LAND USE / LAND COVER CHANGE DETECTION AND THE IMPACTS OF TERRITORIAL DEVELOPMENT PLANS ON THE CHANGE IN MUĞLA

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ABSTRACT

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Forests play a vital role in balancing atmospheric carbon dioxide and thereby diminish the pace of global climate change. Agriculture fights against extreme poverty and feeds a projected 9.7 billion people world population by 2050. Although these natural and agricultural lands are so important for now and the future, they have been shrinking all around the world, especially in developing countries. As in some other developing countries, many metropolitan cities face Land Use (LU)/Land Cover (LC) change in Turkey. Muğla is one of the critical cases because of its unprecedented natural assets leading the development of the tourism and the mining sectors. This thesis aims to analyze the spatio-temporal changes in LU/LC elements from 1995 to 2021 and the possible impacts of the current Territorial Development Plan on these changes in Muğla. Firstly, satellite images for change analysis are classified by the Maximum Likelihood Estimation with five classes which are forest, sparse vegetation, water bodies, agriculture, and built environment. Then, thematic maps representing LU/LC change from 1995 to 2015 in Muğla are created. To observe the possible impacts of the current Territorial Development Plan, a satellite image in 2021 is classified, and a thematic map representing the LU/LC change from 2005 to 2021 is generated. According to the thematic maps, 11 Regions of Interest (ROIs) are determined from where the changes are seen the most. Lastly, the Territorial Development Plan in the ROIs is examined. Results show that Muğla has experienced a serious deterioration in land cover elements, even with an increasing pace. An important reason for these changes is that the majority of the LU/LC change is determined by the current Territorial Development Plan. Moreover, the plan has gaps in the representation of ongoing mining activities. Indeed, land cover elements should be conserved through both spatial allocations and strong planning decisions at any scale for sustainable futures.

Keywords: Land Use Land Cover, Change Detection, Maximum Likelihood, Territorial Development Plan, Muğla

ÖZ

MUĞLA'DAKİ ARAZİ ÖRTÜSÜ / ARAZİ KULLANIMI DEĞİŞİMİ TESPİTİ VE MEVCUT ÇEVRE DÜZENİ PLANININ DEĞİŞİM ÜZERİNDEKİ ETKİSİ

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Ormanlar, atmosferik karbondioksiti dengeleyerek küresel iklim değişikliğini yavaşlatma konusunda hayati önem taşır. Öte yandan tarım alanları 2050 yılına kadar öngörülen 9,7 milyarlık dünya nüfusunu besleyebilme kapasitesiyle aşırı yoksullukla mücadele eder. Bu varlıklar bugün ve gelecek için bu denli önemli olmasına rağmen, başta gelişmekte olan ülkelerde olmak üzere tüm dünyada küçülme eğilimi göstermektedir. Türkiye'de de birçok büyükşehir, Arazi Örtüsü (AÖ)/Arazi Kullanımı (AK) değişikliği ile karşı karşıyadır. Muğla, eşsiz doğal kaynaklarıyla turizm ve maden sektörlerinin odak noktası haline gelmiş ve dolayısıyla değişimin gözlemlendiği kritik örneklerden biri olmuştur. Bu tez, Muğla'da, 1995'ten 2021'e kadar AÖ/AK elemanlarındaki mekansal-zamansal değişiklikleri ve mevcut Çevre Düzeni Planı'nın bu değişiklikler üzerindeki olası etkilerini analiz etmeyi amaçlamaktadır. İlk olarak değişim analizinin yapılacağı uydu görüntüleri En Çok Olabilirlik yöntemiyle sınıflandırılmıştır. Sınıflandırmada, orman, seyrek bitki örtüsü, su, tarım ve yapılı çevre olmak üzere beş sınıf kullanılmıştır. Daha sonra Muğla'da 1995'ten 2015'e kadar AÖ/AK değişimini gösteren tematik haritalar oluşturulmuştur. Ardından, mevcut Çevre Düzeni Planı’nın olası etkilerini gözlemlemek için 2005'ten 2021'e AÖ/AK değişimini temsil eden tematik harita oluşturulmuştur. Tematik haritalara göre, değişikliklerin en çok görüldüğü bölgelerden 11 ilgi bölgesi (ROI) belirlenmiştir. Son olarak, ROI'lerdeki Çevre Düzeni Planları incelenmiştir. Sonuç olarak, Muğla'nın artan bir hızla arazi örtüsü elemanlarını kaybettiği görülmektedir. AÖ/AK değişikliklerinin çoğunun mevcut Çevre Düzeni Planı’nda belirlenmiş olduğu söylenebilir. Öte yandan, devam eden madencilik faaliyetlerinin planda yansıtılmadığı görülmektedir. Sürdürülebilir bir gelecek için stratejik planlardan bireysel projelere kadar her düzeyde, güçlü plan hükümleri ve mekansal kararlar ile arazi örtüsü elemanları korunmalıdır.

Anahtar Kelimeler: Arazi Örtüsü Arazi Kullanımı Değişimi, En Çok Olabilirlik, Çevre Düzeni Planı, Muğla

To the Earth which is always generous to us

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ABBREVIATIONS

LU/LC	Land Use/Land Cover
ROI	Region of Interest
MLE	Maximum Likelihood Estimation
ÖÇKB	Özel Çevre Koruma Bölgesi
ML	Machine Learning
AI	Artificial Intelligence
CNN	Convolutional Neural Networks
ANN	Artificial Neural Networks

CHAPTER 1

INTRODUCTION

Since the settled life began, people have been assigning different meanings to land and valuing it in various ways. The land has been evaluated not only with the quality or properties of its soil but also with its environment. Whenever the economic value of the land is greater than its cover or use, then the land changes. The urbanization of agricultural lands on the periphery of cities or the replacement of the forest cover by large mining activities have been among the commonly seen outcomes. Despite all, in today's conditions, to find solutions to global problems such as climate change and scarcity, it is of great importance to protect forests and agricultural lands. Forest plays a vital role in balancing atmospheric carbon dioxide and thereby diminishing the pace of global climate change (Negassa et al., 2020). The conservation of agricultural lands, on the other hand, is vital to fight against extreme poverty and feed a projected 9.7 billion people world population by 2050. Recent findings show that improvements in the agricultural sector are two to four times more influential compared to other sectors for increasing the household income in the poorest countries (Agriculture and Food, 2020).

Although natural and agricultural lands are so important for now and the future, these areas are steadily being shrinking all around the world, especially in developing countries. One to two million hectares of agricultural land are transformed into housing, industry, infrastructure, and recreation every year in developing countries (Alfiky et al., 2012). On the other hand, forest areas declined by 3% from 1990 to 2015, with approximately 10 million hectares each year (Keenan et al. 2015). From the existing LU/LC classes, the forest is the most threatened by anthropogenic driven deforestation (Fokeng et al. 2019).

As a developing country, many metropolitan cities face LU/LC change in Turkey. Muğla is one of the critical cases because of its natural resources that allow the development of the tourism and mining sector.

In this thesis, the LU/LC change in Muğla is detected, the areas where the change is seen the most are examined, and the impacts of the current Territorial Development Plan in these areas are discussed. The first section covers the problem statement by discussing why Muğla is a problematic case in terms of LU/LC change thereby being the subject of this thesis. In the second section, the aims of the thesis and the research questions are presented. In the third section, the two-pronged approach is put forward as the remote sensing approach which is related to the detection of LU/LC change, and the planning approach which is a discussion of the possible impacts of the current Territorial Development Plan. The fourth section consists of the contribution of the thesis to the current literature. Finally, the organization of the thesis is stated in the last section.

1.1 Problem Statement

Muğla, which contains well-known sea tourism districts such as Bodrum and Marmaris, has become the focal point of the tourism sector. The increasing popularity and demand have increased supply. Tourism accommodation establishments in Turkey must obtain a tourism operation certificate from the ministry within 1 year after obtaining a working license. The number of establishments that obtained tourism operation certificates between 1990-2021 and the number of rooms and beds in these establishments is given in Table 1. The table also shows the number of rooms and the beds per establishment.

Table 1 Tourism Operation Licensed in Muğla (Adopted from *Yearly Statistics,* 2022)

	Establishment	**Room**	**Bed**	***Room / Establishment***	***Bed / Establishment***
1990	156	9,207	19,741	59	127
1991	185	12,525	26,685	68	144
1992	208	14,438	30,589	69	147
1993	227	15,795	33,260	70	147
1994	256	18,401	39,112	72	153
1995	283	-	44,967	-	159
1996	297	22,624	47,902	76	161
1997	304	23,072	48,780	76	160
1998	300	22,732	48,080	76	160
1999	296	23,243	49,362	79	167
2000	275	22,768	48,239	83	175
2001	315	26,962	56,668	86	180
2002	355	30,042	63,372	85	179
2003	388	31,563	66,287	81	171
2004	401	34,051	72,047	85	180
2005	410	36,347	77,332	89	189
2006	396	37,432	80,422	95	203
2007	372	36,097	77,932	97	209
2008	372	37,654	80,980	101	218
2009	378	40,559	87,130	107	231
2010	380	41,188	88,479	108	233
2011	384	42,458	90,163	111	235
2012	376	42,741	90,947	114	242
2013	365	43,740	93,016	120	255
2014	380	48,240	102,806	127	271
2015	393	49,901	106,401	127	271
2016	397	51,146	109,238	129	275
2017	398	51,923	111,178	130	279
2018	403	52,198	111,593	130	277
2019	404	50,988	108,765	126	269
2020	412	51,316	109,388	125	266
2021	423	51,858	110,653	123	262

As can be seen from Table 1, the number of tourism accommodation establishments has more than doubled since 1990. Moreover, it can be deduced that the extent of the accommodations is getting larger over years, regarding the increase in the number of rooms and beds per establishment. It is very important to determine and evaluate the effects of the increasing tourism supply on the environment, since unorganized and uncontrolled development may cause destruction of the natural environment, deterioration of the landscape, air, water, and soil pollution threatening public health (Gürkan Kaya et al., 2011).

On the other hand, Muğla is one of the leading provinces in Turkey in the mining sector, especially in marble production (MTA, 2010). Yatağan, Milas, Kavaklıdere are rich in mining resources, and thereby quite active in the sector (Aras & Gencer, 2011; Bouchal et al., 2017). After 1990, marble production has gained speed in Muğla. In addition to the domestic commercial capacity of 1 billion Turkish Liras, 470 million USD of exports were generated between 2008 and 2017 in the marble sector in Muğla (Güney, 2018). However, the marble quarries in Muğla work with an average efficiency of 7-10%, that is, approximately 10 m3 of land is worn out for 1 m3 of marble production (Özağaç Gedik, 2019). Besides, due to the stepped-hard surfaces resulting from the marble production activities, there is no suitable environment for planting. In addition, due to the complete change in the land structure, the restoration process, that is, creating the same ecosystem, is not possible. For this reason, these areas can only be regained by reclamation activities from different types of usage (Erarslan, 2014). Therefore, it is critically important to ensure the balance between protection and use. If the mining process is not managed well, the adverse effects on biodiversity, pollution of underground and surface waters, soil and environmental effects such as erosion may observe (Karapınar, 2013; Ertuğrul, 2010).

The most important reason why the increase in the built environment in Muğla poses a great threat is that Muğla hosts valuable ecological flora and fertile agricultural lands because of its mild Mediterranean climate and high quality of the soil. According to the 2015 - 2019 Strategic Plan reported by Muğla Municipality (2014), Muğla constitutes 3.4% of Turkey's vegetable production and 2.8% of fruit production with first place in almond production in Turkey. Furthermore, Muğla is rich in biodiversity. To protect the endemic species, it hosts 5 of Turkey's 16 Special Environmental Protection Areas with 296 hectares in total (Gökmen, 2018). However, while protecting these precious areas is an important step, the surroundings should also be considered. According to Turner and Gardner (2015), nature-protected areas are part of broader ecosystems, and changes in land use outside of protected areas can endanger biodiversity by disrupting ecological processes.

1.2 Aims and Research Questions of the Thesis

The thesis aims to analyze the spatio-temporal changes in the land cover elements and the possible impacts of the current Territorial Development Plan approved in 2011 on these changes in Muğla. To achieve this aim, three research questions are put forward to direct the study.

The first question is: *"To what extent have the land cover elements of Muğla decreased or increased since 1995?"*. The answer to this question will reveal the dimensions of the change. There could be three scenarios. The first one is that a little or no change through the years is observed. This will show that the authorities in Muğla present a serious conservative approach for the sake of valuable farmlands and the natural ecosystem. The second scenario is that land cover elements give place to the land use elements. This is a more common practice in the last decades of Turkey because of the growing economic sector of construction. The last case is that land cover elements have increased. In this case, regeneration of land cover is encountered, with the abandonment of previously used lands. Although this scenario can be observed locally, it is unrealistic for Muğla province in general. Land use to land cover change is positive for nature, however, it is almost impossible for these areas to fully regain their initial form. To conclude, the second scenario seems like the worst one, and if Muğla is in the second scenario, the severity must be analyzed to impel the decision-makers.

The second research question is "*If there has been a decrease or increase in the land cover elements in Muğla, where are these changes seen?*". This one is a geospatial question whose answer will lead decision-makers to prioritize their decisions. To create reasonable plans and actions, it is very important to determine the prior intervention areas. Analyzers scanning the thematic map of land cover changes may find the patterns of the most affected areas. For example, they can deduce that the farmlands alongside the sea having slight slopes are mostly transformed into built-up areas. Hence, they can preserve directly these areas to prevent further changes and they can find other lands with similar patterns to conserve with more rigid policies (Abebe et al., 2019; Armenteras et al., 2019; Tolessa et al., 2017; Yan et al., 2016).

The last research question is as follows: *"If there has been a decrease or increase in the land cover elements, does the current Territorial Development Plan have an impact on them or have these areas changed unplanned?".* This question can be answered depending on the first two research questions. Because the areas of the changes will be compared with the decisions of the current Territorial Development Plan and the legality will be questioned whether the developments are planned or not. The importance of the question is investigating the planning and environment by revealing how the LU/LC change studies are used in planning practices and also the legal basis of the developments in Muğla.

1.3 The Approach of the Thesis

The thesis has two approaches as remote sensing and planning. The remote sensing approach consists of LU/LC change detection from satellite imagery, while the planning approach is examining LU/LC changes and the impacts of the Territorial Development Plan.

1.3.1 Remote Sensing Approach

There are several ways to observe LU/LC changes. To collect data, field observations and remote sensing imagery from drones, planes, and satellites are the main data sources. While processing the data, there are two approaches: manual or automatic. To find the best practice, time, effort, cost, and accuracy are key criteria. Field observations could produce accurate information, but the opportunity cost of doing that is too high. It takes too much effort and time which risks the collected information to be out-of-date as lands are too dynamic for changes. Thus, utilizing remote sensing images from drones, planes or satellites would be more effective. This time, the same optimization problem occurs in manually digitizing the LU/LC elements and automatically detecting them by machine learning algorithms. Still, the manual approach is cumbersome and the work quality is subjected to an operator. Furthermore, even with the same operator, the variations in the results are inevitable due to human capabilities (García-Pedrero et al., 2017). On the other hand, automatic classification methods produce highly precise and accurate outputs with contemporary scientific and technological advances. To decide on the type of remote sensing imagery, the quality of imagery can be a measurement tool since it affects the classification results. However, as the resolution of imagery increases, collecting them gets more costly. The cost in this sense could be monetary or time-wise. For example, to cover large areas like a whole city, using drones is impractical, even their sensor resolutions are quite good. Moreover, drone technology is not old enough to catch more than 20 years in Turkey. Taking aerial imagery from planes is costly and unsustainable because the fuel it consumes causes carbon emissions. Also, it is difficult to access the historical data collected in this way. On the satellite side, satellites with super high resolutions (less than 1 m spatial resolutions) are not open source, they are commercial and pricy. Indeed, there is no need for that much resolution since they are computationally intensive to process. Hence, the ideal approach seems like open-source moderate resolution satellites with 10-30 m spatial resolution and processing the images with an automatic approach. Therefore, the classification is performed to Landsat images with Maximum Likelihood Estimation. The model is generated from the popular interpreted programming language, Python. Although it is more practical to use the default tools in GIS software, the programming language adds flexibility to the work. In this way, to benefit from the spatial properties of the image, a supplementary method called "Localized Prior Probability" is developed by improving the prior probability used in likelihood calculations. Details are explained in the Chapter 3.

1.3.2 Planning Approach

After determining the extent of the changes and where they occur with the remote sensing approach, the relationship between LU/LC changes and planning is examined in this thesis. In the planning approach, the causes of the changes and the existence of unplanned activities are questioned. There is a tradeoff in the selection of plan scale which is similar to the tradeoff in the remote sensing approach. Although large-scale plans express clear boundaries of the LU/LC elements, being over-detailed makes them inefficient. The Territorial Development Plan does not express the exact boundaries of allocation; however, it is the highest scaled plan where the decisions about the space are taken. Moreover, it forms a reference plan to the lower-scale plans. Thus, the current Territorial Development Plan, which was approved in 2011, is used in this thesis. The impacts of the plan are examined as a whole with the plan decisions and the plan report.

1.4 Contribution of the Thesis to Existing Knowledge and Practice

Muğla is one of the top cities for vacations by quadrupling its population in summer times. On the other hand, Muğla is one of the leading provinces in mining productions, especially in the marble industry. Although tourism and mining sectors strengthen the economy of the province, they are gradually destroying the land. By taking into account that Muğla has valuable agricultural and natural resources, it is astonishing that there are a few studies about LU/LC change in Muğla in the last few decades. The majority of the existing studies in the context of LU/LC change conducted in Turkey focused on either regional variances in the whole country (Aktürk, 2019; Gülbeyaz, 2007; Ustaoglu & Aydinoglu, 2019) or conducted in different cities such as Istanbul (Aldoğan, 2019; Durmazbilek, 2021), Diyarbakır (Dağlı, 2021), Kocaeli (Yıldız, 2016), or in Muğla but for a specific district (Arda, 2020), or targeted to specific purposes such as analyzing the change areas only in mining areas (Gül et al., 2019), modeling future LU/LC changes for beekeeping suitability analysis (Sari, 2020). Therefore, none of them is a comprehensive study that deals with the LU/LC changes in the province of Muğla in the last few decades. This thesis will fill this gap and also there will be a further discussion about the current Territorial Development Plan to examine their impacts on LU/LC change.

Residents, local NGOs, decision-makers, and urban planners in local municipalities, the Ministry of Environment and Urbanism, and the development agency in the region (Güney Ege Development Agency) are the main beneficiaries of this thesis. First of all, residents and local NGOs will be informed by the process with reliable scientific results. They can create public opinion to make pressure on the authorities to preserve agricultural and environmental resources. Local municipalities, i.e., the metropolitan municipality and the district municipalities, may comprehend the seriousness of the situation and reconsider their decisions on the further expansions of tourism in the critical areas for agriculture and the natural ecosystem. Urban planners especially working in local institutions in Muğla can utilize the resulting LU/LC change map in their analysis process of urban plans. Planners in the Chamber of City Planners can give an additional endeavor to track the legality of the changes with the other environmental and agricultural NGOs. Ministry of Environment and Urbanism which creates Territorial Development Plans in Tukey can review the current plans and they can increase the susceptibility while making plans by including the habitats of the endangered species, fragile ecosystems with high biodiversity, fertile agricultural lands, and land capability classes to the plans. In Turkey, 26 regional development agencies are creating strategic plans. Güney Ege Development Agency is responsible for the south Aegean region including Muğla. The agency can benefit from this thesis by using the study results to extend the conservative strategies and limit the growth of tourism in the most affected and defenseless valuable areas.

1.5 Organization of the Thesis

In the next chapter, a background and literature survey on LU/LC change are presented. The third chapter is devoted to the method. In the fourth chapter, the author presents the results. The fifth chapter is for detailed examination of the LU/LC changes and the impacts of the current Territorial Development Plan. And finally, a conclusion is presented in the last chapter.

CHAPTER 2

BACKGROUND AND LITERATURE REVIEW

This chapter is structured into two sections. In the first section, the main driving factors of LU/LC change are discussed deductively in the scope of planning and environment. In the second section, the background of the method of LU/LC change is introduced and the current literature is reviewed.

2.1 The Condition of LU/LC Elements in the Age of Globalization

In this section, firstly, the concepts of globalization, planning, and environment are introduced, and the impacts of globalization on planning and the environment are examined. Secondly, the impacts of the plans on LU/LC change are detailed.

2.1.1 Globalization, Planning, and Environment

Since the impacts of globalization are experienced anywhere in the last few decades, it would be to the point to research the relationship between globalization, planning, and the environment. The term "globalization" was expressed in the 1980s to describe technical advancements that made international transactions easier and faster (Burlacu & Gutu, 2019). However, it is not so simple to explain globalization only from an economic perspective. Globalization can be expressed by exceeding the national borders in terms of instant communication, transfer of ideas and population, modernization and universalization of culture, and increasing the facilities to meet global market demands. Moreover, it causes the economies of the countries to interconnect each other at certain points, especially with the increase in exports between countries. Thereby, a worldwide financial expansion is observed in the 2000s which made it more straightforward for developing countries to track down capital assets. By doing so, the construction sector would become the principal driver to boost their economy during this period (Özşahin & Özbay Daş, 2021). Due to the economy-triggering feature of construction, especially developing countries have embraced this sector without thinking about the consequences. Hence, the dimension of the effects of globalization is more than what it seems like at first glance. It may result in serious deterioration in the environment if the impacts are not studied beforehand with plans.

Planning is the discipline responsible for creating livable environments. Therefore, planning is not only about shaping urban form or land use but also about building balance between social, economic, and environmental aspects of human habitats by establishing hierarchical coordination of numerous parties that strive to enhance the living conditions of cities and regions. Despite being the force to decrease the negative effects of globalization, planning on the reality, especially in corrupted countries, is profoundly ingrained in the country's political perspectives because of its dependency on a state (Friedmann, 2005). These binds allow local states and even governments to intervene in the planning process. Most of the time, the interventions are either a waste of money for election campaigns or large construction projects for economic profits under the influence of globalization without considering the environment. Although planning keeps pace with global paradigms and updates itself accordingly, certain principles are expected to be preserved such as conservation policies. In the next section, the impacts of spatial plans on LU/LC change are discussed in the scope of globalization.

2.1.2 Planning and LU/LC Change

In this section, firstly the plans that vary according to their scale and purpose will be prologuized. Although the hierarchy of the plans and the definitions are more or less the same in many countries, they can be slight differences in the legal regulations of the country. Therefore, the author emphasizes that in this thesis, the definitions are set according to planning practices in Turkey. Secondly, the impacts of the plans on the LU/LC change are discussed.

2.1.2.1 Plans

The scale of the plan determines the visual language of the allocation. For example, while in small-scale plans, an industrial site is expressed with a single polygon object, in large scale-plans, the roads, buildings, and green areas of the industrial site are also shown with the exact scales. Since the map sheet cannot express everything on itself, there are also text form rules called plan decisions. They express legal limitations in the region. Therefore, while evaluating the impacts of the plans, plan decisions should also be examined.

There are several types of plans according to their purpose and scale. There is no universal definition of which scale belongs to which plan since they are also dependent on the regional characteristics. Nevertheless, it can be said that strategic plans are prepared at the level of cities and city groups (regions). According to the strengths and potentials of the region strategic decisions are taken. Strategic plans guide the following sub-scale plans. In general terms, it is mostly a set of conceptual decisions such as which economic sector the region should advance in, which values it should protect, and how it will cooperate with other regions. The Strategic Plan for Northern Ireland in 2001 is shown in Figure 1 as an example.

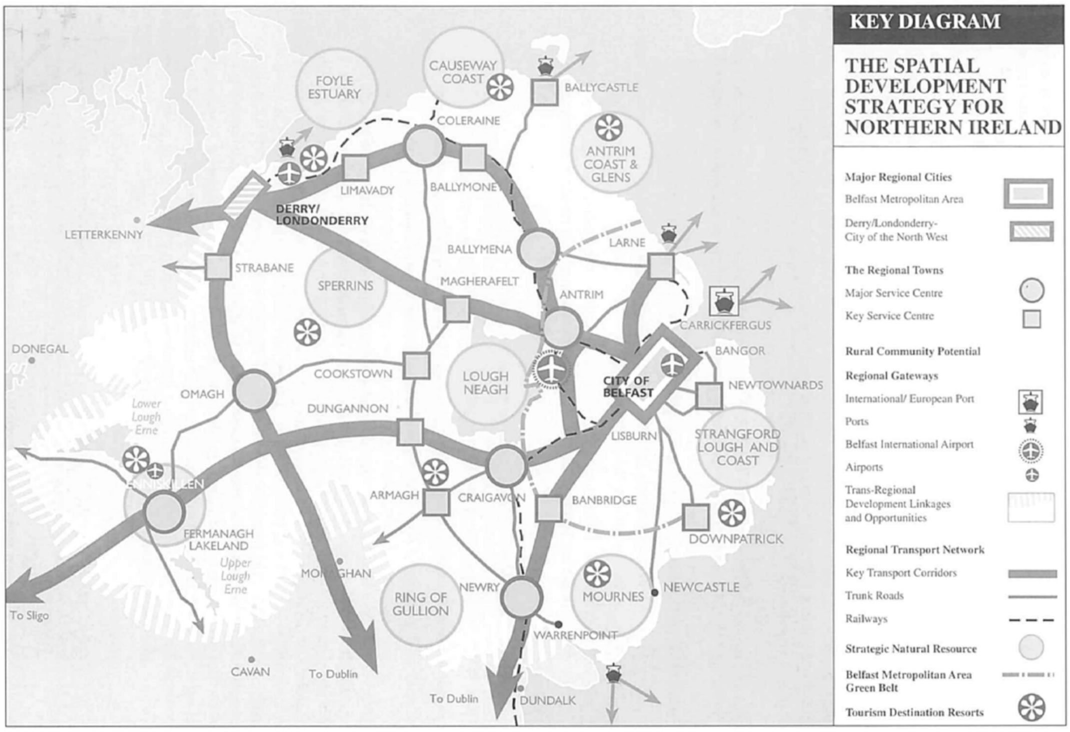

Figure 1 Regional Strategic Planning in Northern Ireland, 2001(Neill & Gordon, 2001)

Territorial Development Plans are the next stage after strategic plans. These plans are usually the smallest scale plans where spatial allocation is performed for various land uses like urban development areas and agricultural and industrial lands. The scales of the elements in this plan do not express the exact dimensions, but it consists of generalizations to guide the sub-scale plans. These plans include macro forms of settlement areas, rural development, natural assets to be protected, and the locations of grand projects, if any, from the decisions of strategic plans. The below figure is created from the current 1/100,000 scaled Territorial Development Plan for Aydın-Muğla-Denizli region, accepted in 2011.

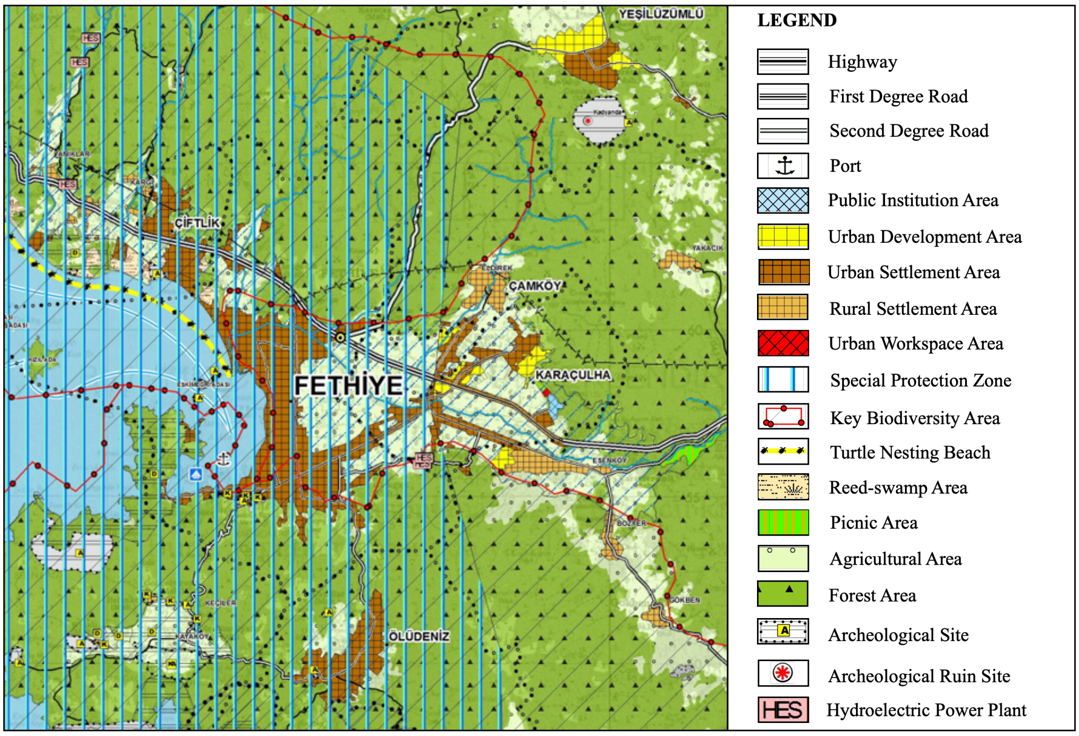

Figure 2 Territorial Development Plan for Aydın-Muğla-Denizli (Ministry of Environment, Urbanization and Climate Change, n.d.)

The master plans, on the other hand, determine where the urban elements differ, where and how they will be located, their relations with each other, and how the areas in the Territorial Development Plans will be constructed more concretely. 2003 Master Plan of Çorlu District in Tekirdağ, Turkey is shown below (Promer Planlama, n.d.). Unlike the Territorial Development Plan, the details such as the fragmentation of residential areas according to their density, central commercial zones, and a more detailed road infrastructure system can be observed.

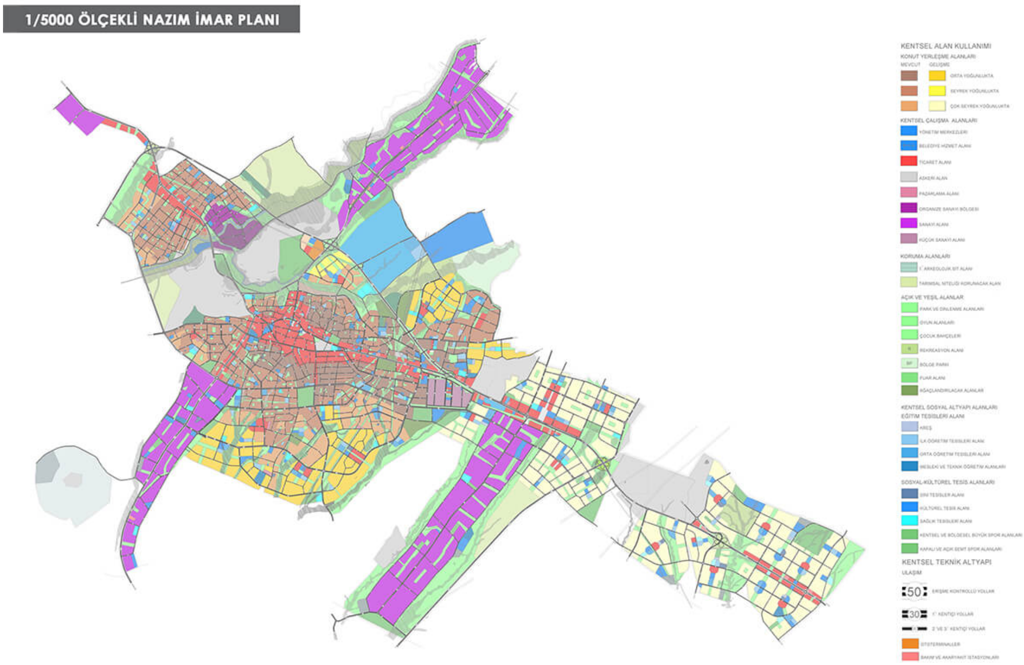

Figure 3 Master Plan in Çorlu, Tekirdağ, 2003 (Promer Planlama, n.d.)

The largest scale plan is land use plans. Land use plans include the location of city elements, their sizes, types of use, and design details at the planning level. It creates an extensional base for architectural projects. It aims to realize the decisions coming from the upper scale plans. Figure 4 shows the Land Use Plan of Başakşehir, which is accepted in 2013 (Promer Planlama, n.d.). It can be easily seen that the plan contains parcel-based land use elements and a road system with exact widths.

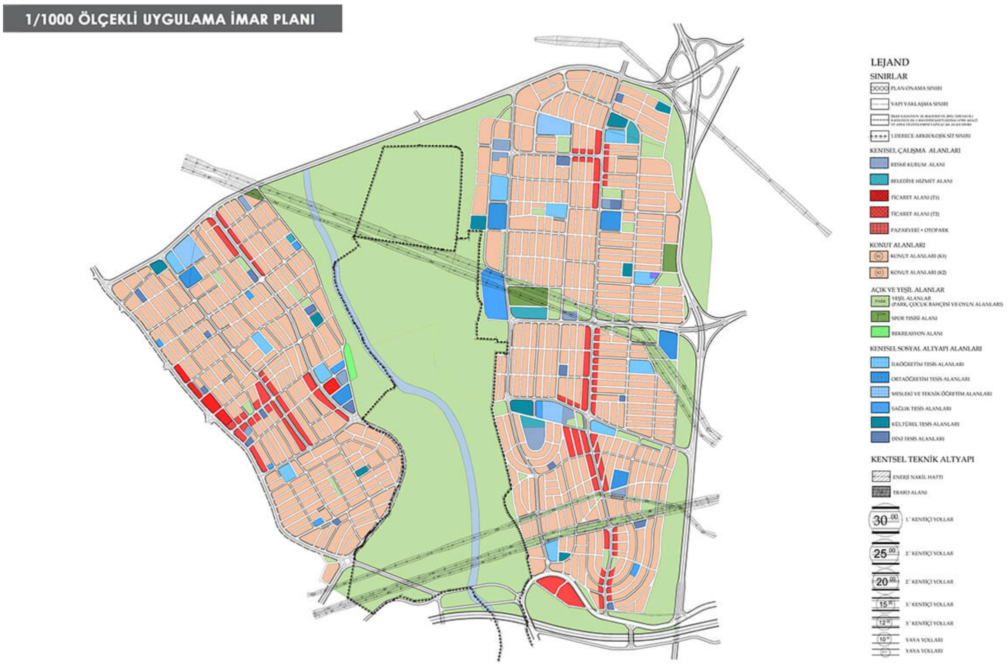

Figure 4 Land Use Plan in Başakşehir, İstanbul, 2013 (Promer Planlama, n.d.)

Hence, it is appropriate to state that spatial plans have a strong relationship with LU/LC change. In the following parts, the impacts of the spatial plans are expanded.

2.1.2.2 The Impacts of the Plans on LU/LC Change

The main purpose of the plans is to shape the environment with the rational allocation of scarce resources for a sustainable future. Thereby they have a great impact on the land. Such that, the more the LU/LC changes overlap with the plan, the better practice it is because the environmental effects of the changes have been considered beforehand. On the other hand, due to the weaknesses in the implementation units of the plans, the changes that do not occur as in the plan may pose a serious threat to the environment. Kilinc & Ozgur (2018) summarize the major problems observed in planning practices in Turkey as lack of control mechanisms, communication problems between the planning actors, prioritizing personal interests over public welfare. Indeed, as an implementing organ of spatial plans, local governments are responsible for this problem. Nevertheless, some turn a blind eye to illegal activities in line with their interests such as election strategies or income gain. For example, the squattering process in Yıldız quarter, Ankara was deliberately ignored by the authorities until the zoning amnesty (Şenyapılı, 2014). On the other hand, the gaps in spatial plans or planning decisions may also adversely affect the LU/LC change due to the absence of legal binding. For example, the 1/5000 and 1/1000 plan revisions in the Central District of Denizli which are sued by the Chamber of City Planners, do not specify maximum building height which is very likely to increase the construction density in the region (Şehir Plancıları Odası, 2011). Thus, the preparation and the implementation process of the plans should be executed conscientiously, otherwise, it may cause irreversible LU/LC changes.

2.2 Land Use Land Cover Change Detection

In this section, firstly the concept of LU/LC change is discussed. Secondly, the remote sensing approach in LU/LC change detection is deeply examined. The remote sensing approach is investigated in two subsections: satellite imagery, and the methods of LU/LC change. At first, satellite image characteristics and satellite image processing are introduced. Secondly, in the methods of LU/LC change, classification methods and the change analysis methods are covered.

2.2.1 The Concept of LU/LC Change

Land use and land cover are two types of attributes of the land. As their meanings are appeal to intuition: "Cover" stands for extent or status, while "Use" stands for functionality. Land cover is the natural form of the land that has been shaped since the Paleozoic Era. It includes topographical elements such as soil, vegetation, glacier, water bodies, and groundwater. Land use can be defined by the human-intervened lands by exploitation of land cover elements to create industrial zones, residential zones, agricultural fields, grazing, mining, and many others (Lambin et al., 2003)

The exponential increase in the transition from land cover to land use is the main objective of the LU/LC change studies. Due to human activities such as excessive construction, agricultural activities, and deforestation LU/LC change accelerates (S. Mishra & Jabin, 2020) causing irreversible impacts on the earth. Moreover, LU/LC change may have a significant effect on the LST (Land Surface Temperature) and rainfall (Gogoi et al., 2019; Hao et al., 2019; Kalnay & Cai, 2003), loss of biodiversity causing a loss in ecosystem services (Rodríguez-Echeverry et al., 2018). Some cases even show that LU/LC change triggers natural disasters like flooding, earthquake (Siddhartho, 2013). To analyze the impacts and extents of LU/LC change several studies are conducted. With the contemporary advances in science and technology, most of the research in classifying LU/LC elements are utilized from Remote Sensing (Juliev et al., 2019; Luo et al., 2021; Roy & Inamdar, 2019)

2.2.2 Remote Sensing Approach

Remote sensing is a technique to acquire information out of an object or a surface that is not in touch with an observing device (Lillesand, et al., 2008). Because of its capability of "sensing" objects, the observing device is called a "sensor". The sense is in the form of electromagnetic signals in different wavelengths. Transferring high amounts of data with a lightweight workload puts forward remote sensing in front of manual observations. That's why remote sensing is widely used in many fields like medical ultrasonography and radiology, mining exploration, hydrology, meteorology, and land surveying (Yavaşlı, 2015). In the field of land surveying, satellite imagery has become more attractive than aerial photography due to the availability of many sensors with high spatial resolution, and high temporal resolution (Aplin et al., 1997; Stabile, 2012).

2.2.2.1 Satellite Imagery

LU/LC changes can be observed on any scale. We can see spatial changes from the imagery published by NASA having city lights on earth at night to even by walking on the street. The aim, the scale i.e., the detail of information, and the extent of the coverage area determines which satellite imagery is suitable to detect the changes. A considerable amount of study examines regional changes which need decades to observe the changes. Abebe et al. (2019) has analyzed 20-year data to observe the development of urban informal settlements. Appiah et al. (2015) has examined the farmland abandonment in the Bosomtwe District of Ghana between the years 1986 and 2014. Another study conducted by Hossen et al. (2019) is about monitoring degradation in Himchari National Park (HNP) beginning from 1977. Since Landsat has the longest continuous temporal records of satellite earth observation since 1970

(*Landsat timeline* 2021), it is utilized in many of the studies in LU/LC literature including the above studies. However, it is still an option to combine different satellites and sensors with Landsat and Sentinel or aerial photography (Abebe et al., 2019; P. K. Mishra et al., 2020). Whether it is worth the effort is discussable since heavy preprocessing is needed for these sensors due to different characteristics. In the following part, how satellite image is formed, the sensor types of satellites, the spectral characteristics, and four types of resolutions are covered to express the main characteristics of a satellite image. In the later part, satellite image analysis is discussed in the scope of basics in preprocessing and classification.

2.2.2.1.1 Satellite Image Characteristics

A satellite image is comprised of electromagnetic signals. First, these signals are received from an interacted object by satellite sensor, then recorded and finally processed to shape an image. The sensor uses either sunlight or its energy as a source. The ones that use sunlight are called passive sensors, and the others are active sensors. Both sensor types have their pros and cons. For instance, active sensors are not dependent on daytime. The microwave radiation of the active sensors can penetrate clouds, rain, and snow. However, they are compute-intensive and costly (Woodhouse, 2017).

A satellite image is expressed by four types of resolutions: Spectral, radiometric, spatial, and temporal. Typically, a satellite sensor has several spectral bands. The bands are different ranges of wavelengths of electromagnetic radiation. The spectral resolution is the total interval of these wavelengths of the bands. They are generated by the sensor while receiving and recording the returned electromagnetic signal from the interacted object. The recorded signal is transformed into Digital Number (DN). The capacity that DN reflects the spectral details of an object is called radiometric resolution. It is dependent on the sensor's sensitivity to incoming energy. Spatial resolution is another important characteristic of satellite imagery. It is expressed by the sharpness of the smallest element in an image. To clarify, it is the ground area represented by one pixel in a digital satellite image and the width (or height) of a pixel can be stated as the spatial resolution of the satellite sensor (Siamak Khorram & Cynthia F. van der Wiele, 2012).

When a satellite is launched, it goes into the orbit of the earth. It scans the world until it is retired. The temporal period to revisit the same geographic location is called the temporal resolution of a satellite. Sometimes to lower the period time or increase the temporal resolution, another satellite is launched with the same characteristics as Sentinel-2A and Sentinel-2B (Ose et al., 2016).

2.2.2.1.2 Satellite Image Processing

Satellite images are processed to understand, visualize, interpret or classify spatial relationships and spatial patterns by statistical methods, machine learning, or deep learning algorithms. Thematic maps and color-coded classified images such as Land Use/Land Cover change maps are the main products of satellite image processing (Siamak Khorram & Cynthia F. van der Wiele, 2012).

To prepare data and enhance accuracy in classification, preprocessing stage is applied. The main practice in preprocessing is reducing distortions via cloud removal methods, atmospheric, radiometric, and geometric corrections (Siamak Khorram & Cynthia F. van der Wiele, 2012). Luo et al. (2021) who analyze LU/LC change in Xiong in their research, utilize temporal redundancy of Sentinel 2 images by taking monthly mean values to mitigate cloud contamination. Negassa et al. (2020) apply a cloud detection method and radiometric correction to reduce noises in their study in forest cover change detection on Komto protected forest priority area. Another LU/LC change research in Rajang River Basin utilizes atmospheric, radiometric, and geometric correction methods to reduce the errors to less than 1 pixel (Oad et al., 2020). After preprocessing stage, the image is ready for classification. In this stage, spectral reflectance is one of the widely used parameters. It is the amount of light reflected by an object in a certain spectral range. It is consistent within the LU/LC class, and it varies between classes. For example, variations of spectral reflectance among the water pixels are far less than the variation between water and vegetation (Siddhartho, 2013). In Figure 5, spectral reflectance of soil, vegetation, and water in different wavelengths are graphed.

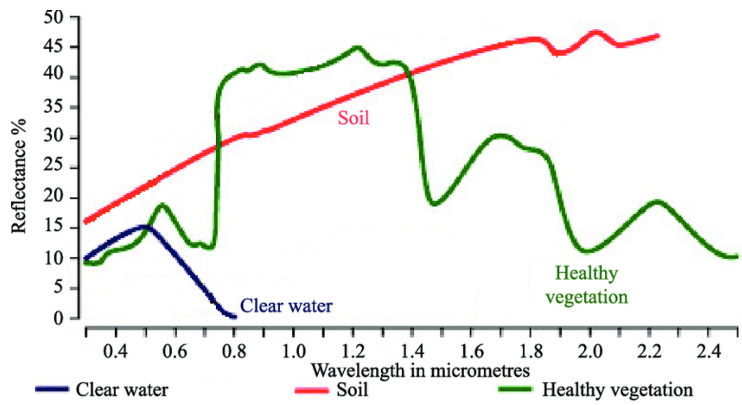

Figure 5 Spectral Reflectance of Water, Soil, and Green Vegetation

(Adapted from Kumar & Tv, 2019)

Although at some points the classes have the same or too close values, most of the other ranges of the wavelength have a significant difference. Another important thing in the figure shows the necessity of more than one band to classify these three classes. Since, when the spectral reflectance of soil and vegetation varies clearly at high wavelengths, the water pixels disappear. Therefore, at least two bands are needed for classification.

2.2.2.2 Methods of LU/LC Change

LU/LC change can be observed in a thematic map generated by the classification of individual images at a specific time range. Therefore, the classification method determines the accuracy of the LU/LC change map. In the further parts, firstly, three types of classification i.e., supervised, unsupervised and hybrid, are examined, and the current studies employing them are discussed. Secondly, the methods of analyzing the LU/LC changes are introduced.

2.2.2.2.1 Classification Methods

The classification methods are applied to multispectral images to extract relevant information such as the segmentation of land use land cover elements. There is no universally accepted method to use. Each has its strengths and weaknesses when applied in a different context. In this part, the classification methods that the majority of the LU/LC studies are utilized are examined. From the very top, there are two classification methods as supervised and unsupervised classification which will be detailed in the next section. The sequential combination of unsupervised and supervised methods is referred to as hybrid classification in this study.

In supervised classification, there are certain numbers of classes that are previously labeled in a sample of dataset called training dataset. The method establishes the relationship between the training dataset and the given features. The process to bind them is named “learning”. After the “machine” learns the relationship, then it predicts the rest of the dataset. Maximum Likelihood Classification is one of the most used methods in LU/LC studies. ML classifier uses training pixels to estimate the mean vector and the covariance matrix of each class. Each class is separated by decision boundaries in multispectral space. According to the location of the multispectral space of the pixel, it is assigned to the maximum probable class or labeled as unknown (Ahmad & Quegan, 2012).

Unsupervised classification or clustering is the method that creates groups whose members resemble each other more than any element in different groups (Bandyopadhyay & Saha, 2013). In digital remote sensing, the machine generates clusters by matching pixels to each other according to their spectral signatures. Hence, the analyzer does not have to know and specify classes beforehand (Wondrade et al., 2014). The Iterative Self-Organizing Data Analysis Technique

(ISODATA) is one of the important unsupervised classification methods that take part in the majority of the studies. At each iteration in ISODATA, the centers of clusters are changed and if the distance of two different cluster centers is less than a predefined threshold, they are merged. And vice versa; if the distance is more than the threshold, they are split (Zheng et al., 2020).

In LU/LC classification studies, the unsupervised classification method is generally used to find the number of classes in the study area (Wang et al., 2020). Afterward, with the spectrally determined number of classes, the supervised classification is performed to finalize the classification. This practice is called hybrid classification. Hybrid classification is especially needed when the spectral variance of the image is so high that the human eye cannot differentiate the classes accurately enough.

Contemporary studies in LU/LC change detection are listed in Table 2. The column "Minimum Accuracy" shows the lowest accuracy of the classification results among the compared years. Although there is much research in LU/LC change detection, the table is comprised of the most recent papers of reputable journals and conferences and the thesis with great contributions to the literature in the last decade. The studies have various targets to detect changes in different land types. Most of the study area consists of water elements, built-up, and vegetation. According to the target of the study, the number of classes changes in between four to twelve types in the examined papers. The majority of the studies are applied Maximum Likelihood Classification. The ML Classifier proved its robustness in different land elements with high classification accuracy. Luo et al. (2021) and Halmy et al. (2015) are implemented the Random Forest method for classification and the results are quite satisfactory from 92% to 98% of the overall accuracy of the confusion matrix.

Table 2 Significant Studies in LU/LC Change

Authors, Published Year	**Citations**	**Change Detection Years**	**Land Types**	**Method**	**Minimum Accuracy**
(Luo et al., 2021)	0	2017-2021, annually	Dry farmland, paddy field, impervious surface, water bodies, forest, reed, non-cropland	Random Forest	Confusion Matrix OA: 98% Kappa coefficient: 0.97
(Wang et al., 2020)	10	1990, 2010	Forest, agricultural land, grassland, shrub, barren, water, built-up	ISODATA, Maximum Likelihood	Kappa statistics: 73%
(Oad et al., 2020)	1	1992-2016, annually	9 types of crops, vegetation, water bodies, urban	Comparison of Maximum Likelihood (ML) and Support Vector Machine (SVM)	Precision in ML: 88% Precision in SVM: 94%

Table 2 (continued)

(S. Mishra & Jabin, 2020)	0	2012,2013,2014	Mountain, settlement, vegetation, water, glacier	Maximum Likelihood	Confusion Matrix OA: 93% Kappa coefficient: 0.83
(P. K. Mishra et al., 2020)	34	1988,1996, 2008, 2017	Dense forest, open forest, agricultural land, built-up, water bodies, barren land	Maximum Likelihood	Confusion Matrix OA: 86% Kappa coefficient: 0.81
(Salem et al., 2020)	8	2010, 2018	Agriculture, urban, desert, water	Maximum Likelihood	Kappa index: 0.93
(Alam et al., 2019)	58	1992,2001, 2015	Forest, agriculture, built-up, plantation, barren, water, shrubs, marshes, pasture	Maximum Likelihood	Confusion Matrix OA: 87% Kappa coefficient: 0.87

Table 2 (continued)

(Liping et al., 2018)	116	1992,2003,2014	Construction, bare land, woodland, farmland, water bodies	Maximum Likelihood	Confusion Matrix OA: 92% Kappa coefficient: 0.90
(Hegazy & Kaloop, 2015)	324	1985, 2000	Agricultural land, barren land, water, built-up	Maximum Likelihood	Confusion Matrix OA: 84% Kappa coefficient: 0.81
(Halmy et al., 2015)	267	1988,1999, 2011	Urban, resorts, croplands, shrubs, water bodies, wetlands, sands, low vegetation, desert	Random Forest	Confusion Matrix OA: 93% Kappa coefficient: 0.92

2.2.2.2.2 Change Analysis

After each image is classified, they are compared visually and statistically to observe changes. Most of the studies represent the changes via numeric results like tables, line graphs, or classified maps of each date side by side (Alam et al., 2019; Oad et al., 2020). While numeric results reflect the amounts of overall changes in the study area, they are not suitable for spatial analysis where the changes exist. Nevertheless, the representation of classified images side by side is not perceptible enough for the reader. Instead, a thematic map showing the displacement of classes would be more intuitive. Indeed, Negassa et al. (2020) is employed this visualization technique for forest cover change analysis. However, their thematic map is too complicated to understand since it includes reciprocatory changes of all five classes resulting in 20 different colors on the map. The ideal solution would be using only the specific class changes in the thematic map for instance land cover elements to land use elements or only the interested classes such as scrublands to the desert and water bodies to the bare land, so on.

2.3 Chapter Summary

In this chapter, firstly, the author has introduced the main driving factors of LU/LC change deductively in the scope of planning and environment. To sum up, although globalization eases and equalizes lives in many ways, it has also produced approaches focused on economic growth with the competitiveness-inducing structure. To keep up with the trends, the environment undergoes planned and unplanned changes. Since the environmental impacts of the unplanned changes are not weighed beforehand, they may cause irreversible degradation of the land. In this context, the LU/LC changes in Muğla and the impacts of the plan will be examined.

Secondly, the background of the method of LU/LC change is introduced and the current literature is reviewed. The characteristics of the satellite image and the image processing, the classification methods, and the change analysis are introduced regarding the current literature. Many studies in the literature utilize Maximum Likelihood Estimation because of its proven capabilities of robustness. Landsat satellites have been mainly the data source of the studies due to their long-term records. In line with the literature, in this thesis Maximum Likelihood Estimation with the Landsat imagery is applied. The details of the implementation are stated in the following chapter.

CHAPTER 3

METHOD

This chapter covers how the LU/LC change is detected. In the first section, the study area is introduced with climate and vegetation characteristics, and determining LU/LC classes. In the second section, the data which are satellite imagery, and the ground truth are declared. Finally, the methodology is explained in the context of preprocessing, classification, and change analysis.

3.1 Study Area

The study is conducted in Muğla which is in the Southwest of Turkey (Figure 6). The province includes the city of Muğla as well as some of Turkey's most touristic holiday resorts such as Bodrum, Marmaris, and Fethiye. The geographic location of the city is 37.928 N – 35.93 N, 27.045 E – 29.87 E. The figure below shows the location in Turkey.

Figure 6 The location of the Muğla in Turkey (*Location map for Muğla* 2009)

3.1.1 Climate and Vegetation Characteristics

Muğla is located in the Aegean-Mediterranean phytogeographic region (Akbaş, 2012). The climate characteristic is the typical Mediterranean climate with hot and dry summers and mild and rainy winters. The amount of precipitation varies between 1180 mm and 775 mm according to the regions (2015-2019 Muğla Strategic Plan, n.d.). The natural vegetation of the Mediterranean phytogeographic region generally consists of coniferous forests and shrubs with maquis. It is accepted that maquis spread in areas where forests were destroyed under Mediterranean climatic conditions (Erinç, 1977).

3.1.2 Determining LU/LC Classes

Determining environmental changes in the land and forming environmental policies, a classification system has been determined by the European Environment Agency. The system is formed to manage the same basic data and to establish a standard database. It consists of 1/100,000-scale land cover maps, called Corine maps with different levels of classes (Corine land cover 2012). In terms of the scope of this thesis, the first two levels are suitable to study as shown in Table 3.

Table 3 Corine Classes (Adopted from Agriculture and Forestry, 2012)

Level 1	Level 2
1. Artificial surfaces	1.1 Urban fabric 1.2 Industrial, commercial, and transport units 1.3 Mine, dump, and construction sites 1.4 Artificial, non-agricultural areas
2. Agricultural areas	2.1 Arable land 2.2 Permanent crops 2.3 Pastures 2.4 Heterogeneous agricultural areas
3. Forest and semi-natural areas	3.1 Forests 3.2 Scrub and/or herbaceous vegetation associations 3.3 Open spaces with little or no vegetation
4. Wetlands	4.1 Inland wetlands 4.2 Maritime wetlands
5. Water bodies	5.1 Inland waters 5.2 Marine waters

As the main purpose of this thesis is to observe the pressure of the built environment on the natural environment, the level 1 classification is preferred among the first two levels. However, going down to level 2 of details would reveal the source of the pressure in more detail such as whether the mining activities (Class 1.3) or industrial, commercial, and transport elements (Class 1.2) trigger the land cover change. However, Landsat imagery does not provide enough resolution to detail the classification even with level 2. Therefore, with the reference of level 1 classes, five LU/LC types are determined in this thesis. As a difference from the level 1 classification, sparse vegetation is separated from forest areas because of widely spread elements of sparse vegetation across Muğla lands. On the other hand, due to the relatively rare distribution of wetland areas, the fifth LU/LC class is determined as sparse vegetation instead of wetland. Hence the classes are as follows: forest areas (red pine, larch, pine, cedar, juniper, liquidambar orientalis), agricultural lands (which includes irrigated and non-irrigated farming, and orchards), sparse vegetation (which includes sclerophyll, vegetation elements less than 25% of the land like bush and thorn), water bodies (which includes the sea, lakes, and rivers) and built environment (which includes all kind of land use elements such as settlement areas, industrial sites, airports, and also mining areas).

3.2 Data

Satellite imagery is utilized to classify LU/LC in Muğla. To train the classifier, test and verify the results, ground truth data is exploited.

3.2.1 Satellite Imagery

Landsat 8 OLI and Landsat 5 TM are used as satellite imagery. The images are downloaded from a freely available website named Earth Explorer from United States Geological Surveys (USGS) via https://earthexplorer.usgs.gov/website. The spectral color, wavelength, and spatial resolution of the bands that are used in this thesis are shown in Table 4.

Table 4 The Metadata of Landsat 8 OLI and Landsat 5 TM Bands (adapted from Markham, 2013 & U.S. Geological Survey, n.d.)

Landsat-5 TM			**Landsat-8 OLI**		
Band Description	**Wavelength (µm)**	**Spatial Resolution**	**Band Description**	**Wavelength (µm)**	**Spatial Resolution**
-	-	-	1 (Ultra Blue)	0.43 – 0.45	30 m
1 (Blue)	0.45 – 0.52	30 m	2 (Blue)	0.45 – 0.51	30 m
2 (Green)	0.52 – 0.60	30 m	3 (Green)	0.53 – 0.59	30 m
3 (Red)	0.63 – 0.69	30 m	4 (Red)	0.64 – 0.67	30 m
4 (NIR)	0.76 – 0.90	30 m	5 (NIR)	0.85 – 0.88	30 m
5 (SWIR)	1.55 – 1.75	30 m	6 (SWIR)	1.57 – 1.65	30 m
7 (SWIR)	2.08 – 2.35	30 m	7 (SWIR)	2.11 – 2.29	30 m

Since the extent of Muğla does not fit one segment of the Landsat image, four segments are mosaicked to cover the whole province. The path and row numbers are illustrated in Figure 7.

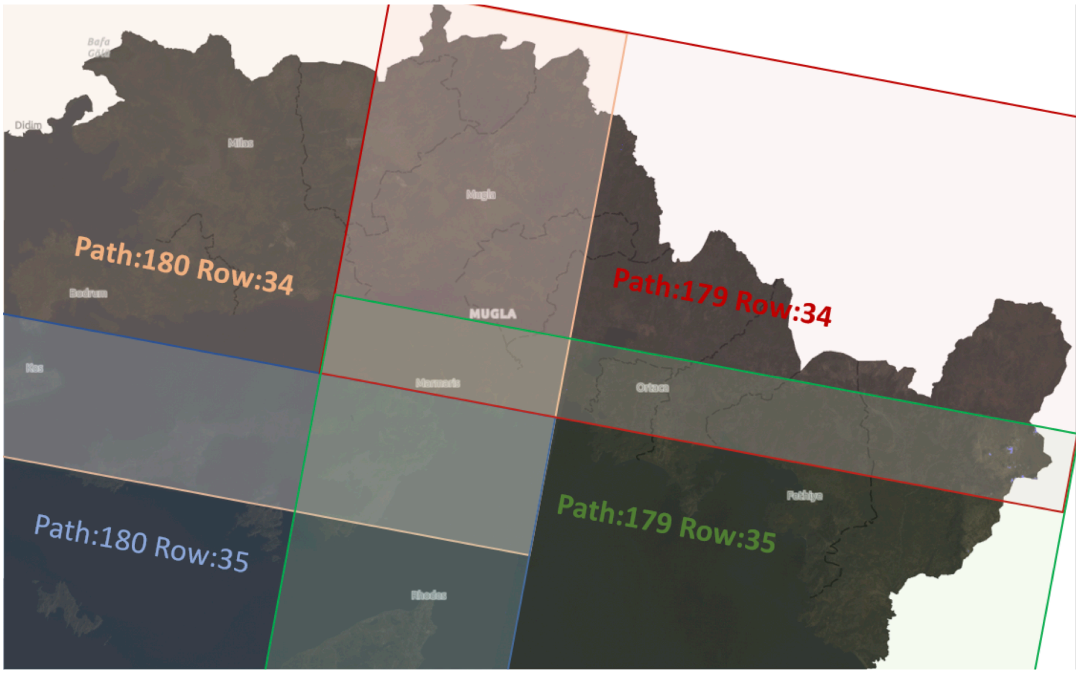

Figure 7 Segments (Paths and rows) of Landsat Images covering Muğla

The years 1995, 2005, 2015, and 2021 are used to compare LU/LC changes. To consider seasonality, two different dates with minimal cloud cover (<5%) are selected. The images from 1995 and 2005 are captured by Landsat 5 TM, while images in 2015 and 2021 are from Landsat 8 OLI. Table 5 shows the acquired dates of Landsat images.

Table 5 Acquired Dates of Landsat Images

	1995	**2005**	**2015**	**2021**
Path:180 Row:34	June, 27	March, 18	June, 18	February, 26
	August, 14	June, 22	December, 27	September, 06
Path:179 Row:34	August, 07	January, 06	September, 13	May, 10
	October, 10	July, 01	December, 04	August, 30
Path:179 Row:35	July, 22	July, 01	September, 13	January, 02
	October, 10	September, 19	November, 18	August, 30
Path:180 Row:35	May, 26	June, 22	September, 06	February, 26
	August, 14	August, 25	November, 18	August, 21

3.2.2 Ground Truth

The ground truth data representing LU/LC types are collected from different sources in different data types as shown in Table 6.

Table 6 The Metadata and the Usage Area of the Data

Institution	Year	Usage	Data	Data Type
Muğla Municipality	2015	To collect ground truth samples	Agriculture	Shapefile - Polygon
			Forest	Shapefile - Polygon
			Water	Shapefile - Polygon
			Province Border	Shapefile - Line
			District Borders	Shapefile - Line
Ministry of Agriculture and Forestry	2000 2006 2012 2018	To collect ground truth samples and location of mining areas	Corine Map	Raster
Google Earth Pro	1995 2005 2015 2021	To collect ground truth samples and to verify the LU/LC changes	Satellite Imagery	Raster
Ministry of Environment, Urbanization and Climate Change	2011	To examine the impacts of the plan on the LU/LC change	Territorial Development Plan	Raster
			Plan Decisions	Text
			Plan Report	Text

To collect ground truth samples, shapefiles from the Municipality of Muğla, Corine map in raster format from Ministry of Agriculture and Forestry, and satellite images of Google Earth Pro are used. Since the Corine map and the shapefiles do not cover all the classification years of the thesis, the labels are generated with the reference of the available dates by the visual vectorization process in GIS. Ultimately, ground truth samples have been collected separately for 1995, 2005, 2015, and 2021. They are generated from homogeneous areas, in all districts of Muğla. As an example, Figure 8 shows the label distribution for the classification in 2005.

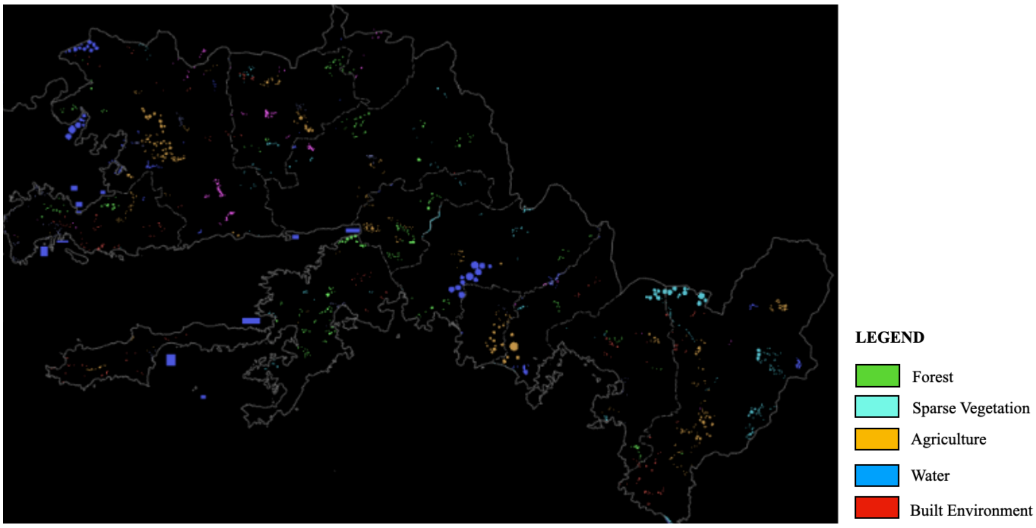

Figure 8 Label Distribution for the classification in 2005

Moreover, to differentiate residential areas from mining areas in the built environment class, the locations where mining activities are ongoing are created with the reference of Google Earth Pro images and Corine Map from the Ministry of Agriculture and Forestry. The locations of the mining activities in Muğla from 1995 to 2021 are shown in Figure 9. The green outline is ongoing mining activities in 1995, the blue one is from 2005, the yellow one is 2015 and the red one is from 2021.

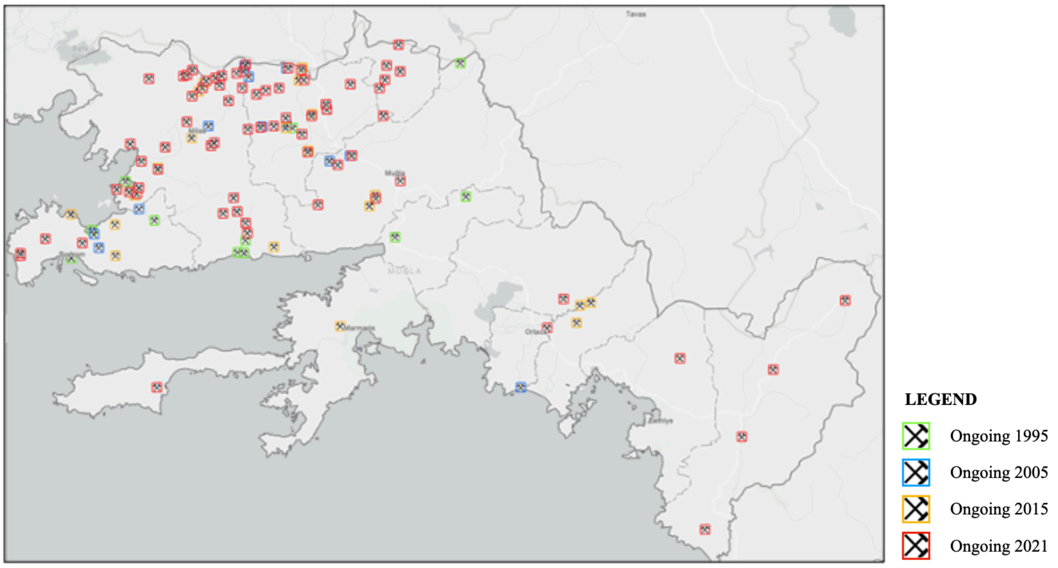

Figure 9 Locations of the Mining Activities in Muğla from 1995 to 2021 (Ministry of Environment, Urbanization and Climate Change, 2019)

3.2.3 Territorial Development Plans

The current Territorial Development Plan of the Aydın-Muğla-Denizli region is used to assess the impacts on LU/LC change. The plan is created by the Ministry of Environment, Urbanization and Climate Change on a 1/100.000 scale approved in 2011 and published via the website of the General Directorate of Spatial Planning (2018). The target year of the plan is 2025, hence it is valid between 2011 to 2025 with the plan revisions during this period. As introduced in Section 2.1.2.1, Territorial Development Plan is created after a Strategic Plan of the region. It is the smallest plan where spatial decisions of LU/LC elements are determined with the generalizations on the map. Being a basis of the following upper-scale plans i.e., Master Plan and Land Use Plan, makes it the appropriate scale to observe the LU/LC decisions (See “Planning Approach” in Section 1.2). The Territorial Development Plan is examined as a whole with the plan decisions and the plan report. The focus is determined to the areas where the LU/LC changed the most which are generated from change analysis of the thesis and where natural and agricultural lands are threatened by the tourism and mining activities as justified in “1.1 Problem Statement”. The main aim is to examine if these changes have been planned or not, since the LU/LC changes in the circumstance of unplanned activities may result in irreversible environmental degradation.

3.3 Methodology

The methodology consists of three steps which are preprocessing, classification, and change analysis. The flowchart of the methodology is demonstrated in Figure 10.

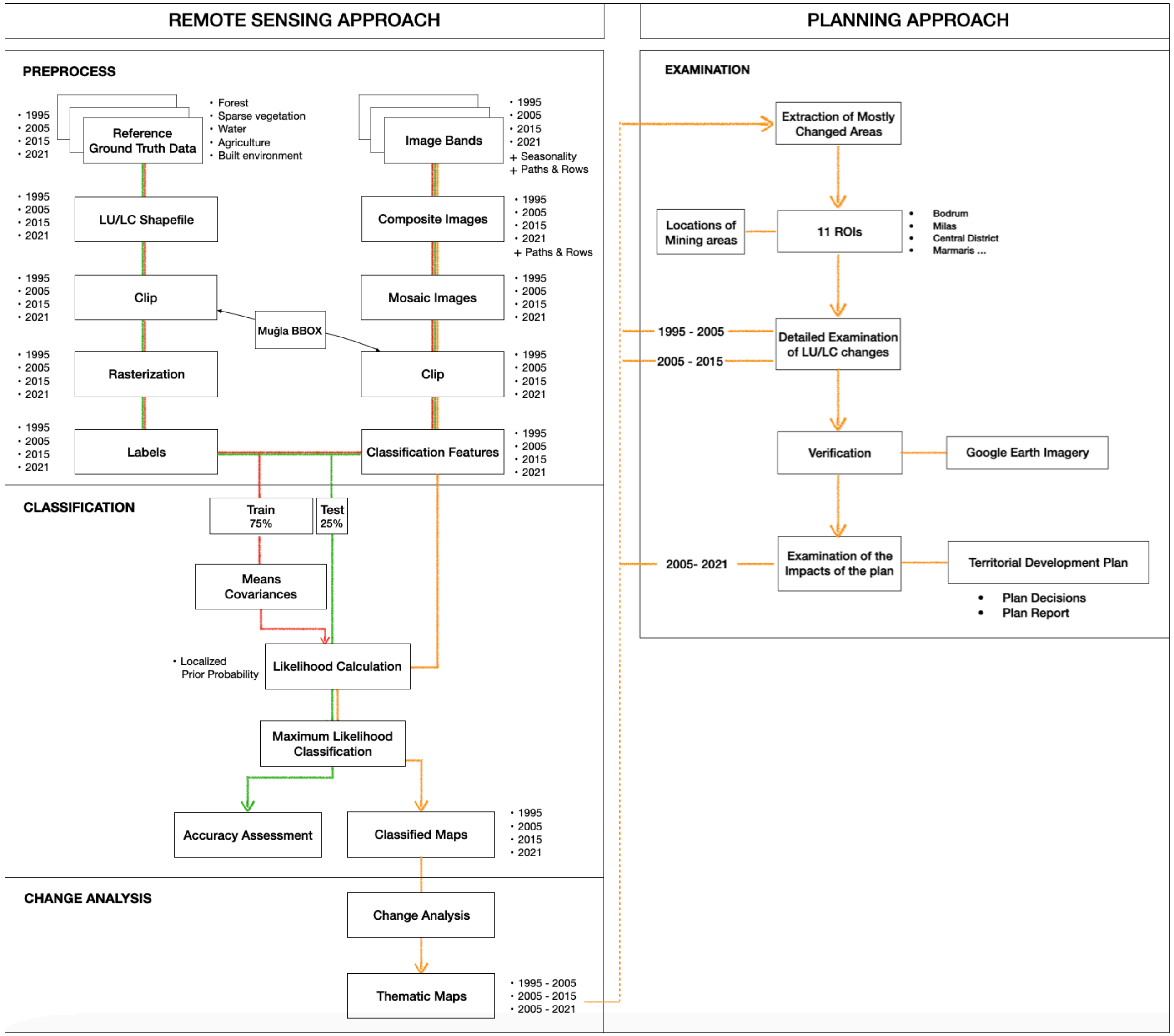

Figure 10 Methodology Flowchart

3.3.1 Preprocessing

As Landsat Collection 2 Level 2 products are atmospherically and geometrically corrected (Landsat collection 2, 2021) and surface reflectance values are generated from DN values, no heavy preprocessing is applied. In this section, the preparation of the data for classification is explained as preprocessing.

Firstly, to create a ground truth (label) images of the four years, the ground truth data introduced in section 3.2.2 are used as a reference. The labels are created from homogeneous areas in all districts of Muğla. Then, the shapefile is clipped by the boundary box of Muğla (Muğla BBOX). It is converted to a raster with a cell size of 30 to align pixels with Landsat image pixels. Secondly, to create features for classification, composite images of bands in each year in each segment of the Landsat imagery (which are Path:180-Row:34, Path:180-Row:35, Path:179-Row:34, Path:179-Row:25) are generated. Then, the composite images of four segments are mosaicked and they are also clipped by the boundary box of Muğla. Finally, the ground truth images and the composite image bands of each year are converted to matrices to be used as labels and features for the classification process. To eliminate the overfitting of the model, the data with labels are randomly split into 75% for training, and 25% for testing.

3.3.2 Classification

The classification process is generated by one of the popular interpreted programming languages, which is mostly used in scientific calculations, Python. Although it would be more practical to use the default tools in GIS software, the programming language adds flexibility to the work. Thereby, to investigate the decision process of MLE, Probability Density Functions of each LU/LC class are graphed by equiprobability contours as a pre-classification analysis in the seaborn package in Python. Besides, a supplementary method is developed to benefit from the spatial properties of the image in MLE. This supplementary method is called

"Localized Prior Probability" which improves the concept of the prior probability used in likelihood calculations. The details about the MLE and the implementations are explained in the following section.

3.3.2.1 Maximum Likelihood Estimation

Maximum Likelihood Estimation is an intuitive, consistent, and robust method that has been proven for many studies in decades (Abebe et al., 2019; Ahmad & Quegan, 2012; Appiah et al., 2015; Juliev et al., 2019). It exploits the sample mean, sample variance, and a prior probability of each class and predicts the probability density function of each class. Since the spectral reflectance values of pixels in an image band fit the normal distribution, the Maximum Likelihood of the Gaussian distribution is compatible for classification. As an illustration, Figure 11 shows the histogram of spectral reflectance of Landsat 5 TM Band 1 image captured by March 2005 in Muğla (Path:180, Row:34). The histogram approximates the random distribution.

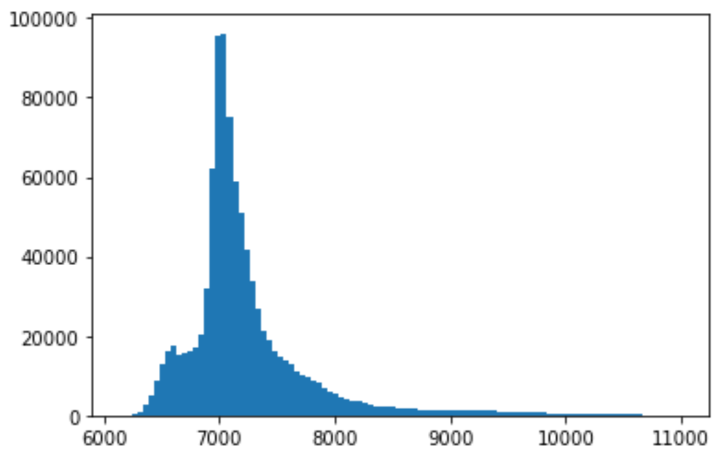

Figure 11 Histogram of Landsat 5 TM Band 1

In Bayes Theorem, a prior probability of being in class i, defined as P(i), and the likelihood of pixel w being in class i, defined as P(w|i) determine a posterior probability of being in class x, as formulated in below.

$$P(i \mid \boldsymbol{\omega}) = \frac{P(\boldsymbol{\omega} \mid i) P(i)}{P(\boldsymbol{\omega})} \tag{1}$$

P(w) is the normalization constant to ensure the sum of probability of pixel w being in each class equals 1. Therefore, to assign the most probable class to each pixel, posterior probabilities of being in each class are compared.

As seen in Eq. 2, i and j are different classes, and if the posterior probability of class i is greater than class j, the pixel w is assigned to class i.

$$\mathbf{x} \in i \quad \text{if } P(i|\omega) > P(j|\omega) \quad \text{for all } j \neq i \tag{2}$$

The likelihood function which is stated as P(w|i) in the above functions, is generated from Multivariate Gaussian Distribution for each LU/LC type to cover both in-class and between-class variances, i.e., covariances. To deal with high decimal numbers in likelihood calculation, and to minimize the computational burden, the logarithm of the likelihood function is taken since it is a monotonous function. The formula representing the log-likelihood is shown in the equation below.

$$\ln P(\boldsymbol{\omega} \mid i) = -\frac{1}{2}(\boldsymbol{\omega} - \boldsymbol{\mu}_i)^t C_i^{-1} (\boldsymbol{\omega} - \boldsymbol{\mu}_i) - \frac{N}{2}\ln(2\pi) - \frac{1}{2}\ln(|C_i|) \tag{3}$$

Since the logarithm of the likelihood function is taken, the logarithm of a prior probability is also calculated and added to the log-likelihood result to calculate a posterior probability for each pixel.

$$\ln P(\boldsymbol{\omega} \mid i) + \ln P(i) \tag{4}$$

Instead of taking a prior probability of each class from the label set, the value is updated regionally during the classification process to take advantage of spatial characteristics. For example, assume that there are four classes in an image with a prior probability of A, B, C and D are 0.4, 0.3, 0.2, and 0.1 respectively. Suppose that Figure 12 shows a subset of the image. While calculating the likelihood of a pixel at the center, a prior probability of A, B, C and D are 0.36, 0.4, 0.2, and 0, respectively.

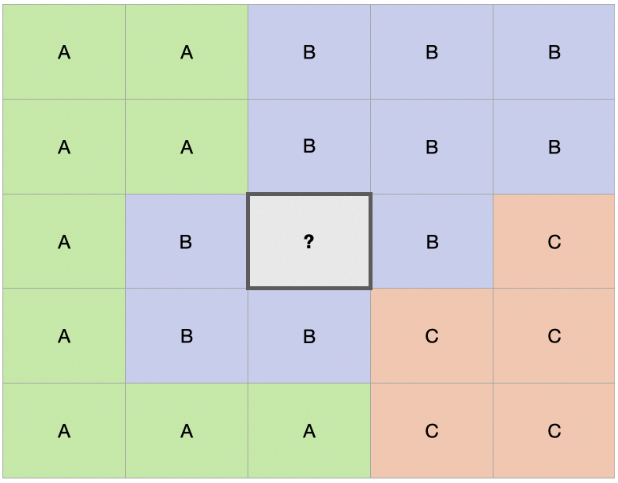

Figure 12 Representation of Subset of an Image

It should be emphasized that if the likelihood of being in class C is much greater than A and B, the loc6 1alized prior probability approach cannot change the result. Thus, not having full control over classification results makes the approach more reliable than various post-classification methods such as the majority filter.

3.3.2.2 Accuracy Assessment

The accuracy assessment is an important process indicating how trustworthy the study is. The confusion matrix is a highly used and reliable technique to assess the classification of remotely sensed images. It consists of Overall Accuracy (OA), Producer's Accuracy (PA), User's Accuracy (UA), and accuracy statistics (Congalton & Green, 2009). Overall Accuracy shows what proportion is the LU/LC classes mapped correctly. PA represents how frequently is the LU/LC class on the ground accurately classified on the map. UA indicates how frequently is the class on the map be present on the ground. Accuracy statistics such as Kappa demonstrates "real" accuracy by removing the probability of occurrence by chance. The measures and the equations of the confusion matrix are tabled below (Table 7).

Table 7 Components of Confusion Matrix (Adapted from Maxwell et al., 2021)

Measure	Equation
Overall Accuracy (OA)	$\frac{\text{Area of map correctly labeled}}{\text{Total area of the map}}$
Kappa	$\frac{\text{OA - expected agreement}}{\text{1 - expected agreement}}$
User's Accuracy (UA)	$\frac{\text{Area of map correctly labeled as class x}}{\text{Area of predicted map labeled class x}}$
Producer's Accuracy (PA)	$\frac{\text{Area of map correctly labeled as class x}}{\text{Area of reference map labeled class x}}$

In addition to quantitative assessment from the Confusion Matrix, visual assessment is used to examine the classification results. For all the results, the same sample area, which includes all LU/LC types used in the classifications, is preferred to compare the performance in between.

3.3.3 Change Analysis

According to the classification maps, quantitative analysis and spatial analysis are applied to observe LU/LC changes. First of all, the five LU/LC classes are combined into three classes: land cover class which consists of forest, sparse vegetation, and agriculture, land use class which is built environment, and water class. In fact, water is a type of land cover class. However, since the Mediterranean Sea is a landmark for Muğla, the locations of the changes can be perceived more easily with the direction of the water elements.

Change analysis consists of two parts to cover the first and the second research questions. The first part covers the analysis of the amount of change to answer the first research question: "*To what extent have the land cover elements of Muğla decreased or increased from 1995?"*. The second part covers the analysis of the spatial extents of the change for the second research question: "*If there has been a decrease or increase in the land cover elements in Muğla, where are these changes seen?"*.

3.3.3.1 Quantitative Analysis

After classifying the years 1995, 2005, 2015, and 2021 the areas of LU/LC classes are calculated in each year. A time-series graph is generated for each LU/LC type to interpret the changes intuitively.

3.3.3.2 Spatial Analysis

To analyze where the changes are seen over the years, thematic maps are created from the years 1995 to 2005, 2005 to 2015, and 2005 to 2021. The first and the second thematic maps are to observe the LU/LC changes in 20 years with equal time intervals to compare the pace of the change objectively. Whereas the last thematic map examines the impacts of the current Territorial Development Plan on the LU/LC changes in Muğla.

3.4 Chapter Summary

In this chapter, the study area, the data, and the methodology are explained in detail. The purpose of this chapter is to convey how the analyzes were carried out, which sources were used, and how the method was developed. To summarize, agriculture, forest, sparse vegetation, water bodies, and built environment classes were determined by taking the Level-1 classes of the Corine Classification as a reference. Images covering the province of Muğla were obtained from Landsat 5 TM and Landsat 8 OLI sensors from 1995, 2005, 2015, and 2021. As ground truth data, shapefiles from Muğla Municipality, Corine Map from the Ministry of Agriculture and Forestry, and satellite images from Google Earth Pro whose resolutions are higher than the Landsat images used for classification were used. The ground truth samples are collected for each classification year. The current Territorial Development Plan is used as another source of data for the examination of the impacts of the areas where natural and agricultural lands were suppressed by tourism and mining activities. The plan is determined as a whole with the plan decisions and the plan report. In preprocessing stage, since Landsat Collection 2 Level 2 products are geometrically and atmospherically corrected beforehand, no heavy preprocessing is needed. The classification is made in MLE and the model is produced with Python. A supplementary method has been developed for MLE, which allows the spatial properties of the image, called "Localized Prior Probabilities”. Finally, it has been explained the change analysis are evaluated with time series analysis quantitatively and with the thematic maps spatially.

CHAPTER 4

RESULTS

In this chapter, the results of pre-classification analysis, classification, and change analysis are examined. In section 4.1, the Probability Density Functions of LU/LC classes are discussed. The classification maps and their accuracy assessments are presented in section 4.2. Finally, Section 4.3 covers the thematic maps representing the changes, and the Time Series Analysis.

4.1 Pre-classification Analysis

Maximum Likelihood Estimation is essentially an estimation of the Probability Density Function of each class from sample values. Based on this estimation, each pixel is assigned to a class that is the most likely to belong in. To examine the PDFs of LU/LC classes, Figure 13 and Figure 14 are generated.

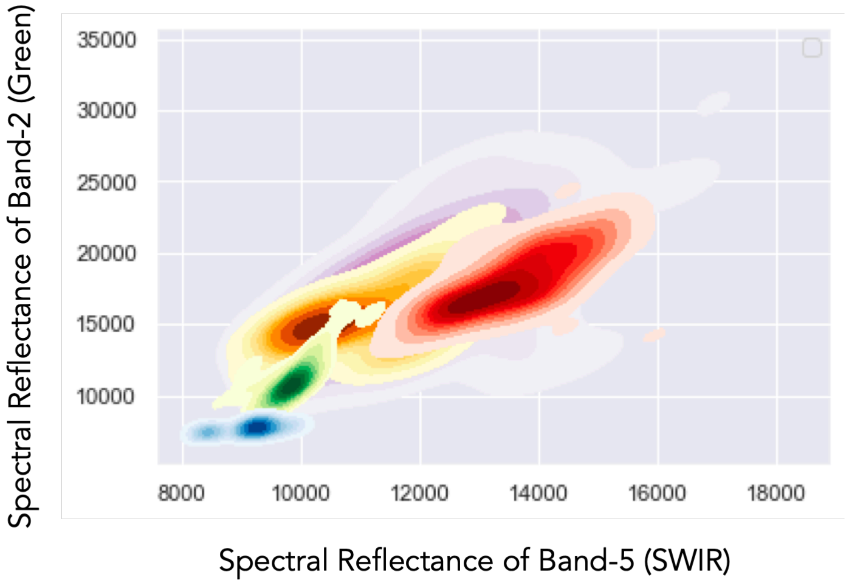

Figure 13 Probability Density Function (PDF) of LU/LC classes from Green, and SWIR bands

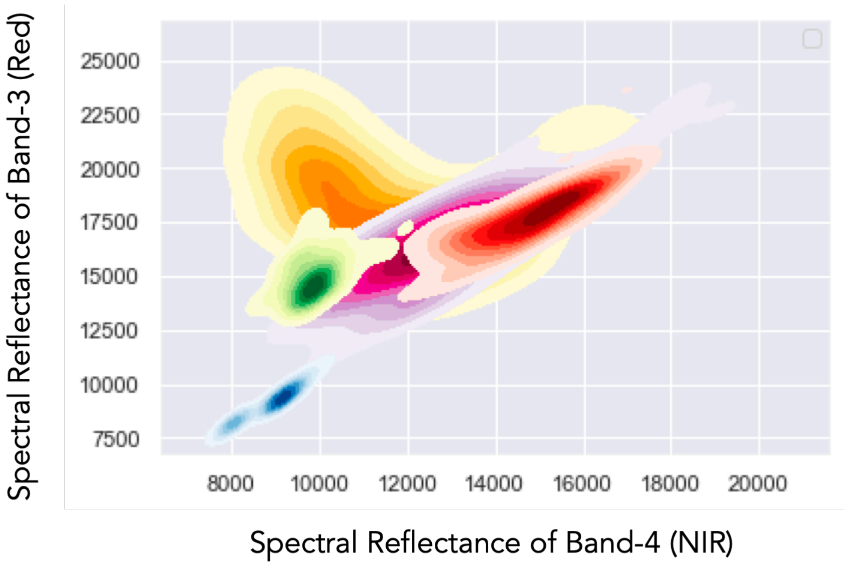

Figure 14 Probability Density Function (PDF) of LU/LC classes from Red and NIR bands

Figure 13 is from the green and SWIR bands of the image captured in March 2005, whereas Figure 14 is from the red and NIR bands of the image captured in September 2005. The plot of the figure is dependent on LU/LC classes, the seasonality of the land cover elements, and the correlation between two axes/bands. The color transitions show the equiprobability contours of the examined class. Because of the visualization limitations in two dimensions, the PDFs are generated from two image bands, even though MLE uses all the features/bands.

As seen in Figure 13, the PDF of sparse vegetation is dispersed, and it highly overlaps with agriculture in around spectral reflectance values of 12000 in the green band, and 13000 in the SWIR band. The model may misclassify the two classes if the other bands would not contain significant information in these areas. Water class seems like the easiest differentiable class due to the stand-alone placement in both figures. Having two different mean values may be interpreted as pixels from deep offshore of the Mediterranean Sea, and the pixels from shallow lakes and rivers inside the land. The built environment and the forest classes are quite independent in both figures. However, they overlap with sparse and agriculture classes. Red and NIR bands can be used to separate the agricultural class from the urban and forest classes as seen in Figure 13. On the other hand, to separate the sparse vegetation from the built environment and forest classes, the Green and SWIR bands can be exploited according to Figure 13.

4.2 Classification Results

In this section, classification maps, accuracy assessments of the classifications, and LU/LC distributions are presented for the years 1995, 2005, 2015, and 2021. For accuracy assessment, Overall Accuracy, Producer Accuracy, User Accuracy, and the Kappa Coefficient generated by Confusion Matrix are used as quantitative assessment. For qualitative assessment visual comparison with the classification imagery is used.

4.2.1 Classification Results in 1995

4.2.1.1 Classification Map

Figure 15 shows the classification map for Muğla in 1995. Sparse vegetation and forest areas cover most of the Muğla lands. The agricultural areas can be observed in clustered areas on the west side of Milas, the west side of Muğla city center, in Ortaca District, and the east side of Fethiye. Built environments are mostly seen in district centers such as Milas, Bodrum, Marmaris, Fethiye. Also, they are seen in the middle of land cover elements apart from urbanized areas, especially in the Northern Muğla. These areas are generally related to mining activities. The detailed examination will be in chapter 5.

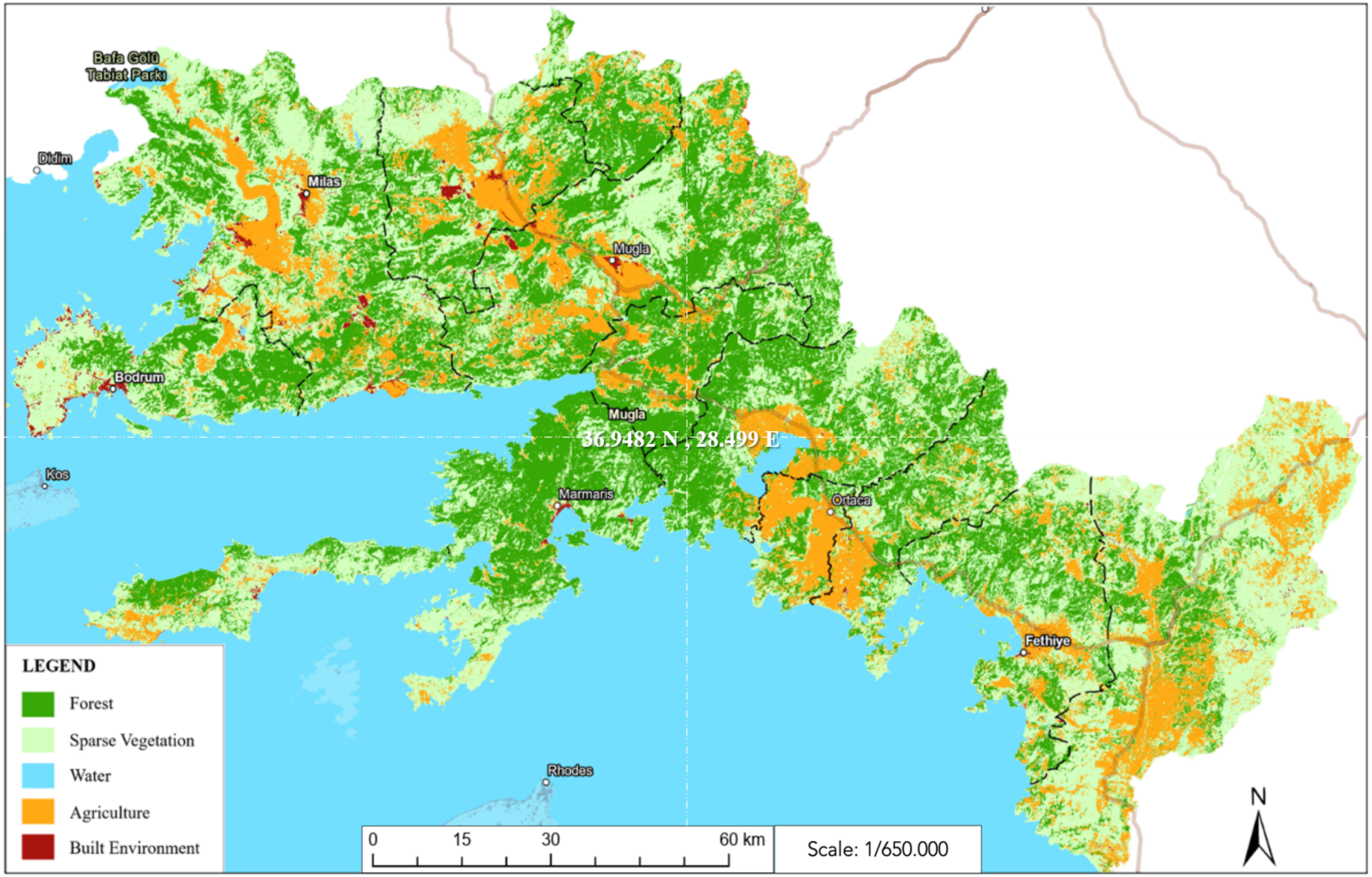

Figure 15 LU/LC Classification Map of Muğla in 1995

4.2.1.2 Accuracy Assessment

4.2.1.2.1 Confusion Matrix

The Confusion Matrix for the classification in 1995 is shown in Table 8.

Table 8 Confusion Matrix for 1995

	Prediction						
Ground Truth	Classes	Forest	Sparse veg.	Water	Agriculture	Built env.	**PA**
	Forest	7593	320	0	42	0	**95.45%**
	Sparse veg.	527	16441	1	499	192	**93.10%**
	Water	5	138	19009	67	0	**98.91%**
	Agriculture	121	1835	0	17457	98	**89.47%**
	Built env.	0	68	0	11	1278	**94.18%**
	UA	**92.08%**	**87.44%**	**99.99%**	**96.57%**	**81.50%**	**OA: 94.03%**

The Overall Accuracy and the Kappa coefficient of the classification are quite promising with 94.03% and 93.76%, respectively. The highest User Accuracy and the highest Producer Accuracy are unsurprisingly from the water class because of being spectrally differentiable as discussed in the pre-classification analysis. Following the water class, the UAs of forest and the agriculture classes are higher than 90%. The PAs of all classes except agriculture are also above 90%. The PA of agriculture is 89.47%. However, the UA of the built environment is the lowest with 81.50%. Because some of the pixels from sparse vegetation and agriculture are misclassified as the built environment. This amount of error is tolerable for image classification with a spatial resolution of 30 meters. Moreover, more than 80% accuracy is still satisfactory.

4.2.1.2.2 Visual Assessment

For a visual assessment of the classification map in 1995, a sample area is shown below with the classified image (Figure 16). This area is the north of Milas which has borders of Bodrum and Yatağan from the south-west and the north-east. The area is chosen for visual assessment because it contains all five LU/LC classes. The distinguished areas in the satellite image which are the sea in the west, agricultural areas extending in the north to south, scattered forest areas with the dark green color in the satellite image, and the built environment in the bright white and pale cream colors are correctly classified in the map. Hence, the classification in 1995 is quite promising according to visual evaluation just as the quantitative results in the confusion matrix.

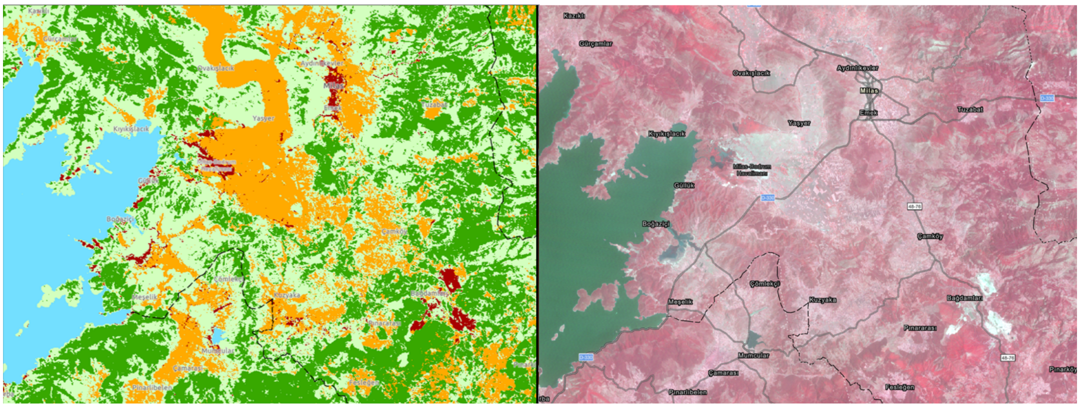

Figure 16 The classification map in 1995 (Left) and the false-color Landsat image in 1995 (Right)

4.2.1.3 LU/LC Distribution

The total surface area of land cover elements which are sparse vegetation, forest, and agriculture constitute 12.209.155 ha area, while the land-use class which is built environment occupies 112.898 ha area in 1995. The distribution can be seen in Figure 17.

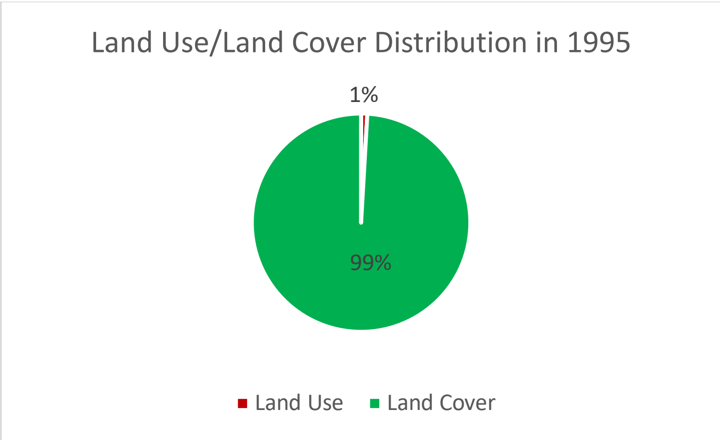

Figure 17 LU/LC Distribution in Muğla in 1995

4.2.1.4 Classification Results in 2005

4.2.1.5 Classification Map

Figure 18 shows the classification map of Muğla in 2005.

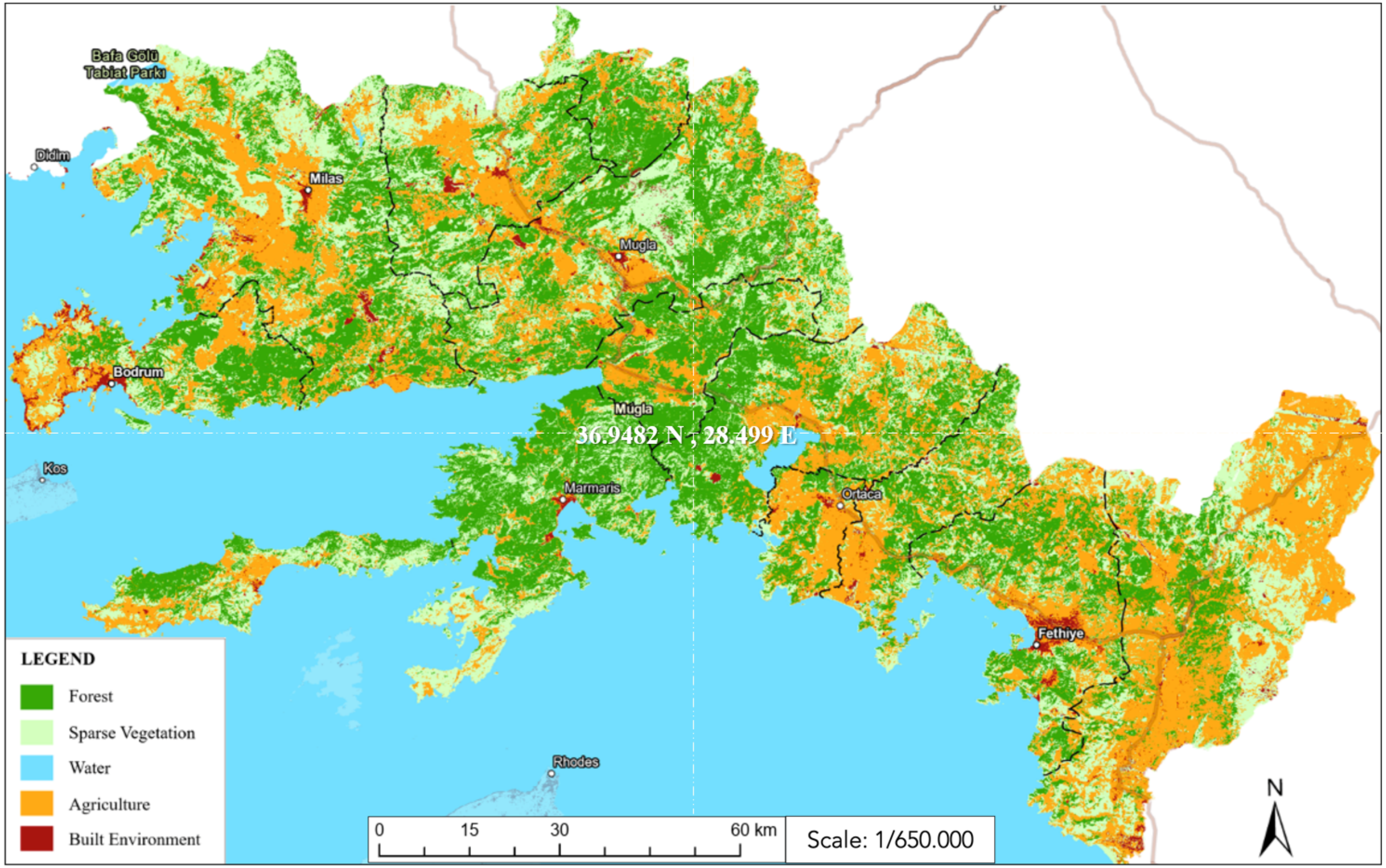

Figure 18 Classification Map of Muğla in 2005

Unlike the classification result of 1995, significant amounts of area in Fethiye are classified as the built environment. This may be due to the increase in greenhouse cultivation. The surface reflectance of greenhouse ceilings canalizes the model to classify as the built environment. Indeed, these areas have closed man-made structures that cannot be interpreted as land cover elements purely. However, it is out of the scope of this thesis.

It is seen that some sparse vegetation areas are classified as agriculture in 2005. These areas are mixed areas with vegetation and agricultural lands and some of the others are sparsely planted orchards. The details will be observed especially in the Bodrum peninsula in chapter 5.

4.2.1.6 Accuracy Assessment

4.2.1.6.1 Confusion Matrix

The confusion matrix of the classification in 2005 is shown in Table 9.

Table 9 Confusion Matrix for 2005

	Prediction						
Ground Truth	Classes	Forest	Sparse veg.	Water	Agriculture	Built env.	**PA**
	Forest	8239	136	0	50	56	**97.14%**
	Sparse veg.	367	15189	0	4092	554	**75.19%**
	Water	9	70	10185	114	7	**98.07%**
	Agriculture	9	277	0	16488	247	**96.87%**
	Built env.	4	416	3	321	4594	**86.02%**
	UA	**95.49%**	**94.41%**	**99.97%**	**78.27%**	**84.17%**	**OA: 89.04%**

The UAs of forest, sparse vegetation, and water are above 94%. The PAs of the forest, water, and agriculture are above 96%. The lowest accuracies are UA of agriculture and PA of sparse vegetation with 78.27% and 75.19% respectively. The main reason for the error is the misclassification of 4092 sparse vegetation pixels as agriculture. The UA and PA of the built environment are satisfactory. Since both of them are more than 84%. The OA of the classification is 89.04%, and the Kappa coefficient is 88.57%. Therefore, the classification in 2005 is straightforward and trustworthy.

4.2.1.6.2 Visual Assessment

In Figure 19, the sample area of the classification map in 2005 and the Landsat image in 2005 are shown.

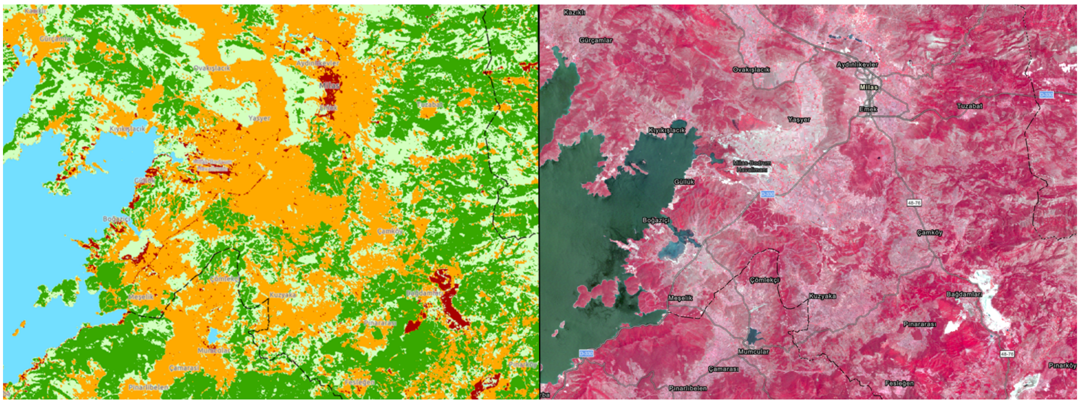

Figure 19 The classification map in 2005 (Left) and the false-color Landsat image in 2005 (Right)

The majority of LU/LC classes are assigned correctly in the classification of 2005. The visual comparison is in line with the accuracy results in the confusion matrix.

4.2.1.7 LU/LC Distribution in 2005

The total surface area of land cover elements constitutes 12.087.888 ha area, while the land use elements occupy 234.165 ha area in 2005. That means the land use elements doubled since 1995. The distribution can be seen in Figure 20.

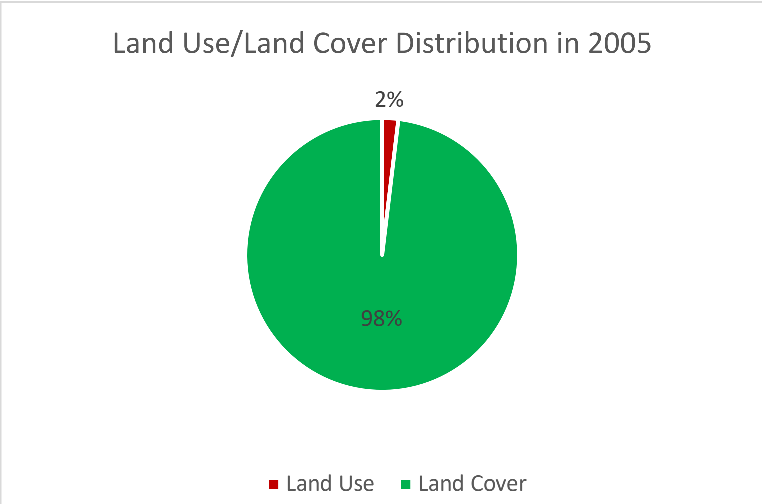

Figure 20 LU/LC Distribution in Muğla in 2005

4.2.2 Classification Results in 2015

4.2.2.1 Classification Map

Figure 21 shows the classification map of Muğla in 2015.

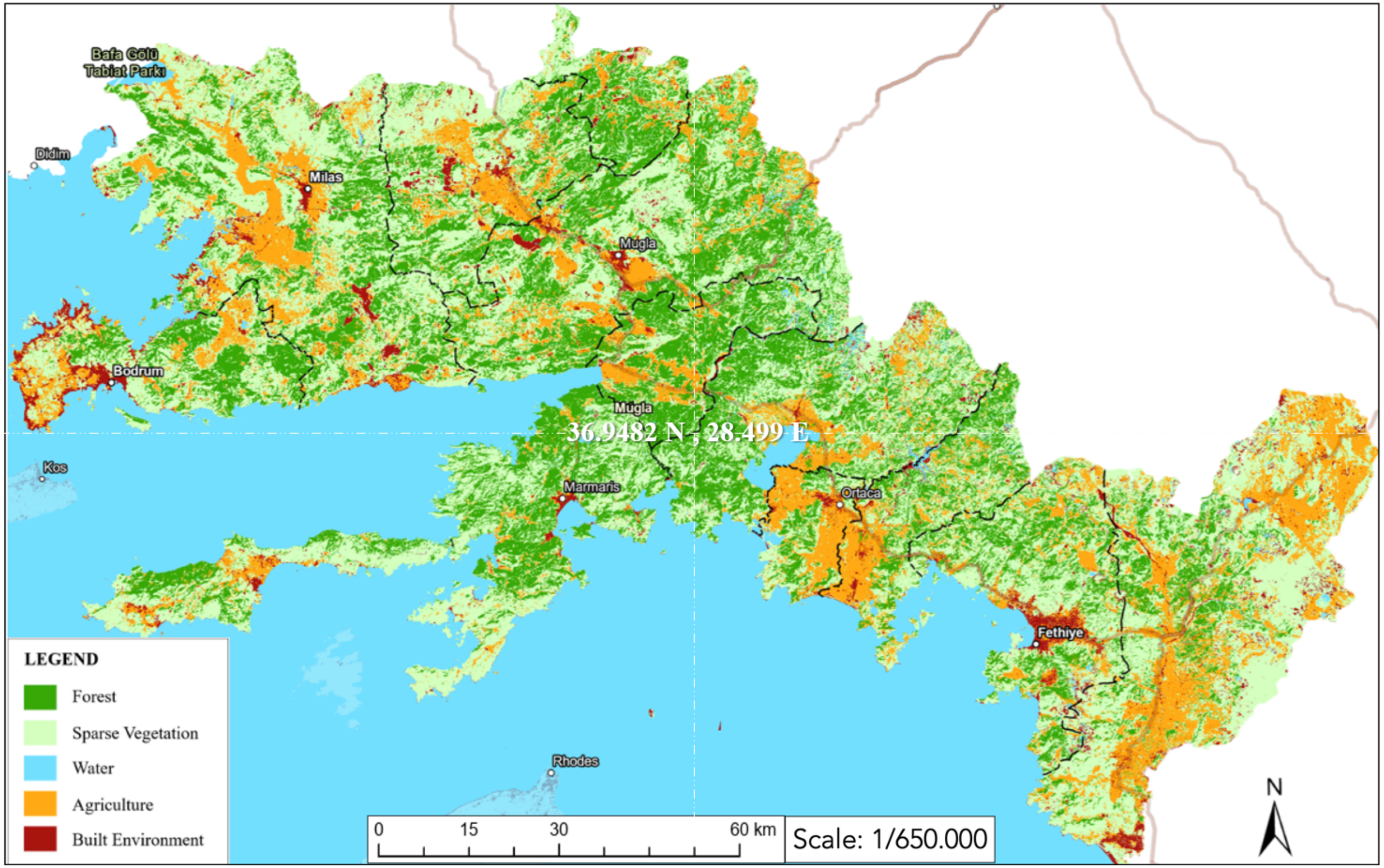

Figure 21 Classification Map of Muğla in 2015

There is a noticeable increase in the built environment compared to 2005 in district centers such as Bodrum, Marmaris, Datça, and Muğla center in 2015. Also, between Milas and Muğla metropolitan center, the built environment occupies substantial amounts of land. These areas are mainly used by the mining sector as expressed previously in the classification of 1995.

4.2.2.2 Accuracy Assessment

4.2.2.2.1 Confusion Matrix

The Confusion Matrix in 2015 is tabled below (Table 10).

Table 10 Confusion Matrix in 2015

	Prediction						
Ground Truth	Classes	Forest	Sparse veg.	Water	Agriculture	Built env.	**PA**
	Forest	7740	93	4	50	0	**98.14%**
	Sparse veg.	45	9620	46	1458	602	**81.73%**
	Water	136	351	16985	291	57	**95.31%**
	Agriculture	9	600	1	15684	426	**93.8%**
	Built env.	1	159	13	115	5569	**95.08%**
	UA	**97.59%**	**85.71%**	**99.62%**	**89.12%**	**82.45%**	**OA: 92.58%**

Forest class shows again a quite high accuracy with more than 97% as in the classifications of 1995 and 2005. The decrease in PA of water class around 4% is due to the tiny lakes that dry out seasonally and turn into semi-wetlands. The built environment performed fairly good accuracy with above 80%. Overall accuracy is quite satisfactory with 92.58%. Moreover, the Kappa coefficient is 92.24% which indicates that the classification in 2015 is reliable even after the elimination of random chance.

4.2.2.2.2 Visual Assessment

In Figure 22, the sample area of the classification map in 2015 and the Landsat image in 2015 are shown.

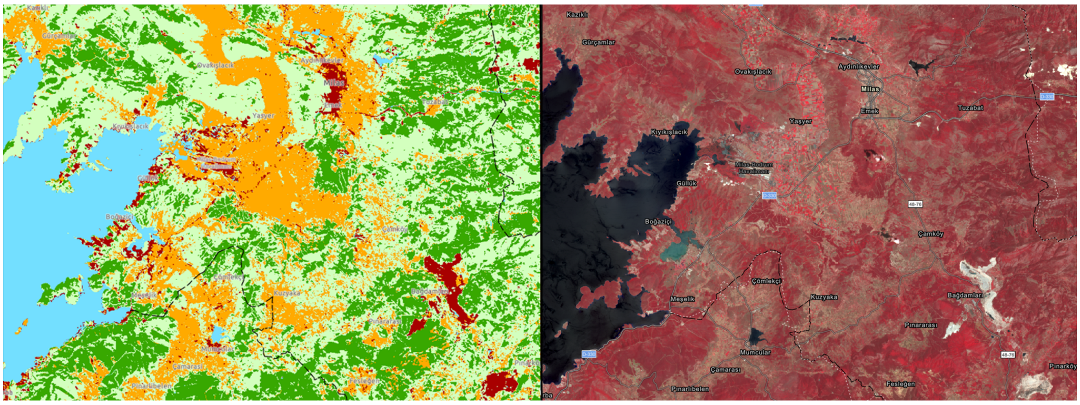

Figure 22 The classification map in 2015 (Left) and the false-color Landsat image in 2015 (Right)

The majority of LU/LC classes are assigned correctly in the classification of 2015 just like the classifications in 1995 and 2005. The visual comparison is in line with the accuracy results in the confusion matrix.

4.2.2.3 LU/LC Distribution

The total surface area of land cover elements constitutes 11.804.744 ha area, while the land use elements occupy 517.309 ha area in 2015. That means the land use elements again doubled since 2005, just as the change from 1995 to 2005. The distribution can be seen in Figure 23.

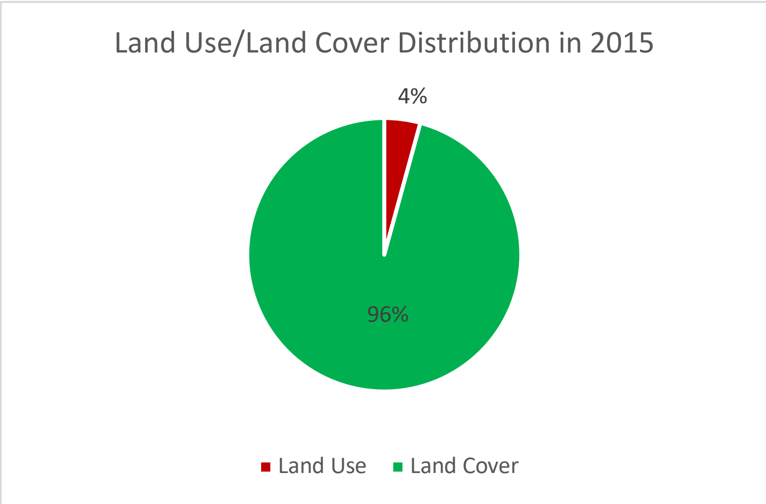

Figure 23 LU/LC Distribution in 2015

4.2.3 Classification Results in 2021

4.2.3.1 Classification Map

The classification map of Muğla in 2021 is shown in Figure 24.

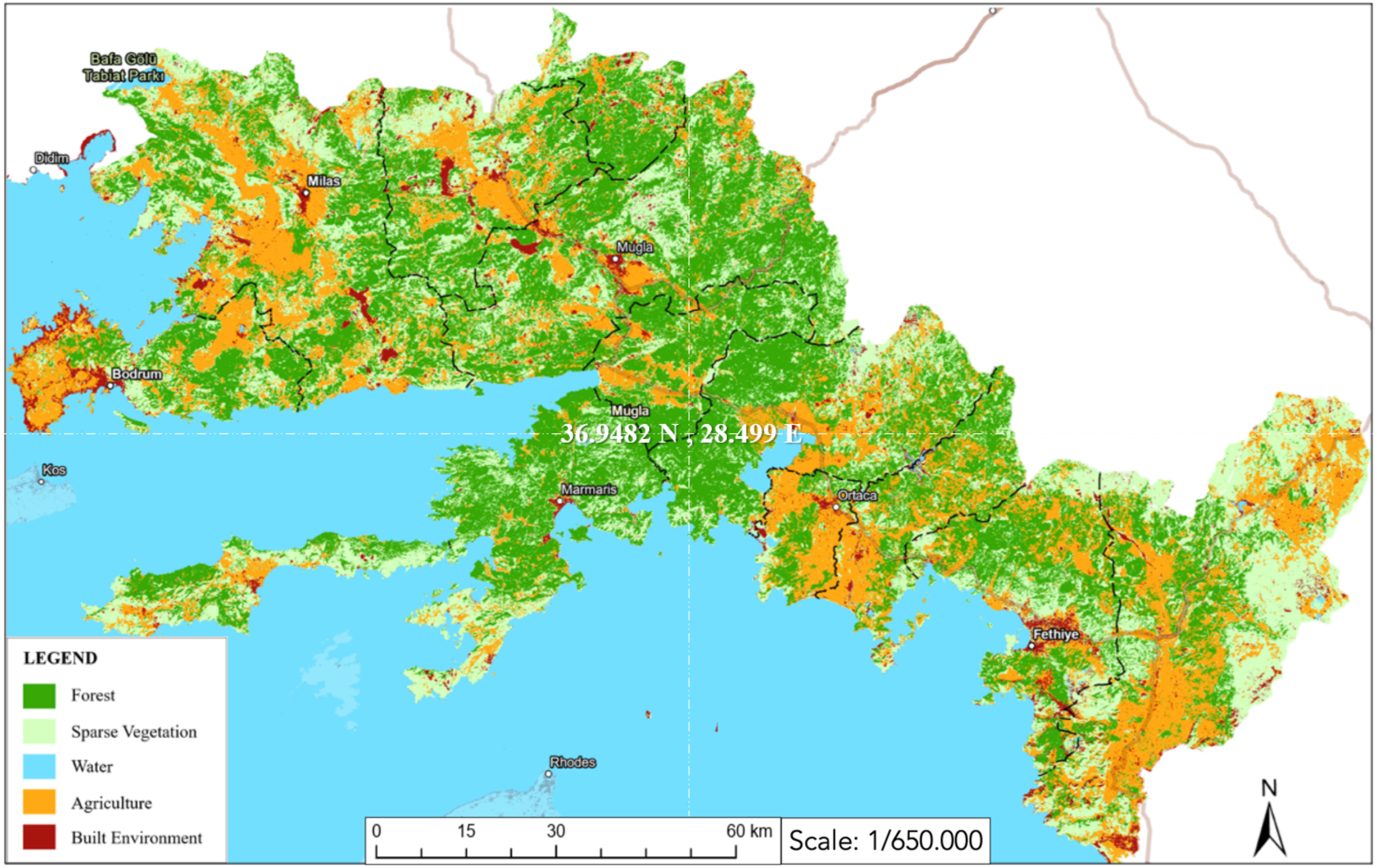

Figure 24 Classification Map of Muğla in 2021

In this classification, the majority of the lands are seen in forest and agriculture class throughout Muğla. Unlike the previous classifications, sparse vegetation areas have been detected less frequently, and forest areas and agricultural areas have taken their place. Agricultural areas consisting of four clusters can be easily observed in the classification map of 2021. Likewise, the built environment elements can be seen quite clearly in Milas, Yatağan, and the central district of Muğla. Moreover, district centers, especially Bodrum, Milas, Marmaris, Fethiye, stand out with their built environment elements. There are areas classified as the built environment in the center of Fethiye and the Karadere-Kumluova region. The details of these areas will be examined in the discussion section.

4.2.3.2 Accuracy Assessment

4.2.3.2.1 Confusion Matrix

The confusion matrix of the classification in 2021 can be seen in Table 11.

Table 11 Confusion Matrix in 2021

	Prediction						
Ground Truth	Classes	Forest	Sparse veg.	Water	Agriculture	Built env.	**PA**
	Forest	7670	63	0	68	7	**98.23%**
	Sparse veg.	206	10838	0	645	189	**91.24%**
	Water	1	17	11500	2	191	**98.20%**
	Agriculture	82	182	0	16140	272	**96.79%**
	Built env.	0	192	0	59	5020	**95.24%**
	UA	**96.37%**	**95.98%**	**100%**	**95.42%**	**88.40%**	**OA: 95.92%**

According to the OA with 95.92%, kappa coefficient with 95.72%, and minimum accuracy in PA and UA with 88.40%, it is clear that the most accurate classification is in 2021. The reason why the built environment is the lowest accuracy is related to the number of labels collected from the class. Since it occupies the least surface area. Moreover, homogenous areas that can be collected for ground truth are quite limited. Although there are elements of larger sizes in mining areas, the buildings in urban areas are smaller compared to the pixel size of 30x30 m. Furthermore, it is even impossible to collect ground truth labels for rural areas due to relatively smaller houses with sparse distribution on land.

4.2.3.2.2 Visual Assessment

In Figure 25, the sample area of the classification map in 2021 and the Landsat image in 2021 are shown.

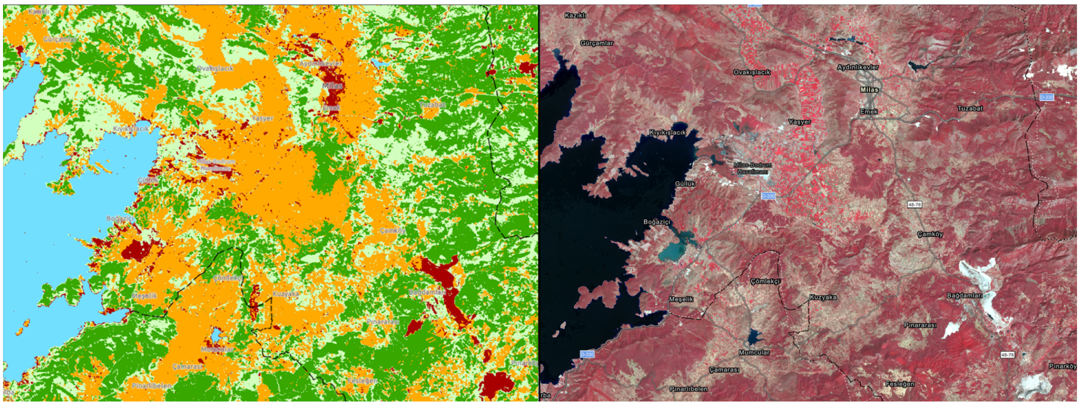

Figure 25 The classification map in 2021 (Left) and the false-color Landsat image in 2021 (Right)

The majority of LU/LC classes are assigned correctly in the classification of 2021 just like all the classifications. The visual comparison is in line with the accuracy results in the confusion matrix.

4.2.3.3 LU/LC Distribution

The total surface area of land cover elements constitutes 11.652.112 ha area, while the land use elements occupy 669.940 ha area in 2021. The distribution can be seen in Figure 26. In six years, LU/LC distribution is changed 1% in favor of land use elements.

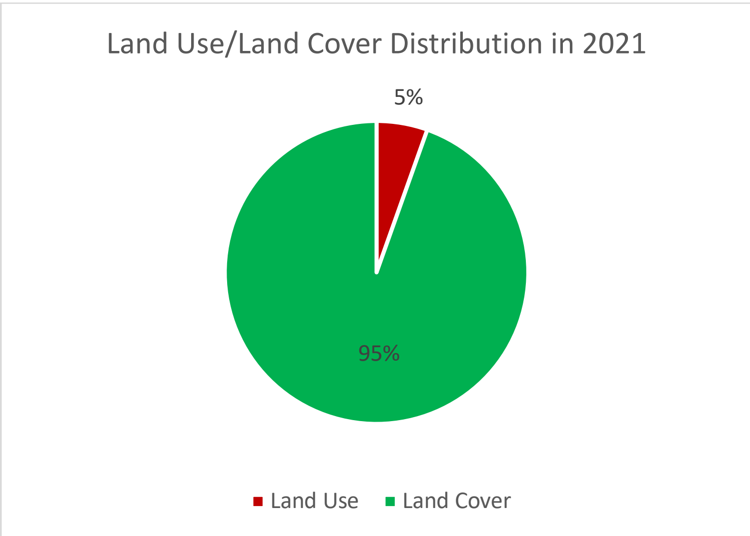

Figure 26 LU/LC Distribution in 2021

4.3 Change Analysis

In this section, the LU/LC changes in the last two decades are represented in the two sub-sections. First, amounts of the LU/LC change are examined to cover the first research question with the time series analysis from 1995 to 2021. Secondly, spatial extents of the change are observed from thematic maps for time ranges from 1995 to 2005, 2005 to 2015, 2015 to 2021, and 2005 to 2021 to answer the second research question. The last range is determined to be able to discuss the impacts of the current Territorial Development Plan which will be examined in the chapter 5.

4.3.1 Quantitative Analysis

4.3.1.1 Time Series Analysis

In this section, time series analysis is performed to be able to answer the first research question which is about the extent of the change. Figure 27 shows the changes in land cover elements from 1995 to 2021.

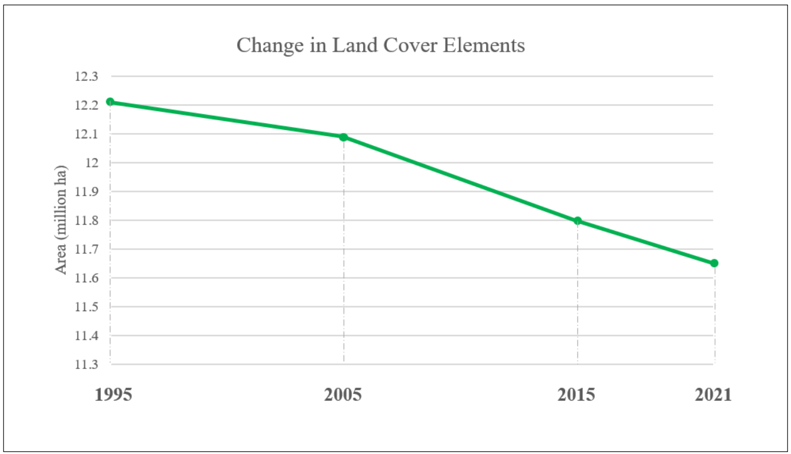

Figure 27 Change in Land Cover Elements, and Change in Land Use Elements

As seen in Figure 27, land cover elements are continuously decreased over the years. While in 1995 the land cover elements extend 12,209,155 ha area, in 2005 they decrease to 12,087,888 ha area. This means the land use elements are almost doubled between 1995 and 2005. Moreover, the rate of the change is even steeper for the values of 2005-2021 compared to 1995-2005. The land cover elements decrease to 11,804,744 ha in 2015 and 11,652,112 ha area in 2021. The acceleration of the change after the 2000s is in line with the construction based economic advancements in these years as discussed in section 2.1.1. Therefore, since the extent of the change is not negligible, the spatial analysis of the changes are needed to determine intervention areas urgently.

4.3.2 Spatial Analysis

Thematic maps are created to spatially examine the LU/LC change areas and thereby create a baseline for the second research question. In thematic maps, the red color represents the changes from land cover to land use elements. The yellow color represents the changes from land use to land cover elements. The cream color and the blue color show no change inland and the water.

4.3.2.1 Thematic Map from 1995 to 2005

In Figure 28, a thematic map representing the changes from 1995 to 2005 is shown.

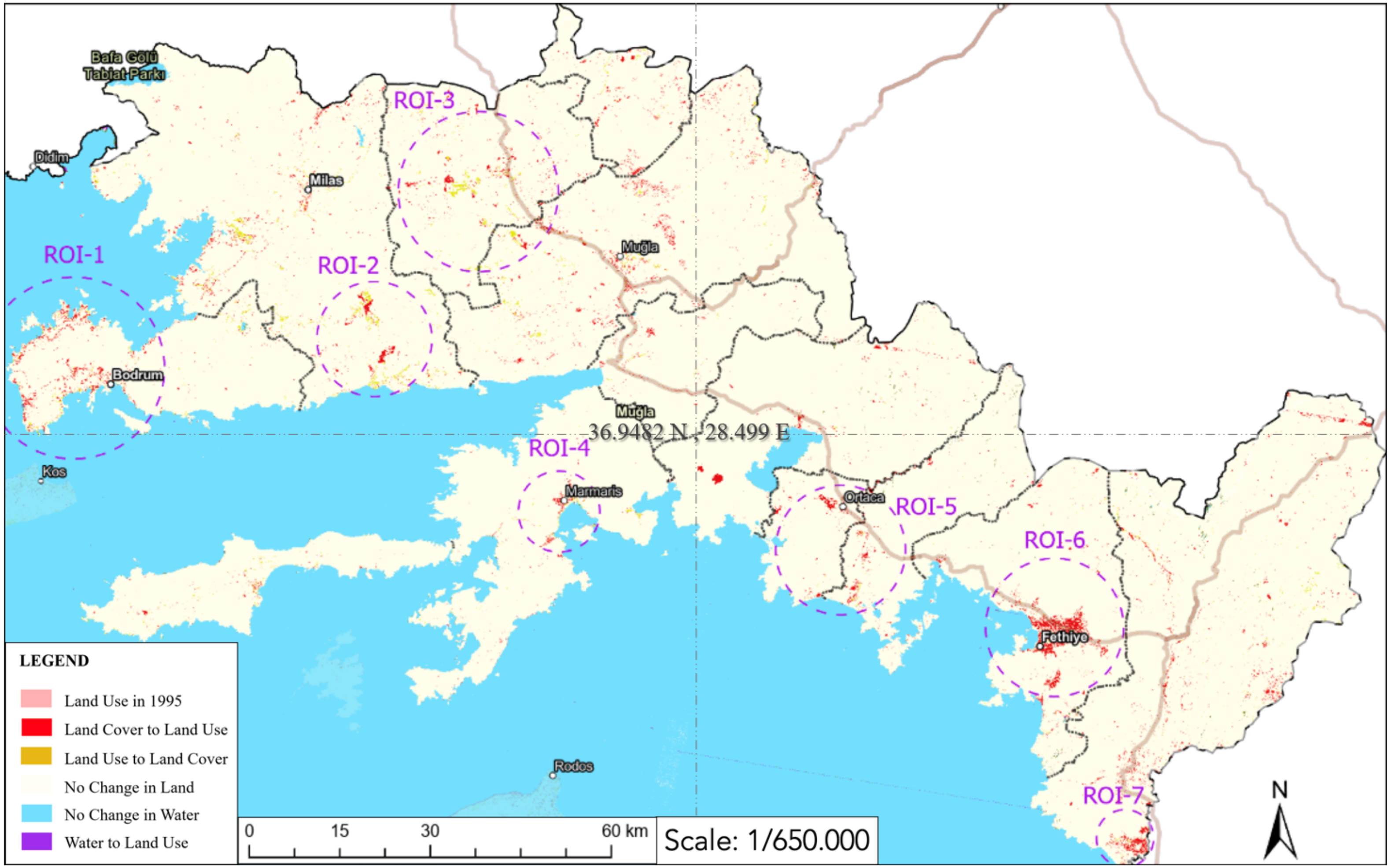

Figure 28 Thematic Map from 1995 to 2005

Seven Region of Interests (ROIs) is determined from where the changes are seen the most from 1995 to 2005. They are categorized into three sub-types of LU/LC as mining, built-up, and greenhouse in Table 12.

Table 12 LU/LC Sub-types in ROIs from 1995 to 2005

Mining	**Greenhouse**	**Built-up**
ROI-2	ROI-5	ROI-1
ROI-3	ROI-6	ROI-4
	ROI-7	ROI-6

These sub-types are determined by the ground truth observations which are introduced in chapter 3.

Although nearly all the district centers have land-use changes, they are not as significant as in the built-up ROIs. Additionally, Milas and the Central District of Muğla have scattered LU/LC changes except for the ROIs. The reason behind these changes is decentralized mining activities. Between ROI-4 and ROI-5, there is densified red region. It is caused by the cloud noise in the image in 2005. Hence, it does not take part in the ROIs.

The Mining ROIs (ROI-2 and ROI-3) show concentrated red and yellow colors. This indicates that there are changes both from land cover to land use and from land use to land cover. The reason for these changes is large-scale mining projects. The change from land cover to land use means some of the projects are started in 2005. The vice-versa is where the mining activities were seen in 1995, but terminated before 2005, and these areas were left idle. After termination, some of the idle areas which are represented in the yellow color, are covered by sparse vegetation. However, it is debatable whether nature can regenerate itself completely.

Land use elements are increased significantly in built-up ROIs, i.e. ROI-1, ROI-4, and ROI-6, from 1995 to 2005 because of the urbanization process. However, the changes in ROI-6 are also caused by greenhouse activities as in ROI-5 and ROI-7. All changes in the ROIs will be examined in detail in chapter 5.

4.3.2.2 Thematic Map from 2005 to 2015

Figure 29 represents the changes from 2005 to 2015. The legend is the same as the thematic map from 1995 to 2005.

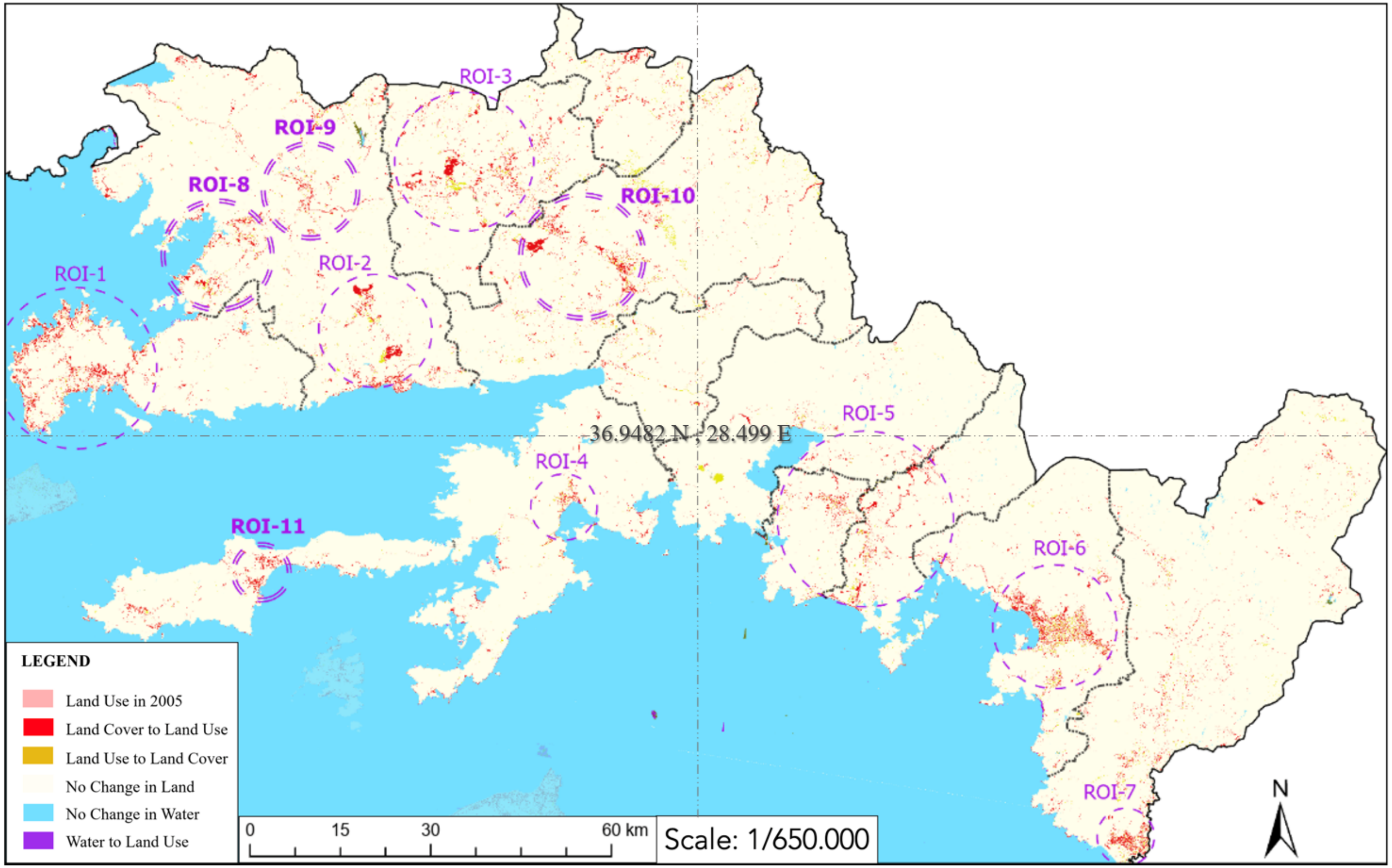

Figure 29 Thematic Map from 2005 to 2015

In the last decade, the west and the southeast sides of Muğla face dramatic changes from land cover to land use elements. Compared to the previous decade, the extent of changes is enlarged. The mining activities in Milas (ROI-2, ROI-8, ROI-9), Yatağan (ROI-3), and Central District of Muğla (ROI-10) are densified. The built-up environment is increased in Bodrum (ROI-1). The other changes can be seen in the ROIs. However, it is not possible to visually compare the number of changes with the changes in the previous decade at this scale. For this reason, detailed evaluation of these areas and discussion of the possible impacts of the current Territorial Development Plan on this change are examined in chapter 5.

ROI-8, ROI-9, ROI-10, and ROI-11 which are represented as double dash circles and bold text, are added to this thematic map in addition to the previous thematic map since significant changes are seen there from 2005 to 2015. Moreover, the circle of the ROI-5 is enlarged because of an increase in the surrounding of itself.

LU/LC sub-types in ROIs from 2005 to 2015 are shown in Table 13. While in ROI-11, most of the changes are due to the increase in built-up lands, ROI-8, ROI-9, and ROI-10 have changes related to the increase in both built-up and mining lands.

Table 13 LU/LC Sub-types in ROIs from 2005 to 2015

Mining	**Greenhouse**	**Built-up**
ROI-2	ROI-5	ROI-1
ROI-3	ROI-6	ROI-4
ROI-8	ROI-7	ROI-6
ROI-9		ROI-8
ROI-10		ROI-9
		ROI-10
		ROI-11

The area between ROI-4 and ROI-5 is seen yellow on the map. As stated in the previous section, it is because of the cloud noise in the image 2005. Since the classification map of 2015 does not have noise right there, it is labeled as land use to land cover transition. Although moderate change is seen in the west side of ROI-11, this is because of the misclassification of dry farmland as the built environment in 2015. Hence, another ROI is not added there.

ROI-2 and ROI-3 still have both-sided changes meaning that while some of the mining projects are terminated before 2015, others are started in the last decade.

4.3.2.3 Thematic Map from 2005 to 2021

Figure 30 shows the thematic map from 2005 to 2021. This thematic map is created to evaluate the effects of the current Territorial Development Plan. Since the current Territorial Development Plan is enured in 2011, the LU/LC change in 2005-2015 would not be sufficient to examine the impact of the plan.

Although there are not many serious changes according to the 2005-2015 thematic map, it is observed that the degree of LU/LC change in the existing ROIs has increased, especially in the ROI-2, ROI-3, ROI-8, and ROI-10. On the other hand, the area shown in the red and purple adjoining left of ROI-5 consists of Ala Lake, Sülüngür Lake, and Iztuzu Beach, where the Dalyan Strait flows. The region is a wetland in the form of a swamp in place to place. The swamp areas and sandy areas of İztuzu Beach are misclassified as the built environment in 2021. That’s why ROI-5 is not scaled-up to cover that area.

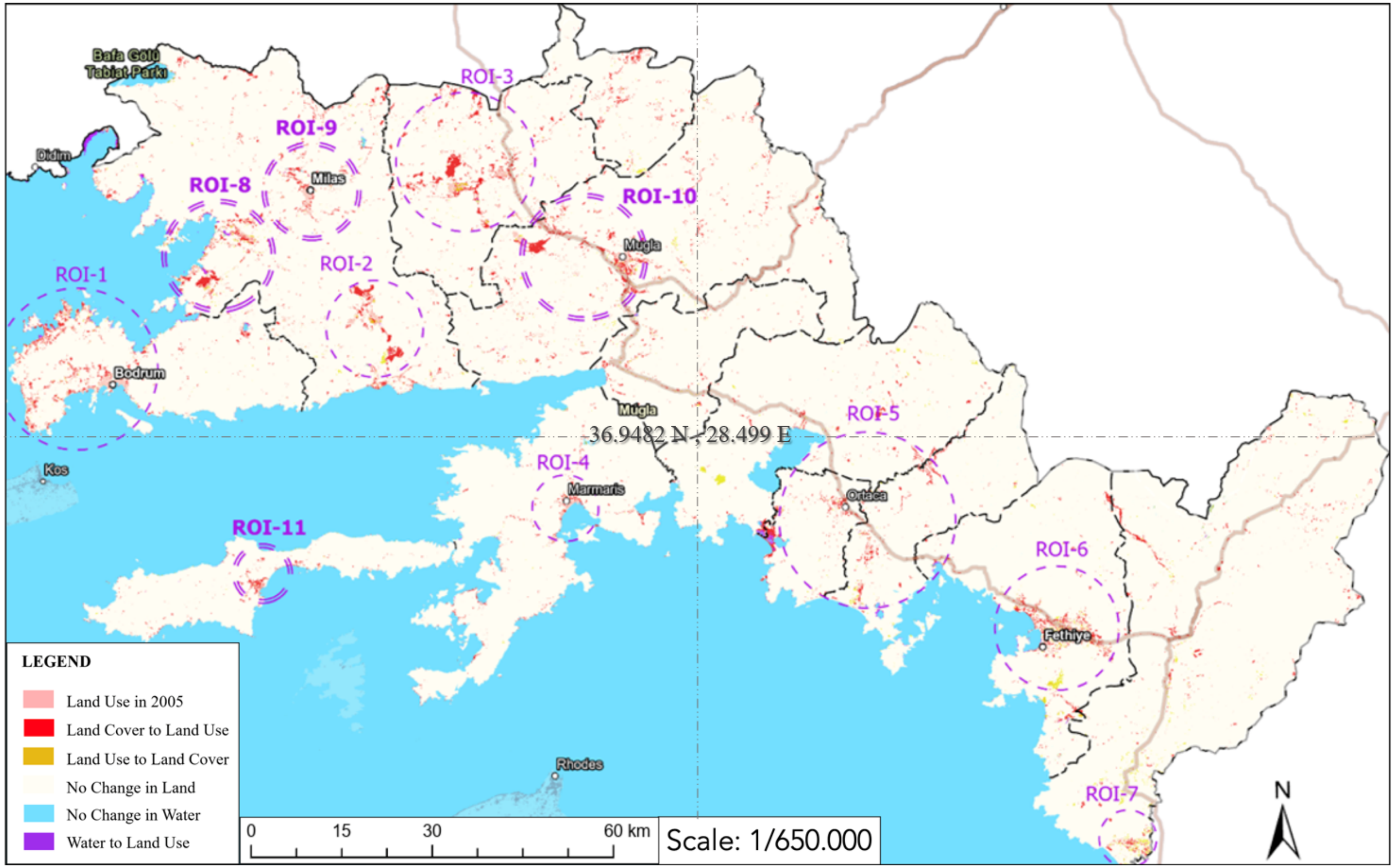

Figure 30 Thematic Map from 2005 to 2021

4.3.2.4 The Amount of the Change in the ROIs

Table 14 shows the land use elements in hectare area in the ROIs from 1995 to 2021. The color scale is determined as the medium value (yellow color) would be the 50th percentile for each ROI. Therefore, the change in land use elements increases from green to red color.

Table 14 Land Use Elements (ha area) in the ROIs

	1995	2005	2015	2021
ROI-1	20523.6	32377.5	67094.1	71075.7
ROI-2	7854.3	10298.7	17632.8	20384.1
ROI-3	12423.6	14280.3	28806.3	39132
ROI-4	4025.7	5906.7	7884.9	9361.8
ROI-5	2251.8	11940.3	27719.1	28468.8
ROI-6	3187.8	28979.1	43713.9	47118.6
ROI-7	739.8	9108.9	18889.2	9151.2
ROI-8	9634.5	10337.4	19212.3	24780.6
ROI-9	6111.9	6600.6	11316.6	15929.1
ROI-10	7383.6	13396.5	26538.3	34267.5
ROI-11	1985.4	1976.4	6728.4	7376.4

Low
Medium
High

Overall, from 1995 to 2021, the land use elements are in an increasing trend except from ROI-7 in 2021. This is because of the misclassification of greenhouse areas as discussed in section 4.3.2.3. The impacts of the current Territorial Development Plan on these changes are examined in the next chapter.

4.4 Chapter Summary

In this chapter, the results of pre-classification analysis, classification, and change analysis are examined. In the pre-classification analysis, the Probability Density Functions of LU/LC classes are discussed so that the classification process of Maximum Likelihood Estimation with the image bands can be perceived. Then, classification maps are presented with accuracy assessments. According to the confusion matrix, while the overall accuracies are 94.03%, 89.04%, 92.58%, and 95.92%, the kappa coefficients are 93.76%, 88.57%, 92.24% and 95.72% in the years 1995, 2005, 2015 and 2021, respectively. In the change analysis section, the first research question investigating the amount of land cover change and the second research question questioning where the change is seen were answered. Between 1995 and 2021, a total of 557 thousand hectares of land cover elements have been transformed with an acceleration rate between 2005 and 2021 compared to 1995 and 2005. Thematic maps have been produced to examine where the change is concentrated. According to these maps, 11 ROIs, which include districts such as Bodrum, Milas, Marmaris, and Fethiye, were determined. These ROIs are categorized based on ground truth as mining activities, construction, and greenhouse activities. In the next chapter, the third research question, whether there is an effect of the current Territorial Development Plan on the changes will be investigated over the ROIs.

CHAPTER 5

A DETAILED EXAMINATION OF LU/LC CHANGE AND IMPACTS OF THE CURRENT TERRITORIAL DEVELOPMENT PLAN

In this chapter, the plan decisions of the current Territorial Development Plan in Muğla are evaluated, then eleven ROIs are examined in detail with the thematic maps representing changes, and the Territorial Development Plan focused on the ROIs.

5.1 The Impacts of Plan Decisions on LU/LC Change

It is seen that the Articles [Such as 5.1.1, 5.1.2, 5.1.4, 5.1.5, see Appendix A] in the plan decisions about ensuring the balance of the protection-utilization of water resources, protection of forest areas, and agricultural lands show a conservative approach to the land cover elements. In addition, a special notated area is determined as “the areas whose natural and ecological form will be protected”. According to the plan report, these areas which include rocky-stony, maquis-shrub-bush, beach-sand, reeds-swamp, canyon, and agricultural areas, are allocated to the areas facing the pressure of urban development, and it has been argued that the pressure will be reduced. These areas are frequently encountered in ROI-1, Bodrum. The approach seems successful in terms of preventing the uncontrolled development of the interior of Bodrum.

On the other hand, although the Articles with the content of protecting fertile agricultural lands (Article 5.2.4 and Article 5.3.4 in Appendix B) display a conservative attitude, the term "fertile" in these articles is not clearly defined by land capability classification (Article 8.3.1 in Appendix B) or any other methods. The proposal of urban development in the agricultural lands between the Central District of Bodrum and Torba District is rationalized in the plan reports by stating that the agricultural lands in this area had already lost agricultural characteristics. Another example can be seen in the proposal of Organized Industrial Zone (OIZ) around agricultural lands and close to water bodies in ROI-9. Indeed, these transformations of land cover to land use can be justified based on the results of the preliminary analysis of the plan for the specific areas, however, in terms of being a basis for the sub-scale plans, the Articles in the Territorial Development Plan should be reconsidered so that they cannot breed uncontrolled land cover transformations.

Lastly, although Article 8.5.4 (See Appendix B) states that new licenses for mining facilities should be reported to the Ministry to be contained in the plan, there is no notation for mining areas in the current Territorial Development Plan. These areas are shown as their initial land cover elements. The gap in the plan in this regard may lead to the opening of new mining facilities only regarding the Environmental Impact Assessment (due to the obligations) which concerns sub-scale impacts, instead of evaluating the holistic impacts of the land in the Territorial Development Plan and the sub-scale plans.

5.2 Detailed Examination of LU/LC Change and the Impacts of Spatial Decisions on the Change in the ROIs

In this sub-section, first of all, where the changes occur in 1995-2005 and 2005-2015 are introduced. Afterward, a thematic map from 2005 to 2021 and the Territorial Development Plan are shown for each ROI. The thematic map from 2005 to 2021 is created to observe the impacts of the current Territorial Development Plan, as it is not possible to observe the effects of the Territorial Development Plan in the first two thematic maps due to the time intervals.

While evaluating the LU/LC change from thematic maps, the significant changes are justified by the ground truth elements of relatively high-resolution images obtained from Google Earth Pro. Since the thematic maps have some margin of errors as shown in the accuracy assessment of each classification in Chapter 4. The most possible causes of the errors can be listed as follows. The first one is the medium spatial resolution of the Landsat images. The most obvious result of the resolution is that a shape smaller than 30x30 meters on the ground is difficult to be detected because of a mixed pixel problem. At the same time, it is difficult to obtain homogenous ground truth labels. Therefore, the number of labels is less than the other classes in the built environment, and also they are not as certain as other classes. The second and the third reasons are the explanations of the variations in errors at the same area in different classification maps. For example, the area is classified as the built environment in 1995, agriculture in 2005, and again built environment in 2015 and 2021. The change in the incidence angle of the sun may cause this problem. Although the images are obtained from the same seasons, they are not on the same day in the years. Therefore, the incidence angle changes in the images. However, even if the images are obtained on the same day, there is still another factor affecting the result which is the variations in atmospheric particle densities. These particles interact with the radiation thereby changing the amount of reflection/transition/scattering in the light which causes variance in the amounts of the light the sensor gathers and the surface reflectance.

The display of thematic maps has been kept simple to be understandable. The representations are as follows. The light red color shows the existing land use elements in the initial year which are 1995 for the first, and 2005 for the second and the third thematic map. The red color and yellow color represent land cover to land use transition, and vice-versa. While mining symbols with yellow outline states that mining activities are terminated, the red outline shows that they are started or continued.

The Territorial Development Plan has many legend elements. The most abundant elements in the region are defined in the following, the special ones are clarified in the ROIs. The dark orange represents the tourism facilities, while the light orange color refers to preferential usage. It is defined as mixed-use areas with tourism facilities, settlement areas, and necessary trade and social infrastructure of urban development. The dark brown and the light brown denote urban residential areas and rural residential areas, respectively. The urban development area is represented as a yellow color. Different shades of purple color are used for various industrial areas such as industrial areas, small industrial sites, organized industrial zone, and industrial warehouses. Shades of green are agricultural areas and natural areas such as forest, scrub, meadow, and pasture.

5.2.1.1 Bodrum (ROI-1)

Figure 31 shows thematic maps representing LU/LC changes. The left map is from 1995 to 2005 and the right map is from 2005 to 2015.

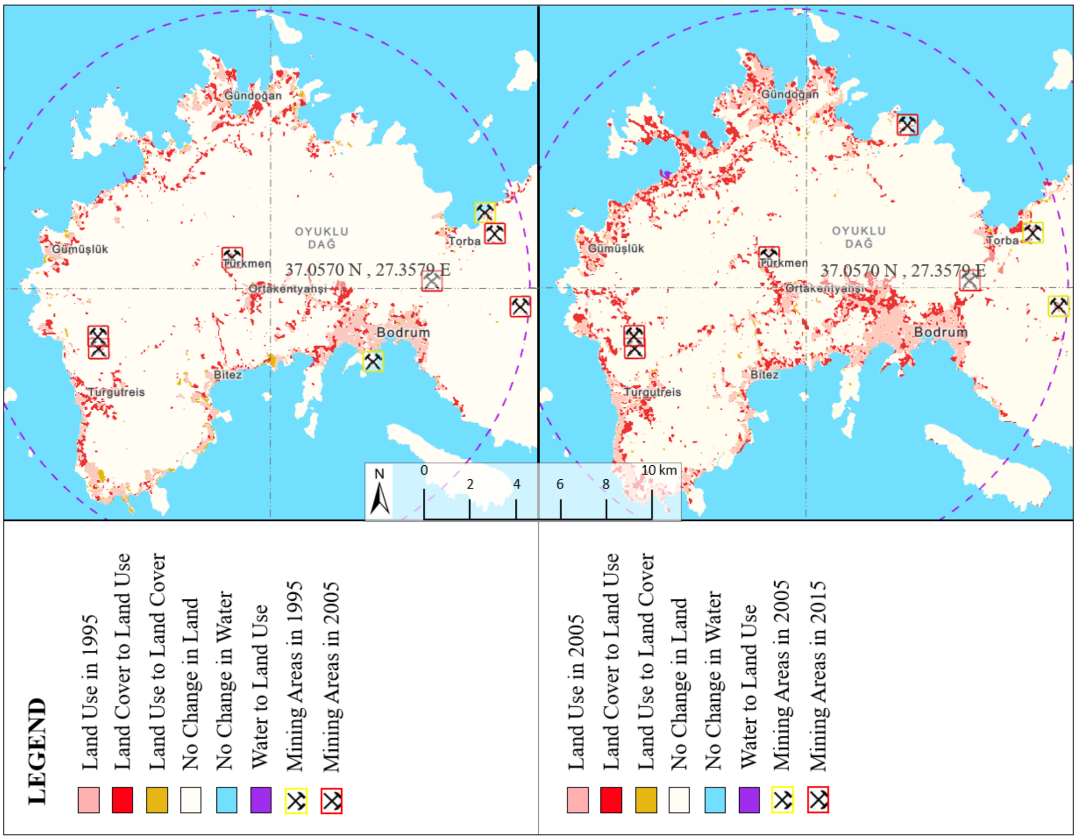

Figure 31 Thematic Maps for LU/LC Change in ROI-1 (Left: 1995-2005, Right: 2005-2015)

From 1995 to 2005, the gaps inside the urban form in Bodrum Center are filled by land use elements. The urban development with increasing compactness in the macroform is positive in terms of sustainable development instead of urban sprawl. However, out-of-center clustering is observed in the Ortakentyahşi District and the North of Bodrum Center. Moreover, especially in Turgutreis, Gündoğan and Bitez, LU/LC change is observed on the coastline. As seen purple in the map, a port was built in Yalıkavak, which is located between Gümüşlük and Gündoğan between 1995 to 2005. In addition, a linear urban development is observed along the road located midland from Yalıkavak to Gündoğan. In 2005, while mining activities are seen in Türkmen, the North of Turgutreis, and on the Torba District, some of the others are terminated in Bodrum Center and Torba District. These activities are relatively micro-scale compared to mining ROIs (ROI-2, ROI-3, ROI-8, ROI-9, and ROI-10).

On the other hand, an increase in land use elements from the coast to the interior area has increased from 2005 to 2015, which is thought to be since the coastline is already full. The direction of the development in Bodrum Center is towards the northwest from Ortakentyahşi to the Türkmen District since the Mediterranean Sea in the South and the Mountain Oyuk in the North form a natural threshold. There is a small thickening in the port in Yalıkavak, this is most probably because of the development of the capacity of the port from 2005 to 2015.

Although a new mining activity was started in the East of Gündoğan between 2005 and 2015, it can be perceived that the activity is small-scale like the others in Bodrum District and therefore did not trigger any significant LU/LC change.

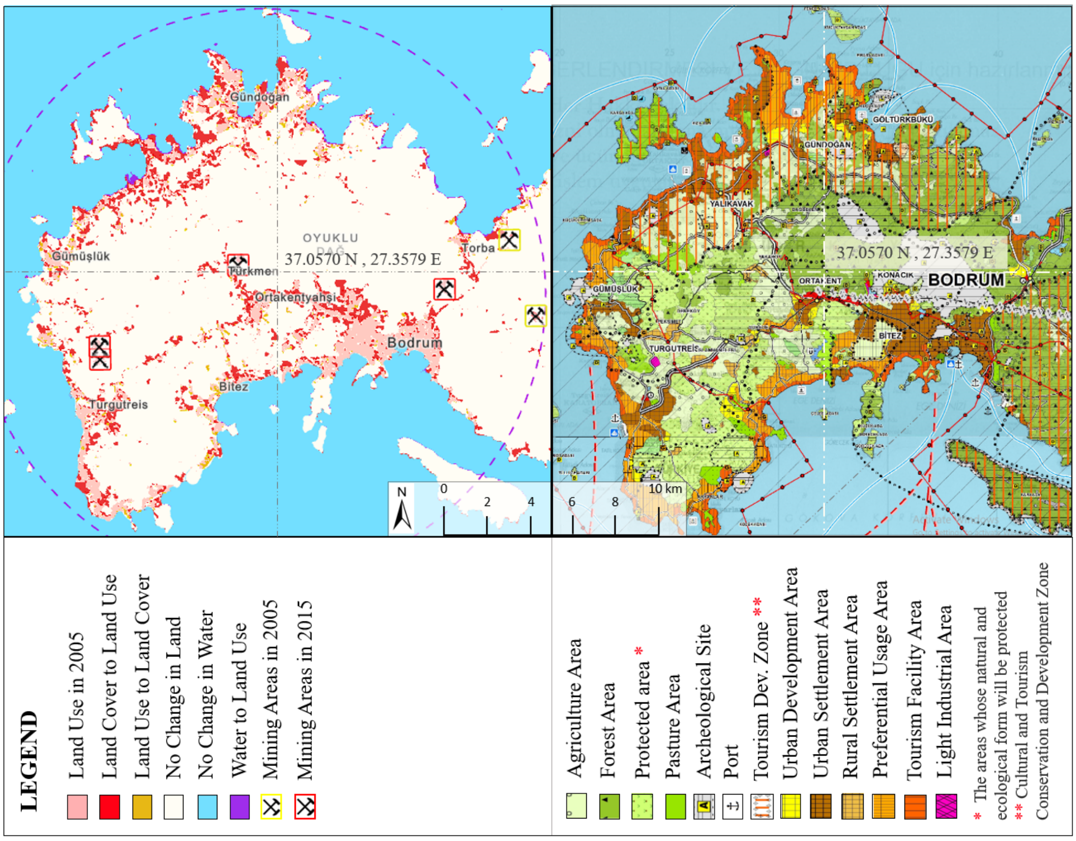

Figure 32 Thematic map for LU/LC change from 2005 to 2021 (Left) and current Territorial Development Plan in ROI-1 (Right)

In the Territorial Development Plan, Yalıkavak and Gündoğan Districts in the North are marked as Cultural and Tourism Conservation and Development Zone and are left to the special-purpose plans according to the plan report. However, the most significant LU/LC change can be observed in that region.

It is seen in the Territorial Development Plan that the LU/LC changes are planned along the coastline. The seafront is determined as a tourism facility area. The preferential usage area is designated to the areas parallel to the tourism facilities. Finally, the interior parts with clustered areas are determined as urban development areas.

The LU/LC changes in Bitez from the coast towards the interior in the direction of Turgutreis and Torba District towards Bodrum Center are also planned changes from Territorial Development Plan. The urban development area in Torba District is justified as an area that has already lost its agricultural character in the plan report.

Also, a small area in the north of Ortakent has been determined as urban development. However, it is seen in the thematic map that LU/LC changes in Ortakent overflow the planned area towards the North. The change, which stretches along the road to Turkmen in the North is unplanned. And with a reference from the Territorial Development Plan, it is seen that these areas are transformed from agricultural lands.

5.2.1.2 South Milas (ROI-2)

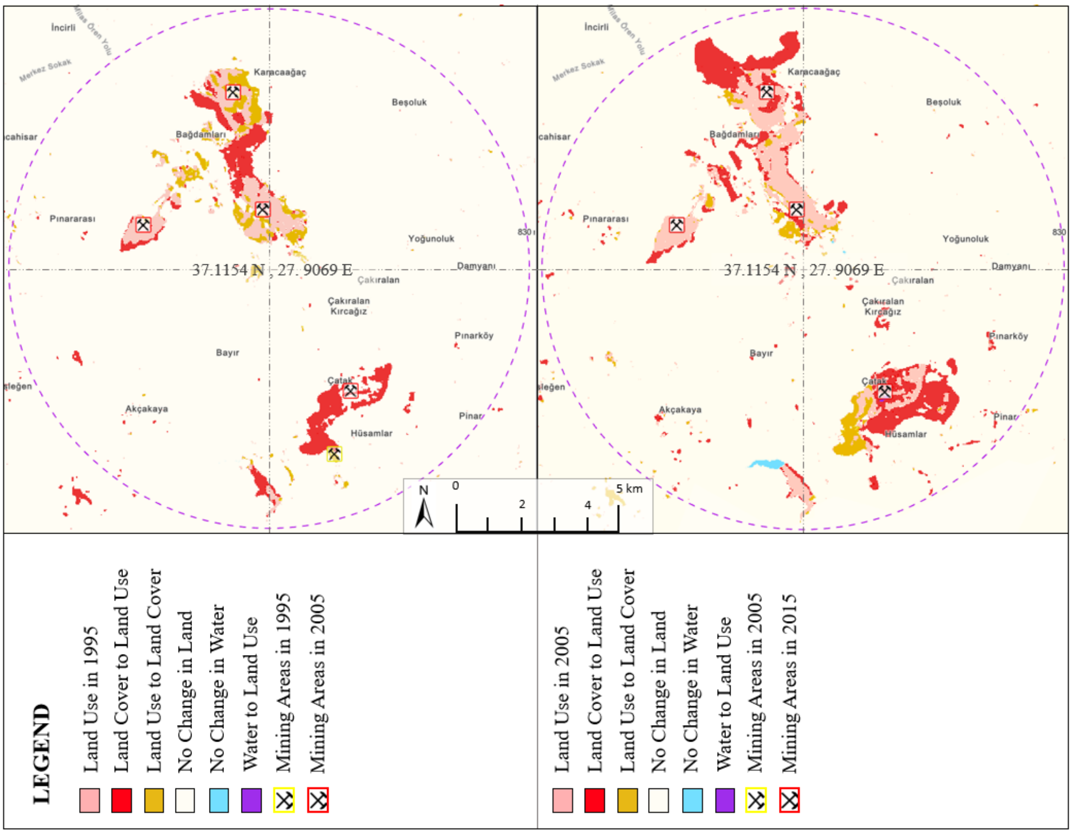

Figure 33 Thematic Maps for LU/LC Change in ROI-2 (Left: 1995-2005, Right: 2005-2015)

In South Milas, large-scale mining projects have been carried out continuously in the last 20 years. While the activities are seen in relatively small regions in Pınararası and Bağdamları in 1995, they are expanded and the gap between these districts are closed in 2005. Moreover, a new mining project is started in Çatak. In the southwest of Çatak, the land cover elements are transformed into a built environment with the construction of Ahmetler Dam from 1995 to 2005.

In 2015, the project in Pınararası expanded a relatively small amount towards the south. However, in Bağdamları the mining activities grow approximately half of the existing project towards Karacaağaç. In Çatak, on the other hand, while the mining activities in the west shifted to the east, the land cover started to regenerate itself in the western lands.

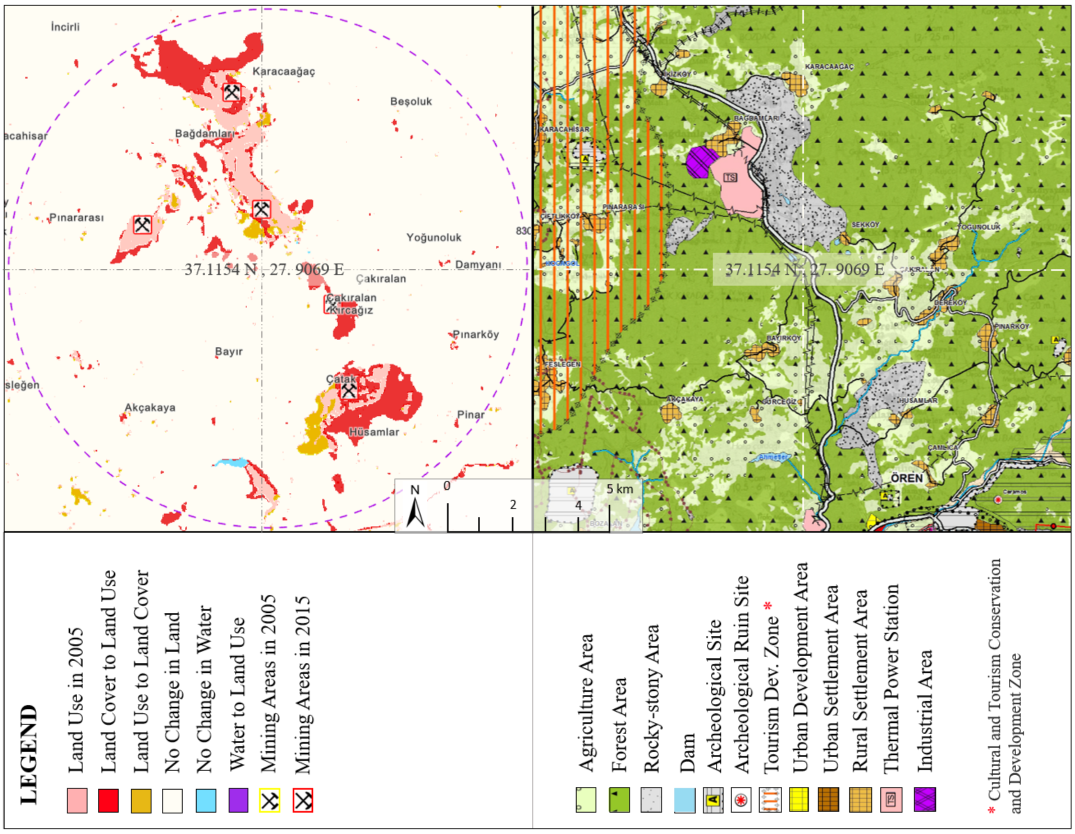

Figure 34 Thematic Map for LU/LC change from 2005 to 2021 (Left) and current Territorial Development Plan in ROI-2 (Right)

In the current Territorial Development Plan, the areas where mining activities take place are not shown. Instead, these areas are demonstrated as their initial land cover elements such as forest, agriculture, and Rocky-stony areas in the plan.

The mining activities in Çakıralan-Kırcağız cannot be observed in the previous thematic maps. Because a new mining project is started there between 2015 and 2021. Even in less than six years, the extent of the LU/LC change in Çakıralan-

Kırcağız is significant. Furthermore, the built environment in the east of Ahmetler Dam is shown as again forest land in the plan.

Therefore, it is obvious that the current Territorial Development Plan is unable to control mining activities even large-scale projects like seen in ROI-2.

5.2.1.3 Yatağan (ROI-3)

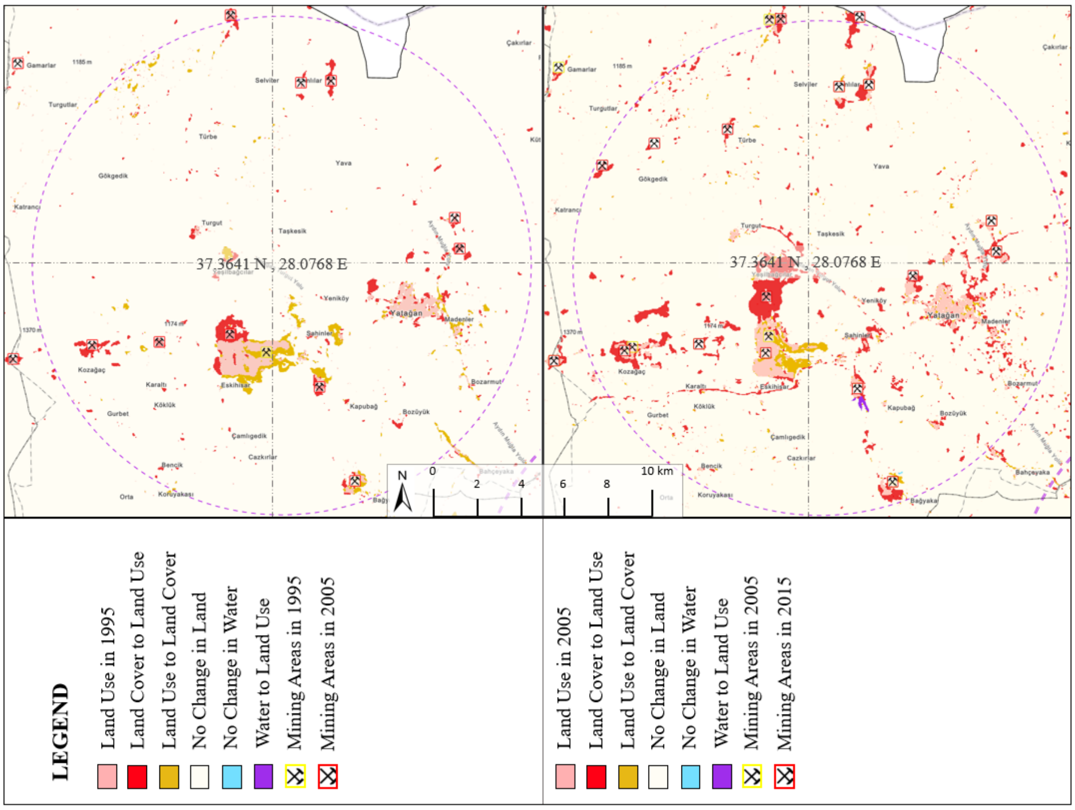

Figure 35 Thematic Maps for LU/LC Change in ROI-3 (Left: 1995-2005, Right: 2005-2015)

Mining activities, which are seen in 1995 in the south of Eskihisar, Bağyaka, and Şahinler, expanded in 2005. In Eskihisar, the expansion is shifted from the east to the north, and the east part of the district is covered by vegetation in 2005. Moreover, new mining areas are built in the north of Selviler, Kozağaç, and the center of

Yatağan District. In 2015, it is seen that the mining areas in Kozağaç, Bağyaka, Şahinler, and Selviler are enlarged more. Although there is a recession on the east side of Eskihisar, the northward growth has almost doubled towards Yeşilbağcılar. New areas are built in the north of Selviler and Gökgedik. Overall, no serious changes are observed in the rural and urban settlements.

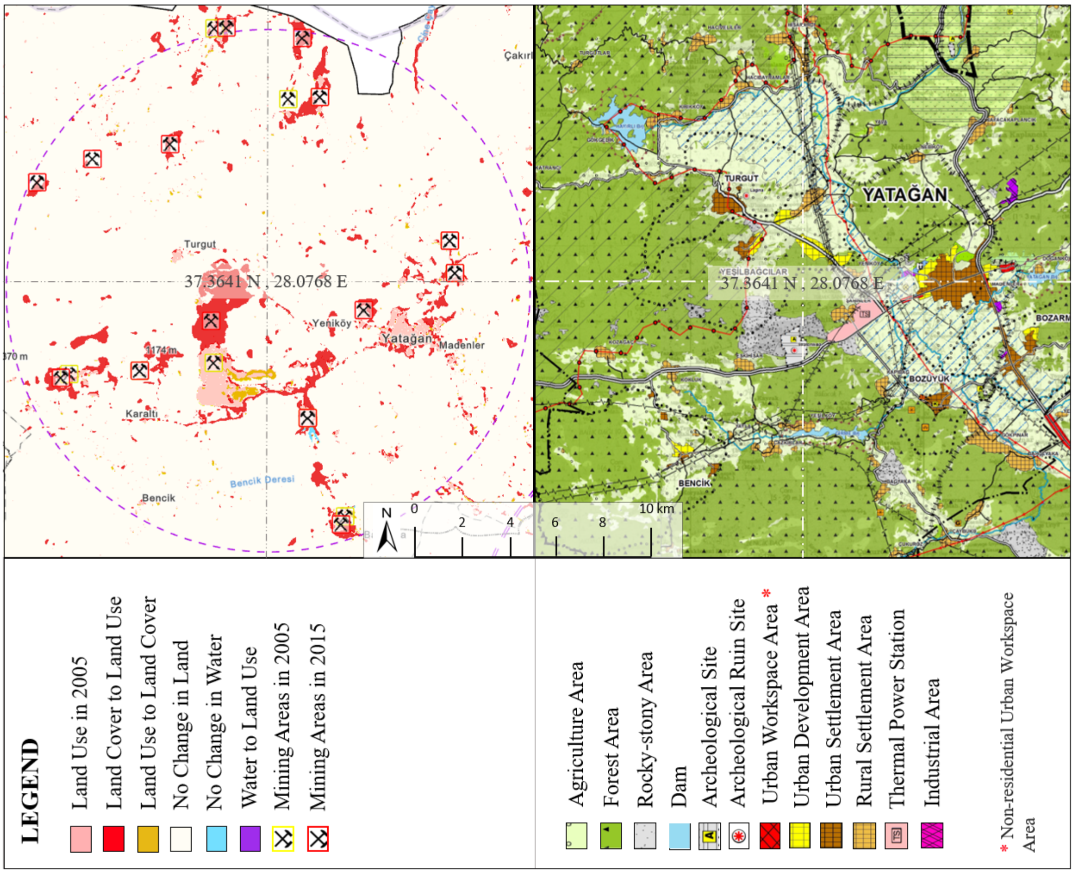

Figure 36 Thematic Map for LU/LC change from 2005 to 2021 (Left) and current Territorial Development Plan in ROI-3 (Right)

Due to the mining activities, a wide range of land cover classes shrinks in Yatağan. The mining activities carried out in fragmented areas are mostly converted from forest lands as seen in the Territorial Development Plan. On the other hand, the large-scale activities in Eskihisar and Bağyaka are transformed from the Rocky-stony area. Furthermore, with the expansion to Yeşilbağcılar in 2015, some of the agricultural lands are lost. Since such increase in the land use elements in small scattered areas induces the ecosystem in Yatağan to fragment, causing deterioration in the characteristics of the remaining land cover elements.

5.2.1.4 Marmaris (ROI-4)

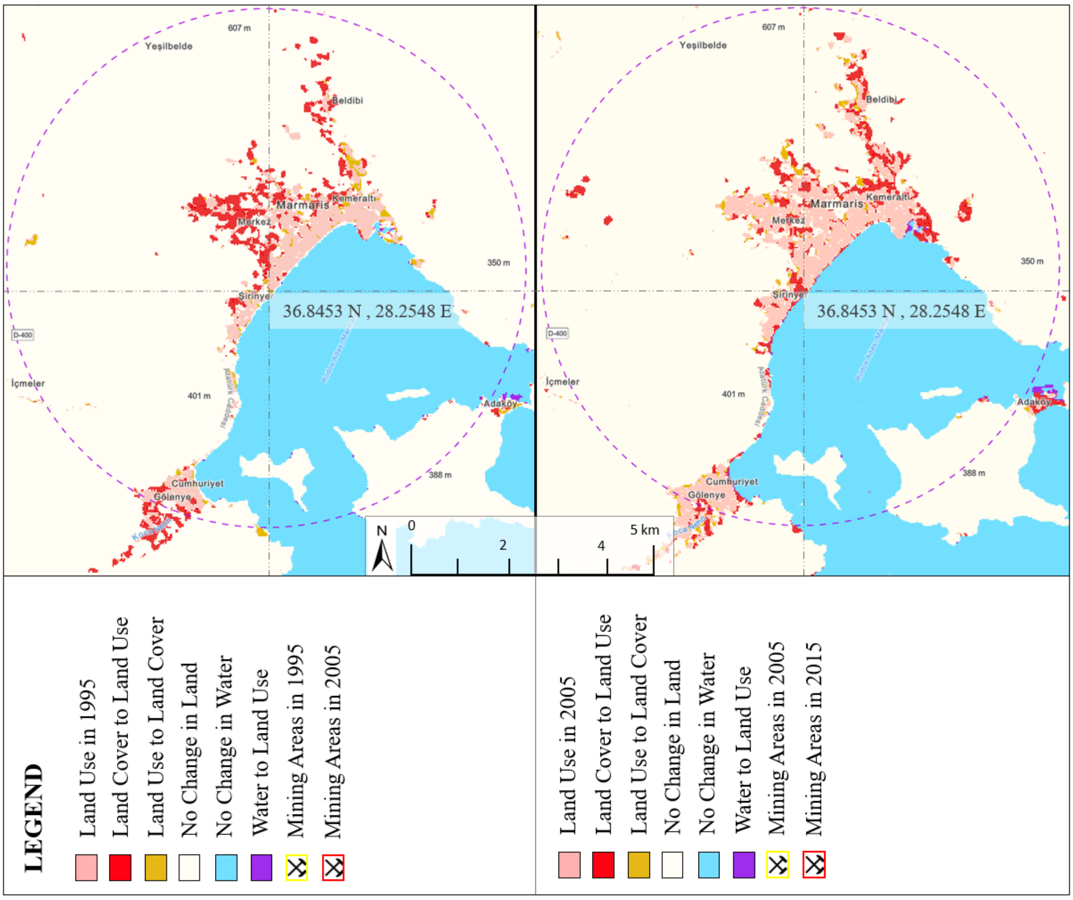

Figure 37 Thematic Maps for LU/LC Change in ROI-4 (Left: 1995-2005, Right: 2005-2015)

Marmaris faces serious LU/LC changes between 1995 and 2005. Since the coastal zone has already full before 1995, the expansion is from coastal to interior areas both in the center and in Cumhuriyet-İçmeler District. The port in Adaköy is expanded both in 2005 and even more in 2015.

Fortunately, the pace of increase in the built environment is reduced in 2015. The transition from land cover to land use occurs inside the existing macroform which is a sustainable way of development. For example, in Cumhuriyet-İçmeler, Şirinyer, and the Marmaris Center, the gaps are filled before 2015.

In Territorial Development Plan, there is no plan decision for Marmaris, because it is determined as Cultural and Tourism Conservation and Development Zone which is stated as an area subject to special law in plan decisions.

5.2.1.5 Ortaca-Dalaman (ROI-5)

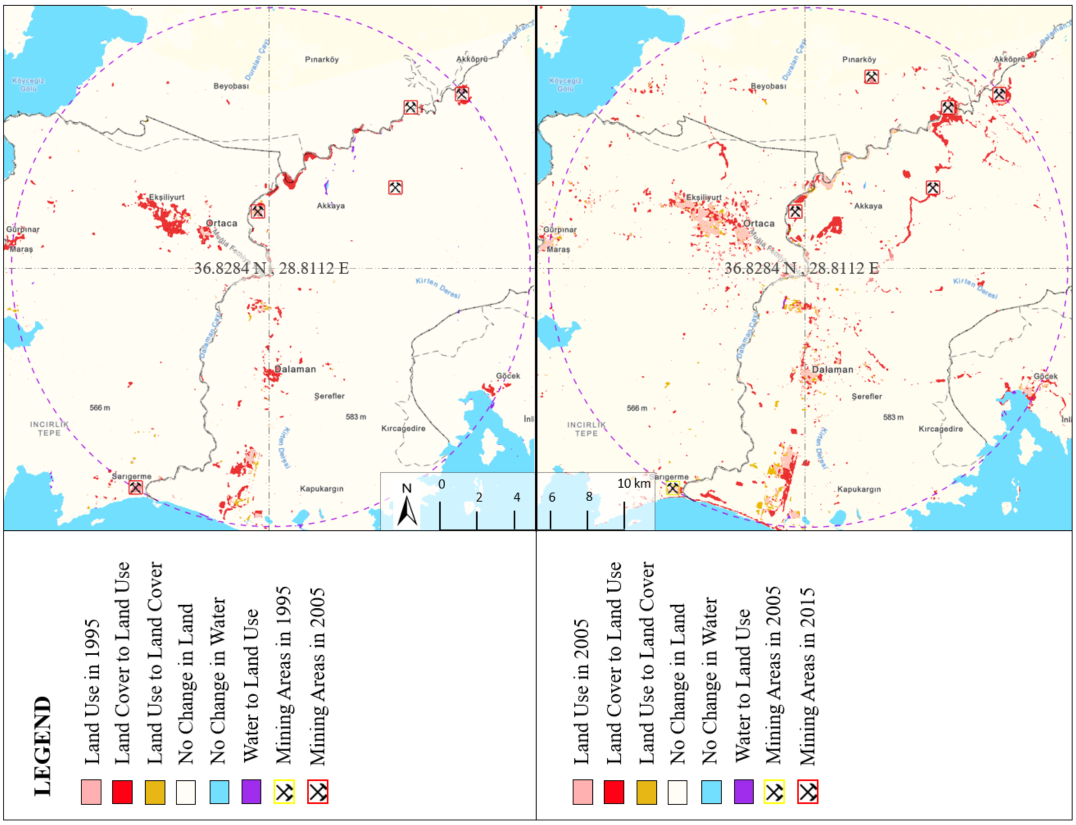

Figure 38 Thematic Maps for LU/LC Change in ROI-5 (Left: 1995-2005, Right: 2005-2015)

In the Ortaca and Ekşiliyurt Districts, greenhouse activities increased at the center from 1995 to 2005. After 2005, they also scaled up in scattered areas inside the agricultural lands. In Dalaman, while the center is expanded on the south, the greenhouses can be seen fringed between agricultural lands on the north side.

It is seen that Dalaman Airport is expanded from 1995 to 2005. The changes in these time ranges are in line with the development and the transformation of the military airport for use of the civils.

Various mining activities are started in Akkaya and Akköprü on the Dalaman Stream in 2005. Furthermore, they all expanded before 2015. Additionally, a small mining facility was opened in Pınarköy.

In the east, a large port has been built in the Gulf Göcek and at the same time, urban development is seen in Göcek Center.

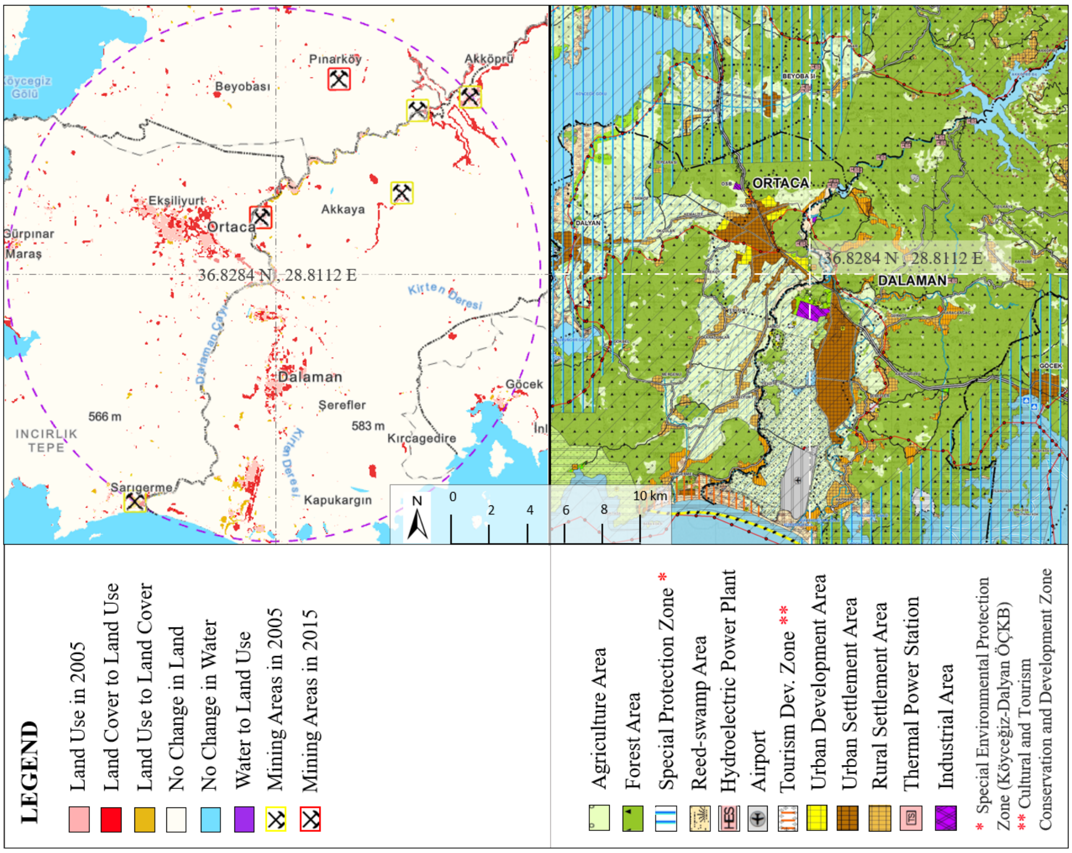

Figure 39 Thematic Map for LU/LC change from 2005 to 2021 (Left) and current Territorial Development Plan in ROI-5 (Right)

The LU/LC changes in Ortaca are planned urban development according to the Territorial Development Plan. The pointy LU/LC changes in the south of Ortaca are indicated as agriculture in the plan and a result of greenhouse activities. On the other hand, the extent of the Dalaman macroform is underrepresented by the thematic map. The probable reason is that apart from the center, the settlement is not dense in Dalaman with the large botanical garden and the fragmented agricultural lands in the city. The Dalaman Airport can also be seen in the Territorial Development Plan.

5.2.1.6 Fethiye (ROI-6)

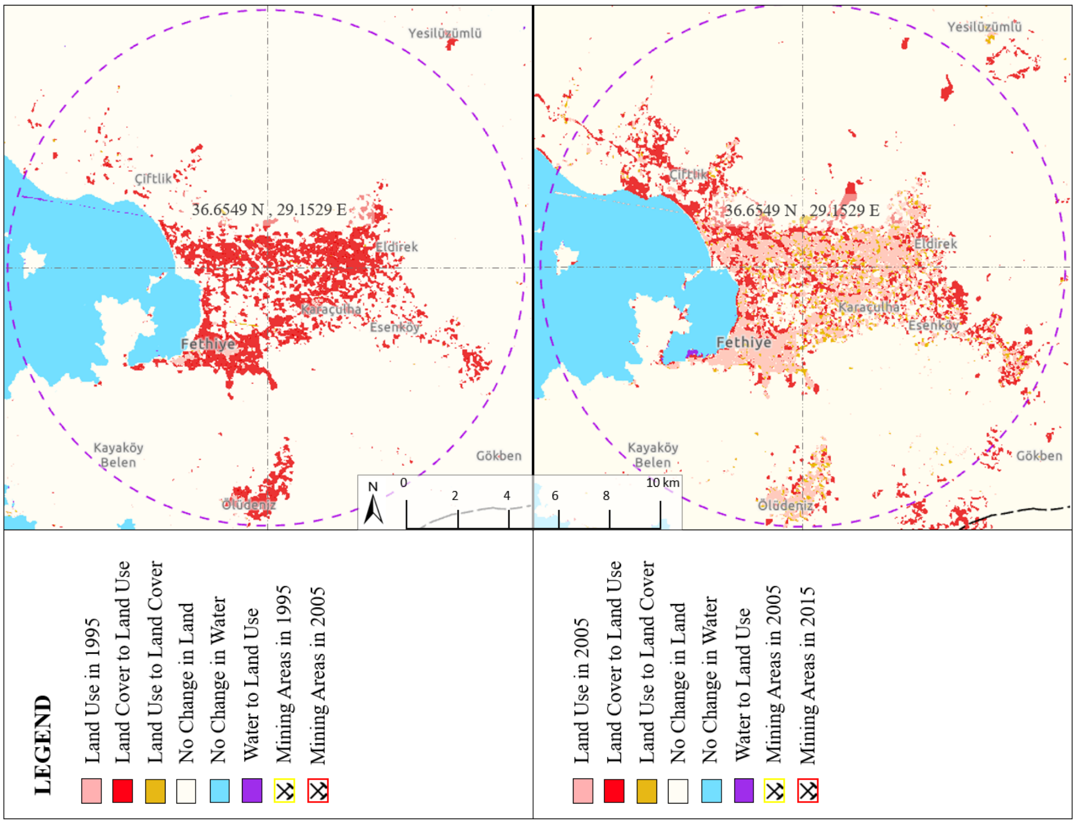

Figure 40 Thematic Maps for LU/LC Change in ROI-6 (Left: 1995-2005, Right: 2005-2015)

From 1995 to 2005, it is observed that the built environment has increased significantly due to intensive greenhouse activities in the Fethiye Plain, extending to Yeni in the north, Eldirek and Eserköy in the east, and Karaçulha in the south. It is understood from the ground truth regions that the built environment in the center of Fethiye is caused by urban development. In Ölüdeniz, while there was a sparse rural area surrounded by agricultural lands in 1995, these agricultural lands turned into urban elements in 2005. It is seen that a port was built in Fethiye in 2005. While in 2015, the port is seen as thickened because more boats are berthed with the increase in the capacity of the port.

It is clear that a significant amount of greenhouse activities continue in the region in 2015, and there is even an increase towards the north in Esenköy on the Fethiye Plain. At the same time, there is a serious increase in land use elements in Karagedik and Kargı in the north. The seaside has been lost to urban development, although the vast majority is greenhouse-based.

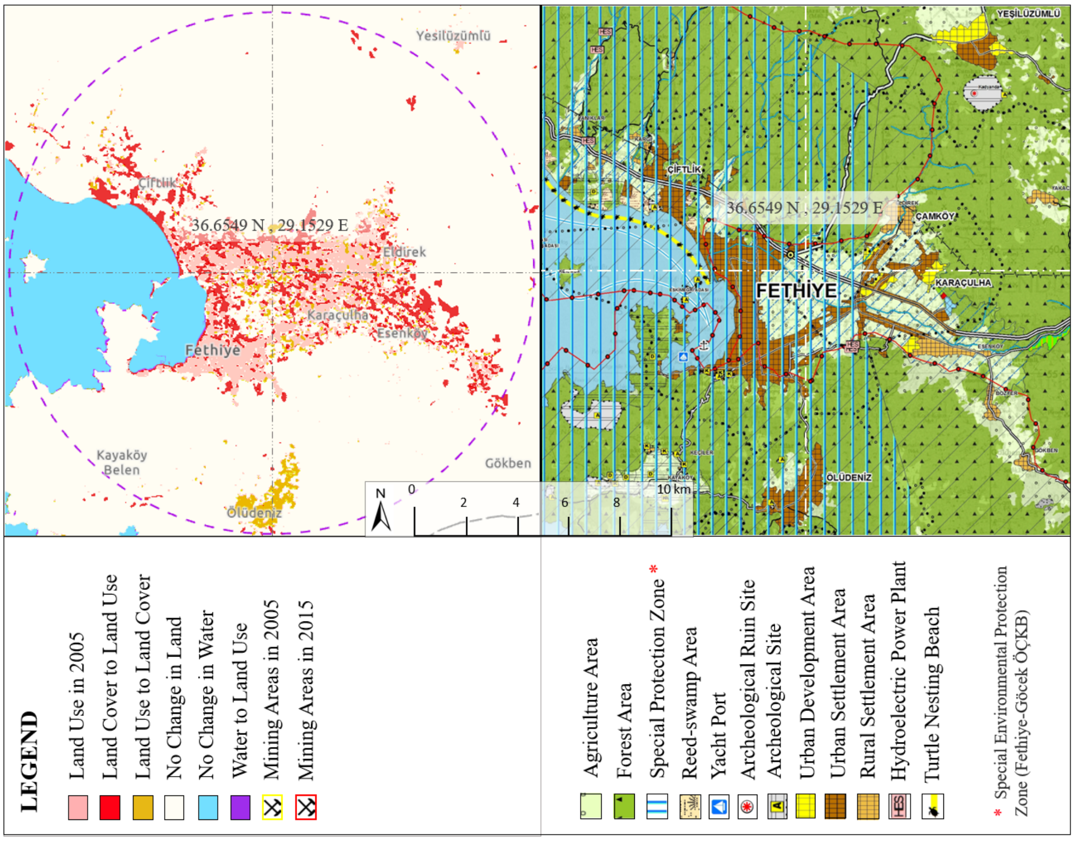

Figure 41 Thematic Map for LU/LC change from 2005 to 2021 (Left) and current Territorial Development Plan in ROI-6 (Right)

As indicated by the blue vertical lines in the Territorial Development Plan, a large area in Fethiye, including Fethiye Center and Ölüdeniz, is the Fethiye-Göcek Special Environmental Protection Zone. Therefore, the LU/LC elements in the year the plan is prepared to remain the same in the Territorial Development Plan. Although urban development has been suggested in Karaçulha, the impact of this decision on the change cannot be observed because the greenhouse activities make it to be indistinguishable from the urban texture.

5.2.1.7 Karadere-Kumluova (ROI-7)

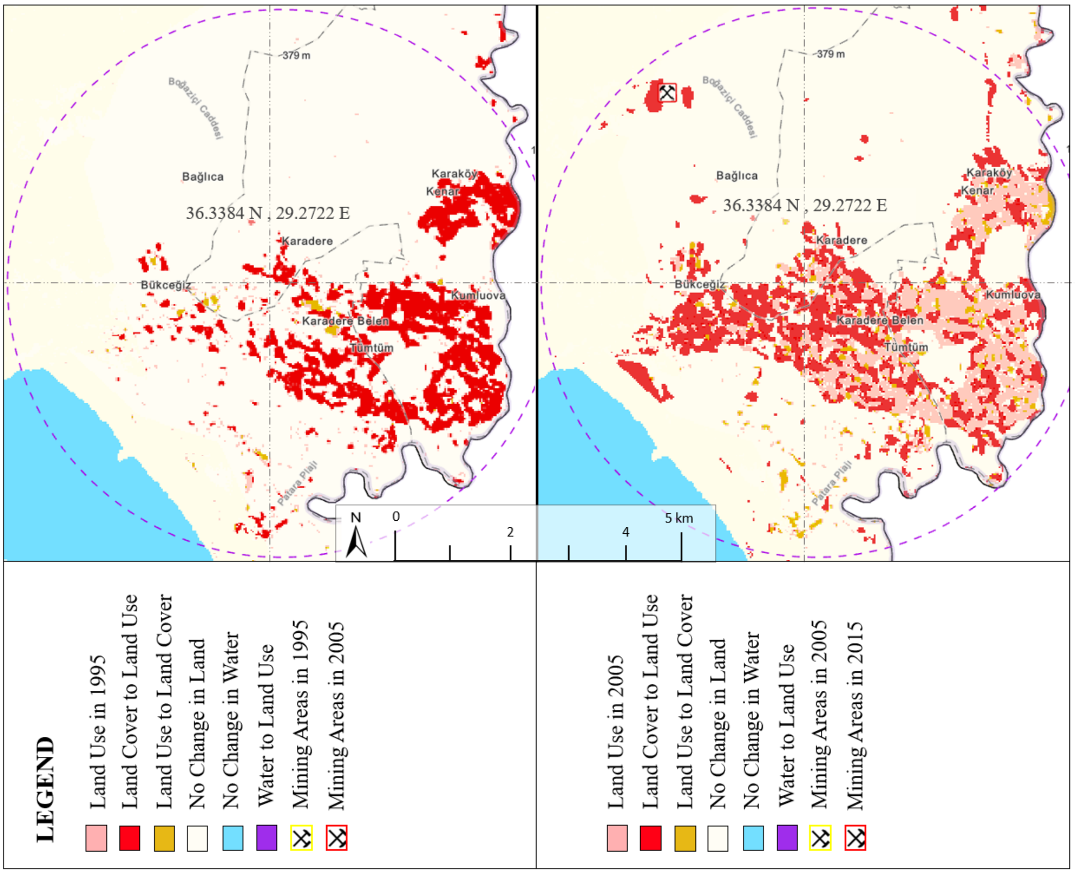

Figure 42 Thematic Maps for LU/LC Change in ROI-7 (Left: 1995-2005, Right: 2005-2015)

In Karadere-Kumova, it is observed that the land use elements increased between 1995 and 2005 due to greenhouse activities. Between 2005 and 2015, a new mining area is seen in the northwest of Bağlıca, and medium-scale land cover degradation is observed there.

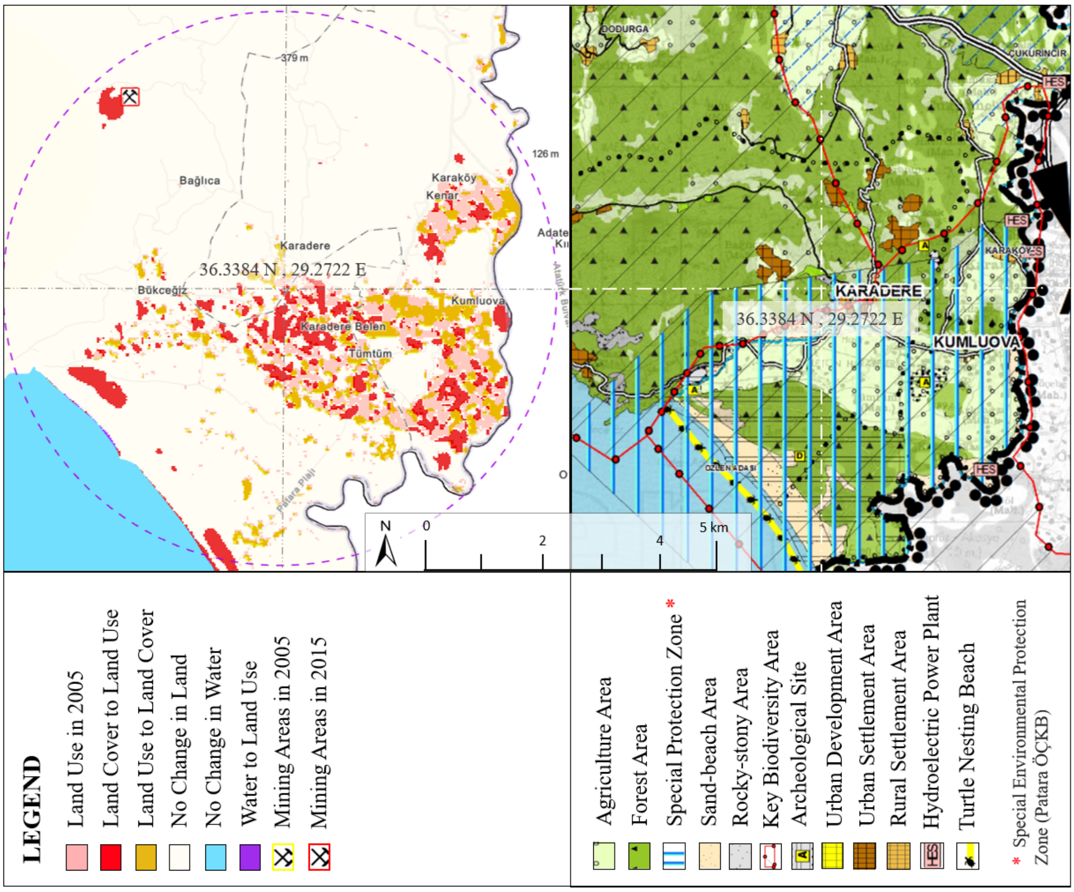

Figure 43 Thematic Map for LU/LC change from 2005 to 2021 (Left) and current Territorial Development Plan in ROI-7 (Right)

It is observed in the thematic map that some regions in Karadere-Kumluova have transformed from land use elements to land cover elements between 2005 and 2021. According to ground truth, it can be said that the greenhouse activities are not decreased in these regions which means that these areas are not detected correctly. However, in Karadere-Kumluova, greenhouse agriculture is still a major LU/LC type, and the thematic map represents the situation. On the other hand, the two clusters of land use elements located by the sea on the thematic map are due to the misclassification thought to be caused by the sandy structure of Patara Beach.

Karadere-Kumluova is a Special Environment Protection Zone as indicated by the blue vertical lines in the Territorial Development Plan. For this reason, the area has been left as it is in this plan. Although the northwest of Bağlıca faces LU/LC change from 2005 to 2015, the area is neither included in the Special Environment Protection Zone nor in the Territorial Development Plan, like the other mining activities.

5.2.1.8 North-West Milas (ROI-8)

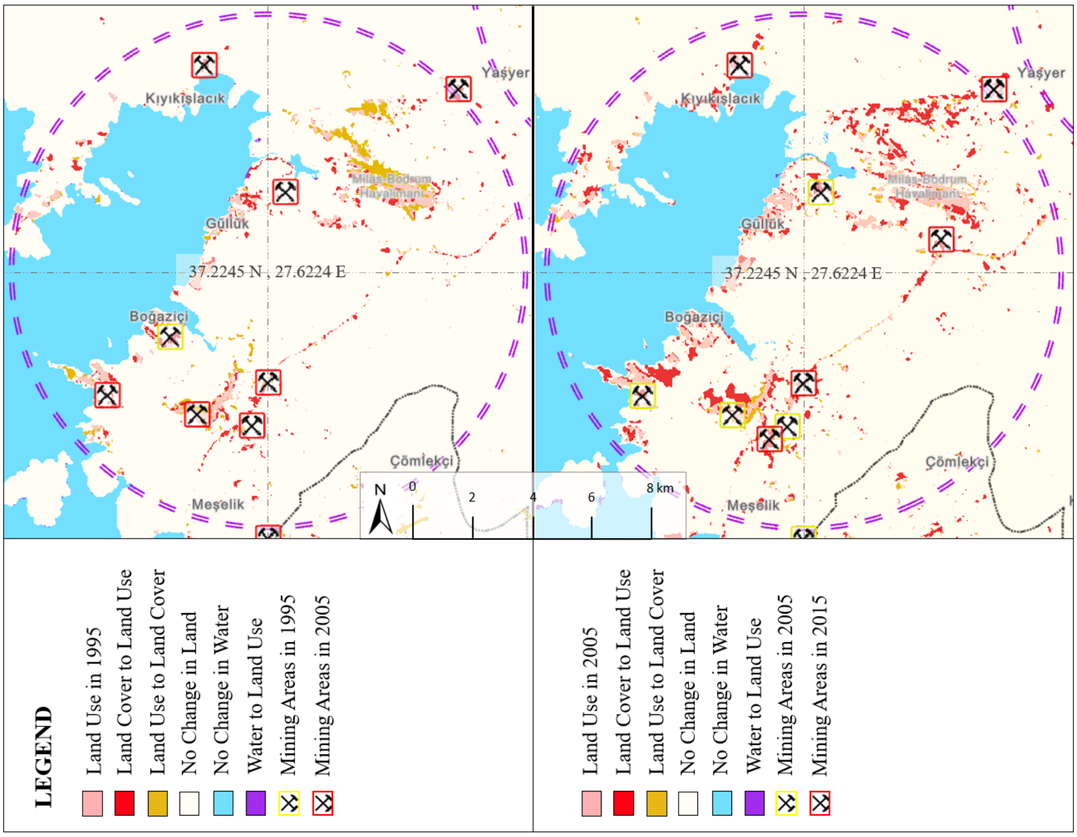

Figure 44 Thematic Maps for LU/LC Change in ROI-8 (Left: 1995-2005, Right: 2005-2015)

Milas-Bodrum airport can be seen on the thematic maps. Although the airport was built before 1995, the reason why it appears as a LU/LC change is that the area was designated as a land cover in 2005. Similarly, there is a classification error in the north of the airport. However, the increase of the LU/LC change over time through 2015 is undeniable there. From ground truth observations, it is deduced that fish farming facilities are concentrated in these areas. While some of these facilities are covered with greenhouses, some of the others are carried out in an earthen pond.

Therefore, the classification of these lands is not easy with the medium spatial resolution images.

While the line running south of the airport is seen as thickened between 1995 and 2005, it became more dominant in the second time range. At the end of the line, there is a clustered LU/LC change caused by many mining activities, especially during the last decade.

Located just above the clustered mining area, there is Kavaklarboğazı Creek, where the Canal Boğaziçi flows. While the south of this creek was in marsh-reed form, it was shown as a land use element in 1995 and 2005. In 2015, its expansion to the north in two parts can be perceived as the widening of the marsh-reed section in the creek. Figure 45 shows that Kavaklarboğazı Creek in 1995, 2005, 2015, and 2021 was created from the Landsat images in which the classification was applied.

Figure 45 Kavaklarboğazı Creek in 1995, 2005, 2015, and 2021 in natural colors

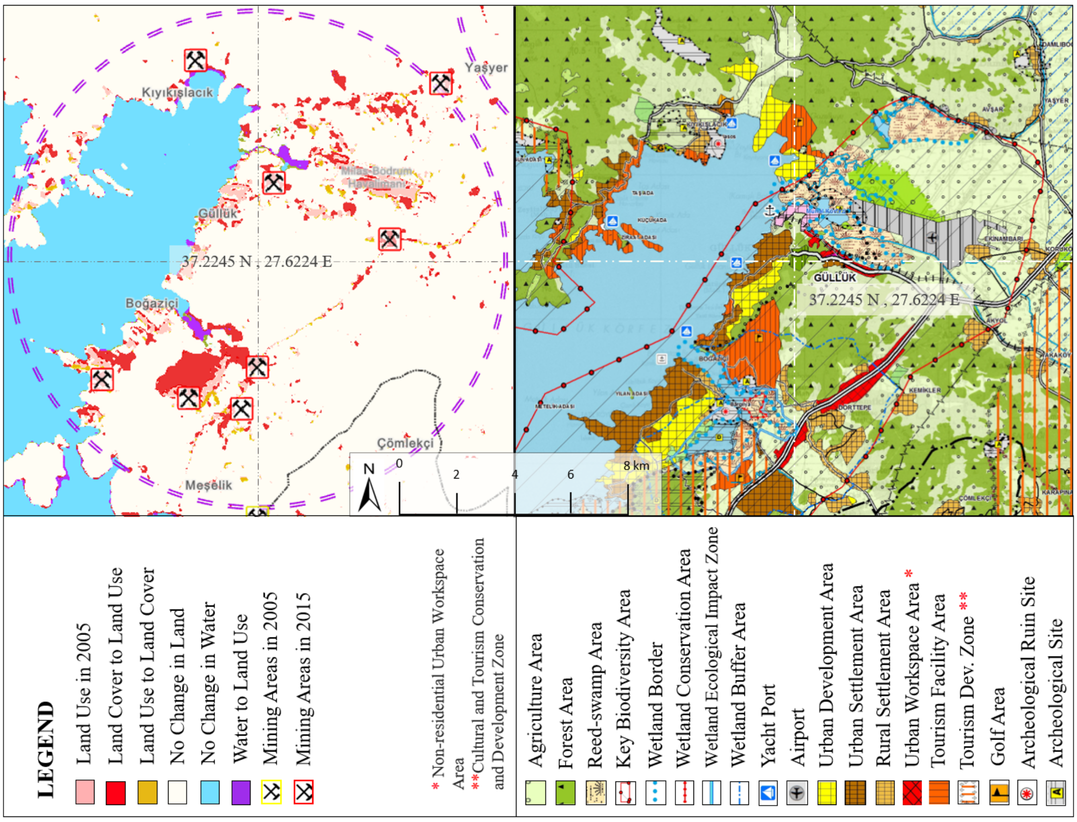

Figure 46 Thematic Map for LU/LC change from 2005 to 2021 (Left) and Current Territorial Development Plan in ROI-8 (Right)

It is seen that the line starting from the mining area and extending to the airport is planned LU/LC changes with the proposals of first-degree road and the urban working area. On the branch of this road extending to Güllük, the urban working area is proposed as a thin line on both sides of the road which can be seen as LU/LC change in the thematic map. Overall, there are no unplanned changes in the region.

5.2.1.9 Milas Center (ROI-9)

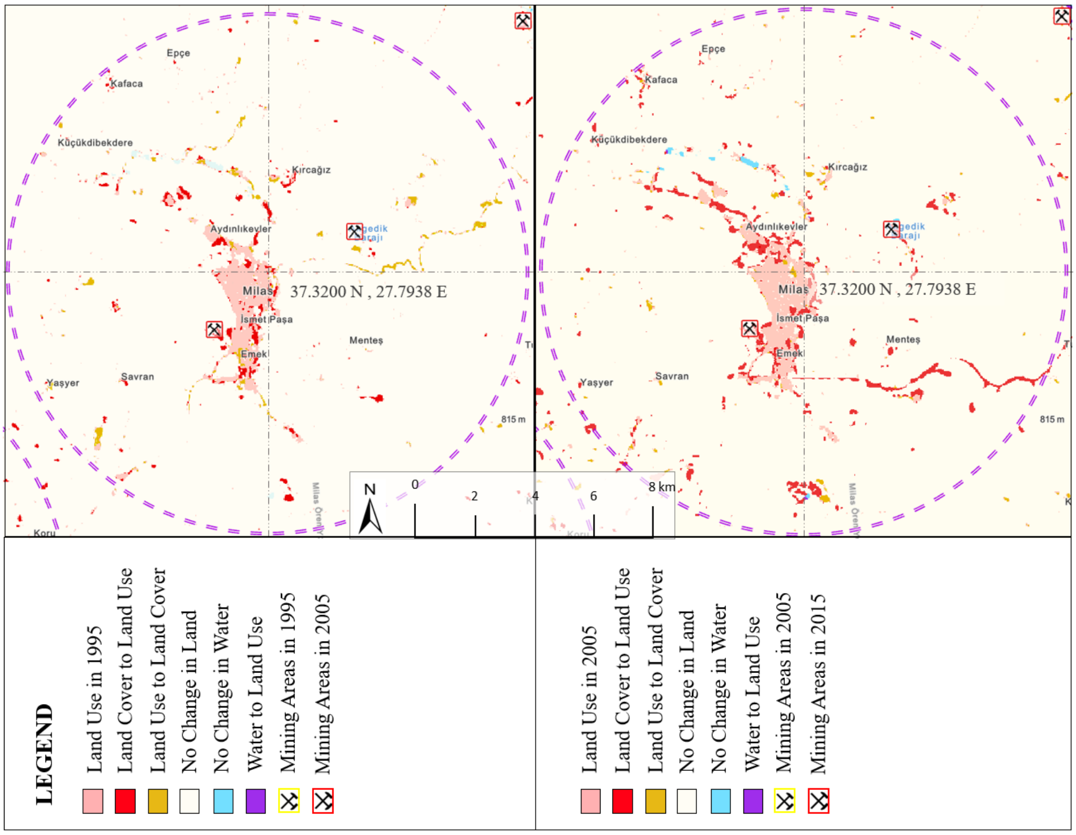

Figure 47 Thematic Maps for LU/LC Change in ROI-9 (Left: 1995-2005, Right: 2005-2015)

Milas has the lowest rate of LU/LC change compared to the other ROIs according to the thematic maps. From 1995 to 2005, it is seen that the city vacancies are filled. In addition, LU/LC change due to mining activities is observed in the area close to the city center, to the west of İsmet Paşa and Emek.

From 2005 to 2015, between Aydınlıkevler and Küçükdibekdere, a linear urban development is seen along the road. In addition, in the south of Emek and Menteş, there is a significant structure in land use elements like a road. Finally, in the south of the ROI, clustered land use elements are observed in the west of the Milas-Ören road.

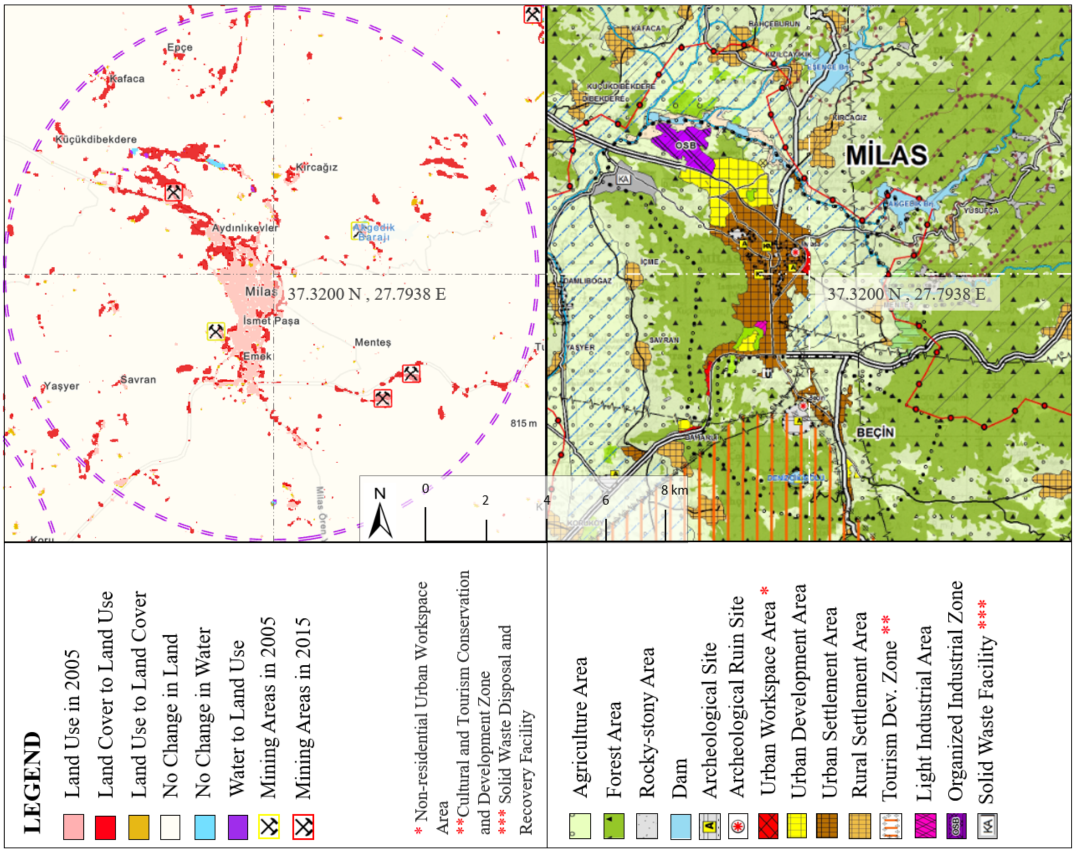

Figure 48 Thematic Map for LU/LC change from 2005 to 2021 (Left) and current Territorial Development Plan in ROI-9 (Right)

The road in the east of Emek, which is discussed in the thematic map from 2005 to 2015, is marked as a first-degree road in the Territorial Development Plan. From the ground truth observations, it is understood that this road has already existed before and has expanded in 2010. Therefore, it is not the decision of the current plan. On the other hand, the road extending from Aydınlıkevler to Küçükdibekdere in the northwest of the thematic map is a planned road in the current Territorial Development Plan and was widened in 2014 according to the ground truth observations. The LU/LC transition located between the north of the road and Stream Sarıçay is marked as an Organized Industrial Zone (OIZ) in the Territorial Development Plan. The OIZ, whose construction was started in 2017, has reached the current state seen on the thematic map. In the Territorial Development Plan, the area between Milas and the OIZ and in the south the gap in the macroform of Milas are designated as urban development zones. Until 2021, roadside development was observed in the northern development zone, while the southern land preserved its land cover elements. The reasons why the north is transformed before could be that the transformation of plain agricultural lands is easier than the region with maquis covered elevations in the south. Also, it is more convenient in terms of logistics due to the proximity of the road and OIZ in the north.

It can be said that the reason why some parts of Stream Sarıçay, located in the north of the OIZ, are classified as land use, is the change in the texture of the stream due to the pollution of the water. While it was seen as water in the change maps between 1995 and 2015, the reason for this change in the classification in 2021 can be due to the wastes of the industry poured out of the stream. The local newspaper of Milas has published an article on this issue (Milas Önder Gazetesi, 2019).

5.2.1.10 Central District of Muğla (ROI-10)

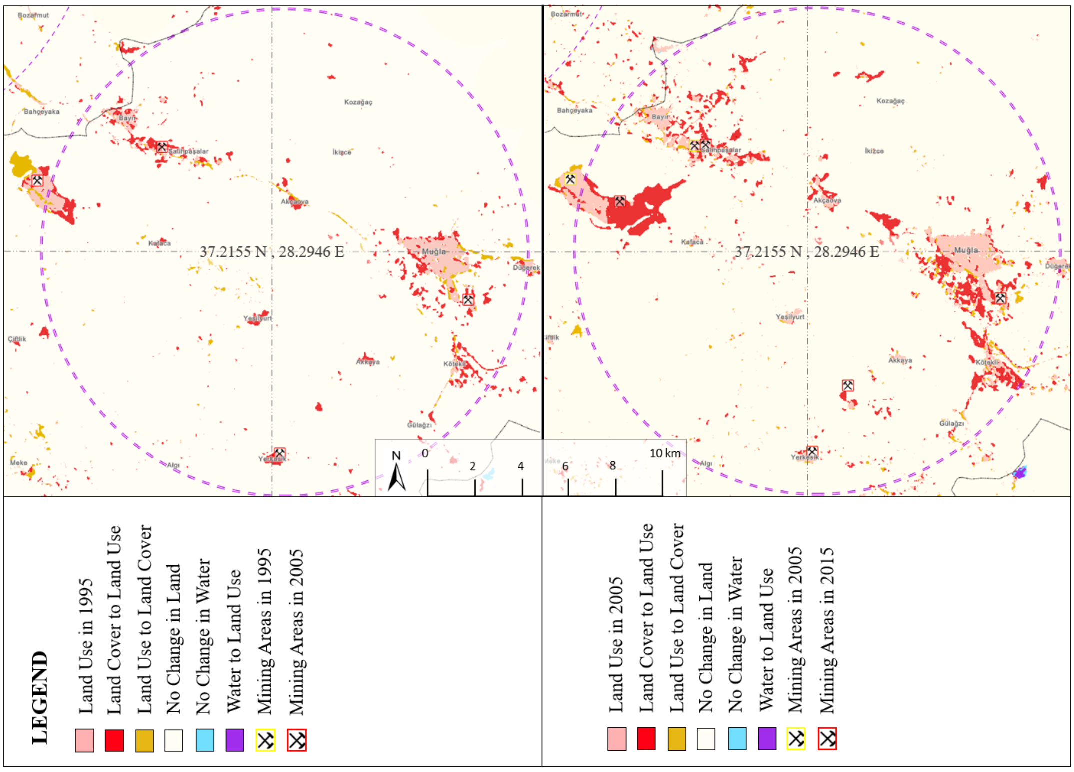

Figure 49 Thematic Maps for LU/LC Change in ROI-10 (Left: 1995-2005, Right: 2005-2015)

LU/LC change is observed due to the mining activity initiated in Salihpaşalar between 1995 and 2005. In addition, it can be said that large-scale mining activity is active in the southwest of Bayır and is expanding towards the southeast. The mining activities are terminated in 2005 in the northwest of the area and land cover elements are started to grow there as seen in yellow color. The region faces an expansion in mining activities to the east considerably between 2005 and 2015. It almost reaches the Salihpaşalar District. It can be deduced that the LU/LC change seen in districts such as Akkaya, Yeşilyurt, Akçaova, and Kafaca is due to the expansion of settlement areas. It is observed that the mining-induced land use elements have increased in Yerkesik and its north. In the center of Muğla, densified land use elements can be seen from Kötekli to Akçaova in the south.

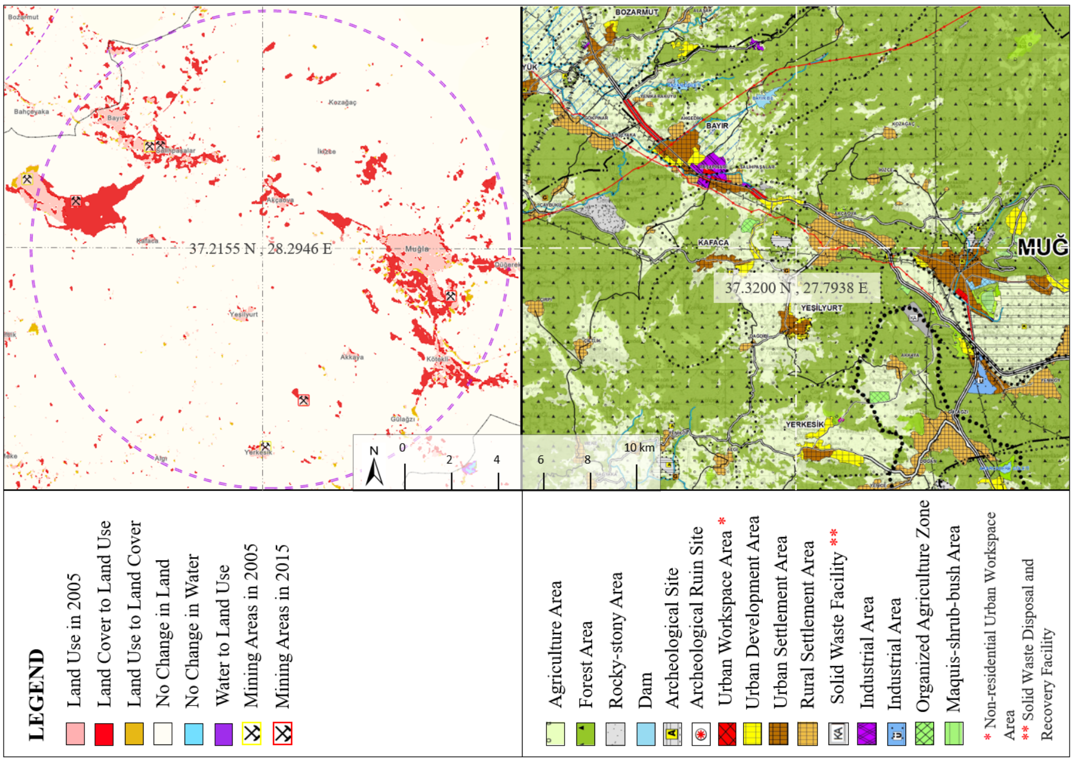

Figure 50 Thematic Map for LU/LC change from 2005 to 2021 (Left) and Current Territorial Development Plan in ROI-10 (Right)

University of Muğla Sıtkı Koçman is located in Kötekli in the Territorial Development Plan. In the thematic map, it is seen that the university is developed towards the south in 2005 and towards the west in 2015.

Urban development has been proposed in the northeast of the Muğla Center, in Düğerek, in the east and the north of Yerkesik, in the east of Kafaca, in the south of Bayır and in between Bayır and Akçaova. Overall, the sides of the districts facing the Muğla center are chosen to be developed as most probably for logistic purposes. Moreover, an industrial area is proposed on the road in the southeast of Bayır in the Territorial Development Plan. Some of these proposals can be seen in the thematic map such as the development of the industrial zone, the urban development areas in between Bayır and Akçaova, and in the northwest of Kötekli.

The only unplanned area seen in the thematic map is the south of the center. However, the LU/LC change is generated because of the misclassification in 2021. The reason could be the fallow technique where the agricultural lands are classified as vacant land use areas there.

5.2.1.11 Datça (ROI-11)

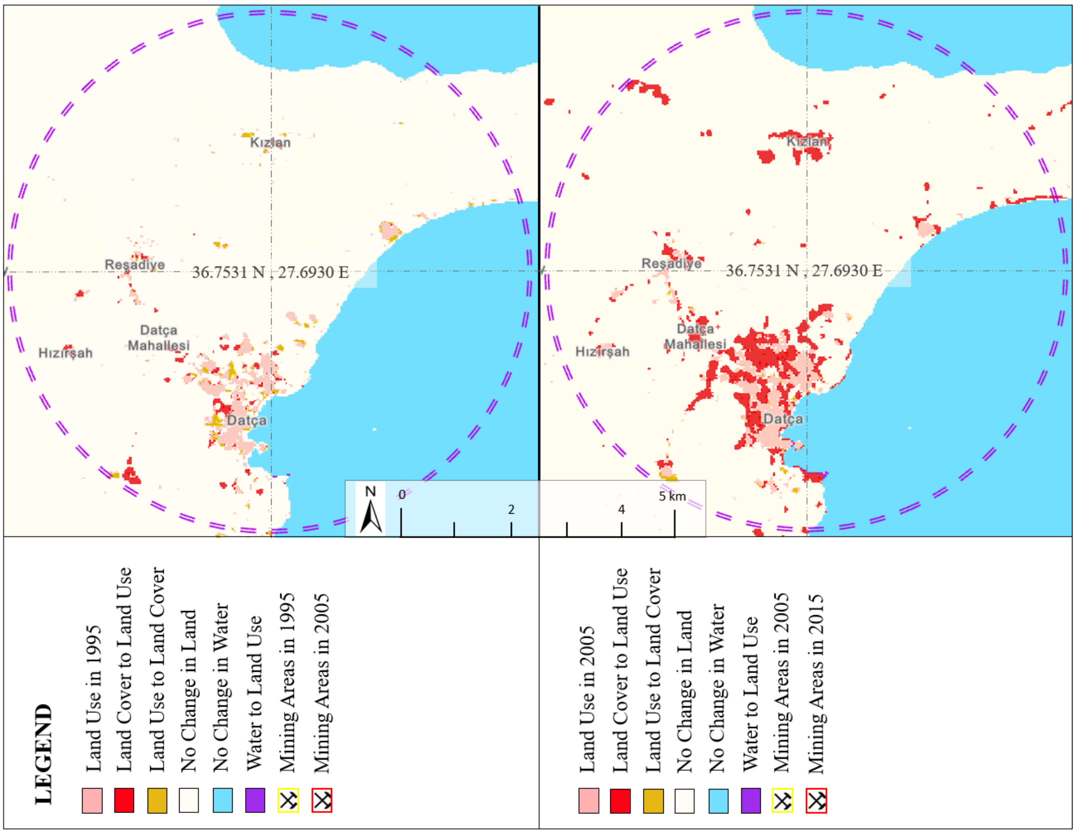

Figure 51 Thematic Maps for LU/LC Change in ROI-11 (Left: 1995-2005, Right: 2005-2015)

Datça has undergone little change between 1995 and 2005 which are in Hızırşah, Reşadiye, Kızlan, and the south-west of the center. Between 2005 and 2015, the gaps in the center of Datça are filled with the land use elements and the city grew towards Reşadiye. In addition, it is observed that land use elements have increased in Reşadiye and Kızlan even more.

Since ROI-11 is completely in the Special Environment Protection Zone, no decision has been made in the Territorial Development Plan.

5.3 Chapter Summary

In this chapter, the causes of the LU/LC changes, the impacts of the current Territorial Development Plan on these changes, and the existence of unplanned activities are questioned, thereby the third research question is answered which is: "*If there has been a decrease or increase in the land cover elements, does the current Territorial Development Plan have an impact on them or have these areas changed unplanned?*". After 11 ROIs are examined in detail, it is seen that the overall LU/LC changes are planned in the current Territorial Development Plan. However, mining activities have not taken place in the plan which may cause uncontrolled growth of mining areas and thereby nature destruction (See Section 1.1). On the other hand, as an interesting output, there is not only a one-way transition from land cover to land use elements. In the areas where large-scale mining activities are carried out, it is seen that activities were terminated in some regions and land cover elements revive in these abandoned areas over the years. However, since the mining activity damages the natural forms of the land, it is debatable to what extent it can be completely restored as discussed in Section 1.1.

On the other hand, due to the increase in greenhouse activities from year to year in Fethiye Center, in Karadere-Kumluova District in Fethiye, and Ortaca, the classification maps show that land use elements are significantly increased. However, it is not irrelevant to classify the artificially closed structure of greenhouses as built environment in the model. In the next chapter, the conclusion of the thesis will be covered.

CHAPTER 6

CONCLUSION

This thesis is a comprehensive study that detects the LU/LC changes in the province of Muğla from 1995 to 2021 and discusses the impacts of the current Territorial Development Plan on the change. Thereby it contributes to the literature in both the remote sensing approach and the planning approach (See Section 1.3 and Section 1.4) since the contemporary studies neither cover the overall LU/LC changes in Muğla nor the impacts of the plans on the LU/LC change.

First of all, LU/LC change in Muğla province has been detected from 1995 to 2021 with Landsat imagery by Maximum Likelihood Estimation. While Landsat is preferred because of having long-term records, Maximum Likelihood is chosen because of its robustness and reliability since it is exploited in the majority of the LU/LC studies in the current literature (Section 2.2.2). The Maximum Likelihood model is generated using the Python programming language, and thus a supplementary method called "Localized Prior Probability" has been developed, which enables the use of spatial attributes in the image. The overall accuracies of the classifications are 94%, 89%, 93%, 96% for 1995, 2005, 2015 and 2021 respectively.

The results show that LU/LC change gains speed after 2005. While land cover elements have decreased 120.000 ha between 1995 and 2005, the change has been even higher between 2005 and 2015 with 280.000 ha. In addition, in the period from 2015 to 2021, land cover elements are degraded at the same rate as 2005-2015, and the land cover decreased from 11.8 million to 11.6 million ha.

With the worldwide economic expansion in the 2000s, the developing countries have gained capital and they invest in the construction sector (Özşahin & Özbay Daş, 2021). Due to the boosting mechanism of the construction sector, the economy has developed, and the construction activities have expanded even more with the developing economy. Furthermore, the public authority in Turkey took on a "construction focused growth model" during 2010 and 2015 (Orhangazi, 2019). Additionally, the government has also supported the mining sector during these periods. The number of firms getting incentive certificates in the mining sector and the total amount of investments are 64 firms – 79 million USD, 260 firms – 8.715 billion USD and 177 firms – 2.346 billion USD in 2001, 2013, and 2017, respectively (Ministry of Industry and Technology 2018). Although these governmental interventions are trigger the economic development and increase the living conditions of the people, since the developing sectors are non-renewable, the land has also undergone great changes. Thus, in this thesis, a reflection of this situation can be seen in Muğla by increasing the trend of land use elements from 1995 to 2021 with an acceleration between 2005 and 2021.

Since the overall change is so serious with increasing momentum, the 11 ROIs are have been determined from the problematic areas where the change is observed the most. Then, the impacts of the current Territorial Development Plan on these changes have been examined. In Bodrum, LU/LC changes have been observed in the areas with proposals such as tourism facilities and preferential usage areas in the Territorial Development Plan. According to the examination of 11 ROIs, it is thought that a considerable amount of the increase in tourism facilities with operating certificates (See Section 1.1) are constructed there. On the other hand, although a significant change in LU/LC is observed in Marmaris District and Datça District, there is no proposal in the current Territorial Development Plan because Marmaris is a Tourism Protection and Development Zone and Datça is a Special Environmental Protection Zone.

From the ground truth observations, it is understood that the source of the serious LU/LC changes in the south of Milas, Yatağan, and the Central District of Muğla is mining activities. According to the discussion above and also in Section 1.1, it can be propounded that with the investments in the mining sector in Turkey, the development of the marble industry in Muğla is dependent on these areas. Since these areas cannot return to their former natural forms, a very careful protection-use balance should be established. However, the current Territorial Development Plan does not represent the mining areas on the map which means that the regional impacts of mining activities are not evaluated in the plan. Considering that 59% of Muğla's lands have been licensed for mineral exploration (Tema, 2020), the construction of new mining activities without a detailed evaluation of the land may cause serious degradation of the environment.

On the other hand, since the method of the study has limitations discussed in section 5.3, contemporary advancements in machine learning algorithms may produce more promising results. The AI approaches such as ANN, CNN, PCC develop new ways to solve these problems (Zareie et al., 2016; Scarpa et al., 2018; Wang et al., 2018). On the other hand, Google Earth Engine which is a cloud-based geospatial analysis platform could have been exploited as a platform to perform analysis instead of using a local machine. Moreover, it enables ready-to-use imagery, high-speed processing time with distributed computed system (Google Earth Engine, n.d.). Lastly, Sentinel-2 imagery with 10 m spatial resolution can also be used as a data source by resampling the Landsat imagery of the years before 2015, since the Sentinel 2 has been launched in 2015 (Sentinel, n.d.).

To conclude, this thesis shows that Muğla has been facing a serious LU/LC change since 1995. If strict conservation decisions are not taken, it will result in irreversible environmental degradation. Indeed, land cover elements should be conserved through both spatial allocations and strong planning decisions at any scale for sustainable futures.

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APPENDICES

A. The Original Names of the Terms

Table 15 The Original Names of the Terms

Territorial Development Plan	Çevre Düzeni Planı
Master Plan	Nazım İmar Planı
Land Use Plan	Uygulama İmar Planı
Special Environmental Protection Zone	Özel Çevre Koruma Bölgesi (ÖÇKB)
Plan Decisions	Plan Hükümleri
Plan Report	Plan Açıklama Raporu
Article	Plan Hükmü Maddesi
Province	İl
District	İlçe
Liquidambar orientalis	Anadolu Sığla Ağacı / Günlük
Ministry of Environment, Urbanization and Climate Change	Çevre, Şehircilik ve İklim Değişikliği Bakanlığı
Ministry of Culture and Tourism	Kültür ve Turizm Bakanlığı
Ministry of Agriculture and Forestry	Tarım ve Orman Bakanlığı
Areas whose nature and ecological form will be protected	Doğal ve ekolojik yapısı korunacak alan
Key Biodiversity Area	Önemli Doğa Alanı
Archeological Ruin Site	Ören Yeri

B. Plan Decisions of Territorial Development Plan Examined in the Thesis

Table 16 Plan Decisions of Territorial Development Plan Examined in the Thesis

Article No	Content	İçerik
5.1.1	Ensuring the protection of environmental values in the planning area in a way that maintains the protection-use balance.	Planlama bölgesinde çevresel değerlerin koruma-kullanma dengesi gözetilecek şekilde korunmasının sağlanması.

Table 16 (continued)

5.1.2	Protection of forest areas	Orman alanlarının korunması
5.1.4	Protection of ecologically important areas such as lakes and wetlands rich in flora and fauna.	Flora ve fauna açısından zengin sulak alanlar, göller v.b. gibi ekolojik açıdan önemli alanların korunması.
5.1.5	Protection of agricultural lands has an important share in crop production, and aquaculture areas and their environments.	Bitkisel üretimde önemli paya sahip olan tarım toprakları ile su ürünleri üretim yerleri ve çevrelerinin korunması.
5.2.4	Development of the areas specified in the plan without damaging highly fertile agricultural lands and energy resource areas	Planlama bölgesinde yer alan tüm gelişme alanlarının, verimi yüksek tarım arazilerine ve enerji kaynak alanlarına zarar vermeyecek biçimde geliştirilmesi.
5.3.4	Preventing unplanned industrialization that puts pressure on fertile agricultural lands and controlling the environmental effects of existing industries	Verimli tarım arazilerine baskı yapan plansız sanayileşmenin önlenmesi ve mevcut sanayilerin çevresel etkilerinin kontrol altına alınması.
8.3.1	The agricultural lands shown in this plan are not divided into agricultural lands classes defined in "The Soil Protection and Land Use Law" No. 5403 and the relevant regulation. The classification of agricultural lands will be made by the relevant institutions or organizations.	Bu planda gösterilen tarım arazileri, 5403 sayılı toprak koruma ve arazi kullanımı kanunu ve ilgili yönetmeliğinde tanımlanan tarım arazileri sınıflarına ayrılmamış olup tarım arazilerinin sınıflaması, ilgili kurum ya da kuruluşlarca yapılacaktır.
8.5.4	Submitting the coordinates of mining facilities that have obtained mining operation licenses to the ministry for processing into the Territorial Development Plan	Maden işletme ruhsatı alınan alanlar, Maden İşleri Genel Müdürlüğü'nce, bu Çevre Düzeni Planının veri tabanına işlenmek üzere 1/25.000 ölçekli koordinatlı haritalara işlenerek, sayısal olarak bakanlığa gönderilir.