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GIS-Based Approach to Determine Suitable Settlement Areas Compatible with the Natural Environment

ABSTRACT

This study determined the settlement areas that were suitable for the natural environment in the Seydikemer District in Turkey. Within this context, databases related to the natural environment of the region and existing land uses were created using Unmanned Aerial Vehicle images that were digitized and analysed using geographic information systems. Land cover was classified using Random Forest and Maximum Likelihood Classification methods for remote sensing. The natural environmental properties of the study area were determined based on the resulting classification, and the criteria for the suitability of the settlement areas were defined by the Multi-Criteria Decision Analysis and Analytic Hierarchy Process. Accordingly, eight main criteria and their classes of suitability were analysed and evaluated. Assessment of the natural suitable structure of the area was conducted using weighted overlay analysis. Sixteen percent of the survey area was suitable, while 69.01% was moderately suitable and 14.97% was not suitable for use as a settlement area. Considering that this region is in the process of rapid urbanization, The findings of the study are expected to make a significant contribution to the future settlement and land-use plans of the city.

Key words: *land-use planning, Multi-Criteria Decision Analysis (MCDA), suitable settlement, Unmanned Aerial Vehicle (UAV), Geographic Information System (GIS)*

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INTRODUCTION

The rapid growth of cities has led to the emergence of concepts such as planned growth, physical planning and urban planning (*Kozlowski and Hughes 1972*). The development and growth of urban settlements depend on many physical and cultural criteria (*Sýkora 2017*). These criteria are composed of land use, transportation, settlement, industrial and agricultural production, consumption, social activities and cultural structure, which have significant impacts on natural resources during the planning phase (*Hersberger et al. 2018*). The natural environment is adversely affected by the scattered development of today's cities and the expansion of large urban areas into complex structures (*Amato et al. 2016*). To reduce the negative effects of urban sprawl on the natural environment, ecological planning approaches should be adopted and included in the planning stages (*Haaland and van den Bosch 2015, Bai et al. 2018*). Additionally, the protection of natural resources and prioritization of sustainability should be achieved (*Rad et al. 2018*). The main goal of the sustainable ecological planning approach is to protect nature and increase urban quality (*social, cultural and spatial quality; Selim et al. 2017, Lantitsou 2017, Li et al. 2017*).

Although ecological approaches are important for urban planning, in recent years in Turkey, it has not been fully implemented during the application stage. In the preparation of urban plans at the regional and local scale, the ecological structure should be carefully considered (*Alphan and Güvensoy 2016, Berberoğlu et al. 2016*). In order to harmonize economic development with the natural environment, it is necessary to define a planning concept that integrates environmental components and to incorporate this planning model in development plans, environmental policies and ecological planning processes (*Lennon 2015, Geneletti et al. 2017, Hamma 2018*). Ensuring the sustainable use of natural resources depends on the correct implementation of land-use plans that are compatible with the natural structure of the environment (*Bryan et al. 2016, Rad et al. 2018*). Turkey is experiencing a process of rapid urban transformation; and during this process, the conservation of natural resources and preparation of urban master plans that are compatible with the land's natural structure are critical (*Aksoy and Selim 2020*).

Mugla Province has cultural, historical and touristic

value; and for that reason, it is the most important tourism and agricultural destination in Turkey. Seydikemer is one of the most important agricultural regions in the Mugla Province and was selected for this study to determine settlement areas that could align with the principles of sustainability. As there is an increasing need for settlements in this region due to rapid population rise, the natural environment needs to be safeguarded and the efficient use of natural resources should be sustained. As a result of the rapid population growth trend in the region, the existing physical plans are inadequate, and local governments are unable to meet demand while finding an ecological balance. Consequently, due to increased concreting, the natural environmental structure is deteriorating and urban forests, green areas and fertile soils that provide many ecosystem services (*Hosseini et al. 2019*) are declining. Natural ecological systems suffer and lose their resilience. Therefore, it is necessary to develop physical plans and future scenarios for a given region to meet expectations and goals for sustainability, construction and social structure (*Ekpodessi and Nakamuro 2018, Long and Qu 2018*).

The necessity to use social, cultural, physical and ecological criteria together in land-use plans makes the use of Multiple-Criteria Decision Analysis (MCDA) preferable in such studies (*Jeong 2018, Uhde et al. 2015, Sani et al. 2016, Selim et al. 2018, Ristić et al. 2018, Fernandes et al. 2018*). The use of MCDA in conjunction with Analytic Hierarchy Process (AHP) is preferred in land-use planning as a synthesis method that systematically examines the advantages and disadvantages of different alternatives and different criteria to obtain valuable results (*Mosadeghi et al. 2015, Yatsalo et al. 2016, Adem Esmail and Geneletti 2018*).

The main objective of this study is to determine suitable settlement areas that are compatible with the natural environment of the Seydikemer District, which is not yet densely populated, by using MCDA and AHP. Within this context, the socio-cultural, physical and ecological criteria of the region were evaluated and a set of criteria were selected for analyses. The findings of the study provide insight for local and regional governments and decision-makers about the district. Moreover, this study can serve as an important guide for decision-makers from different disciplines as it presents a methodology that allows different criteria to be evaluated for sample areas, thus potentially having a large impact on the methodological set-ups of future land-use planning projects.

MATERIALS AND METHODS

The Seydikemer city centre and surrounding area located in southwest Anatolia was selected as the study area. The province is located in the Mediterranean Region, surrounded by small cities and the Eşen River. Geographically, the study area is located between 36º 17’ – 37º 02’ N and 29º 07’ – 29º 48’ E and has an area of 2,028.37 km² (**Figure 1**). The boundary of the study area is denoted as a circle with a radius of 5 km, which includes all the settlements and buildings in the city center.

Seydikemer District was chosen as the study area due to a rapid increase in the urbanization rate of the region to the direction from Mugla province to the district due to its topographic structure and its potential in terms of agricultural lands and natural resources.

In the present study, 1/25000-scale geological and topographical maps of the area with master plan and WorldView-3 with GeoEye Ortoready pansharpened satellite images at a resolution of 50 cm with 4 bands (RGB+NIR) were used. These maps were used for the classification of land cover. Additionally, Unmanned Aerial Vehicle (UAV) images were used to control and correct the actual master plan of the region. Infastructure, such as roads, buildings, etc., which were not included in the current master plans, were identified by land surveys. Their high-resolution images were taken with UAV and integrated into satellite images, resulting in land-cover classification made with high accuracy and control.

The study methods consisted of three stages (**Figure 2**). In the first stage, the baseline information (such as zoning plans, residential area limits, population, soil maps, green areas, etc.) of the study area were prepared and/or collected using literature reviews, field studies and materials obtained from public institutions and organizations. A large inventory covering the region was executed and a database was created.

In the second stage, the current state maps needed for the determination of areas suitable for settlement were digitized using Geographic Information Systems (GIS). In this regard, land-use capability classes and maps of drainage areas were digitized using the 1/100000 scale Muğla province land assessment map. Geological formations and fault lines maps, slope, elevation maps and hydrology maps were created using topographic maps. Land-use status maps with a controlled classification of satellite images and Principal Component Analysis (PCA) with high accuracy were obtained. In the controlled classification process, 100 training and 300 test pixels

Figure 1. Geographical location of the study area.

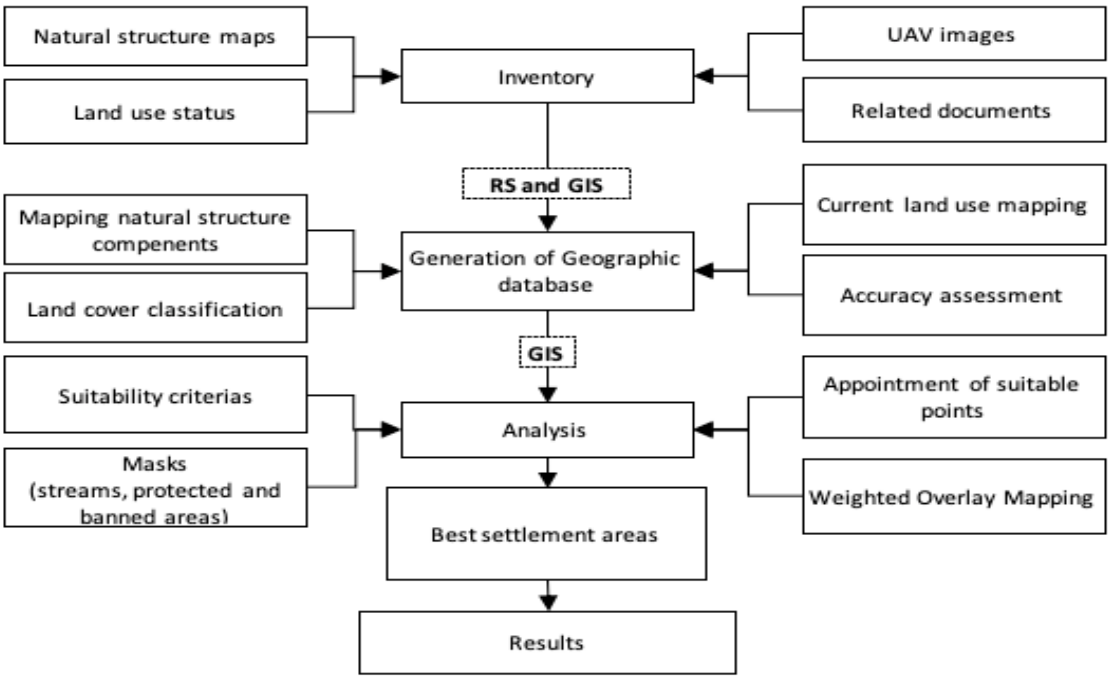

Figure 2. Method flowchart in determining suitable settlement areas.

were created for each land-use class and graded with Random Forest (RF) and Maximum Likelihood Classification (MLC) methods. At the end of the classification, a confusion matrix algorithm (a technique used to measure the performance of a classification algorithm) was used to calculate the classification accuracy for RF and MLC (**Table 1**). The calculations indicated that the classification using the RF method had the highest accuracy value, and thus the classified image obtained by this classification technique was used for further analysis.

In the last stage, the obtained data were evaluated with MCDA. MCDA is an integrative approach that evaluates physical, ecological, economic and social data (*Martinez and Alonso 1995, Lier 1998, Matthews et al. 1999, Weerakoon 2002, Bagheri et al. 2012, Mosadeghi et al. 2015, Selim et al. 2018*). First, the main criteria and sub-criteria were determined for assessing eligibility for settlement (*McHarg 1969, Matthews et al. 1999, Ardahanlioglu 2014, Mosadeghi et al. 2015*). To increase sensitivity of the analyses, the conformity values of the

Table 1. Random Forest and Maximum Likelihood Classification.

	Near-Infrared		Red-Green-Blue		Principal Component Analysis	
	Mean	**Kappa**	**Mean**	**Kappa**	**Mean**	**Kappa**
MLC	78.48	0.7579	81.22	0.7887	72.00	0.6850
RF	83.74	0.8171	78.44	0.7575	84.92	0.8304

sub-criteria were formed according to a five-point rating system. The scores of the sub-criteria that did not show similarity with the sub-criteria of previous studies were determined based on expert opinion. More specifically, literature studies were taken into consideration with the opinion of seven experts (one architect, landscape architect, environmental engineer, land expert, hydrologist, geologist and geographer) who were knowledgable about the region. The weights of the criteria were then obtained using MCDA. In determining the points in the sub-criteria, suitability as a settlement area was considered. Accordingly, if the sub-criteria was considered very suitable for use as a settlement area, it was given five points, four points if it was deemed appropriate for use as a settlement area, three points if moderately appropriate, two points if it was unsuitable and one point if it was never suitable for use as a settlement area. Compliance coefficients were also determined by using the criteria as a settlement area (**Table 2**).

Subsequently, suitability status maps were created for settlement areas. First, the maps created in vector format were converted to raster format with a cell size of 1×1 m to increase the sensitivity of the analyses. Next, the determined conformity values of the sub-criteria in each criterion were assigned to the maps converted to raster format. For the determination of settlements that are compatible with the natural environment, the conformity maps were subjected to weighted overlay analysis taking into account the conformity criteria. As a result of the analysis, the most suitable settlement areas were mapped and classified according to availability.

RESULTS AND DISCUSSION

The findings of the research consisted of the sub-criteria values obtained as a result of the MCDA analysis and the percentage of the criteria taken as a result of that analysis. The results of the analysis of the main criteria (land-use class, drainage, geological formation, hydrology, elevation, slope, maintenance and existing land uses) defined as natural environment components are given in (**Table 3**).

Table 2. Assessment criteria, sub-criteria and conformity values selected in the determination of settlement areas suitable for the natural environment.

Criteria	Sub-criteria	Suitability value (SV)*	Suitability coefficient (SC)
Land-use capability class	I	1	0.28
	II	1	
	III	2	
	VI	4	
	VII	5	
Drainage	Drainage problem	1	0.05
	No drainage problem	5	
Geological formation	Kmo Peridotit	4	0.22
	Plcgo Old alluvion	1	
	Q1d Late alluvion	1	
	Qal Alluvion	1	
	Qt Latest alluvion	1	
	Te Sandstone-Mud	3	
	Trjd Limestone	4	
Proximity to stream or still water as use and flooding	0-100 m	1	0.08
	100-500 m	5	
	500-1000 m	4	
	>1000 m	3	
Elevation	0-200 m	5	0.05
	200-400 m	3	
	400-600 m	2	
Slope	% 0-2 Flat-close to flat	3	0.15
	% 2-6 Light slopy	5	
	% 6-12 Moderate slopy	3	
	% 12-20 Vertical slopy	2	
	% 20-30 High vertical slopy	1	
	> % 30 Vertical	1	
Aspect	S, SE, SW	5	0.07
	E, W	4	
	NE, NW	3	
	N	1	
	Flat	3	
Current land use	Present settlement	5	0.10
	Farm-Garden	3	
	Forest	1	
	Others	1	

Table 3. Numerical data of the natural environment components of the city of Seydikemer and its vicinity.

Criteria	Sub-criteria	Suitability value (SV)*	Suitability coefficient (SC)
Land-use capability class	I	984.53	12.58
	II	1088.64	13.91
	III	688.63	8.80
	VI	1232.38	15.75
	VII	3832.87	48.96
	Toplam	7827.04	100
Drainage	Drainage problem	1926.25	24.61
	No drainage problem	5900.79	75.39
	Tamplam	7827.04	100
Geological formation	Kmo Peridotit	2136.01	27.29
	Plcgo Old alluvion	490.81	6.27
	Q1d Late alluvion	704.71	9
	Qal Alluvion	1719.73	21.97
	Qt Latest alluvion	17.66	0.23
	Te Sandstone-Mud	2754.31	35.19
	Trjd Limestone	3.81	0.05
	Total	7827.04	100
Elevation	90-130	1030.56	13.17
	130-170	1954.58	24.97
	170-210	1495.61	19.11
	210-250	1175.33	15.02
	250-290	930.94	11.89
	290-330	657.67	8.40
	330-370	374.83	4.79
	370-410	168.66	2.15
	410-465	38.86	0.50
		7827.04	100
Slope	% 0-2 Flat-close to flat	1687.90	21.57
	% 2-6 Light slopy	1069.95	13.67
	% 6-12 Moderate slopy	937.41	11.98
	% 12-20 Vertical slopy	1461.37	18.67
	% 20-30 High vertical slopy	624.20	7.97
	> % 30 Vertical	2046.21	26.14
	Toplam	7827.04	100

Table 3. Numerical data of the natural environment components of the city of Seydikemer and its vicinity. (cont.)

Criteria	Sub-criteria	Suitability value (SV)*	Suitability coefficient (SC)
Aspect	Flat surfaces	4330.17	55.32
	N	137.40	1.76
	NE	503.79	6.44
	E	373.09	4.77
	SE	546.00	6.98
	S	413.82	5.29
	SE	581.22	7.43
	W	417.20	5.33
	SW	524.35	6.70
	Total	7827.04	100
Proximity	0-100 m	654.13	8.36
	100-500 m	1372.06	17.53
	500-1000 m	1494.27	19.09
	>1000 m	4306.58	55.02
	Toplam	7827.04	100
Current land use	Present settlement	293.67	3.75
	Agricultural land	1256.75	16.06
	Forest	4722.34	60.33
	Water	47.17	0.60
	Other	1507.11	19.26
	Total	7827.04	100

Within the boundaries of the research area, I, II, III, VI and VII class soils constituted 12.58% of the research area, and approximately half of the classes were located in the city center within the boundaries of the zoning plan. Class II soil covered 13.91% of the research area, class III soil covered 8.80% of the total area, class VI soil covered 15.75% and class VII soil constituted 48.97% of the area. These results indicate that 64.71% of the total land area was suitable as a settlement area in terms of land-use class, while 8.80% was unsuitable and 26.49% was mostly unsuitable, with 35.29% of the total area not suitable for settlement use (**Figure 3**).

Approximately 24.61% of the research area had drainage problems, and certain parts of these lands were located within the zoning boundaries. There was no drainage problem in 75.39% of the total area. Examination of the suitability status map and numerical data revealed that 27.34% of the research area was suitable as a settlement area in terms of geological structure, 35.19% of the area was moderately suitable and 37.47% of the area was not suitable as a settlement area. Geologically, 27.29% of the research area was peridotite (Kmo), 6.27% was old alluvion (Plcgo), 9.00% was late alluvion (Q1d), 21.97% was alluvion (Qal), 35.19% was sandstone-mudstone (Te) and 0.05% consisted of limestone (Trjd) formations.

The majority of the research area consisted of high slope groups. There were low slopes around the D400 highway in the north and south of the city and west of the Eşen River within the boundaries of the zoning plan.

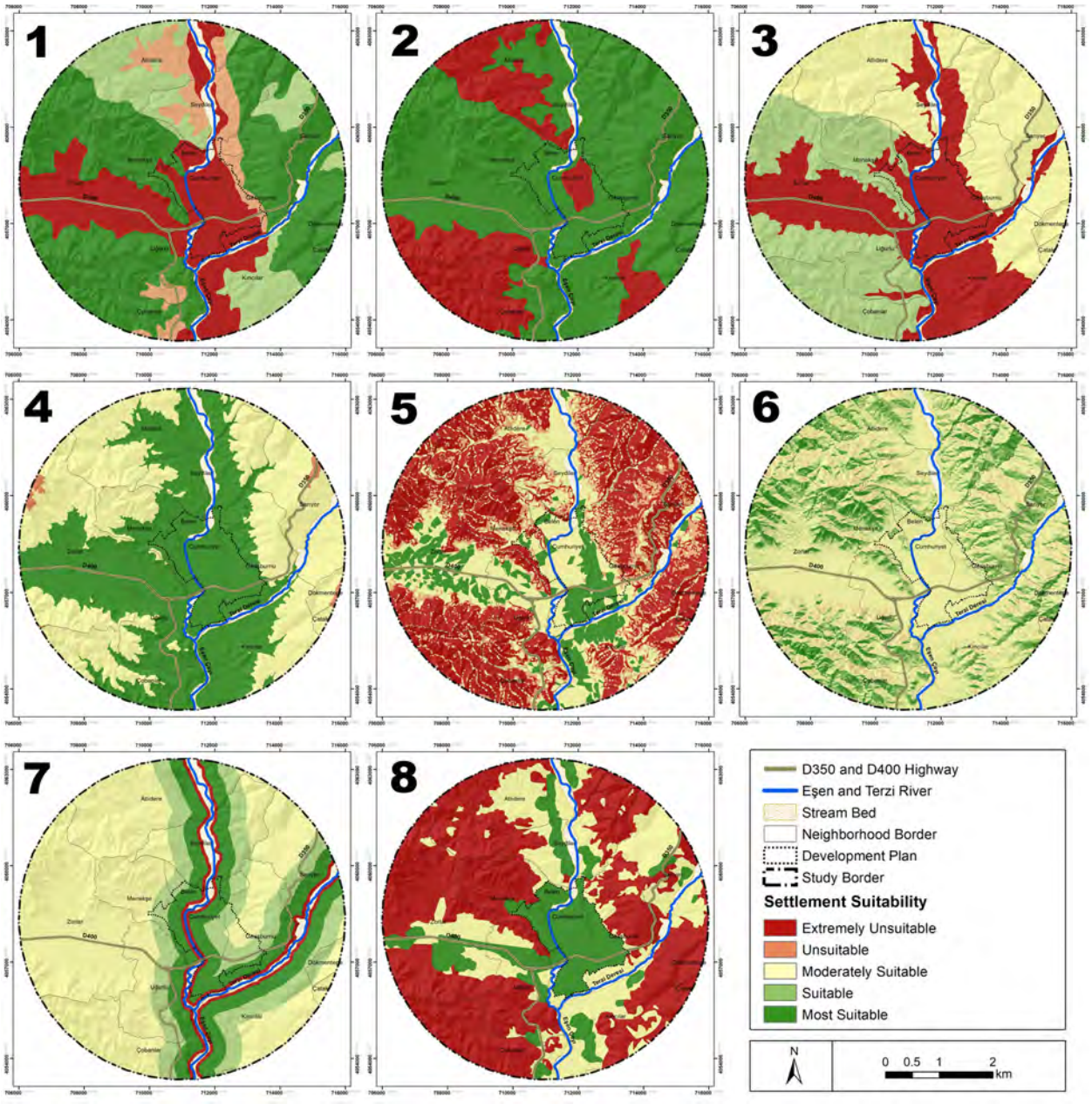

Figure 3. Land-use maps for settlement: (1) Land-use capability class; (2) Drainage suitability map; (3) Geological formation suitability map; (4) Elevation suitability map; (5) Slope suitability map; and (6) Aspect suitability).

In terms of slope groups, 13.67% of the land was very suitable as a settlement area, 33.55% of the total land was moderately suitable as a settlement area and 52.78% of the area was unsuitable. In the research area, the city centre within the boundaries of the zoning plan was located 90-170 m in elevation. Elevation increased when moving east, north-west and south-west from the city center.

According to the elevation map results, 52.80% of the research area was very suitable, 46.41% was moderate suitable and 0.79% was not suitable as a settlement area. Most of the city center within the zoning plan consisted of flat areas in southern directions of the district. According to the results of the aspect map, 19.70% of the survey area was very suitable and 29.80% of the total land was suitable to be a settlement area, while 68.44% was moderately suitable for being a settlement area and 1.76% of the land was not suitable for the settlement areas.

Water, which is a critical resource in social and ecological systems (*Malenab et al. 2016*), is an important factor affecting settlement in the region. In terms of

important streams are the Eşen River and Terzi Stream. The Karanlık Stream and Toplar Stream located in the northeast, Babaveli in the west and İnce Stream in the southwest of the research area run into the Eşen River. In terms of proximity to streams and still water sources with flood hazard, 17.53% of the survey area was very suitable and 36.62% of the total area was suitable to be a settlement area in terms of its proximity to streams and still water resources, while 55.02% was moderately suitable for being a settlement area and 8.36% of the land was not suitable for settlement areas.

The study area consisted of the following: 6.50% urban areas; 7.90% rural settlements; 54.43% forest areas; 25.38% agricultural areas and integrated plant areas for agriculture; 0.89% trade area; 0.24% small industrial area; 0.47% school area; 0.13% fair area; 0.39% landslide; and 3.68% rocky stony area. According to the current land use, 3.75% of the research area was very suitable for being a settlement area in terms of the existing land use, while 16.06% was moderately suitable for being a settlement area and 80.19% of the land was unsuitable for being a settlement area in terms of existing land use (**Figure 4**).

Based on the map of suitability status of the Seydikemer city center and its close surroundings (5 km buffer zone), the Zorlar, Seydiler and Cumhuriyet neighbourhoods and Eşen Stream were not suitable as settlement areas in terms of the natural environment. The districts of the Gerişburnu, Belen, Kıncılar and Atlıdere neighbourhoods were moderately suitable for settlement, while the regions located in the vicinity of the Menekşe, Sarıyer and Uğurlu neighbourhoods were suitable for settlement. However, some parts of Atlıdere, Seydiler, Sarıyer, Gerişburnu, Kıncılar, Dökmentepe and Çatak neighbourhoods were not geologically suitable due to landslides. Furthermore, the places within the zoning borders were moderately suitable and partly unsuitable for settlement. Class I and II agricultural lands were not ecologically appropriate as settlement areas. Therefore, the construction for the boundaries of the Cumhuriyet neighbourhood where these agricultural lands are located should be limited. Additionally, this analysis showed that the development direction of the city is not suitable for the neighbourhoods of Seydiler and Zorlar around Eşen Stream. The direction of urban development towards the Menekşe, Uğurlu and Çobanlar neighbourhoods seems to be more appropriate (**Figure 5** and **6**).

Stream coasts are generally used as settlements and that the highway route and its surroundings show rapid urbanization (*Chandra et al. 2018, Sahana et al. 2018,*

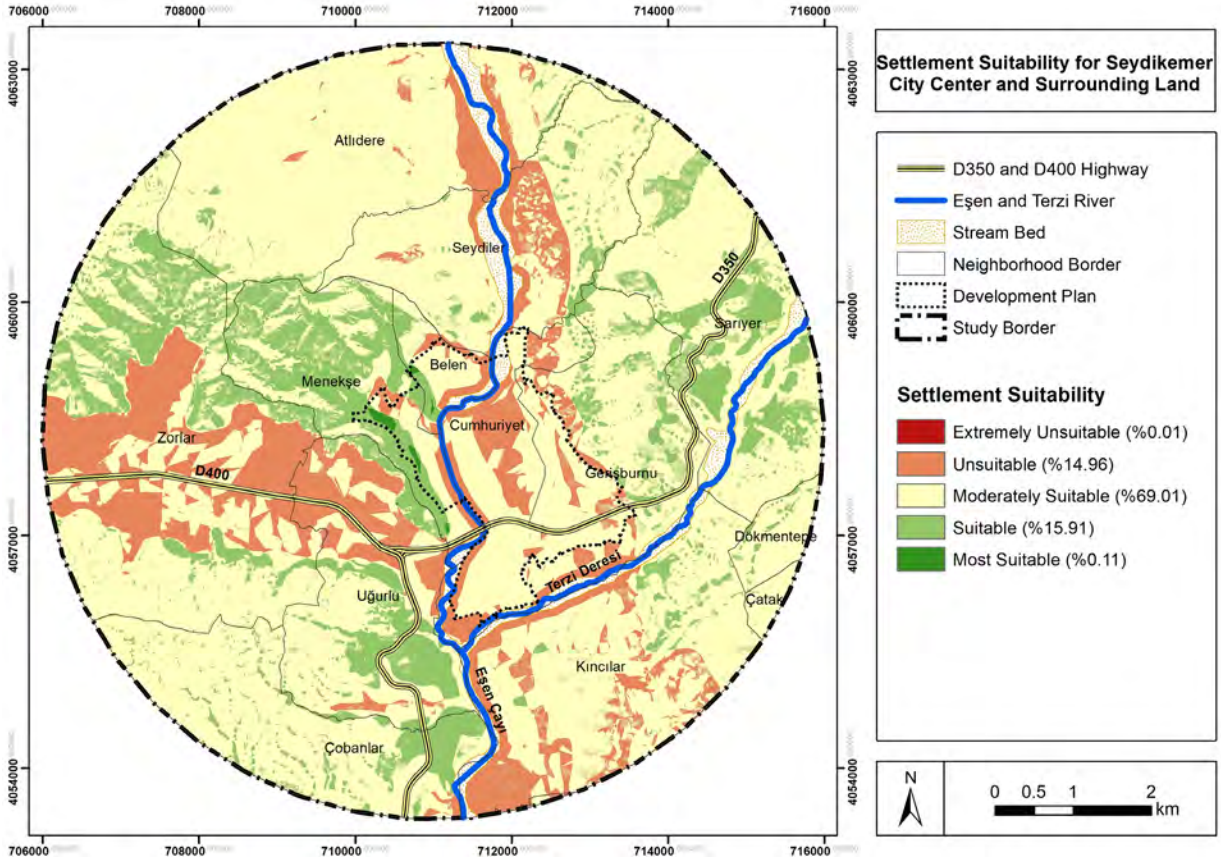

Figure 4. Suitability map of settlement compatible with the natural environment.

Figure 5. View of unsuitable lands for settlement obtained by UAV (1. Ugurlu and Zorlar neighborhoods; 2. Zorlar neighborhood; 3. Cumhuriyet neighborhood; 4. Belen neighborhood; 5. Cumhuriyet, Menekşe and Gerişburnu neighborhoods; 6. Gerişburnu neighborhood).

Figure 6. View of suitable lands for settlement obtained by UAV (1. and 2. Menekşe neighborhood; 3. Ugurlu neighborhood).

Zambon et al. 2019). The main reasons for this are a lack of economic opportunities and infrastructure (*Maithani et al. 2019*). However, stream coasts and low slope areas are known to have soil structures that are mostly suitable for agriculture (*Tromboni and Dodds 2017, Roy et al. 2018, Wild et al. 2019*). It is important to use these areas for agriculture within the scope of sustainable agriculture policies, especially in developing countries, and to include and protect them as agricultural land in master plans (*Langat et al. 2019*). This study found that the region, which has entered a rapid urbanization process, has generally developed along the stream coasts and the highway route. This current development puts pressure on fertile agricultural land. In developing countries such as Turkey, it is important to determine the direction and speed of urban sprawl and to develop recommendations to ensure environmental and economic sustainability in development plans.

This study presents an important methodological guide that can be used at both national and international levels. Various classification algorithms have been used in many land-use planning studies that used remote sensing techniques (*Huang et al. 2018, Zhang et al. 2019*). Generally, only one classification method is used and this classification result is expected to have a high accuracy (*Islam et al. 2018, Zhang et al. 2018*). In this study, two different classification techniques using different algorithms were tested and the one with higher accuracy was chosen. Land surveys were carried out and UAV images were included in the current classification to increase accuracy. Thus, sensitive and up-to-date data were obtained and decisions for suitable settlement areas were developed. MCDA, which evaluates the region according to different criteria, was also used in the study methodology. MCDA is known to have high accuracy and is preferred in the evaluation of multiple criteria and even their sub-criteria (*Jeong 2018, Musakwa 2018*). Several studies argue that expert opinions should be considered when determining the criteria and their weights (*Kazemi*

and Akinci 2018, Badia et al. 2019). Although many MCDA studies do not include expert opinions (*Samanta et al. 2016*), the views of experts who live in the region and/or have knowledge about the region were included in the methodology, which allowed the criteria to be accurately weighted in terms of different disciplines..

CONCLUSIONS AND RECOMMENDATIONS

Human activities and unsustainable interventions have caused significant damage to the natural environment (*Bruna et al. 2013, Janda et al. 2014, Cervenka et al. 2014*). These changes in the natural environment can significantly affect ecosystems (*Foley et al. 2005, Verburg et al. 2009*). Considering that urbanization activities are still very recent in Seydikemer, it is crucial that development plans be compatible with nature within the scope of landscape planning to prevent problems associated with the unsustainable use of the area in this region (*Lier 1998, Rich and Yilmaz 2008, Yesil and Yilmaz 2013*). This study, which presented an important example for this region, settlement areas compatible with the natural environment were determined. It was found that 16.02% of the survey area was suitable for use as a settlement area, 69.01% was moderately suitable for use as a settlement area and 14.97% was unsuitable for use as a settlement area. As a result of the analysis of the settlement areas compatible with the natural environment and the existing rural and urban settlements, 13.51% of the existing rural settlements were found to be suitable, 61.84% moderately suitable and 24.65% were unsuitable for settlement. Of the existing urban settlements, 7.03% were found to be suitable, 68.12% moderately suitable and 24.85% were unsuitable for settlement.

This study propose the following recommendations to help facilitate the sustainable development of the city and respond to future expectations. For the settlements that have been removed from the status of municipality and have been transformed into a neighborhood, agricultural activities should continue in a controlled way in the settlements located on fertile agricultural lands watered by the Eşen River. If the agricultural areas in the Seydikemer city center and its surrounding areas are allowed to be built, there will be loss of agricultural land due to improper land use on fertile land. The sustainability of agricultural activities in the region should be ensured now and in the future, considering that the rural fabric of the region is still intact and the livelihoods in the region are predominantly based on agriculture. Therefore, suitable areas for agricultural activities should be preserved and designated for agricultural use in zoning plans. Regarding the development of social and cultural opportunities in the region, existing urban areas and the regions that are suitable for the development of recreational areas should be taken into consideration in the zoning plans, and the recreational areas that address the whole of the city and have equal distribution in the region should be incorporated in the plans.

The maps and study results created within the scope of ecological planning are a very important knowledge base that can be integrated into the planning processes of central and local governments. Therefore, taking these and similar scientific studies into account in all planning stages related to the region and acting jointly with related professional disciplines is crucial for the sustainable social, cultural, ecological and economic development of the region. This study supports the understanding of sustainable urbanization in the region, which has not yet completed urban development plans, and offers applicable suggestions to decision-makers by presenting a methodology that can be adapted to local and regional settings. It is expected that this study will play an important role in the future physical planning of Seydikemer and will be a reference especially in regions that has not yet completed urban development plans.

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