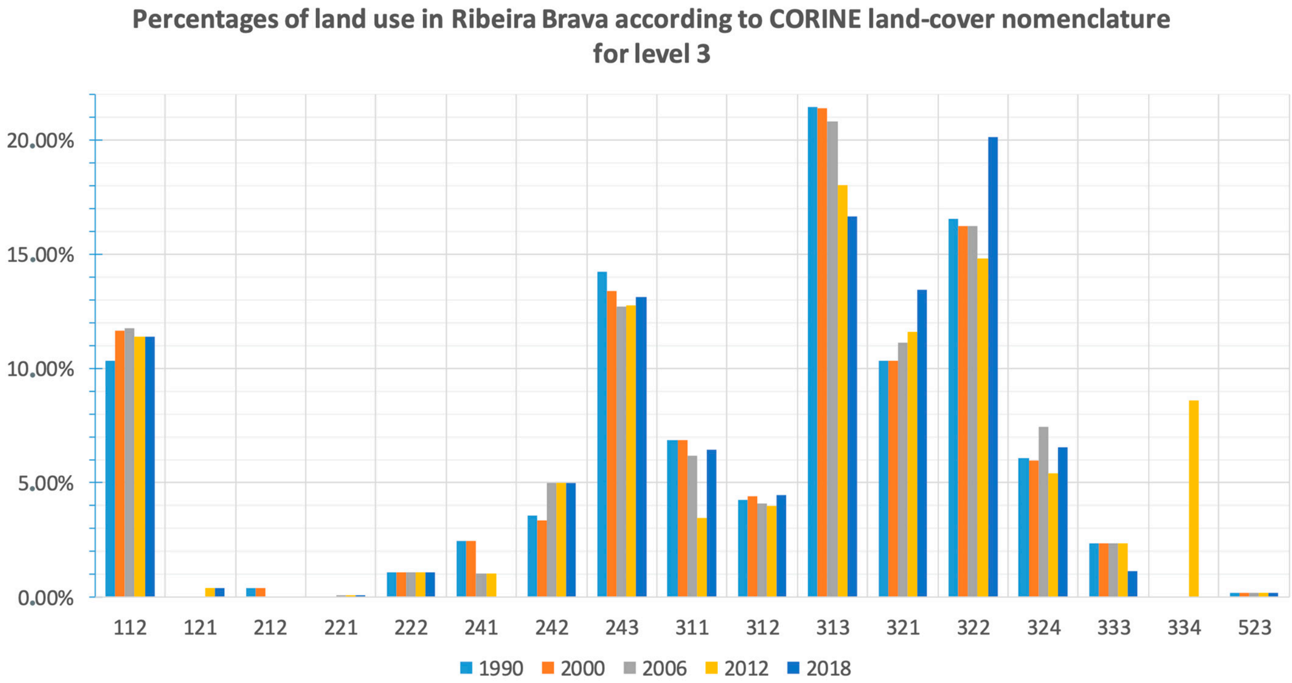

Figure 6. Percentage of land use in the municipality of Ribeira Brava classified as level 3 of the CLC terminology (source: authors).

Additionally, using ArcGIS 10.5, geographic information systems (GIS) software, it was feasible to illustrate each area's location (thematic cartography) more correctly, specifically according to each area's individual CLC ratings and time variance, as shown in Figures 7–11.

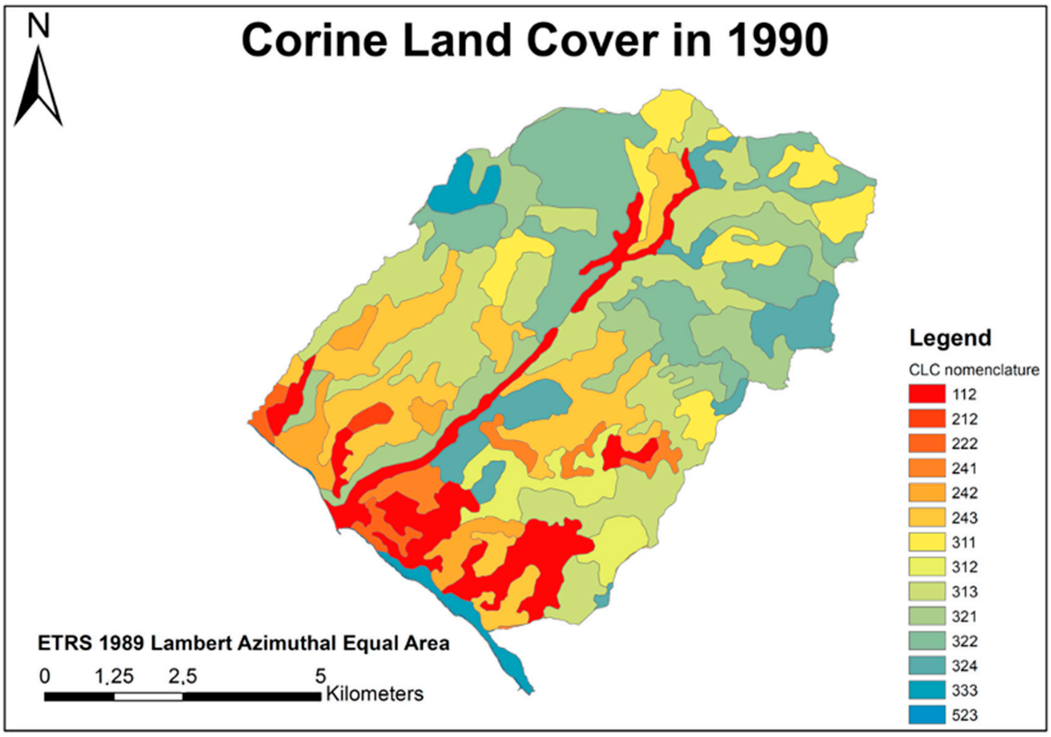

Figure 7. Level 3 CLC designation land uses in the municipality of Ribeira Brava in 1990 (source: authors by ESRI ArcGIS, 2020).

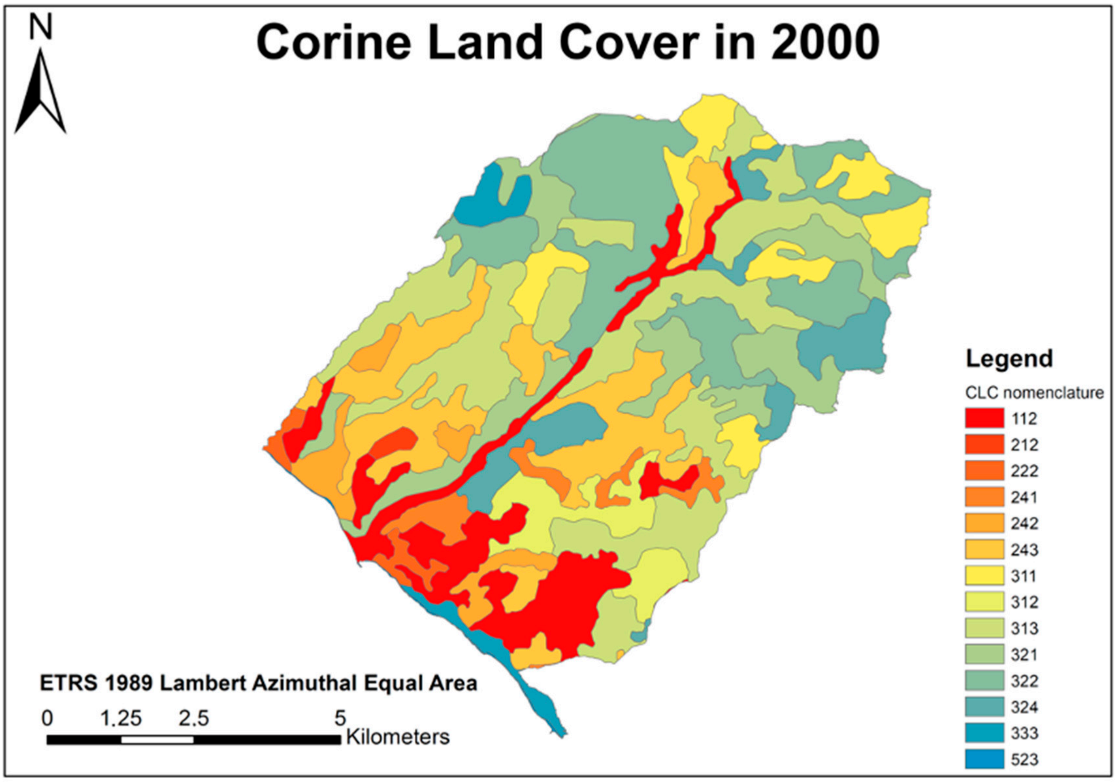

Figure 8. Level 3 CLC designation land uses in the municipality of Ribeira Brava in 2000 (source: authors by ESRI ArcGIS, 2020).

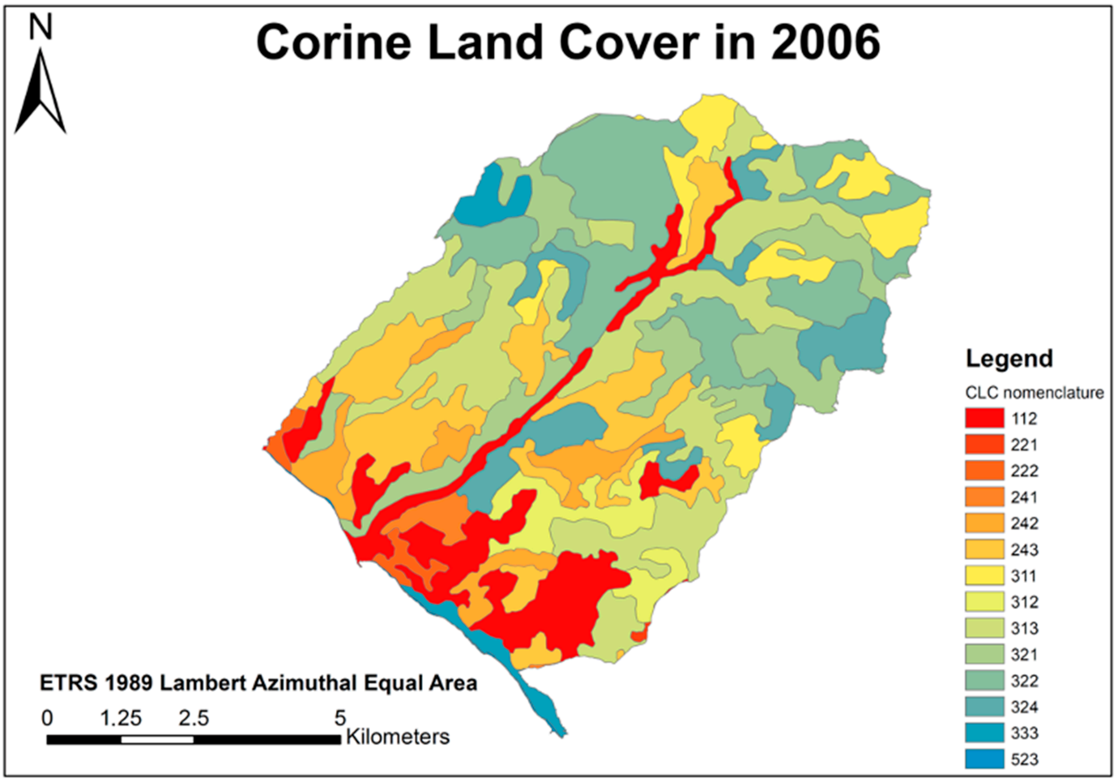

Figure 9. Level 3 CLC designation land uses in the municipality of Ribeira Brava in 2006 (source: authors by ESRI ArcGIS, 2020).

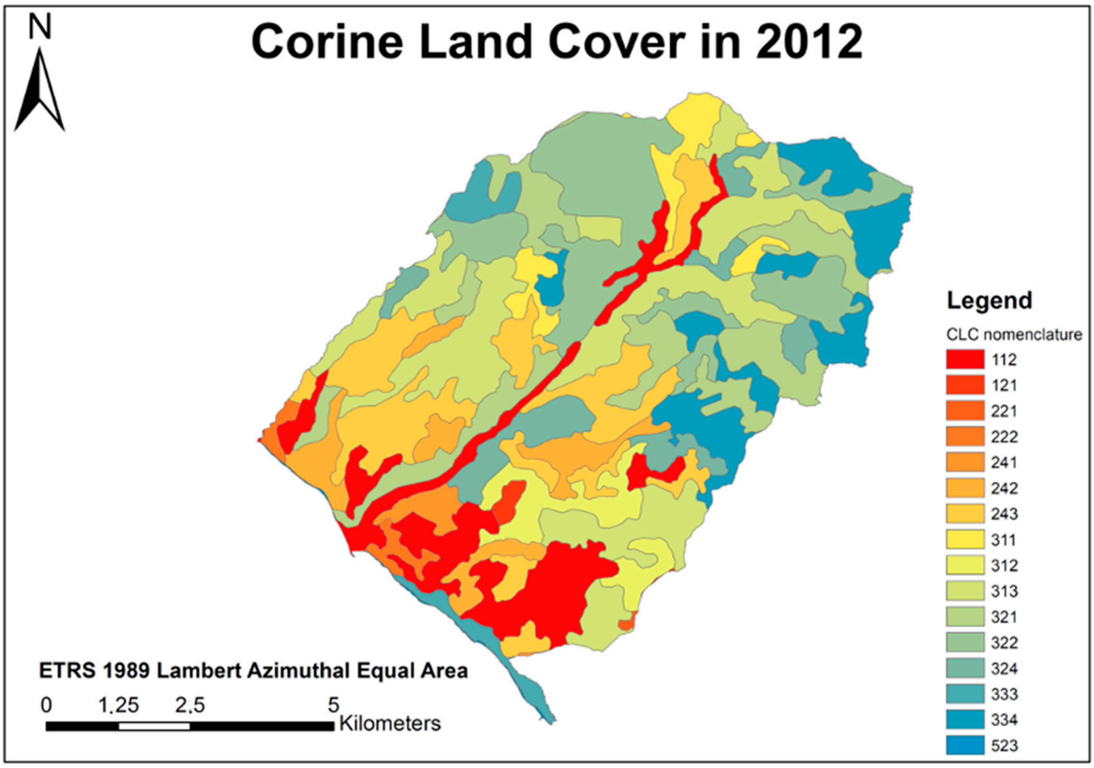

Figure 10. Level 3 CLC designation land uses in the municipality of Ribeira Brava in 2012 (source: authors by ESRI ArcGIS, 2020).

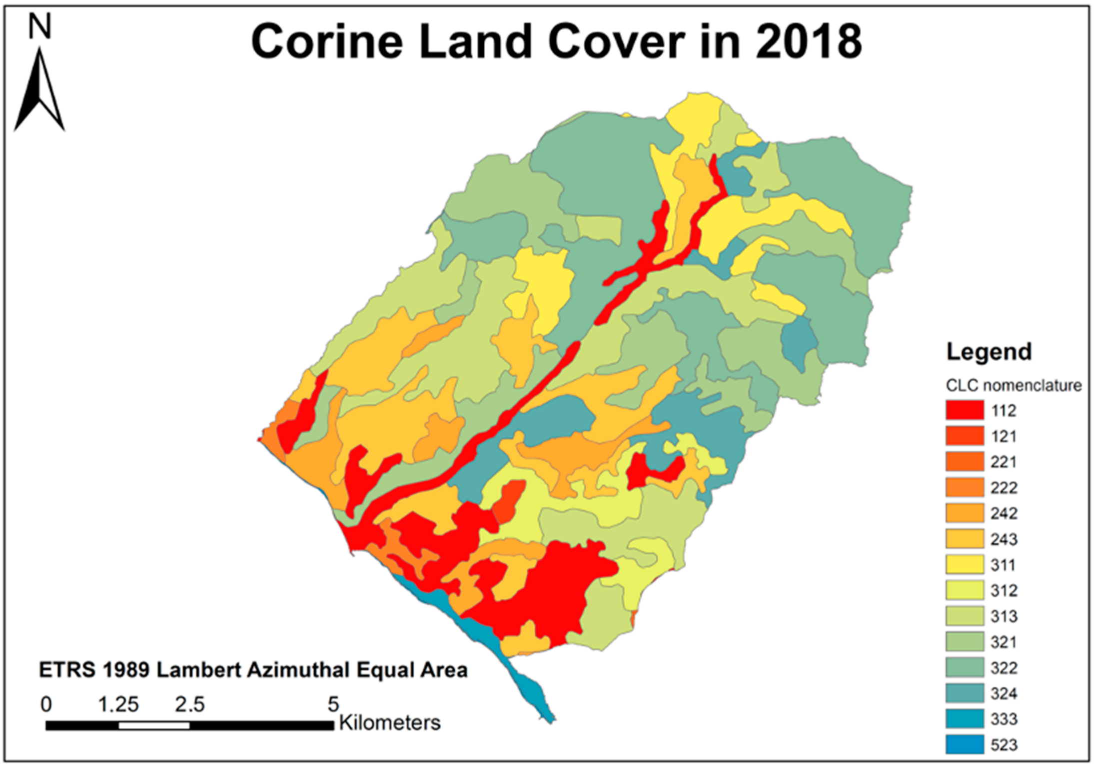

Figure 11. Level 3 CLC designation land uses in the municipality of Ribeira Brava in 2018 (source: authors by ESRI ArcGIS, 2020).

4. Discussion

After applying the methodology previously described, it is possible to analyze each of the classifications according to their respective variation. Class CLC-112 (discontinuous urban fabric surfaces) refers to the class of discontinuous urban fabric, which is assigned when urban structures and associated transport networks, vegetated areas and free surfaces are present and occupy significant surfaces in a discontinuous space pattern [58]. One of the main characteristics is the level of soil permeability, as impermeable areas such as buildings, roads and artificial surface areas vary from 30 to 80% of soil cover [58]. For the case study, the soil permeability for the municipality of Ribeira Brava increased from 10.32% in 1990 to 11.40% in 2012, remaining constant until 2018; the maximum value of the class was 11.79% in 2006. This parameter indicates that there was not a significant increase in the urban fabric, which can be explained by the difficulty of construction due to the irregularity of the land, the distance from the economic center of the island—i.e., Funchal—and the gradual population reduction.

As with the CLC-112 classification (discontinuous urban fabric surfaces), the CLC-121 classification (industrial or commercial units) refers to the implementation of artificial surfaces and with a lower soil absorption capacity. In this sense, this class is assigned to land units that are in industrial or commercial use or serve as public service facilities [58]. In the case of Ribeira Brava, there was an increase from 0.00% in 1990 to 0.39% in 2012, which remained until 2018. Therefore, this indicator suggests that there was only a small increase in the amount of commercial or industrial infrastructure, which was enough to meet local demand. These parameters are very important for the municipality of Ribeira Brava, as it is one of the municipalities in the region that suffer the most from flood events in the entire Madeira Island, so much so that "*this municipality is so called because its valley is crossed by a very large stream in the rainy season, a fact that caused a lot of damage along its 8 km route*" [55]. So, regions with low soil absorption capacity cause rapid saturation to occur and, thus, allow surface runoff [59], leading to the accumulation of water that exceeds the runoff capacity of the urban drainage system. Thus, the entire volume of excess water from the most intense rainfall tends to cause economic and humanitarian damage [60]. Therefore, the analysis of the progress of the CLC-1 classification (artificial surfaces) becomes essential for the implementation of mitigation measures for the impacts of floods in urbanized regions, both from an administrative perspective—e.g., implementation and optimization of the Municipality's Master Development Plan—and from a structural perspective—e.g., construction of detention basins or optimization of the existing drainage system [61].

Regarding the CLC-212 classification (permanently irrigated land), it refers to agricultural plots that are permanently or periodically irrigated, using permanent infrastructure such as irrigation canals, drainage networks and additional irrigation facilities. Furthermore, most of these crops cannot be grown without an artificial water supply [58]. For the municipality under study, this class corresponded to 0.39% of the territory in 1990 and 2000; however, it did not exist as of 2006.

Concerning the CLC-221 classification (vineyards), these are areas planted with vines. Specifically for Madeira Island, it is viewed as a common practice to plant vines without a commercial nature, that is, only for their own consumption. Therefore, this factor justifies the very low percentage of land cover for this class, which increased from 0.00% in 1990 and 2000 to 0.08% in 2006 and 2012 and, finally, reduced to 0.03% in the last analysis carried out in 2018. It is necessary to point out that for such low percentages, the variation may have small procedural errors due to the quality of the satellite images used to obtain each of the classifications.

The CLC-222 classification (fruit trees and berry plantations) corresponds to plots cultivated with fruit trees and shrubs, intended for the production of fruits, including nuts [58]. The planting pattern can include either a single- or mixed-fruit species, both associated with permanent grass surfaces [58]. For the municipality under study, this classification indicates that there was evidence of stabilization in this type of cultivation, as the percentage of soil cover for this activity remained at 1.06% from 1990 to 2000, decreasing slightly to 1.05% in 2006 and maintaining the same index until 2018. As mentioned above, this small percentage variation can only be the product of small procedural lapses.

On the other hand, the CLC-241 classification (annual crops associated with permanent crops) refers to areas cultivated with non-permanent crops—i.e., primarily arable land—associated with permanent crops, such as fruit trees, olive trees or vineyards, in the same region [58]. The analysis of this classification indicates its extinction in the municipality under study, as the percentages remained at 2.43% from 1990 to 2000; however, they reduced to 1.02% in 2006 and 2012 and finally to 0.00% in 2018.

Regarding the CLC-242 classification (complex cultivation), which refers to the development of specific agricultural production in the case of the municipality under study, a percentage value of 3.54% was reported in 1990, which reduced to 3.33% in 2000, then increased to 4.97% in 2006 and 2012, and further increased to 4.99% in 2018.

Finally, we analyzed the last classification that belongs to the CLC-2 class (agricultural areas) found in this study, the CLC-243 classification (land occupied by agriculture). This class refers to areas mainly occupied by agriculture, interspersed with significant natural or semi-natural areas—e.g., forests, shrubs, swamps, bodies of water, mineral outcrops—in a mosaic pattern [58]. The analysis of the data indicates that there was a tendency of percentage decrease for this type of land occupation between 1990 with 14.24% and 2006 with 12.70%. However, there was a small percentage increase in 2018, corresponding to 13.15% of the area of the municipality.

To start the analysis of the CLC-3 class (forests and semi-natural areas), we analyzed the CLC-311 (broad-leaved forest) classification, which deals with the vegetation composed mainly of trees—i.e., including shrubby understory and shrubs—where foliage is predominantly broadleaf species [58]. This classification indicates that this type of vegetation is not predominant in the region, corresponding to 6.88% of the area occupied in 1990 and 2000 and reducing to 6.19% in 2006. In the analysis carried out in 2012, a significant reduction to 3.42% was noted; however, there was also a significant increase in the 2018 study, returning to 6.44% of the area of the municipality under study.

The CLC-312 classification (coniferous forest) refers to vegetation composed mainly of trees, including shrub understory and shrubs, predominantly coniferous species [58]. This classification is also not predominant in the municipality of Ribeira Brava, which varied from 4.25% in 1990 to 4.46% in 2018. This vegetation is located mainly in the higher altitude regions of the municipality, due to the cold boreal climate of the locality.

The CLC-313 classification (mixed forest) corresponds to the vegetation composed mainly of trees, where broadleaf and coniferous species do not predominate [58]. This type of vegetation was predominant in the municipality under study with a percentage value of 21.43% in 1990 and 2000; however, its percentage has been gradually reducing and was recorded as 20.81% in 2006, 18.03% in 2012 and 16.68% in 2018.

Unlike previous forest classifications, CLC-321 (natural grassland) corresponds to grasslands under no or moderate human influence and with low productivity fields. This type of land occupation is often located in areas of rough, uneven terrain and steep slopes, which corresponds precisely to the type of relief in the municipality under study. This type of land occupation has gradually increased, from 10.33% in 1990 and 2000 to 13.45% in 2018.

Another classification that has gradually increased its percentage is CLC-322 (moors and heathland), becoming predominant in the area of the municipality under study. This classification corresponds to the presence of vegetation with low and closed cover, dominated by shrubs and dwarf shrubs—e.g., heather, broom and laburnum. The analysis carried out in 1990 indicated that this classification was present in 16.55% of the total area of the municipality, increasing to 16.22% in 2000 and 2006. As in the previous classifications, in 2012, there was a noticeable reduction in the occupied area, rising to 14.84%. However, in the study carried out in 2018, it is noted that there was a significant recovery of the lost vegetation, which now corresponds to 20.12% and is the predominant vegetation in the area of the municipality under study.

Following the same trend as the previous type of vegetation, the CLC-324 classification (transitional woodland shrub) also showed growth until 2006, with a land-use percentage of 7.46%. However, the 2012 study also suggests a noticeable reduction to 5.37%, and subsequent recovery, increasing to 6.57% in 2018.

Regarding the classification CLC-333 (sparsely vegetated areas) for the municipality under study, there was a constant percentage value between 1990 and 2012 of 2.33%, which subsequently decreased to 1.11% in 2018.

These significant reductions in 2012 and recovery in 2018 can be explained through the classification CLC-334 (burnt areas), which refers to natural woody vegetation affected by recent fires. For the municipality under study, the classification reported a burned area value of 0.00% until the year 2012, which showed a loss of 8.58% of native vegetation in the municipality of Ribeira Brava. This value is the product of a large fire that hit Madeira Island in July 2012, which supposedly stemmed from an environmental crime [62].

Finally, we analyzed the CLC-523 classification (sea and ocean), which corresponds to the seaward zone of the lowest tide limit. For the municipality under study, this classification corresponds to the region of the river mouth of Ribeira Brava, which has depression zones that are flooded by the effects of the tide. The percentages obtained do not vary significantly, from 0.17% in 1990 and 2000 to 0.16% in 2006 and remaining constant until 2018.

From a global view, from 1990 to 2018, it can be concluded that 20.69% of the territory of Ribeira Brava underwent changes. In total, 10.34% of the changes decreased (CLC-212, 222, 241, 243, 311, 313, 333 and 523), while the other 10.35% increased (CLC-112, 121, 221, 242, 312, 321, 322 and 324). More than half of the changes occurred in forests and semi-natural areas (CLC-3), where 4.75% of mixed forests disappeared (CLC-313) and the changes increased by 7.19% regarding shrub and/or herbaceous vegetation association (CLC-32). The latter type of cover performs important ecosystem service functions, especially in pollination processes and in the regulation and retention of water flows [63].

5. Conclusions

The main purpose of the present study was to evaluate the variation in land use and occupation and the regional implications that these changes can cause. Therefore, as shown, the municipality of Ribeira Brava presented stagnation in the growth of its urban fabric and alteration of the predominant vegetation, due to the morphology of this municipality, as can be observed in Figure 2.

The stagnation of the urban fabric has a positive effect, especially regarding the non-aggravation of the effects of extreme climatic phenomena of precipitation, such as the floods and alluviums that occurred in February 2010 [64]. On the other hand, this indicator may denote economic and population stagnation in the region. Therefore, it is evident that it is only possible with the CLC-1 class (artificial surfaces) to carry out various analyses on the municipality under study, both in the economic sphere and in terms of urban and social development.

For the CLC-2 class (agricultural areas), the promising applicability of the methodology for managing agricultural areas and cataloging the main farming activities in the municipality under study is notorious. This indicator can also suggest a change in priority in relation to plantations in the locality, which can change the entire local economic dynamics.

Regarding the CLC-3 class (forests and semi-natural areas), the great potential for handling and preserving forest areas, as well as the inspection of legal activities or the identification of illegal practices of burning or deforestation, is evident. The application of this methodology tends to have even greater relevance in regions of dense forests and with dimensions so accentuated that local quantification becomes unfeasible, as is the case in the Amazon Forest.

Finally, the CLC-5 class (water bodies) was not considered as it has no relevance to the study developed.

In short, through the analysis of land-use change models (land-use changes—LUC), together with practical information on the territory, instructions and guidelines for sustainable development, it is possible to outline the following in relation to the municipality of Ribeira Brava. Changes in land uses are an obvious sign of human impact on the natural world [65,66]. For proper planning, geographical distribution, and administration of the territory, as well as the subsequent implementation of land-use change, variables and natural characteristics such as physiography, slope, relief, soil, and vegetation, among many others, are viewed as essential [65,67].

In addition to what has previously been reported, a lack of planning and information results in the destruction of natural resources, which has a significant negative impact on nearby communities [68–70]. In fact, in these island territories and in this specific case of the municipality of Ribeira Brava, the correct definition and identification of risk areas (while taking into account the domain of land-use planning and management) are critical requirements to prevent and mitigate the damage caused by natural events, as well as hazardous activities [71–73]. Accordingly, this issue is even more relevant in territories with uncontrolled growth [74,75]. This uncontrolled growth has often been associated with the absence of an adequate planning process [74]; we do not have to associate growth only with the number of inhabitants of the aforementioned municipality, which is not the case, but with the infrastructure created from different scopes to serve the local population. As mentioned, built-up areas help to increase the vulnerability of the soil, favoring the possibility of natural disasters [76,77], that is, in cases of erosion or landslides, if we take into account local and territorial characteristics, as well as the increase in waterproofed areas that maximizes the values of surface runoff, as the rainwater drainage systems no longer have adequate response capacities [78,79]. This situation, as previously described, can generate significant problems, affecting the population of the aforementioned municipality of Ribeira Brava, the environment and, consequently, the local economy, meaning that it can lead to a decrease in tourism. Contextually, considering urban and spatial planning criteria, in addition to urban growth-related restraints, namely natural catastrophes, such as those that have already occurred in the recent past in the municipality of Ribeira Brava, the need to establish land-use classes increases [80].

Furthermore, in a manner that is pertinent, the relief can also have an impact on urban expansion and development [81], since it forces the city either to disperse or to become relatively disorganized, leading, ultimately, to urban voids. In this case, it would create a topographic barrier, that is, a natural obstacle to urban expansion; this barrier would, in a certain way, safeguard the fragmentation of natural habitats. In fact, this scenario is often associated with cities that are located in hilly regions, i.e., regions that present a substantial fluctuation in altitude and steep slopes [82]. The change in land uses in the municipality of Ribeira Brava is ultimately significantly influenced by this circumstance. However, regardless of the limitations related to territorial relief, barriers such as the ones previously mentioned would probably enrich this municipality from an environmental perspective, which would enable social and economic growth, as well as the promotion and utilization of endogenous natural resources. Therefore, in this case, it is vital to promote a cooperative relationship between economic activities and the environment, in order to stimulate sustainable growth in this region; in this particular case, due to its unique natural resources, ecosystems and landscapes, there could be enough space to promote sustainable development in this municipality. In addition, the enhancement of agriculture—since there is a strong cultural heritage, not only in Ribeira Brava, but in Madeira Island as a whole, in terms of agriculture, that is emphasized by the existence of multiple typical crops, such as bananas, sugar cane and vines—must be significantly promoted, in line with sustainable development strategies.

Thus, if sustainable development policies are implemented by all concerned parties and the dependent community, they can be measured by the so-called obstacles present in the municipality of Ribeira Brava, the subject of this case study.

As a consequence of this study, it was possible to analyze not only the dynamics of land-use variations in this region, but also the impacts that those changes had for this municipality. Additionally, considering the results obtained through this study, as well as the information empirically obtained from this territory, it became plausible to identify opportunities and restraints regarding Ribeira Brava's sustainable development. In terms of restraints, these can be perceived as challenging, because it is necessary to take into account this municipality's physical spatial dimensions and the difficulties that are associated with promoting a reconversion of land uses. Therefore, a reasonable set of actions that considers the fragile nature of the county, and thus the significant impacts that such policies could have in terms of long-term sustainable development and inhabitants' quality of life, is required from policy makers.

Hence, studies on land-use variation patterns can be considered as crucial to comprehend regional dynamics and trends, and, therefore, to guide decision makers regarding the sustainable development of this region.

As a final consideration, land uses can be understood as another tool that can be used to understand the county by evaluating the past and envisioning the future.

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