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Modelling land use changes in Karaburun by using CLUE-s

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Abstract:
Land cover of earth has been changing dramatically by human activities. These changes have direct impacts on component of environment like soil, water and atmosphere and are thus directly related to many environmental issues of global importance. For that reason, land use changes are key elements in studying global environmental changes. The detection of the changes, the understanding of the underlying processes as well as modeling of scenarios for future development are precondition for the set up of sustainable land-use planning schemes and integrated environmental management.

In this research, land uses in Karaburun Peninsula were modelled based on CLUE-s modelling approach. The model was calibrated using historical data describing the land use patterns between 1984 and 2010. Land use maps for these dates were derived from LANDSAT TM images. The validation process based on multiple resolution technique shows the ability of the CLUE-s model to predict the land-use changes at the research area. Scenario for future development was defined based on Environmental Plan for Manisa-Kutahya-Izmir Planning Region. Demand of land use classes for 2025 was determined according to this plan. Land use changes were modelled between 2010 and-2025.

Keywords: *CLUE-S, modelling, land use changes, Karaburun peninsula*

Introduction

By clearing forests, practicing subsistence agriculture, intensifying farmland production, or expanding urban centers, humans are changing the world's landscapes. Land-use activities—whether converting natural landscapes for human use or changing management practices on human-dominated lands—have transformed a nearly 50 % of the planet's land surface (Entwisle, 2005; World Bank, 2008). The earth has entered a period of hydrological, climatological and biological change that differs from previous episodes of global changes in the extent to which it is in human in origin. To explain or predict the course of the present global environmental changes, one must therefore understand the human sources, consequences and responses, some of which can alter the course of global change (Stern et al., 1992).

Moreover many global and local environmental problems can be described as the most important variable affecting environmental (Nurlu *et al.*, 2008). Therefore, studies on understanding of land use change within the cause and effect relation as well as the prediction of future land uses to support decision making process have been of great importance for the last decades (Verburg *et al.,* 2006).

Nonetheless, land use changes are complex, dynamic processes that link together natural factors such as soil, climate, geology, etc., and economic, social and cultural factors in time and space (Koomen and Stilwell, 2007). Thus, tools are needed to understand and explain these processes. Land use change modeling, especially if done in a spatially-explicit, integrated and multi-scale manner, is an important technique for the projection of alternative pathways into the future, for conducting experiments that test our understanding of key processes in land use changes (Veldkamp and Lambin, 2001).

More broadly, models can be considered as abstractions, approximations of reality which is achieved though simplification of complex real world relations to the point that they are understandable and analytically manageable (Briassoulis, 2000). Models can be identified within land use change researches as important tools used for explaining, predicting and evaluating impacts and providing solutions for land use changes (Agarwall *et al.,* 2002). Models are also defined as very powerful learning tools (Singh, 2003). In other words, models are tools that test our understanding of key processes of complex land use system (Veldkamp and Lambin 2001).

Land use changes are the results of many interacting processes. Each of these processes operates over a range of scales in space and time (Verburg *et al.,* 2003). Spatial details are important in understanding of these processes and land use systems (Engelen *et al.,* 1995). For that reason, in land use change modeling. The spatial modeling techniques have more relevance than other methods of modeling (Singh, 2003). Recently, a lot of spatial land use change models have been developed thanks to improvement of remote sensing and geographical information systems.

The diversity of modeling approaches can be explained by the wide range of research questions in which models are used as a tool, the different scales of application, ranging from the very local to the global extent, and the absence of an all-compassing theory of land-use change (Verburg *et al.,* 2006).

In this research, CLUE-s (***C****onversion of* ***L****and* ***U****se Change and its* ***E****ffects at Small Regional Extent*) modeling approach is used for dynamic modeling of land use change. CLUE-S is specifically developed for the spatially explicit simulation of land use change based on an empirical analysis of location suitability combined with the dynamic simulation of competition and interactions between the spatial and temporal dynamics of land use systems (Verburg *et al.,* 2002; Verburg and Veldkamp, 2004, Verburg, 2010). The model is a multi-scale land-use change model used for understanding and predicting the impact of biophysical and socio-economical forces that drive land-use change (Verburg *et al.,* 2002). The model is especially useful for assessments of changes in complex spatial patterns of land-use change due to the explicit attention that is given to linkages between the temporal and spatial dynamics of land use change. (Verburg *et al.,* 2002).

In contrast to most empirical models, it is possible to simulate multiple land-use types simultaneously through the dynamic simulation of competition between land-use types.

The methodology for the development of scenarios is based on the extrapolation of the spatial relationship between current pattern and a set of explanatory factors or location factors. The CLUE-S model can be divided into two modules, a non-spatial demand module and a spatially explicit allocation module, operating at the respective regional and pixel level.

The CLUE-s consists of two modules; a non-spatial demand module and a spatial explicit allocation module, operating at respectively the regional and pixel level. The demand module, calculates the area change for all land-use types at the aggregate level. Within the allocation module of the model these demands are translated into land use changes at different locations within the study region using a raster-based system. The allocation module is based upon a combination of empirical, spatial analysis, and dynamic modeling. In the allocation module of the model it is possible to define which changes are allowed, based on user defined decision rules. Two types of decision rules are incorporated in the model. The first type with the name decision elasticity indicates the stability of land use types. The second type with the name decision matrix can label cells as protected area, in which no changes are allowed. Once all input (regression results, decision rules in combination with actual land-use map, and the demand) are provided CLUE-s model calculates the most likely changes in land-use through the allocation procedure.

Land use change is one of the most visible effects of human intervention on earth and can have effects on both human health and ecological systems. Also, land use change is one of the most important landscape change indicators.

Material and methods

Material

Land use maps were derived from LANDSAT TM images of 09.06.1984 and 11.06.2010. Ancillary data such as standard 1/25000 scale topographic maps for 1990-2000 1/25 000 scale soil and geology maps. ASTER GDEM (*Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Mode*l) with resolution 30x30 m were used in the study. Also, the site areas were defined based on Ministry of Culture and Tourism Izmir Cultural and Natural Conservation Board No: 1 Site maps with scale 1/25 000.

Study area

Karaburun Peninsula is located in the west end of the Aegean Region (Figure. 1). Peninsula, surrounded by seas on three sides, covers an area of 426 $km^{2.}$ It is lying between 26°21′ –26°38′ longitudes and 38°40′–38°25′ latitudes (Nurlu *et al.* 2003, Nurlu *et al,* 2008, Nurlu *et al.,* 2009).

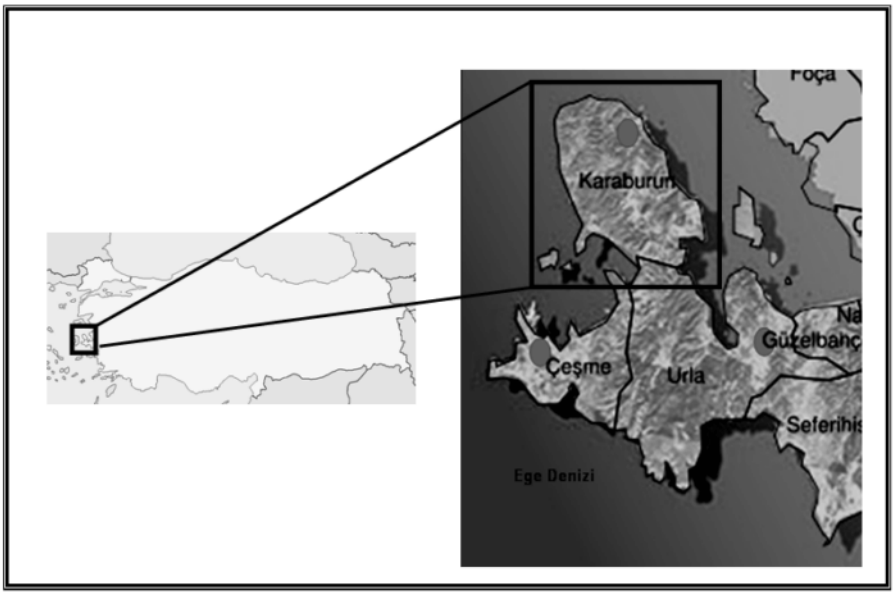

Figure 1. *Location of study area*

The elevation in the area varies from sea level up to 1,300 m., with the highest peak Akdag. The steep descent of mountains to the sea greatly influences population, settlements and land uses in the peninsula (Nurlu *et al.* 2008). The area experiences typical Mediterranean climate with mild rainy winters and dry hot summers. Mean annual temperature ranges between 15°C and 20°C and mean annual precipitation varies between 650 and 750 mm, which is mainly concentrated in the winter months (Nurlu *et al.,* 2009). The study area includes three different vegetation types; forest, maquis and garrigue. The dominant species of the coniferous forest is *Pinus brutia* Ten. (Nurlu *et al.*, 2009).

Karaburun Peninsula is one of the least disturbed sites in the Aegean region because of difficulties of transportation due to the rough topography of the area (Sarıçam, 2007). At the same time, study area has great importance for flora and fauna and thus had to be protected at national and international level. The land supports 384 species of flora from 255 genera and 70 families. Bird life is also diverse with 204 terrestrial and marine species, including many endemic, internationally recognized as endangered species (Veryeri *et al., 2003*). Peninsula is also home to some rare, endangered mammals including the Eurasian Otter (*Lutra lutra),* the Mediterranean monk seal (*Monachus monachus), and* Audouin's Gull-(*Larus audouinii).* Caracal (*Caracal caracal*) is also one of important mammal species. A part of study area is covered by natural site areas (Veryeri *et al*., 2003; Sarıçam, 2007, Nurlu *et al.,* 2009).

Although its rough topography, agricultural activities in Karaburun peninsula always have maintained priority in economic activities. In particular, in peninsula cultivation of grapes and olives, citrus, artichokes, bay, narcissus and hyacinth has great importance (Nurlu *et al.,* 2008)

Tourism sector in peninsula is based on secondary houses especially intensified around Karaburun and Mordoğan. Tourism sector in economic sense could not be a common source of livelihood for the peninsula. However, there is not enough natural area to meet tourism needs of Izmir, Turkey's third largest city in terms of population. In this context, to protect natural and cultural structure of peninsula for future development alternatives, tools like models are needed.

Method

The CLUE-s (Conversion of Land Use and its Effects at Small regional extent) modeling approach has been used for this study. The calibration of the model was performed using historical data describing the land-use patterns between 1991 and 2000. The validation process shows the ability of the CLUE-s model to predict the land-use changes at the local level. To evaluate possible future development land uses in Karaburun peninsula were modeled between 2010 and-2025.

In this context, research was carried out in three steps; model calibration, model validation and simulation of possible future development. For the calibration of model, demand for each land use types was calculated for the period between 1984 and 2010. The statistical analysis with CLUE-s was carried out on 2010 land-use map based on logistic regression analyses. Simulations were started in 1984 and a comparison between model performance and real changes was made for 2010. Land use maps were derived from LANDSAT TM images of 09.06.1984 and 11.06.2010. Land use map of 1984 was handled as the information basis for the starting year and also it was used to detect changes between 1984 and-2010. Land use map of 2010 was used in logistic regression analysis performed to extrapolate spatial relationship between current pattern and driving factors and also it was used in model validation.

The land use classes were determined according to the CORINE LC classification. Classification was made at the Level 2. However, because arable land, permanent crops, pasture and heterogeneous agricultural areas could not be separated in supervised classification, these classes were classified at the Level 1 as Agricultural Areas. Also, maquis and garrigue considered in sclerophyllus vegetation at the level 3 were covered a big part of study area and they have been influenced different driving factors. For that reason maquis and gariggue were classified separately. Nevertheless, in early application of model modelling results were not significant for inland wetlands and artificial ponds classified as inland waters, because they cover a very narrow area in the study area. Also, class of forest includes both natural forest and afforestation areas. Afforestation areas and natural forest have different characteristics and they have been affected by different driving factors. For that reason, modelling results also was not significant for forest class. Thus, in final application of model inland wetlands, inland waters and forests has been classified as "other". This land use class was created according to land use map for 2010 and added to land use map 1984 with similar properties. It was assumed as unchanged, and has been masked in both data sets.

Logistic regression analysis was performed to extrapolate quantified relation between land uses and driving factors. Logistic regression analysis was separately performed for each land use class based on 2010 land use map. The results of logistic regression analysis were validated by using ROC analysis.

The decision rules in CLUE-S determine which conversions are allowed. Two types of decision rules are incorporated in modeling process. The first type with the name “conversion elasticity” indicates the stability of land use types. The second type with name “conversion matrix” can label cells as protected area, in which no changes are allowed (Soepher, 2001).

After providing all input (regression results, decision rules in combination with actual land-use map, and the demand) CLUE-s model calculates the most likely changes in land-use through the allocation procedure. Simulations were started in 1984 and a comparison and an assessment between simulation and real land use were made for 2010 by using multi resolution procedure. The scenario for future development was defined based on Environmental Plan for Manisa-Kutahya-Izmir Planning Region
For processing and analyzing spatial data Arc GIS 9.3, for processing and supervised classification of satellite images Erdas Imagine 8.6, for calculating demand Microsoft Office Excel 2003, for statistical analysis SPSS 11.0 and for modeling process Dyna CLUE software were used.

Results
In the research carried out for modelling land use changes of Karaburun Peninsula land uses were classified as Artificial Fabrics, Agricultural Areas, Maquis, Garrigue, Open Vegetation with Little or No Vegetation and Other. According to 2010 land use map nearly 88 % of peninsula was covered by natural vegetation. Human uses affecting natural structure of peninsula were shaped by agriculture and tourism sectors. In spite of rough topography, agriculture was always the most important source of income on the peninsula. Nonetheless, after a major cultural change experienced in the peninsula in the 1920s, viniculture covering very large areas were abandoned and agricultural activities on the peninsula drastically decreased (Sarıçam, 2007).

The decline of agricultural activities has caused migration of young people through to Izmir to reach better condition for education and employment. Because of increasing non-arable land and relatively cheaper land prices Number of secondary houses has increased rapidly on the peninsula. Tourism activities on the peninsula have developed mainly around Karaburun and Mordogan. Specially, difficulties of transportation to peninsula and the lack of quality of beaches are important obstacles to gain tourism incentives in the peninsula. For calibration of model, demand of land use classes was determined based on land use maps for 1984-2010 (Figure 2). It was assumed that the change in demand between 1984 and 2010 is linear (Table 1).

Table 1. *Changes of land use between 1984-2010 in Karaburun peninsula**

LAND USE	1984 area (ha)	2010 area (ha)	Change (ha)
Artifial Fabrics	248,31	728,1	-479,79
Agricultural Areas	7667,28	4534,47	3132,81
Maquis	12536,37	17576,64	-5040,27
Garrigue	11077,47	8453,52	2623,95
Open Vegetation with Little or No Vegetation	8055,63	8292,33	-236,7

** It was assumed that changes between 1984-2010 were linear.*

No change was assumed for land use class “other” between these years. This increase largely occurred on agricultural land. Accordingly a significant decrease in agricultural areas has experienced.

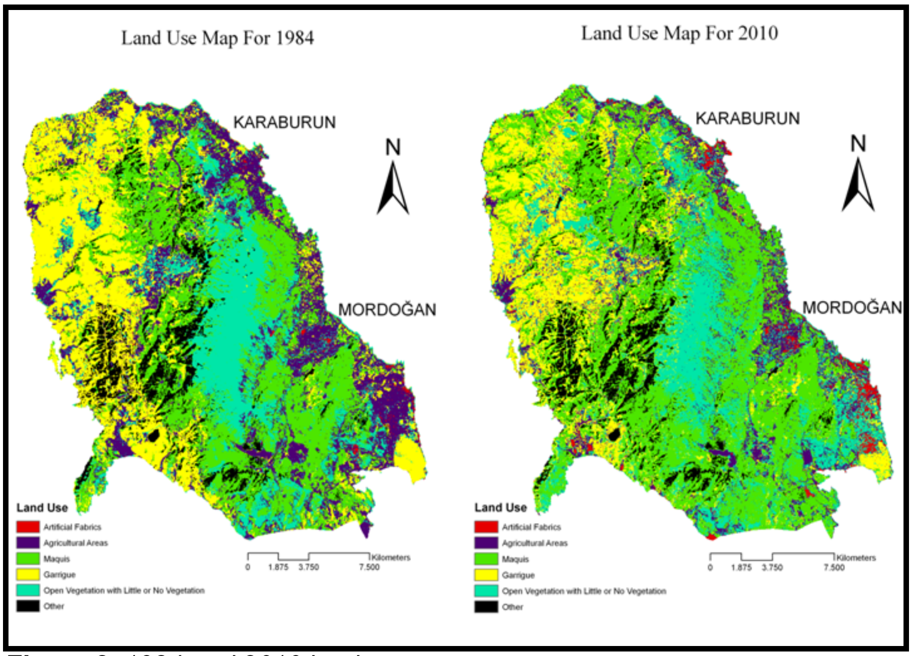

Figure 2. *1984 and 2010 land use maps*

Potential driving factors influences land use changes in peninsula were determined by evaluating changes of land use and reviewing previous studies.

Results of logistic regression analysis performed for each land use class with driving factors are given Table 2. Validation of logistic regression analysis was tested by using ROC analysis. A dummy regression was created for other class because it was excluded from the calculation.

According to the results of regression analysis, between urban areas and elevation, aspect, distance to beaches, distance to centers of districts there is a negative relationship. Accordingly, an increase that may occur in these driving factors reduces probability of artificial fabrics. Also there is a negative relation between elevation, slope, erosion level and distance to villages. However, there is a positive relationship between agricultural areas and depth of soil.

Decision rules for land use changes were determined in two ways as conversion elasticities and conversion matrix. Conversion of classes of agricultural areas, maqui, garrigue and open vegetation with little or no vegetation is allowed but conversion of artificial fabrics and other is not possible. Also, in allocation process conversion to artificial fabrics from other land use classes was not allowed at site areas defined by Ministry of Culture and Tourism Izmir Cultural and Natural Conservation Board No: 1.

In spatial allocation procedure change of demand for land use classes between in 1984-2010 was allocated based on results of logistic regression analysis and decision rules. Allocation was made yearly basis. 2010 simulation land use map derived from allocation procedure was compared to 2010 real land use map by using multi resolution procedure to validate and assess model (Figure 3). According to results of multi resolution procedure model was accepted for simulating future land use changes. (Figure 4).

Table 2. *Results of logistic regression analysis performed between land uses and driving factors **

	Artifial Fabrics	Agricultural Areas	Maquis	Garrigue	Open Veg. with Little or No Vegetation
Constant	-0,583	0,917	-0,027	-2,596	-0,941
Elevation	-0,008	-0,001	-0,0002	-0,002	0,003
Slope	-	-0,051	0,030	-0,025	-0,005
Aspect	-0,001	0,0004	-	-	-
Depth of Soil	-	0,117	-0,309	-	-0,305
Erosion Level	-	-0,508	-0,229	0,83	-0,561
Distance to Beaches**	-0,0003	-	-	-	
Distance to Roads**	-	-	-	-	
Distance to Centre of Disticts**	-0,00011			-	
Distance to Villages***	-	- 0,0001		-	
ROC Curve*	**0.897**	**0.743**	**0.702**	**0.722**	**0.718**

** Roc Anaylsis was performed to assess result of regression results. Upper values than 0.700 shows regression results can be acceptable.*
*** Factors considered only for artificial fabriz*
**** Factors considered only for agricultural areas*

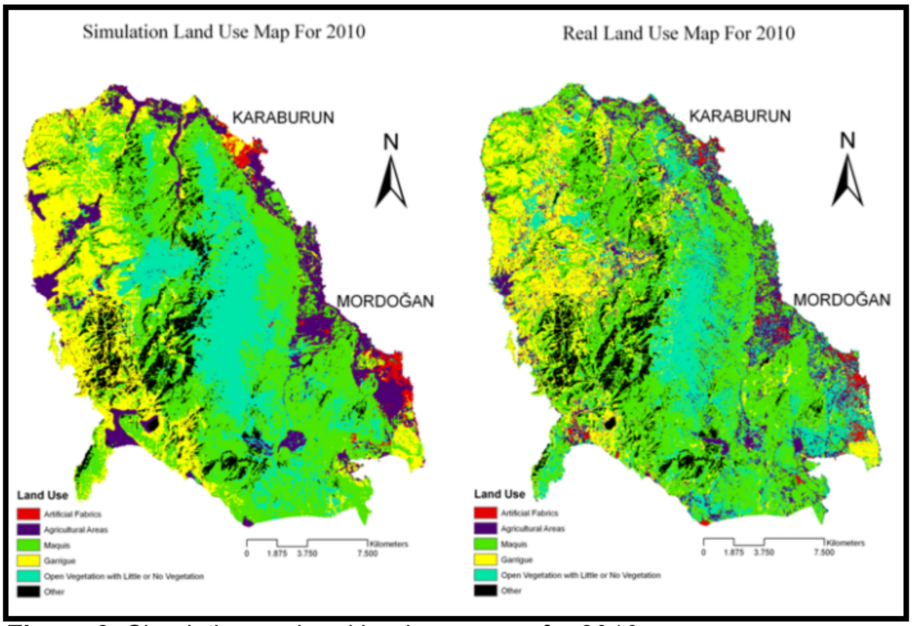

Figure 3. *Simulation and real land use maps for 2010*

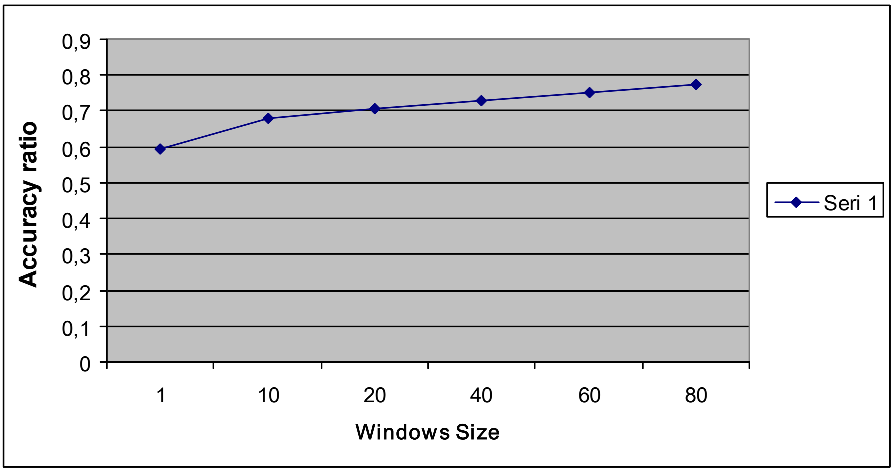

Figure 4. *Validation of modelling processes by using multi resolution procedure.*

The scenario for future development was defined based on Environmental Plan for Manisa-Kutahya-Izmir Planning Region. In this plan 700 ha increase in artificial fabrics was predicted for Karaburun Peninsula. According to this increase simulation map for 2025 was derived (Figure 5).

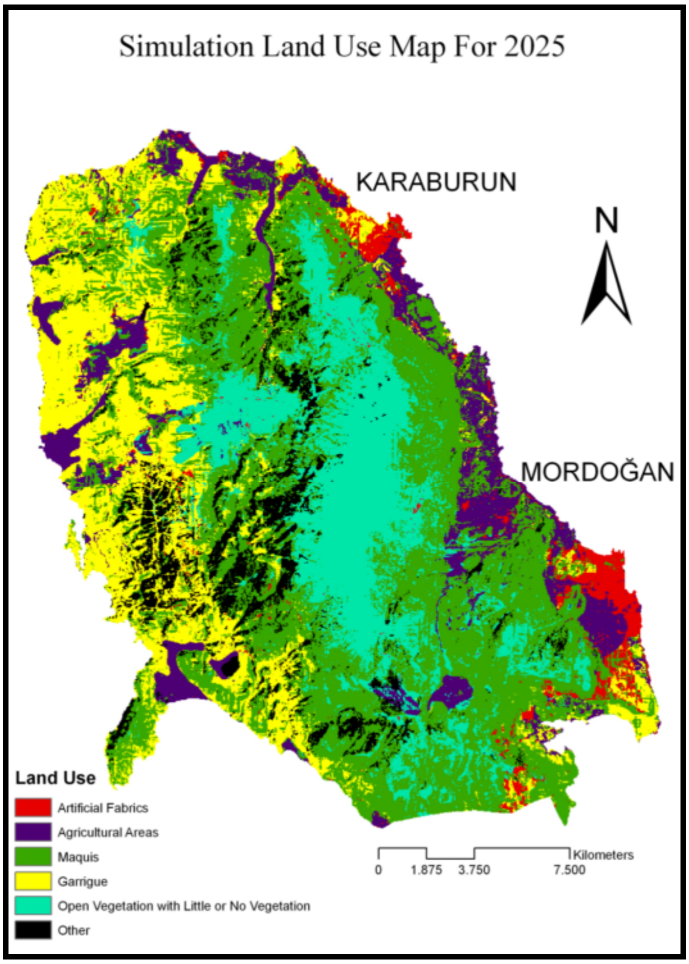

Figure 5*. Simulation land use map for 2025*

Conclusion

In the research land use changes were modeled by using CLUE-s modeling approach in a case study of Karaburun Peninsula. Quantified relationships between land uses of Karaburun Peninsula and driving factors influencing these land uses were extrapolated by using logistic regression analysis. And last, a modeling process was performed based on these relationships. Model was calibrated between 1984-2010 to validate and assess model performance. And then a 2010 simulation land use map was created. By using multi resolution procedure 2010 real and simulation land use maps was compared and model was accepted for simulating future scenarios. Future scenarios in the research was based on Environmental Plan for Manisa-Kutahya-Izmir Planning Region for period from 2010 to 2025.

Simulation land use map for 2025 shows that increasing artificial fabrics will intensify around Karaburun and Mordoğan as it is the case today. However, these areas are very important breeding areas for Mediterranean seal and they can be damaged by expansion of artificial fabrics. Besides, nearly all of expansion of artificial fabrics will be on agricultural areas. This situation can affect negatively agricultural production most important means of livelihood on peninsula, which has agricultural areas very arrow areas.

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Karaburun'da alan kullanım değişimlerinin CLUE-s ile modellenmesi

Günümüzde, doğal peyzajın, tarım, otlatma, ormancılık, sanayileşme, kent gelişimi ve ulaşım ağları gibi doğrudan insan kullanımları kapsamında dönüştürülmesi nedeniyle, dünya yüzeyinin %50'si değişime uğramıştır (Entwisle, 2005 ve World Bank, 2008). Dünyamız, yoğunlaşan bu insan faaliyetleri nedeniyle, büyüklük ve şiddet bakımından önceki zamanlardan oldukça farklı hidrolojik, klimatolojik ve biyolojik değişimlerin yaşandığı bir sürece girmiştir. Son derece önemli olan bu küresel değişimlerin nedenlerini ve sonuçlarını açıklayabilmek ve tahmin edebilmek için öncelikle insan davranışlarının, tepkilerinin ve sonuçlarının anlaşılması gerekmektedir (Stern et al., 1992).

İnsan aktiviteleri ve doğal yapı arasındaki karşılıklı etkileşimler sonucunda ortaya çıkan, dinamik ve son derece karmaşık yapıya sahip olan alan kullanım değişimleri hava, toprak, su ve biyolojik yapı üzerinde doğrudan ve dolaylı etkiler yaratmaktadır. Bu nedenle, günümüzde karşı karşıya olduğumuz ve her geçen gün şiddetleri artmakta olan küresel ve yerel çevre sorunlarını etkileyen en önemli değişken olarak gösterilen alan kullanım değişimlerinin saptanması, izlenmesi ve geleceğe yönelik öngörülerin ortaya konulmasına yönelik çalışmalar giderek artmaktadır. Bu kapsamda, uluslararası platformda ve çok farklı ölçeklerde, çok disiplinli ve çok uluslu çalışmalar gerçekleştirilmiş ve gerçekleştirilmektedir.

Bu noktada, alan kullanım değişimlerinin, neden-sonuç ilişkileri kapsamında analizine olanak tanıyan ve böylece geleceğe yönelik gerçekçi öngörülerin oluşturulabilmesini mümkün kılan dinamik modelleme yaklaşımları, son yıllarda büyük önem kazanmıştır. Özellikle uzaktan algılama ve coğrafi bilgi sistemlerinde yaşanan gelişmeler, alana yönelik verilere ulaşılmasını ve bu verilerin işlenmesini büyük oranda kolaylaştırması, ayrıca, bilgisayar hız ve kapasitelerinde meydana gelen artışlar, mekansal dinamik modellerin gelişimini hızlandırmış ve kullanımlarının yaygınlaşmasına neden olmuştur. Modelleme çalışmaları ile alan kullanım değişim süreçlerinin tanımlanması, açıklanması, tahmini, etkilerinin değerlendirilmesi, çözüm önerilerinin getirilmesi ve değerlendirilmesi amaçlanmaktadır.

Gerçekleştirilen bu çalışma ile dinamik modelleme yaklaşımlarından biri olan CLUE-S (Conversion of Land Use and its Effects at Small regional extent) Modelleme Yaklaşımı, Karaburun Yarımadası örneğinde uygulanmıştır. Doğal, kültürel, ekonomik ve sosyal verilerin birlikte analizine olanak tanıyan CLUE-S modelleme yaklaşımının uygulanması ile alan kullanım değişimleri ve yönlendirici faktörler arasında sayısal bir ilişki kurulmuş, geleceğe yönelik değişim senaryoları belirlenmiştir. Böylece, ulaşım güçlüğü nedeniyle nispeten doğal ve kültürel yapısını günümüze kadar koruyabilmiş nadir bölgelerden birisi olan ve biyoçeşitlilik açısından son derece önemli alanları barındıran Karaburun Yarımadası'nda, gelecekte alan kullanımlarından etkilenebilecek alanlar belirlenmiştir.

Önemli Bitki Alanı durumunda olan ve IUCN Kırmızı Listesi'nde bulunan Akdeniz Foku ve Ada Martısı için yaşam ve üreme alanı durumundaki yarımada, bu nedenle uluslararası ölçekte de büyük önem arz etmektedir. Yarımadada yerel halkın başlıca geçim kaynağı tarım olup, bu kapsamda agroturizme yönelik faaliyetler sürdürülmektedir. Bununla birlikte, son yıllarda Yarımada'da gelişmeye başlayan ikinci konutlara bağlı turizm faaliyetleri önem kazanmaktadır. Yarımadada alan kullanım değişimleri, bu iki sektör tarafından şekillendirilmektedir.