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RESEARCH PAPER

Determining the Change of Natural Diversity at Landscape Level: The Case of Denizli Province of Türkiye

Duygu DOĞAN[1]
[1]*Pamukkale University, Faculty of Architecture and Design, Landscape Architecture Department, Denizli, Türkiye.*

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*** Corresponding Author**
E-mail: duygudogan@pau.edu.tr
https://orcid.org/0000-0003-2865-0569

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Abstract

Especially in recent years, with the increase of anthropogenic effect in land use, species diversity at the patch level is decreasing. As a result, biodiversity is decreasing, and species are in danger of extinction. Long-term conservation of biodiversity depends on the conservation of biodiversity elements at different natural levels, from the lowest scales (genetic and species) to landscapes.

This study aims to reveal the changes in diversity in the Denizli province of Türkiye according to the years. The change at the landscape level of the diversity in natural and semi-natural areas in Denizli province between the years of 2000 and 2018 was revealed with Shannon index using the CORINE Land Use/Land Cover data. The area was divided into zones to spatially determine the change in diversity. According to the analysis, diversity has decreased in zones 1 -11, 15, and 19. These areas are also the areas where the anthropogenic effect causes change.

This study, which was carried out in Denizli province, is one of the pioneering studies in the literature in terms of both the spatial determination of diversity and revealing the change over the years. With this study, it is anticipated that the biological diversity of the Denizli province will be protected and transferred to future generations. It is important to determine the change of biodiversity at the landscape level over the years and the reasons for this change, as it is a guiding factor for the planning studies to be carried out.

INTRODUCTION

Biodiversity is decreasing due to fires, cultural practices, and hunting. Changes in land use, especially in recent years, are one of the most important reasons for this decrease.

According to the United Nations (1993) "the biologic variability is defined as variability among living organisms from all sources, including inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and ecosystems." Therefore, biodiversity includes a wide spectrum of factors from genetic diversity to species diversity to habitat, and ecosystem diversity at landscape level (Walz, 2011).

The diversity at landscape level can be explained as the complexity and diversity of landscape elements in terms of composition, structure, and function. Therefore, landscape diversity consists of patch, landscape type, and pattern diversity (Bojie and Liding, 1996). Since the change in land uses cause a change in patch, landscape and pattern diversity, studies of determining the diversity at landscape level and the change of this diversity has been gaining importance.

The diversity at landscape level can be measured using various indices. Diversity indices consist of two components: richness and evenness. Richness means the number of patch types present. Evenness refers to the distribution of the area between different patch types

(McGarigal *et al*., 2012; Doğan, 2016). Shannon and Simpson diversity indices are the most widely used indices (Nagendra, 2002; Doğan, 2016). The Shannon diversity index emphasizes the richness component and rare vegetation types, while the Simpson diversity index places more emphasis on the evenness component and dominant vegetation types (Nagendra, 2002; Doğan, 2016). In this study, vegetation types were considered as land cover.

The aim of this study within the scope of what has been told is to reveal the diversity change at landscape level in Denizli province between the years 2000 and 2018. In the study, while determining the change in diversity, natural and semi-natural areas between the years of 2000 and 2018 were considered. Within the scope of landscape level patch analysis, Shannon diversity index, which gives importance to richness component (as the patch richness will support species diversity), was used (Pino *et al*., 2000, Krauss *et al*., 2004, Jönsson, 2006; Doğan, 2016). The Shannon index formula is shown below (Nagendra, 2002):

$$SHDI = -\sum_{i=1}^{m} (P_i \circ \ln P_i)$$

In the formula, m is the number of species, Pi is the ratio of the area occupied by the patch type "i" in the landscape (McGarigal and Marks, 1995). This index ranks theory from 0 to infinity (Nagendra, 2002). Shannon index increases as the number of different patch types increases, or as the proportional distribution of area between patch types becomes more even, or as both the number of patch types increase and the area distribution becomes more even (McGarigal and Marks, 1995). Analysis was performed using the software Patch Analyst (https://www.ferit.ca/patchanalyst/Patch5_2_Install.html, 2022).

As a result of the study, the zones where the change increased and decreased, and their reasons were revealed. With the study, it was also revealed which cover type changes was dominant in the zones where the change decreased. In conclusion, areas, especially those under human influence were determined and suggestions were developed to ensure the sustainability of the diversity of these areas.

MATERIALS and METHODS

The main material of the study is the provincial border of Denizli lying at 28° 30'E – 29° 30'E longitude and 37° 12' – 38° 12N latitude (Özdemir, 2015). Denizli is surrounded by Uşak and Manisa in the north, Afyonkarahisar and Burdur in the east, Aydın in the west and Muğla in the south (Figure 1). In the study, CORINE Land Use/Land Cover (CORINE LU/LC) data was used. CORINE LU/LC data is Land Use/Land Cover data with a minimum mapping unit of 25 ha, obtained by digitizing satellite images. The standard CORINE Land Cover terminology includes 44 land cover classes. These classes are grouped in a three-level hierarchy. CORINE 2000 LU/LC data was generated using Landsat-7 ETM satellite imagery with a geometric accuracy of ≤ 25 m. CORINE 2018 LU/LC data was produced using Sentinel-2 and Landsat-8 satellite images with a

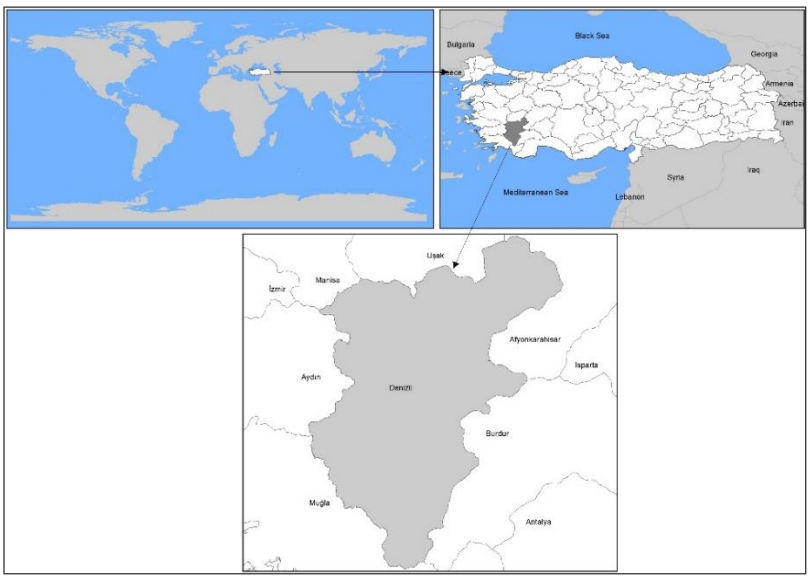

Figure 1. Location map.

geometric accuracy of ≤ 10 m. Both data were produced with ≥ 85% thematic accuracy (Büttner and Kosztra, 2017).

The CORINE 2018 LU/LC data used in this study is the data prepared under the ownership of the European Commission (http://land.copernicus.eu/ 2022). CORINE 2000 LU/LC, river, lake, and dam data were obtained from the PEYZAJ-44 project (Şahin *et al*., 2013) through the former Ministry of Environment and Forestry Information Processing Department.

The highway data used for determining the zones were obtained from geofabric (https://download.geofabrik.de/europe.html, 2018).

The study was carried out in three stages. In the first stage, the change of land use/land cover in the study area was examined according to years.

In the second stage, the measurement was made by dividing the study area into zones. Zones were determined by using barriers (roads) separating the patches. Since the algorithm used only allows measurements at landscape level, it was not possible to descend to the class level in the study. However, the measurement made by calculating the variation in diversity in each zone was reflected on the general patch classes in the zone. At this stage, measurements were made for the years 2000 and 2018. The results were divided into five equal parts and classified as very high, high, medium, low, and very low. These classes were obtained by evaluating the measurement values of the analyzed year according to the years. The classification made is relative because the index grades the measurement result from 0 to infinity. Therefore, the value evaluated as high in this study may be evaluated as low in another study.

In the third stage of the study, the diversity changes of land use/land cover between the years 2000 and 2018 was compared and the zones where the diversity increased and decreased were determined.

RESULTS and DISCUSSION

In this study, for the years of 2000 and 2018, third-level classes of CORINE LU/LC data were used, and the results of the analysis were evaluated based on the zones. Class codes and descriptions used in the evaluation are given in

Table 1. Class codes and descriptions (EEA Technical report, 2006).

Code	Explanation	Code	Explanation
243	Land principally occupied by agriculture, with significant areas of natural vegetation	323	Sclerophyllous vegetation
311	Broad-leaved forest	324	Transitional woodland shrub
312	Coniferous forest	331	Beaches, dunes, and sand plains
313	Mixed forest	332	Bare rock
321	Natural grassland	333	Sparsely vegetated areas

Table 2. CORINE LU/LC and Covered Areas in 2000 and 2018.

		Area		Area	
Land Use/Land Cover		**2000 (ha)**	**2000 (%)**	**2018 (ha)**	**2018 (%)**
Artificial Surfaces		22647,56	1,86	27018,7	2,22
Agricultural Areas		383997,83	31,62	397445	32,73
Wetlands		11962,97	0,98	6433,45	0,52
Water Bodies		6513,75	0,53	7069,19	0,58
Burnt Areas		1746,2	0,14	0	0
Analyzed Patches	Land principally occupied by agriculture, with significant areas of natural vegetation	98456,38	8,1	119239,4	9,81
	Broad-leaved forest	3097,8	0,25	3236,8	0,26
	Coniferous forest	230906,68	19,01	252764,9	20,81
	Mixed forest	43407,93	3,57	16690,65	1,37
	Natural grassland	28125,63	2,31	28076,09	2,31
	Sclerophyllous vegetation	64580,57	5,31	62530,86	5,14
	Transitional woodland shrub	166448,2	13,7	198674,6	16,36
	Beaches, dunes, and sand plains	1198,07	0,09	718,997	0,05
	Bare rock	21890,9	1,8	16873,92	1,38
	Sparsely vegetated areas	129453,42	10,66	77484,81	6,38
	Analyzed patches total	787565,58	64,8	776291,027	63,87

Table 1.

LU/LC of Denizli province according to CORINE LU/LC nomenclature for level three in 2000 and 2018 are given in Table 2. Accordingly, while natural and semi-natural areas covered 64.8% of the district's surface area with 787565.58 ha in 2000, they covered 63.87% with 776291.027 ha in 2018 (Figures 2a and 2b).

According to the LU/LC change analysis conducted between the years of 2000 and2018, landscape diversity is decreasing throughout the province (Table 3).

Table 3. Shannon Diversity Index (SDI) values by year.

Year	SDI
2000	1,84658
2018	1,7495

As a result of the analysis made according to the zoning study carried out in the second stage of the study, none of the patch classes evaluated in zone 18 in 2000 and 2018 were present (Table 4, Figures 3a and 3b).

According to the diversity measurements made in 2000, there is no diversity in zones 12 and 13. Diversity is very low in zone 14, low in zones 16 and 17, moderate in zones 8 and 19, high in zones 3, 4, 5, 11, and 15, and very high in zones 1, 2, 6, 7, 9, and 10 (Table 4 and Figure 3a).

According to the diversity measurements in 2018, there is no diversity in zone 12. Diversity is very low in zone 13, low in zones 8 and 14, moderate in zones 5, 15, 16, 17, and 19, high in zones 2, 3, 4, 6, 10, and 11, and very high in zones 1, 7, and 9 (Table 4 and Figure 3b).

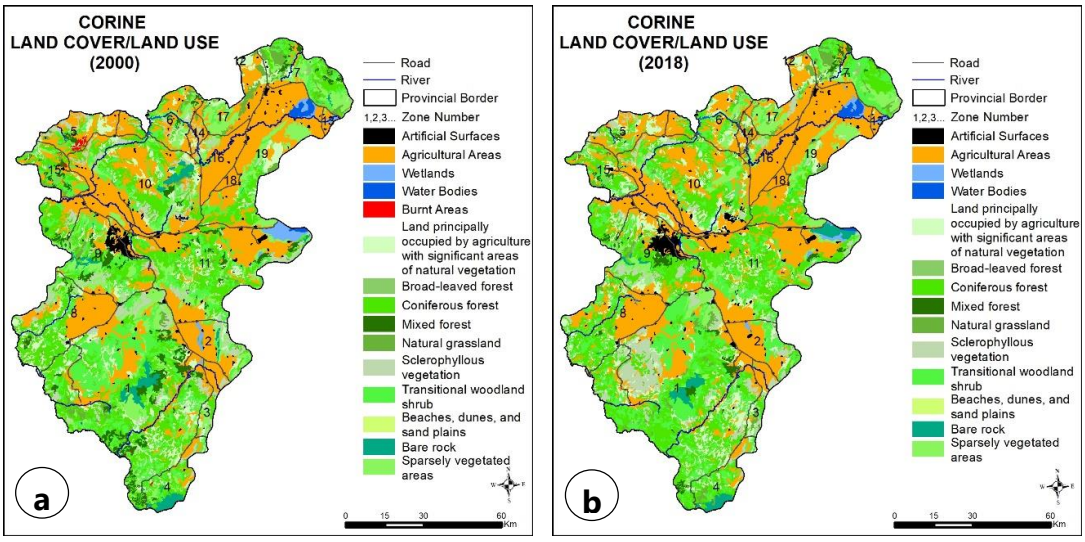

Figure 2. a) 2000 CORINE LU/LC, **b)** 2018 CORINE LU/LC.

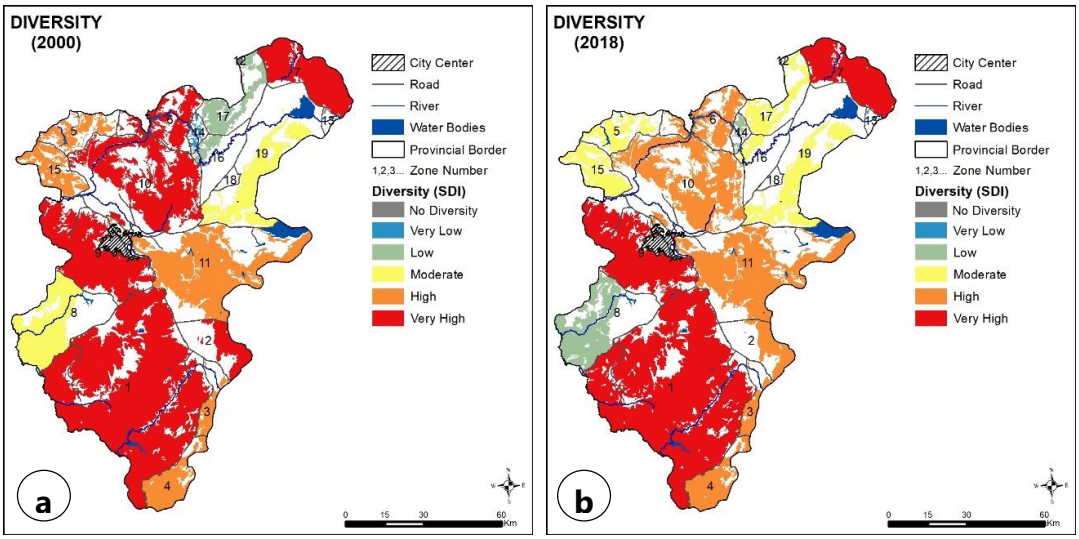

Figure 3. a) The diversity analysis according to the zones for the year 2000, **b)** The diversity analysis according to the zones for the year 2018.

Table 4. Shannon Diversity Index (SDI) for the years 2000-2018 by the zone.

	SDI	
Zone	**2000**	**2018**
Z1	1,80628	1,65969
Z2	1,69869	1,54019
Z3	1,59315	1,56633
Z4	1,67829	1,64346
Z5	1,64107	1,52015
Z6	1,84603	1,646
Z7	1,76475	1,65217
Z8	1,51933	1,3217
Z9	1,84316	1,77026
Z10	1,75614	1,55697
Z11	1,66276	1,53886
Z12	0	0
Z13	0	1,17175
Z14	1,0558	1,30671
Z15	1,59416	1,52587
Z16	1,33094	1,49742
Z17	1,3028	1,47114
Z18	-	-
Z19	1,47041	1,42341

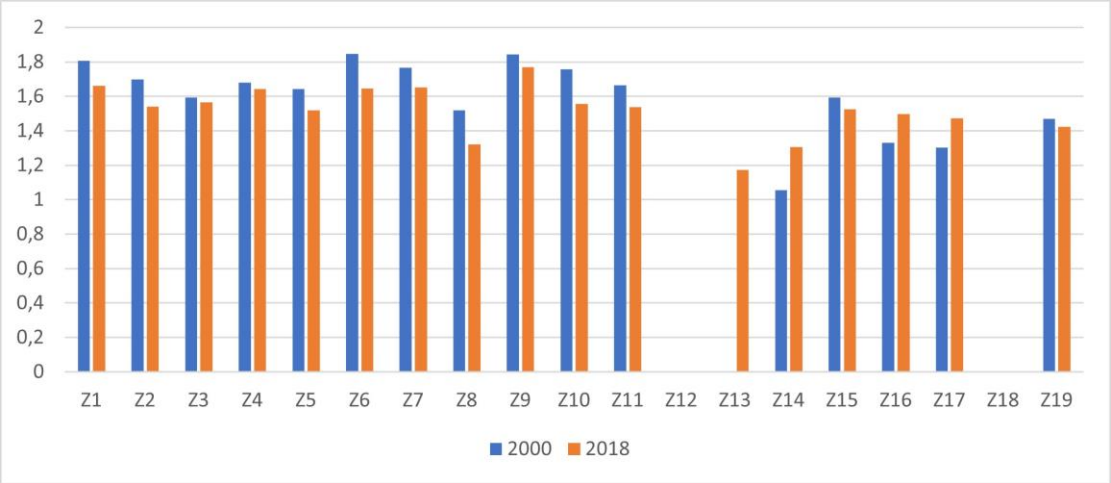

Figure 4. SDI values and change by zones for 2000-2018.

Measurements made using CORINE LU/LC data were compared by year. The change in diversity between the years of 2000 and 2018 was calculated and the calculated values were given as areas where diversity increased, decreased, and remained unchanged. According to the change analysis made, there is no diversity in zone 12 as it contains a single patch class in this zone. Diversity increased in zones 13, 14, 16, and 17. The zone with the highest increase is zone 13. Diversity decreased in zones 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, and 19. The zone with the highest decrease is zone 6 (Figures 4 and 5).

In the planning studies, the reasons for the change in the land cover should be investigated firstly. Diversity can vary in several ways according to Shannon index:

1- The changes among natural and semi-natural areas without the loss of the patch type in the area (change in the total areal size proportion of the patch),

2- Loss of any patches in natural and semi-natural areas,

3- Consist of a natural and semi-natural patch type that did not exist in previous years in the area,

4- Conversion of natural and semi-natural areas to artificial surfaces or agricultural areas, or vice versa.

The study was focused specifically on the areas where changes were caused by the anthropogenic effects. Accordingly, an increase

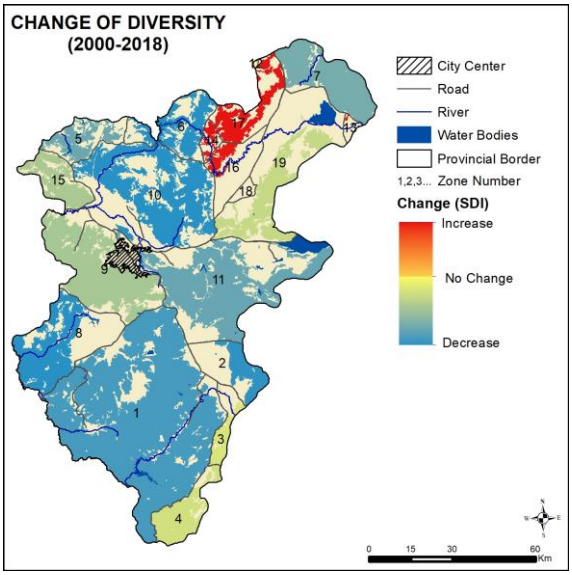

Figure 5. SDI values and change for the years 2000-2018.

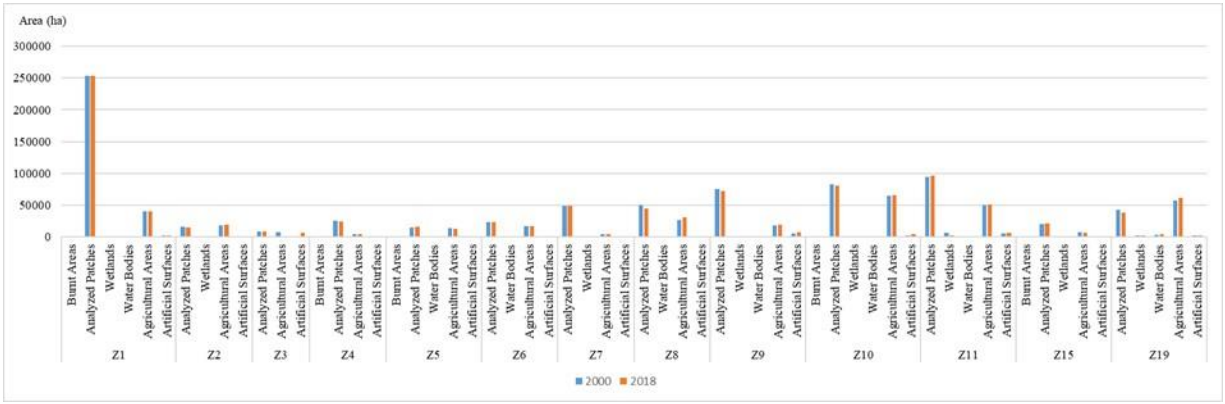

Figure 6. LU/LC change by zone.

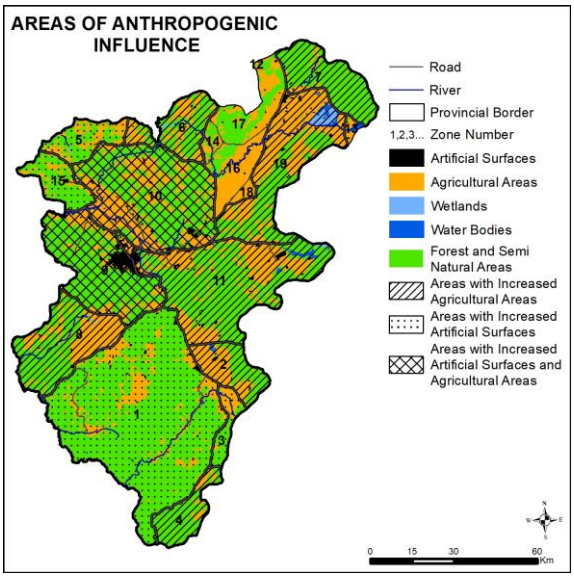

Figure 7. Areas of Anthropogenic Influence.

is observed in artificial surfaces in zones 1, 3, 5, and 15, in agricultural areas in zones 2, 4, 6, 7, 8, 11, and 19, and both artificial surfaces and agricultural areas in zones 9 and 10 (Figures 6 and 7).

CONCLUSION

Shannon index has been used for different purposes in different studies. Brakstad *et al*. (1994) used Shannon index as a biological measure of pollution impact in their study to present a strategy for constructing multivariate models that can predict changes in community structure from environmental data. Krauss *et al*. (2004) used Shannon index while measuring the landscape diversity in pastures to measure the effects of habitat area, isolation, and landscape diversity on the plant species richness of calcareous pastures. La Rosa *et al*. (2013) in a state-wide study on conservation and rehabilitation measures for landscape protection planning, as one of the metrics, Shannon index was used to measure diversity. Gastauer *et al*. (2021) used the Shannon index as a measure of tree species diversity under the name of Tree Shannon diversity in their study on the determination of the rehabilitation status in mining areas. In the study, measurements were made by dividing the area into landscape units. Sun and Ren (2021) used the Shannon index to reflect the structure of energy consumption in their study.

This study, which was carried out in Denizli province, is one of the pioneering studies in the literature in terms of the scale of the study, the spatial determination of the diversity and the change according to the years. The zoning study put forward within the scope of the study is important in several aspects. Shannon index can measure only at landscape level. Therefore, it cannot be determined where and what kind of change occurred in the space. The zoning study put forward within the scope of the study is important in terms of determining the diversity spatially. In addition, landscape diversity expresses not only the complexity and diversity of landscape elements in terms of composition, structure, and function but also the spatial arrangement of different patch types and the connectivity of these patches. (Bojie and Liding, 1996). Identifying the spatial variation of regional diversity is also important in terms of connectivity. Especially in areas where anthropogenic effects are concentrated, the correct construction of connectivity will ensure the protection of biodiversity.

Although the Shannon diversity index used within the scope of the study gives an idea of the diversity at the landscape level and based on patch, diversity should be included in diversity studies based on species. In addition, since the index measurement takes a value between 0 and infinity, a common evaluation cannot be made in the measurement of diversity according to years. This situation causes an area with high diversity value to be evaluated as having a high diversity value in 2018, even though its diversity value decreased in 2000. Therefore, it would be a more accurate approach to evaluate the change in diversity measures.

Diversity measurements at landscape level are important for the determintion of biological diversity. The presence of different patch types in the area also means that there are different habitats in the area. However, this should be supported by other diversity analyses.

Within the scope of this study, the administrative boundary of Denizli province was considered as the study area boundary. The boundary of study area is sufficient within the scope of study scale of the research. However, in ecological measurement studies it is important to work at the upper scale ecological boundaries to get more accurate results of the measurement of patches. For instance, in a study where hydrological processes are considered, basin should be taken as a boundary. On the other hand, in corridor studies based on fauna mobility, it should be studied within the ecological boundaries where both the barrier effect is taken into consideration and the patches are evaluated holistically (Doğan and Şahin, 2015; Doğan, 2016).

ADDITIONAL INFORMATION

This research was presented at the 1st International Symposium of Biodiversity Studies and was published in the abstract e-book in the proceedings of the Symposium.

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