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Chapter 2

Dynamics of the Land Use Changes and the Associated Barriers and Opportunities for Sustainable Development on Peripheral and Insular Territories: The Madeira Island (Portugal)

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Abstract

Considering the complex dynamics, patterns, and particularities that peripheral and insular territories/regions present—e.g., as the fragility, they show to achieve a sustainable development and growth—a study that analyzes the land uses of this territories is seen as pivotal to identify barriers and opportunities for a long-term sustained development. Contextually, a general analysis was carried out through case study research methods covering those territorial typologies of the insular territory of Madeira Island, Portugal. The study, which was carried out through GIS mapping tools, enabled us to identify the land use changes in the last decades over the territory—allowing to establish a relation and identification of the associated barriers and opportunities presented by the territories to face the emerging sustainable development challenges. The study reveals the evident limitations of "ultra-peripheral" territories not only by the physical spatial dimensions but also by the difficulty to reconvert land uses. Thus, the main actors and their policies over the territory are even more relevant and need to be conducted in a more reasonable way—considering the fragility of this regions; such actions present higher impact over the territory and over their inhabitants' life's quality standards and finally on the long-term sustainability.

Keywords: insular territories, peripheral regions, land use changes, sustainability, territorial dynamics

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1. Introduction

The need for knowledge and information on the state of our planet's surface and its occupation has boosted several initiatives to study land uses and cover and their patterns and dynamics [1, 2]. Several sets of global or continental land cover data, most of them from the Earth's observation by satellite, were promoted and created, and there is a variety of different mapping standards [2].

The quantity of available products reflects the wide scope of interests. It is important to highlight the Global Land Cover (GLC2000) created for the year 2000 at a global level in Europe, the Pan-European Land Cover Monitoring (PELCOM) based in 1996 images, and the Coordination of Information on the Environment (CORINE) maps at regional and national levels [1].

In Europe, many efforts to quantify a standardized way of the land cover have been done. In this regard, the CORINE Land Cover (CLC) has been created and processed by the EEA based on the guidelines for "land and ecosystems" of the System of Environmental and Economic Accounting (SEEA), and it is used by many of the organizations [3].

Since 2006, in several countries, such as Germany, Austria, the United Kingdom, Sweden, Switzerland, and others, the map is obtained from generalization techniques from national maps with greater detail than the traditional photo satellite interpretation [4]. These different methods conduct to heterogeneity in the land cover maps, which have been a discussion topic [4]; nevertheless, the different ways of producing CORINE maps have been used to analyze soil applications [1].

The land use and land cover maps can play an important role in the balance of the socioeconomic, political, cultural, and environmental factors of a certain territory [5]. In fact, they allow analyzing significant changes in the landscape, study cycles, and trends. Several studies have been conducted in the European territories concerning land uses and their patterns and dynamics; however, in relation to the case of peripheral and insular territories/regions as is the case of the Autonomous Region of Madeira (RAM) (Portuguese Island), such typology of studies has not been carried out—increasing the relevance of the work toward a better understanding of the territorial dynamics, barriers, and opportunities for a sustainable growth and development.

Contextually, insular territories are affected by their geographic position, which gives them a high degree of isolation and their small dimensions (spatial constraints), and so they represent a specific challenge and fragility in the face of changes [6]. This typology of territory is affected directly and indirectly by the proximity to the sea and is considered a coastal territory.

In this sense, the territorial planning is a fundamental instrument to attribute conditions of prosperity to its inhabitants and consequently to future generations, promoting the mitigation of social inequalities and spatial imbalances, as well as a catalyst tool for sustainable development. In this context, the sustainable development allows not only to respond to the problems discussed above but also to create opportunities and more competitive territories.

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Facing today's society and its demands, territorial planning must inevitably consider its future, and it should be constructed in an organized way to satisfy the public needs and not be dictated by a casuistic and uncontrolled evolution from the point of political and/or individual interests. Thus, sustainable development and growth are undoubtedly the main concerns and objectives of the regional territories [7–10].

With the Brundtland report [11], the sustainability has become a worldwide concern, since we are stakeholders in the process. Issues like the meaning or how to measure sustainability, which strategies should be implemented, have been studied [12, 13]. Although there is a high interrelation between the economic, social, and environmental dimensions, in practice they are considered separately, which can lead to non-sustainable trends [12]. Limited land and water resources make the insular territories a case, where the harmonization of the different dimensions of sustainability is a challenging process since it can lead, for example, to the degradation of the natural habitats [12, 14].

The overall objective of this study is to analyze and assess the land use changes in peripheral or "ultra-peripheral" and insular territories—i.e., islands, through a practical approach to a case study—the Madeira Island, Portugal. Moreover, through the understanding of the land use changes and consequently the territorial dynamics and tendencies, barriers and opportunities for a sustainable growth and development will be explored and addressed.

2. Material and methods

The present study is based essentially on CORINE Land Cover (CLC). The CLC is a vector map with a scale of 1:100000, a minimum cartographic unit (MCU) of 25 ha, and a geometric accuracy better than 100 m. It maps homogeneous landscape patterns, i.e., more than 75% of the pattern has the characteristics of a given class from the nomenclature. This nomenclature is a three-level hierarchical classification system and has 44 classes at the third and most detailed level (**Table 1**). To deal with areas smaller than 25 ha, a set of generalization rules were defined [15].

In this regard, the years of 1990, 2000, 2006, and 2012 were analyzed through direct and indirect tools and methods. Thus, exploratory tools were used as is the case of GIS tools, CLC, or the site analysis conducted by the authors. Moreover, a literature review has been performed in order to properly describe, discuss, and understand the obtained results—the land use change dynamics in Madeira Island.

Nevertheless, later in the present chapter, these methods will be exposed and further developed.

2.1. Case study: the Madeira Island

The Madeira Archipelago is located in the North Atlantic Ocean. Covering an area of 802 km^2, the Madeira Archipelago is composed of the following islands: Madeira (742 km^2) (**Figure 1**),

Level 1	Level 2	Level 3
1 Artificial surfaces	11 Urban fabric	111 Continuous urban fabric
		112 Discontinuous urban fabric
	12 Industrial, commercial, and transport units	121 Industrial or commercial units
		122 Road and rail networks and associated land
		123 Port areas
		124 Airports
	13 Mine, dump, and construction sites	131 Mineral extraction sites
		132 Dump sites
		133 Construction sites
	14 Artificially and nonagriculturally vegetated areas	141 Green urban areas
		142 Sport and leisure facilities
2 Agricultural areas	21 Arable land	211 Nonirrigated arable land
		212 Permanently irrigated land
		213 Rice fields
	22 Permanent crops	221 Vineyards
		222 Fruit trees and berry plantations
		223 Olive groves
	23 Pastures	231 Pastures
	24 Heterogeneous agricultural areas	241 Annual crops associated with permanent crops
		242 Complex cultivation patterns
		243 Land principally occupied by agriculture, with significant areas of natural vegetation
		244 Agroforestry areas
3 Forest and seminatural areas	31 Forests	311 Broad-leaved forest
		312 Coniferous forest
		313 Mixed forest
	32 Scrub and/or herbaceous vegetation associations	321 Natural grasslands
		322 Moors and heathland
		323 Sclerophyllous vegetation
		324 Transitional woodland shrub
	33 Open spaces with little or no vegetation	331 Beaches, dunes, and sands
		332 Bare rocks
		333 Sparsely vegetated areas
		334 Burned areas
		335 Glaciers and perpetual snow

Level 1	Level 2	Level 3
4 Wetlands	41 Inland wetlands	411 Inland marshes
		412 Peat bogs
	42 Maritime wetlands	421 Salt marshes
		422 Salines
		423 Intertidal flats
5 Water bodies	51 Inland waters	511 Water courses
		512 Water bodies
	52 Marine waters	521 Coastal lagoons
		522 Estuaries
		523 Sea and ocean

Source: http://www.igeo.pt/gdr/pdf/CLC2006_nomenclature_addendum.pdf

Table 1. CLC nomenclature.

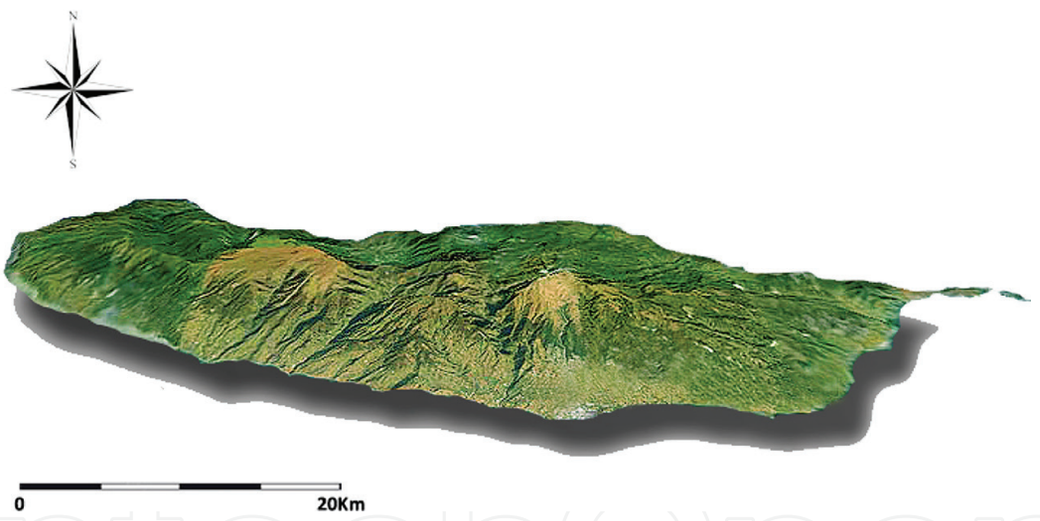


Figure 1. Madeira Archipelago—Madeira Island, Portugal.

Porto Santo (43 km^2), Desertas (14 km^2), and Selvagens (3 km^2). The main features of Madeira Island will be exposed in the following (**Table 2**).

Madeira Archipelago presents particular conditions for the occurrence of potential natural disasters—i.e., wildfires; the high exposition of urban areas to natural disasters (rugged terrain promotes vertical impulsion of maritime tropical air masses coming from the southwest); free surface flow's fast convergence into the river channels and the high drainage density levels (floods); deeply changed volcanic geological substrate and consequently less permeable; and embedded V-shaped valleys, enabling greater interaction between landslides and river patterns, among many other extreme phenomena [19–21]. Also, the specific and rough geomorphology of Madeira Island occupies most of the land cover—i.e., 120 watersheds occupying almost the entire territory (741 km^2) correspond to 40% of the total island surface [21, 23].

Physical features	
Average altitude	646 m
Highest peak	Pico Ruivo (1862 m)
Average slope	56%
Perimeter	177.3 km
Area	742 km^2
Predominant soils	Andosols (42%)
Average daily temperature:	23 °C
Maximum (August)	5.4 °C
Minimal (February)	
Prevailing winds:	N-NE
Direction	30 km/h (S-SW)
Maximum average velocity (and direction)	
Weighted average annual precipitation	1628 mm
Population	256,424 (inhabitants)

Table 2. Main features of Madeira Island [16–22].

Moreover, the high human pressure under the territory should be also considered. In fact, in these particular territories, human activities and densities are more critical for the success or failure of a sustainable development and growth—considering the limitations presented by these "ultra-peripheral" territories.

3. Results and discussion

The results come from the analysis of the land use changes for RAM in the years 1990, 2000, 2006, and 2012. The results will be exposed through the graphs and tables. This typology of results exposed allows to extract the most relevant information and to characterize the evolution of land use based on the 44 uses of the soil determined by CLC. The information is organized as presented from **Tables 3–7**, in percentage.

At **Table 3**, it is possible to analyze the behavior of the artificial surfaces; by far the highest values have been found on the land use 112 (discontinuous urban fabric), which also increased over the years (where the tendency is located). The second most representative land use, considering artificial surfaces, is for the uses 121, 124, and 142 (industrial or commercial units, airports, and sport and leisure facilities)—presenting close values and oscillation patterns among them. The policies of urban and infrastructural expansion carried out by the successive autonomic governments for the Madeira Island territory may explain these results. For example, the case of the touristic *boom* that the region as felt in the last few decades was lead

Code		111	112	121	122	123	124	131	132	133	141	142
Year	1990	0.21	**9.16**	0.10	0.00	0.06	0.22	0.00	0.00	0.06	0.05	0.00
	2000	0.22	**12.76**	0.22	0.04	0.08	0.26	0.00	0.04	0.10	0.05	0.22
	2006	0.31	**13.16**	0.32	0.04	0.08	0.26	0.15	0.08	0.09	0.01	0.33
	2012	0.31	**13.20**	0.35	0.04	0.08	0.26	0.15	0.06	0.01	0.01	0.36

Bold identifies the higher value founded.

Table 3. Artificial surfaces.

Code		211	212	221	222	231	241	242	243	244
Year	1990	0.16	0.49	0.11	0.74	0.94	0.90	4.83	**10.68**	0.25
	2000	0.16	0.49	0.11	0.46	0.91	0.90	3.02	**9.47**	0.47
	2006	0.04	0.04	0.18	0.31	0.32	0.23	2.80	**10.05**	0.00
	2012	0.04	0.04	0.21	0.31	0.32	0.23	2.77	**10.08**	0.00

Bold identifies the higher value founded.

Table 4. Agricultural areas.

Code		311	312	313	321	322	324	331	332	333	334
Year	1990	**20.89**	5.90	14.24	8.34	10.50	6.56	0.11	0.07	1.91	0.00
	2000	**20.67**	5.74	13.99	8.22	10.41	6.33	0.11	0.07	1.91	0.06
	2006	**20.82**	5.29	13.14	9.07	10.77	6.25	0.11	1.52	1.75	0.24
	2012	**19.27**	4.72	11.98	8.70	9.06	5.58	0.11	1.52	1.75	6.23

Bold identifies the higher value founded.

Table 5. Forest and seminatural areas.

Code		523
Year	1990	**2.55**
	2000	2.52
	2006	2.25
	2012	2.25

Bold identifies the higher value founded.

Table 6. Water bodies.

Level		Artificial surfaces	Agricultural areas	Forest and seminatural areas	Water bodies
Year	1990	9.86	19.10	**68.52**	2.55
	2000	13.99	15.99	**67.51**	2.52
	2006	14.83	13.97	**68.96**	2.25
	2012	14.83	14.00	**68.92**	2.25

Bold identifies the higher value founded.

Table 7. Evolution of the occupied surfaces, according to levels (in the period 1990–2012).

to the actors to carry unsustainable politics of construction—jeopardizing, in many occasions, the natural and unique heritage of the island. In fact, this phenomenon not only occurs in this particular insular territory; the same scenario has been described in the Canary Islands [24, 25]—or even generalizing further, we can pick some high touristic demand territory, and, unfortunately, similar results are easily found [26–30].

Through the analysis of **Table 4**, it is possible to verify the behavior of the agricultural areas; once again the highest values have been clearly found in one single land use, the 243—land principally occupied by agriculture, with significant areas of natural vegetation—which as decreased over the years (with an exception for the period of 2000 where it has decreased and recovered back in 2006). The second most representative land uses, considering artificial surfaces, is for the land use 242 (complex cultivation patterns), followed closely by the land uses 231, 241, and 222 (pastures, annual crops associated with permanent crops, and fruit trees and berry plantations). Those outcomes, as is the example of the decrease of the surface occupied by agriculture with significant natural vegetation, are not unexpected. Once again the territorial governance may play a key role in these results once the politics carried out toward the preservation of natural vegetation and traditional agriculture are not so profitable for the land owners, contrary to the reconversion of the land for a different use or agricultural technique—tendency that seems to be dangerous not only for the local heritage preservation as well as for a long-term sustainable development and growth.

In **Table 5** the behavior of the forest and seminatural areas is shown, with the highest values found in one land use, the 311—broad-leaved forest—which decreased over the years (with some oscillations in the 2000–2006 period). The second most representative land uses, considering artificial surfaces, is for the land use 313 (beaches, dunes, sands), followed closely by the land uses 322 and 321 (moors and heathland and natural grasslands). Here, the change of positions—in the period of 2006–2012—of the land use 324 (transitional woodland-shrub) replaced by the land use 334 (burned areas) should be highlighted; this results may be explained by the natural events as wildfires occur in the island—i.e., in fact, in 2016 wildfire events occurred once again in Madeira Island consuming several hectares of natural vegetation, agricultural areas, and urban areas leading to numbers that are even getting worst in future studies related to land use changes in Madeira Island. In this regard, the high values of the land use 313 (beaches, dunes, sands) are expected—considering the territorial features (island). In fact, where could be identified a barrier—once this use typology practically impossible to reconvert; nevertheless, and analyzed from another perspective, there is an opportunity to develop a touristic sustainable activity over this land use.

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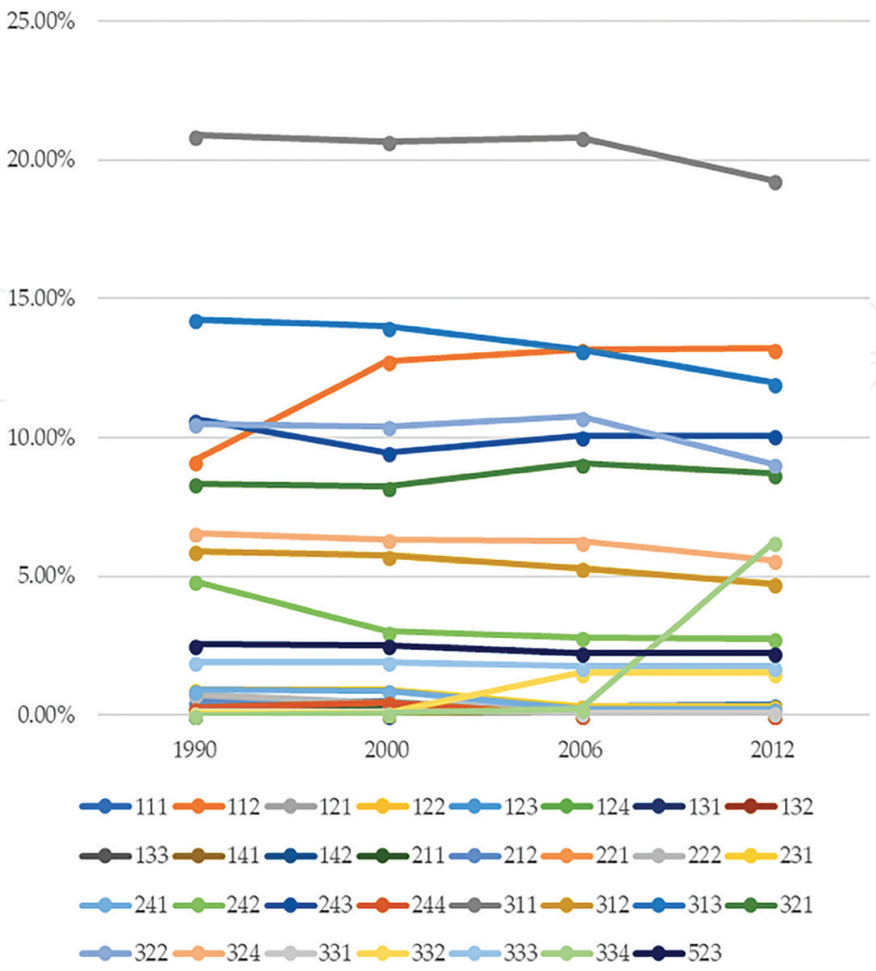


Figure 2. Evolution of the land cover through the years.

Finally, the land uses regarding water bodies have decreased over the last decades; once again expansionary and unsustainable politics may be at the core of the answer. In **Figure 2**, it is possible to verify that in most of the cases there is stability in the land uses. However, the land use 334 (burned areas), which has significantly increased, should be highlighted, within the last decade, and consequently the land use 311 (broad-leaved forest) has decreased. Also, the increases of the land uses 112 and 322 (discontinuous urban fabric and moors and heathland) should be highlighted.

In **Table 7**, the land use changes over the last decades according to levels 1, 2, 3, and 5 (artificial surfaces, agricultural areas, forests and seminatural areas, and water bodies) are presented. By far, the most representative level is the third (forests and seminatural areas), followed by the artificial surfaces (1), which became more representative in the last years in Madeira Island territory than the land use 2 (agricultural areas).

3.1. Barriers and opportunities

The changes in the land use could be understood as a direct manifestation of human activity over natural environments [31, 32]. Therefore, the natural factors and features—i.e., geomorphology, slope, relief, soil, and vegetation, among many others— are critical for the proper organization

and distribution of the territory and their consequent land uses [31]. The lack of knowledge aligned with an existence of planning conducts to the destruction of the natural resources causing relevant (negative) impact on the local communities [33]. Thus, the proper identification and defining of risk areas—considering the planning and territorial management—are pivotal conditions for the prevention and minimization of the damages resulting from the phenomena and dangerous activities [34]. The uncontrolled growth (due to the lack of well-planning process) to built-up areas contributes to increasing the soil vulnerability and increasing the risk of natural disasters [35, 36], as is the case of erosion or landslides [37]—considering the local geomorphic features. In this regard, the urban expansion toward topographically "more" inclined and geologically unstable ground can cause problems and affect the population, the environment, and the local economy. The slope is assumed to be fundamental for the occurrence of slope movements, mainly due to the higher slope and the greater influence of gravity forces on the existing materials in the slopes that, if they are fragile, easily will disintegrate and move along the slope—which is their case in RAM [38]. Therefore, and considering the geomorphological risks, the slope assumes the main role, since it interacts with and for the erosion increasing in a geomorphological context and in the lithology allowing to define critical slopes for landslides—even in the vegetal cover ground, eliminating natural resources of the island [39]. The definition of land uses consistent with the risk degree that characterizes it and the prohibition or limitation to the urban expansion in the unstable areas are some of the options pointed out by Zêzere [37] to avoid such risks. In fact, the crossing of the constraints to urban growth with risk areas leads to the determination of land suitability for each category of use and respective infrastructure implementation. The limitation groups lead to the analysis of the urban land use capacity at the level of the existing one and at the level of areas of urban expansion (urbanizable land), consolidation, and reconversion [39–41]. Contextually, it is important to define classes and levels for specific land uses, based on urban and spatial planning criteria as well as in accordance with urban growth limitations, including the possibility of occurrence of natural hazards and disasters in specific areas [39].

On the other hand, the relief could also influence the urban growth and development [42]—once it forces the city to grow in a dispersed or apparently disorganized way, creating urban voids. In this case, it works as a topographical barrier and constitutes a natural element of obstruction to the urban expansion and as a barrier protecting (somehow) the fragmentation of the natural habitats. Such phenomenon is more relevant in cities located in hilly areas where the variation of altitude is large and there are steep slopes. Thus, the land uses of Madeira Island have been assessed from different perspectives and methods at RAM according to the abovementioned; in fact, the geomorphology of the territory strongly affects its development and growth.

Nevertheless, despite all the limitations inherent to the territorial relief, such topographic barriers at RAM will value the environmental dimension—considering as fundamental in a perspective of social and economic well-being, promoting the full exploitation of the values and endogenous natural resources. For this, the relationship between the economic activities and biodiversity and nature conservation is strongly influenced, namely, by the *unique fauna* and *flora* of the island as well as their ecosystems, natural landscapes, and humanized landscapes; in fact, these factors could also be seen as opportunities to promote sustainable development.

The valorization of the agricultural heritage of RAM (despite the stagnation of land use for agriculture) should be preserved and protected in a sustainable way; once in Madeira Island, there are several typical crops—i.e., banana, sugarcane, and vineyards, among many others.

In this way, and if sustainable development policy will carry out all the involved actors and depending population, it could be valued by the so-called barriers existing in this "ultra-peripheral" territory.

4. Final remarks

Through the present study, it is possible to understand the impact of the land use changes and their dynamics on the specific insular territory. Also, throughout the analyses of the land use change patterns along with empirical knowledge of the territory, barriers and opportunities for a sustainable development and growth have been identified. Moreover, the limitations of such "ultra-peripheral" territories are evident, not only by the physical spatial dimensions presented but also by the difficulty to proceed to the reconversion of the uses. Considering such remarks and the particularity of these territories, the main actors/decision-makers and their policies and action over the territory are even more relevant and need to be conducted in a more reasonable way—considering the fragility of this region; such policies and actions present higher impact on the territory as well as on their inhabitants' life's quality standards and finally on the long-term sustainable development.

Therefore, the study of the land use change patterns is seen as pivotal to understand the dynamics and tendencies of these territories as well as to provide clues for the main actors to where the efforts toward a sustainable development and growth should be placed.

As the final remarks, the land uses could be understood as another tool for the knowledge of the territory—assessing the past and envisioning the future.

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