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Fragmentation and Connectivity Assessment in Mediterranean Coastal Landscapes: The Cases of Urla and Seferihisar IZMIR

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Abstract

Anthropogenic pressures present a significant threat to natural landscape connectivity and cause habitat fragmentation. This is also the frequent case for Mediterranean landscapes. The study areas of Urla and Seferihisar are coastal settlements in the Izmir metropolitan area. Once, Izmir was a relatively small Mediterranean coastal town with a low-density settlement character in the 1960's. It became a metropolitan city that sprawled along the transportation network and coastline towards Urla to the west and Seferihisar to the southwest. Urla and Seferihisar have also been subjected to suburban development in the vicinity of the metropolitan city of Izmir. These cases, therefore, present good examples of assessing landscape fragmentation and connectivity based on urban development and transportation networks. This study examined Mediterranean shrubland and the degree of forest fragmentation and connectivity that was caused by a transportation network and urban expansion for 42 years. Shrubland and coniferous forests in Mediterranean landscapes are the dominant natural land covers and important wildlife habitats. The fragmentation and connectivity were quantified on the basis of 1963 and 2005 land use/cover and transportation maps using Area and Edge Metrics (CA-class area, PLAND-percentage of landscape, GYRATE_AM-radius of gyration, AREA_MN-patch area distribution), Aggregation metrics (PD-patch density, LSI-landscape shape index, NP-number of patches, and ENN_MN-euclidean nearest neighbor distance distribution). Furthermore, with Ordinary Least Square Regression Analysis, it focused on identifying the influence of urban development and a transportation network over forest and shrubland fragmentation. The results showed that road density was significantly related to the fragmentation, while population density and proximity to urban areas had no significant effect.

Introduction

Mediterranean landscapes shaped by natural disturbances and intense human impacts from early times to the present (Allen, 2003) were home to many ancient civilizations throughout the course of human history. Over time, this also caused significant degradation and large-scale land-cover changes on the natural landscapes in most of the areas.

However, the Mediterranean has still preserved a great deal of its bio-diversity as a region with one of the world's highest number of plant species and levels of endemism (Allen, 2003). In the Mediterranean landscapes the coastal areas are particularly important because they are very sensitive to development pressures (Kılıç et al, 2004; Vogiatzakis et al, 2005) and suffer from uncontrolled coastal urban sprawl that have caused the disappearance of valuable coastal habitats (Blue Plan and Regional Activity Centre, 2001). Many major cities and ports are located along the coast with much industrial and tourist development. It is estimated that 50-70% of the population in Mediterranean countries live within 60 km of the coast and this growth has been increasing (Caffyn et al. 2002).

The metropolitan city of Izmir is located on the coastal landscape of the Aegean region. Like other coastal Mediterranean landscapes, Izmir has been experiencing rapid urban development. Izmir, the third-largest metropolitan city in Turkey, had maintained its urban identity (Gündüz, 1991) as a typical Mediterranean coastal city until the 1950's when it started to succumb to rapid urban sprawl (Özsoy, 2009). Since the 1980's, Izmir has faced an accelerated process of urban expansion. It has expanded its borders along the transportation networks and especially along the coastline (Hepcan at al., 2013). Urban growth has been dominated by residential development, primarily vacation homes, along the coastline towards the Urla and Seferihisar districts (Karadağ, 2000). Both towns evolved into suburbs of the metropolitan city of Izmir. This process brought in a lot of people and urban infrastructure including freeways and highways as well as housing developments onto natural and agricultural areas that caused fragmentation and loss of natural landscapes.

Based on literature reviews such as Forman and Alexander (1998); Trombulak and Frissell (2000); Heilman et al., (2002); Hawbaker et al (2004) and Irwin and Bockstael, (2007), three variables stood out in assessing fragmentation; road density, population density and proximity to urban areas. Hawbaker et al (2004), for instance, found a strong relationship between fragmentation and road density. Similarly, Irwin and Bockstael (2007) also confirmed a positive correlation between fragmentation and proximity to urban areas in Maryland. Therefore, in this paper, it was initially hypothesized that these three variables would significantly affect fragmentation in the cases of Urla and Seferihisar. This study investigated the degree of Mediterranean shrubland and forest fragmentation and connectivity associated with the aforementioned three variables for 42 years because shrubland and coniferous forests in the Mediterranean landscapes are the dominant natural land covers and important wildlife habitats.

Study Area

The study area (38°26'49" and 38°1'51" North, 26°28'46"and 27°2'16" East) includes the Urla and Seferihisar districts of Izmir province. Both districts are located on the western part of Izmir and cover an area of 809, 24 km² with a population of 85,155 (TurkStat, 2014) (Figure 1). Since the 1950's, the study area has been developing residential, mostly vacation, homes and recreation areas for Izmir's urban residents. The urbanization process was started in the 1980's and accelerated after 1995 with the construction of the İzmir-Çeşme highway (Sönmez, 2009).

Seferihisar represents a distinctive landscape with its natural features and its historical and archeological sites. It is a popular tourist destination that attracts many nearby visitors from Izmir (Coskun Hepcan et al., 2014). Seferihisar is also the first Slow City in Turkey.

In recent years, the Urla district has seen a somewhat unconventional development of the suburban areas. There has been a growing interest among the upper/middle-income people from different cities in Turkey to develop greenhouses, organic farming, vineyards and wineries, animal farms and to convert agricultural land and shrubland into sports fields for different activities (Coskun Hepcan, 2013).

Material and Methods

In this study 1963 and 2005 land use/cover maps and road maps were used. The land use maps provided by Coskun Hepcan (2013) were reclassified into 5 classes. They were urban (built up, roads, mineral extraction area), agricultural land (agricultural land, olive groves, fruit plantation), forest (coniferous forest, afforestration), shrubland (maquis, maquis-phrygana, phrygana), and water bodies (lake, pods, dams, coastal marshes).

The population information was obtained from the Turkish Statistical Institute (TurkStats, 2014). The road map was provided by the General Command of Mapping of Turkey. The road density (km/km²), population density (people/km²), and distance to urban areas layers were calculated using Spatial Analyst in ArcGIS10 based on the road map and the population map, respectively (ESRI, 2011).

The change of forest and shrubland between 1963 and 2005 were defined using change detection. The fragmentation and connectivity level of the Mediterranean forest and shrubland were quantified using landscape metrics that were Area and Edge Metrics (CA-class area, PLAND-percentage of landscape, GYRATE_AM-area-weighted mean patch radius of gyration, AREA_MN-patch area distribution), Aggre-

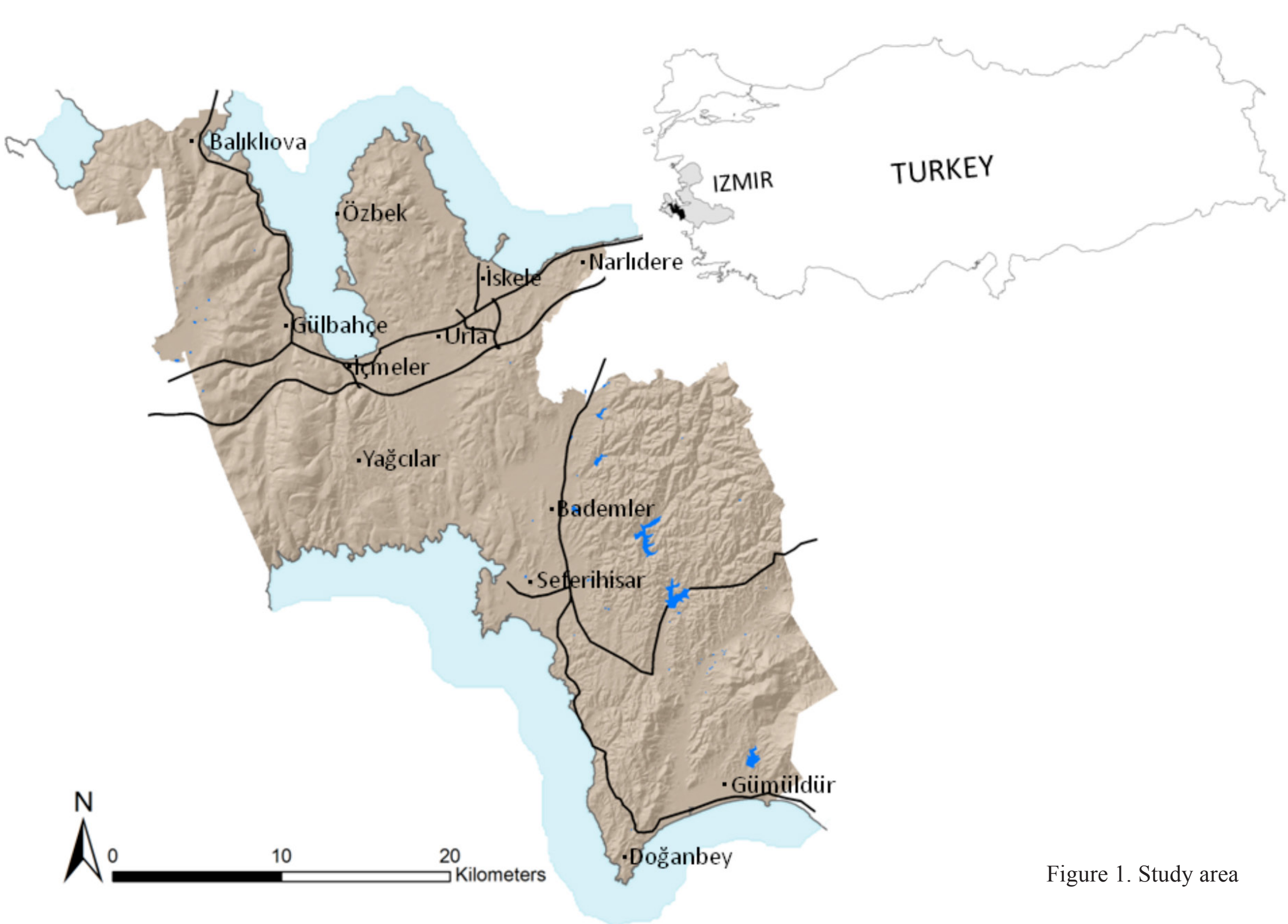

Figure 1. Study area

gation metrics (PD-patch density, LSI-landscape shape index, NP-number of patches and ENN_MN-euclidean nearest neighbor distance distribution). Analyses were conducted in FRAGSTATS 3.4. (McGarigal and Marks, 2003; Botequilha Leitao et al., 2006).

Using the Spatial Statistical Tools in ArcGIS the Ordinary Least Square (OLS) Regression Analysis was run to identify the relationship between fragmentation and road density, population density and proximity to urbanization. The Spatial Autocorrelation tool was run to check whether or not the residuals exhibit a random spatial pattern of the OLS result. The OLS regression is a common statistical technique used for determining what contributes to the phenomena (in this case, its fragmentation) and to what degree (Scott and Janikas, 2010).

Results and Discussion

Interpretation of landscape metrics

In this study a set of metrics that include four area and edge metrics and four aggregation metrics were employed because they are common core metrics that are directly or indirectly related to landscape fragmentation and connectivity assessment (Botequilha Leitao et al., 2006).

It is obvious that the landscape pattern of the study area has changed over time. Figure 2 depicts the changes of forest and shrubland vegetation in the region. Likewise, the landscape metrics' results proved that both shrubland and forest vegetation have been subjected to fragmentation to different degrees (Table 1).

The most noticeable contrast between 1963 and 2005 was the difference in NP, PD and AREA_MN for both shrubland and forest. The NP values increased while the AREA_MN values significantly decreased (Table 1). This indicated that the average size of shrubland and forest patches became smaller. The increasing LSI values reflected that the shape of the patches became more complicated.

The results suggested that the shrublands have experienced dramatic change in regard to forest vegetation. That can be explained with the fact that the shrublands were mostly replaced by urbanization-vacation homes and agricultural land because shrubland is not strictly protected by law and so, more vulnerable to anthropogenic pressures. Likewise, Coskun Hepcan and Ozkan (2007) and Sönmez (2009) explained the fragmentation of natural vegetation with the construction of the Çeşme-Urla highway and urbanization (primarily vacation homes).

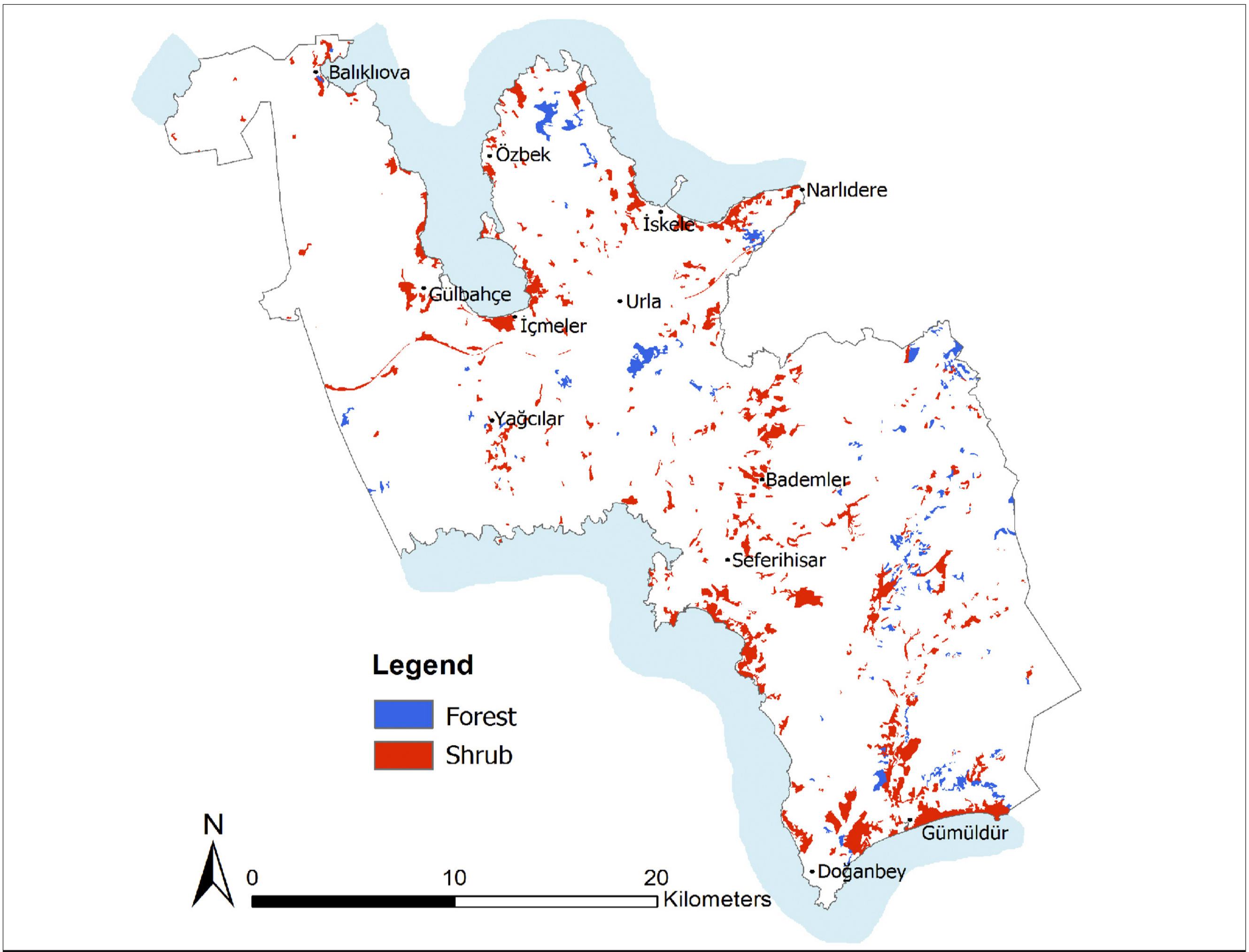

Figure 2. The loss of forest and shrubland patches between 1963 and 2005

The extensive changes to the shrubland pattern took place in the coastal areas around the coastal villages like Gümüldür and Seferihisar in the South, and İskele, Güzelbahçe in the North. The large and continuous shrubland patches in the east and southern part of the study area were divided into smaller patches over time and ended up with lower connectivity. The fragmentation of the shrubland patches along the main roadways that connect Narlıdere, Seferihisar and Gümüldür is obvious, if Figure 2 is examined carefully. This sug-

Table 1. Metric results of 1963 and 2005

	CA	PLAND	NP	PD	LSI	AREA_MN	GYRATE_AM	ENN_AM
1963								
arable	13512.26	16.69	164	0.20	22.59	2183.65	2104.55	114.08
shrub	55747.95	68.88	118	0.14	21.77	39581.22	11795.18	25.98
urban	799.01	0.98	134	0.16	17.11	33.78	269.89	722.36
forest	10843.82	13.38	230	0.28	24.70	1063.82	1589.34	108.64
water	21.53	0.02	35	0.04	7.92	2.65	89.89	1801.76
2005								
arable	12392.70	15.31	189	0.24	23.45	62.27	1686.38	130.89
shrub	52425.78	64.78	184	0.22	24.49	284.92	7511.43	29.53
urban	5078.82	6.27	148	0.18	22.08	34.31	1993.15	277.34
forest	10768.42	13.30	307	0.37	26.73	35.07	1607	102.48
water	258.85	0.31	57	0.07	8.7	4.54	421.82	1661.30

gests that the roadway network is one of the major causes of fragmentation of the shrublands in the region as is the case almost all over the world (Forman and Alexander, 1998; Trombulak and Frissell, 2000; Heilman et al 2002; Hawbaker et al 2004 and Irwin and Bockstael, 2007). But, in his study the impact of the transportation network has been investigated further with the OLS in order to identify its statistical significance to fragmentation.

GYRATE_AM provides a measure of landscape continuity. If the GYRATE_AM value is high, the landscape continuity is high (McGarigal and Marks, 2003). In this study the GYRATE_AM value of shrubland dramatically dropped from 11,795 to 7,511. The results indicated that the composition of shrubland was turned into a very patchy and scattered configuration over the years.

ENN_AM measures for patch isolation (McGarigal and Marks, 2003). The higher ENN_AM value represents more patch isolation. The increasing ENN_AM value of shrubland, showed the isolation of shrubland patches.

On the other hand, ENN_AM and GYRATE_AM values for forest vegetation slightly decreased. It can be explained by the conversion of small forest patches scattered throughout the study area into other land use/cover types between 1963 and 2005.

Interpretation of OLS regression analysis

OLS creates an equation that represents the relationship between the model to be explained and explanatory variables (Scott and Janikas, 2010). The hypothesis of this study was to explain fragmentation with road density, population density and proximity to urban areas or how much fragmentation can be explained or correlated with road and population density and proximity to urban areas in the study area.

The OLS results indicated that there was a statistically significant positive relationship between fragmentation and road density (Table 2). This means that as the road density increases, the fragmentation of forest and shrubland goes up. This finding was also

Table 2.The OLS results with four and two variables respectively

Variable	Coefficient	StdError	t-Statistics	Probability	Robust_SE	Robust_t	Robust_Pr	VIF[]
Intercept	-0.3375	0.4370	-0.7723	0.4434	0.4340	-0.7761	0.4403	---------
RD	0.9770	0.1277	7.6470	0.0000*	0.1179	8.2821	0.0000*	1.4715
DUR	0.0342	0.0944	0.3628	0.7181	0.0894	0.3829	0.7033	1.2927
PD	0.0001	0.0004	0.3328	0.7405	0.0003	0.3365	0.7378	1.4115

OLS Diagnostics

Number of observations	56	Number of variables	4
Degree of freedom	52	Akaike's Information Criterion (AIC)[2]	139.4339
Multiple R-Squared [2]	0.6426	Adjusted R-Squared [2]	0.6220
Joint F-Statistic [3]	31.1745	Prob (>F), (3.52) degrees of freedom	0.0000*
Joint Wald Statistic [4]	112.7917	Prob (>chi-squared), (3) degrees of freedom	0.0000*
Koenker (BP) Statistic [5]	2.3889	Prob (>chi-squared), (3) degrees of freedom	0.4956
Jarque-Bera Statistic [6]	0.5778	Prob (>chi-squared), (2) degrees of freedom	0.7490

Summary of OLS Results

Variable	Coefficient	StError	t-Statistic	Probability	Robust_SE	Robust_t	Robust_Pr
Intercept	-0.3052	0.3569	-0.8552	0.3961	0.3305	-0.9236	0.3597
RD	1.0168	0.1036	9.8092	0.0000*	0.0940	10.8173	0.0000*

OLS Diagnostic

Number of observations	56	Number of variables	2
Degree of freedom	54	Akaike's Information Criterion (AIC)[2]	135.7678
Multiple R-Squared [2]	0.6405	Adjusted R-Squared [2]	0.6338
Joint F-Statistic [3]	96.2223	Prob (>F), (1.54) degrees of freedom	0.0000*
Joint Wald Statistic [4]	117.0150	Prob (>chi-squared), (1) degrees of freedom	0.0000*
Koenker (BP) Statistic [5]	0.0563	Prob (>chi-squared), (1) degrees of freedom	0.8124
Jarque-Bera Statistic [6]	0.6392	Prob (>chi-squared), (2) degrees of freedom	0.7264

* statistically significant at the 0.05 level

consistent with Forman and Alexander (1998) and Heilman et al (2002). In that research, they analyzed road density and forest fragmentation in the USA. Hawbaker et al (2004) also found a strong relationship between fragmentation and road density.

On the other hand, according to Table 2, there was a positive relationship between fragmentation and population density and proximity to urban areas but they were not statistically significant. This simply meant that these variables did not help the model. When the OLS was run using only the road density variable, the results did not change much.

In another words, population density and proximity to urban areas did not affect the forest and shrubland fragmentation significantly in this study area. This result seemed not to support the initial hypothesis of this paper because it was hypothesized that all three variables, including road density, population density and proximately to urban areas would significantly affect fragmentation in the region. The results showed that one of them affected fragmentation significantly, which is road density, while the others did not. But this is the case in the study area. For further studies, some other variables or causes such as agriculture need to be studied to explain landscape fragmentation in the region. In a way, the results of this study contradict some literature that shows that both population density and proximity to urban areas are significant factors that affect fragmentation. Hawbaker et al (2004), for instance, found a strong relationship between fragmentation and road density and housing density. Similarly, Irwin and Bockstael (2007) confirmed that fragmentation increased as the distance to urban areas increased in Maryland.

The variance infatuation factor VIF value explains the redundancy. If the VIF value for any of the variables is larger than 7.5, it means one or more of the variables are telling the same story (Woolridge, 2003). As all the variables had lower values than 7.5 in this model, none of the variables explained the same situation (Table 2).

The Jarque-Bera test measures whether or not the residuals from a regression model are normally distributed. If this test is statistically significant, it means that the model is biased. In this case, since it was not statistically significant, the model was trustable (Table 2).

The Adjusted R-squared value ranges from 0 to 1.0 and gives the information about how much of the variation in the dependent variable has been explained by the model. In this research, when the four variables were used for the OLS, the Adjusted R-Squared value was 0.62. When 2 variables were used for the OLS, the Adjusted R-Squared value was 0.63. This indicated when using the road density variable alone, the model explained 63% of the forest and shrubland fragmentation (Table 2). The population density and proximity to urban area variables were actually ineffective for the model as mentioned before. This model could be improved and the Adjusted R-Squared value could be increased by adding new variables that may affect fragmentation such as elevation, slope, and proximity to agricultural land.

The results also showed that explanatory variables were stationary (the Koeker test was not statistically significant) (Table 2). That means none of the variables be changed based on the geographical locations. The Spatial Autocorrelation results showed that the regression residuals were randomly distributed and the z-score was not statistically significant.

Conclusions

This study looked at the correlation among Mediterranean shrubland-forest fragmentation and road density, population density and proximity to urban areas and hypothesized that road density, population density and proximity to urban areas would significantly affect fragmentation. However, the results highlighted a statistically strong relationship between fragmentation and road density, but not population density and proximity to urban areas in the study area. As it has been discussed before, these results are partly consistent with the relevant literature. It is obvious that road density was the main factor for fragmentation of the Mediterranean coastal landscapes in Urla and Seferihisar. But new variables such as agricultural expansion over natural habitats should be added to road density in search of fragmentation in the study area.

The variable that is statistically significant to landscape fragmentation in this study is consistent with other empirical evidence. But two other variables that were proved statistically insignificant in the study area remain a question mark.

Based on the findings of this study, urban development and population density may not be immediate concerns in terms of landscape fragmentation. This can be explained by the fact that the study area is not heavily urbanized. But it does not mean that urbanization in the form of vacation homes does not threaten the well being of the natural habitats. Residential development is on the rise in the region due to its huge tourist and recreational potential.

The region definitely needs sustainable spatial planning that sets the boundaries very clearly between urban development and habitat protection. Green infrastructure planning could be a spatial tool to accommodate the needs of both development and habitat conservation without causing further fragmentation. Traditional spatial planning approaches such as environmental plans and urban master plans have failed to develop ecologically sustainable growth strategies in Turkey (Hepcan et al. 2013). As stated by Steiner (2011), new approaches are required in urban planning. Green infrastructure planning can supplement traditional urban planning by putting ecological principles and sustainability first in urban and transportation planning and avoid creating large-scale landscape fragmentation in the future (Hepcan 2013).

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