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# *Estimation of Biodiversity of Eastern Black Sea Mixed Forests in Turkey*

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***ABSTRACT:*** *Biodiversity, the variety of life, has been recognized as one of the key components of environmental sustainability. Human actions, however, often lead to irreversible losses in terms of diversity of life on earth. So importance of measurement of biological diversity is increasing and need for biodiversity assessment methods to enable biodiversity to be measured is outlined. The biodiversity indices are statistical method which is planned to evaluate the variety of a data group consisting of different types of components. Eastern Black Sea Region of Turkey is rich in biodiversity compared to other regions and endemism is high. Eastern Black Sea forest is dominated by* ***Picea orientalis, Abies spp., Pinus sylvestris, Fagus orientalis, Quercus*** *ssp.****, Castanea satvia, Alnus glutinosa, Carpinus betulus*** *and* ***Fraxinus angustifolia****. Data were collected 40 temporary sample plots from the mixed stands of Karadeniz Technical University Research Forest in Eastern Black Sea Region. In this study, aim to compare biodiversity using biodiversity indices such as Shannon-Weaner Index, Simpson Index, MacArthur Index, Pielou Regularity Index. The calculations are based on species composition as well as basal area distribution.*

***Keywords:*** *Biodiversity index, mixed forest, species composition, ratio of number of tree, ratio of basal area.*

## *Türkiye Doğu Karadeniz Karışık Ormanlarında Biyoçeşitliliğin Hesaplanması*

***ÖZ:*** *Yaşamın çeşitliliği olan biyoçeşitlilik, çevresel sürdürülebilirliğin ana bileşenlerinden biri olarak kabul edilmiştir. Bununla birlikte, insan eylemleri, çoğu zaman, yeryüzündeki canlı çeşitliliği açısından geri dönüşü olmayan kayıplara neden olmaktadır. Bu nedenle biyolojik çeşitliliğin ölçümünün önemi artmakta ve biyoçeşitliliğin ölçülebilmesi için özel yöntemlere ihtiyaç duyulmaktadır. Biyoçeşitlilik indeksleri, farklı bileşen türlerinden oluşan bir veri grubunun biyolojik çeşitliliğini değerlendirmek için geliştirilmiş istatistiksel bir yöntemdir. Doğu Karadeniz Bölgesi, biyoçeşitlilik bakımından diğer bölgelere göre zengin olup endemik tür sayısı fazladır. Doğu Karadeniz Bölgesi ormanları* ***Picea orientalis, Abies spp., Pinus sylvestris, Fagus orientalis, Quercus*** *ssp.****, Castanea satvia, Alnus glutinosa, Carpinus betulus*** *ve* ***Fraxinus angustifolia*** *türlerinden oluşmaktadır. Çalışmada kullanılan veriler, Doğu Karadeniz Bölgesi'ndeki Karadeniz Teknik Üniversitesi Araştırma Ormanı'ndaki karışık meşcerelerden alınan 40 adet geçici örnek alandan elde edilmiştir. Bu meşcerelerin Shannon-Weaner, Simpson, MacArthur ve Pielou Düzenlilik İndeksleri hesaplanarak biyoçeşitlilikleri karşılaştırılmıştır. Hesaplamalar hem sayı hem de göğüs yüzeyi bakımından türlerin karışım oranına göre yapılmıştır.*

***Anahtar Kelimeler:*** *Biyoçeşitlilik indeksi, karışık meşcere, tür karışımı, ağaç sayısı oranı, göğüs yüzeyi oranı.*

## INTRODUCTION

The earth is made up of ecosystems and ecological features which are supported by biodiversity; yet many people do not understand the meaning of biodiversity or what the impact of its loss would mean. The fact is that all the species of flora and fauna, including humans, are dependent on each other, and the extinction of any one of these species can trigger a domino effect on the other species, which are directly or indirectly depend on it.

Biodiversity has been shown to play a key role at all levels of the ecosystem service hierarchy (Mace *et al*., 2012; Gao *et al*., 2014). The diverse habitats

and microhabitats contained in forest ecosystems hold the majority of the world's terrestrial species (Ozanne *et al*., 2003; Gao *et al*., 2014). However, these biologically diverse systems are increasingly being threatened by deforestation and forest degradation via varied direct or indirect mechanisms (Singh *et al*., 2001; Dirzo and Raven, 2003; Gao *et al*., 2014). Therefore, conserving forest biodiversity has become a critical task at local, national and global level.

To discern the influence of forest management intervention on forest biodiversity conservation among management regimes, we need to explore the effects of environmental and human forest use variables on species richness, diversity and density (Hooper *et al*., 2005; Kalonga *et al*., 2016). Generally, easily accessible forests are more affected by human activities (Sassen and Sheil, 2013) depending on tree species (Ndangalasi *et al*., 2007); although effective forest management planning could reverse the situation (Ball, 2011; Kalonga *et al*., 2016).

Turkey is among few temperate countries with the highest diversity in its fauna and flora. Because of its special position between Asia and Europe, and Africa, fauna and flora comprises elements from these continents. Turkey is in the interface of three different biogeographically regions where consist from European-Siberian, Mediterranean and Irano-Turanian regions. Of the Euro-Siberian Biogeographical Zone contain Kolshic zone aka Eastern Black Sea. This is the climatic region with the highest rainfall and is largely covered with forests. Eastern Black Sea forest is dominated by *Picea orientalis, Abies spp., Pinus sylvestris, Fagus orientalis, Quercus ssp., Castanea satvia, Alnus glutinosa, Carpinus betulus* and *Fraxinus angustifolia*.

Various diversity indices are used to determine the biodiversity. Diversity index is a statistical method which is planned to evaluate the variety of a data group consisting of different types of components. Features of a population such as number of existing species (Richness), distribution of individuals equally (Evenness) and total number of existing individuals underlie the basis of diversity indices (Wilhm and Dorris 1968; Allan, 1975). Thus, any changes in any of these three features will affect the whole population, so that the diversity indices depending upon these features are used effectively to determine the changes in a population (Dügel 1995; Mandaville, 2002; Turkmen and Kazanci, 2010). In this study, aim to compare biodiversity using biodiversity indices such as Shannon-Weaner Index, Simpson Index, MacArthur Index, Pielou Regularity Index. The calculations are based on species composition and species distribution as well as basal area and number of tree.

## MATERIALS AND METHODS

The data used in this study were collected from mixed forests in Karadeniz Technical University Research Forest in Eastern Black Sea Region of Turkey. Study area located 40° 48' 45" - 40° 43' 25" N and 39° 36' 41" - 39° 28' 39" E and average attitude 1420 m. In this area, from the various age and site classes 40 temporary sample plots which size range 400 $m^2$ to 800 $m^2$ were taken. Diameter at breast heights all trees was measured and identified to species in each sample plots. Ratios of basal area and number of tree to species in each sample plots were calculated. Shannon-Weaner Index, Simpson Index, MacArthur Index, Pielou Regularity Index were used for statistical analyses of biodiversity.

### Shannon-Weaner Diversity Index

This is an index applied to biological systems by derived from a mathematical formula used in communication area by Shannon in 1948 (Mandaville, 2002). It's the most preferred index among the other diversity indices. The index values are between 0.0-5.0.

Results are generally between 1.5-3.5, and it exceeds 4.5 very rarely (Kocatas, 1992). The values above 3 indicate that the structure of habitat is stable and balanced but the values under

1indicate that there are pollution and degradation of habitat structure (Turkmen and Kazanci, 2010).

$$H = -\sum_{i=1}^{n} P_i \times \ln P_i \quad (1)$$

*H*: Shannon-Weaner Diversity Index

$P_i$: Ratios of each species according to basal area or number of tree

**Simpson Diversity Index**

It's a diversity indices derived by Simpson in 1949 (Mandaville, 2002). Simpson index values are between 0 - 1. But while calculating, final result is subtracted from 1 to correct the inverse proportion (Turkmen and Kazancı, 2010).

$$H = 1 - \sum_{i=1}^{n} P_i \quad (2)$$

*H*: Simpson Diversity Index

$P_i$: Ratios of each species according to basal area or number of tree

**MacArthur Diversity Index**

It was derived from Shannon-Weaner index by MacArthur in 1965.

$$H = \frac{1}{\sum_{i=1}^{n} P_i} \quad (3)$$

H: MacArthur Diversity Index

$P_i$: Ratios of each species according to basal area or number of tree

**Pielou Regularity Index**

It was derived from Shannon-Weaner index by Pielou in 1966. The ratio of the observed value of Shannon-Weaner index to the maximum value gives the Pielou Regularity Index result. The values are between 0- 1. When the value is getting closer to 1, it means that the individuals are distributed equally (Pielou, 1966; Turkmen and Kazanci, 2010).

$$R = \frac{H}{\ln S} \quad (4)$$

R: Pielou Regularity Index

H: Shannon-Weaner Diversity Index

S: Number of species

**RESULTS**

Biodiversity in 40 sample plots in mixed forest in Karadeniz Technical University Research Forest in Eastern Black Sea Region were calculated to use 1-4 formulas. In calculation, ratios of basal area and number of tree of species in sample plot were used. The calculation of one of the sample area has shown Table 1 and 2.

The values of Shannon-Weaner diversity index were between 0.38-1.35. The lowest value was for plot 495 and the highest value was for plot 467 (Table 3 and 4). All results were found under the expected ranges (1.5-3.5). Although plot 1007 has five species, it has lower value than plot 467. The reason of this is a behalf of one species has high ratio.

The values of Simpson diversity index were between 0.18-0.73. The lowest value was for plot 495 and the highest value was for plot 467 (Table 5 and 6). The result of this index and the result of Shannon-Weaner index were found highly resemble to each other. The values of the four plots (plot 467, 628, 339 and 745) which had the fourth highest values were the same in both indices.

Table 1. Biodiversity indices according to ratio of basal area in sample plot 214.
Çizelge 1. Göğüs yüzeyi oranına göre 214 nolu örnek alanın biyoçeşitlilik indeks değerleri.

| Species<br>Türler | Basal area<br>Göğüs yüzeyi | Ratio of basal area<br>Göğüs yüzeyi Oranı | Shannon-Weaner | Simpson | MacArthur | Pielou Regularity |
|---|---|---|---|---|---|---|
| *Oriental spruce* | 1.61 | 0.72 | | | | |
| *Oriental beech* | 0.62 | 0.28 | | | | |
| *Oriental hornbeam* | 0.01 | 0.01 | | | | |
| Total | 2.24 | | 0.63 | 0.41 | 1.69 | 0.57 |

Table 2. Biodiversity indices according to using ratio of number of tree in sample plot 214.
Çizelge 2. Ağaç sayısı oranına göre 214 nolu örnek alanın biyoçeşitlilik indeks değerleri.

| Species<br>Türler | Number of species<br>Türlerin Birey sayısı | Ratio of number of trees<br>Türlerin birey sayısı oranı | Shannon-Weaner | Simpson | MacArthur | Pielou Regularity |
|---|---|---|---|---|---|---|
| *Oriental spruce* | 23 | 0.58 | | | | |
| *Oriental beech* | 15 | 0.38 | | | | |
| *Oriental hornbeam* | 2 | 0.04 | | | | |
| Total | 40 | | 0.84 | 0.53 | 2.11 | 0.76 |

Table 3. Sample plots which have highest Shannon-Weaner index value.
Çizelge 3. En yüksek Shannon-Weaver indeks değerine sahip örnek alanlar.

| Sample plot no<br>Örnek alan no | Oriental spruce<br>Ladin | Oriental beech<br>Kayın | Oriental fir<br>D.K.Göknarı | Alder<br>Kızılağaç | Oriental hornbeam<br>Gürgen | Hazelnut<br>Fındık | Shannon-Weaner |
|---|---|---|---|---|---|---|---|
| Ratio of basal area (Göğüs yüzeyi oranı) | | | | | | | |
| 467 | 0.24 | 0.30 | | 0.32 | | 0.14 | 1.35 |
| 1007 | 0.65 | 0.11 | 0.01 | 0.11 | 0.12 | | 1.05 |
| 628 | | 0.21 | | 0.28 | 0.51 | | 1.03 |
| 339 | 0.33 | 0.14 | | 0.53 | | | 0.98 |
| 745 | 0.40 | 0.50 | | | 0.10 | | 0.95 |

Table 4. Sample plots which have lowest Shannon-Weaner index value.
Çizelge 4. En düşük Shannon-Weaver indeks değerine sahip örnek alanlar.

| Sample plot no<br>Örnek alan no | Oriental spruce<br>Ladin | Oriental beech<br>Kayın | Oriental fir<br>D.K.Göknarı | Oriental hornbeam<br>Gürgen | Shannon-Weaner |
|---|---|---|---|---|---|
| Ratio of basal area (Göğüs yüzeyi oranı) | | | | | |
| 463 | 0.19 | 0.81 | | | 0.49 |
| 246 | 0.86 | 0.12 | | 0.02 | 0.48 |
| 718 | 0.05 | 0.87 | | 0.08 | 0.45 |
| 1108 | 0.16 | | 0.84 | | 0.44 |
| 495 | 0.90 | 0.10 | | | 0.33 |

Table 5. Sample plots which have highest Simpson index values value.
Çizelge 5. En yüksek Simpson indeks değerine sahip örnek alanlar.

| Sample plot no<br>Örnek alan no | Oriental spruce<br>Ladin | Oriental beech<br>Kayın | Oriental fir<br>D.K.Göknarı | Alder<br>Kızılağaç | Oriental hornbeam<br>Gürgen | Hazelnut<br>Fındık | Simpson |
|---|---|---|---|---|---|---|---|
| Ratio of basal area (Göğüs yüzeyi oranı) | | | | | | | |
| 67 | 0.24 | 0.30 | | 0.31 | | 0.15 | 0.73 |
| 628 | | 0.21 | | 0.28 | 0.51 | | 0.62 |
| 339 | 0.33 | 0.14 | | 0.53 | | | 0.59 |
| 745 | 0.40 | 0.50 | | | 0.10 | | 0.58 |
| 971 | 0.33 | 0.11 | 0.56 | | | | 0.57 |

Table 6. Sample plots which have to lowest Simpson index values.
Çizelge 6. En düşük Simpson indeks değerine sahip örnek alanlar.

| Sample plot no<br>Örnek alan no | Oriental spruce<br>Ladin | Oriental beech<br>Kayın | Oriental fir<br>D.K.Göknarı | Alder<br>Kızılağaç | Oriental hornbeam<br>Gürgen | Simpson |
|---|---|---|---|---|---|---|
| Ratio of basal area (Göğüs yüzeyi oranı) | | | | | | |
| 272 | 0.82 | 0.08 | | 0.10 | | 0.31 |
| 1108 | 0.16 | | 0.84 | | | 0.27 |
| 246 | 0.86 | 0.12 | 0.02 | | | 0.25 |
| 718 | 0.05 | 0.88 | | | 0.07 | 0.22 |
| 495 | 0.90 | 0.10 | | | | 0.18 |

The values of MacArthur Diversity Index were between 1.22-3.73. The lowest value was for plot 495 and the highest value was for plot 467 (Table 7 and 8). Also result of this index and the result of Shannon-Weaner and Simpson index were found highly resemble to each other. The values of the four plots (no. of 467, 628, 339 and 745) which had the fourth highest values were the same in other (Shannon-Weaner and Simpson index) indices.

The values of Pielou Regularity Index were between 0.41-0.99. The lowest value was for plot 718 and the highest value was for plot 1050 (Table 9 and 10). Unlike other indices (Shannon-Weaner, Simpson and MacArthur indices) plot 467 doesn't have to highest value. The reason is that, Pielou is derived from Shannon-Weaner Diversity Index and even if the value of Shannon-Weaner index is high, due to the number of species is increased Pielou is decreased. In plot 465 and 1108, we found that the individuals evenly distributed into species.

Table 7. Sample plots which have highest MacArthur index values value.
Çizelge 7. En yüksek MacArthur indeks değerine sahip örnek alanlar.

| Sample plot no<br>Örnek alan no | Oriental spruce<br>Ladin | Oriental beech<br>Kayın | Oriental fir<br>D.K.Göknarı | Alder<br>Kızılağaç | Oriental hornbeam<br>Gürgen | Hazelnut<br>Fındık | MacArthur |
|---|---|---|---|---|---|---|---|
| Ratio of basal area (Göğüs yüzeyi oranı) | | | | | | | |
| 467 | 0.25 | 0.30 | | 0.32 | | 0.13 | 3.73 |
| 628 | | 0.21 | | 0.28 | 0.51 | | 2.63 |
| 339 | 0.33 | 0.14 | | 0.53 | | | 2.46 |
| 745 | 0.40 | 0.50 | | | 0.10 | | 2.40 |
| 971 | 0.32 | 0.12 | 0.56 | | | | 2.30 |

Table 8. Sample plots which have to lowest MacArthur index values.
Çizelge 8. En düşük MacArthur indeks değerine sahip örnek alanlar.

| Sample plot no<br>Örnek alan no | Oriental spruce<br>Ladin | Oriental beech<br>Kayın | Oriental fir<br>D.K.Göknarı | Alder<br>Kızılağaç | Oriental hornbeam<br>Gürgen | MacArthur |
|---|---|---|---|---|---|---|
| Ratio of basal area (Göğüs yüzeyi oranı) | | | | | | |
| 272 | 0.82 | 0.08 | | 0.10 | | 1.45 |
| 1108 | 0.16 | | 0.84 | | | 1.34 |
| 246 | 0.86 | 0.12 | 0.02 | | | 1.34 |
| 718 | 0.05 | 0.86 | | | 0.09 | 1.29 |
| 495 | 0.90 | 0.10 | | | | 1.22 |

Table 9. Sample plots which have highest Pielou Regularity index values value.
Çizelge 9. En yüksek Pielou Regularity indeks değerine sahip örnek alanlar.

| Sample plot no<br>Örnek alan no | Oriental spruce<br>Ladin | Oriental beech<br>Kayın | Oriental fir<br>D.K.Göknarı | Oriental hornbeam<br>Gürgen | Hazelnut<br>Fındık | Pielou<br>Regularity |
|---|---|---|---|---|---|---|
| Ratio of basal area (Göğüs yüzeyi oranı) | | | | | | |
| 1050 | 0.54 | | 0.46 | | | 0.99 |
| 273 | 0.46 | 0.54 | | | | 0.99 |
| 660 | 0.56 | 0.44 | | | | 0.99 |
| 1029 | 0.60 | | 0.40 | | | 0.97 |
| 467 | 0.24 | 0.30 | | 0.32 | 0.14 | 0.97 |

Table 10. Sample plots which have to lowest Pielou Regularity index values.
Çizelge 10. En düşük Pielou Regularity indeks değerine sahip örnek alanlar.

| Sample plot no<br>Örnek alan no | Oriental<br>spruce<br>Ladin | Oriental<br>beech<br>Kayın | Oriental fir<br>D.K.Göknarı | Alder<br>Kızılağaç | Maple<br>Akçaağaç | Ash<br>Dişbudak | Oriental<br>hornbeam<br>Gürgen | Pielou<br>Regularity |
|---|---|---|---|---|---|---|---|---|
| Ratio of basal area (Göğüs yüzeyi oranı) | | | | | | | | |
| 272 | 0.82 | 0.08 | | 0.10 | | | | 0.54 |
| 587 | 0.23 | 0.73 | | | 0.03 | 0.01 | | 0.53 |
| 495 | 0.90 | 0.10 | | | | | | 0.47 |
| 246 | 0.86 | 0.12 | 0.02 | | | | | 0.43 |
| 718 | 0.05 | 0.87 | | | | | 0.08 | 0.41 |

The increase in the distribution of species in the area in favor of a species has reduced the biodiversity indices (Table 11). While ratio of basal area of Spruce (L) %46 in sample plot 243, when this ratio increase to %90 in sample plot 495, biodiversity indices reduce.

Mean values of biodiversity indexes by species in sample plot shown Table 12. When number of species increased, biological diversity was also increased. But biological diversity decreased when number of species 4 and 5 because of lack of sample plots (Table 12).

## CONCLUSIONS

Forest management include protect, develop and sustainability of biodiversity. So when forest managing, biodiversity is calculated using biodiversity indices. In this study, Shannon-Weaner Index, Simpson Index, MacArthur Index, Pielou Regularity Index were used for calculate to biodiversity.

As a result, as the number of species increase, as the distribution ratios of species approach each other, biodiversity indices have increased also. Biodiversity indices have increased in proportion to the number of species in regions where the ratio is behalf of a species. Biodiversity indices are higher in areas where the ratios are close to each other than areas have the ratios are distributed in behalf of one species. This result shows that, the distributions of ratios between species are important.

Table 11. Effect of species ratios on biodiversity indices.
Çizelge 11. Türlerin oransal dağılımının biyolojikçeşitlilik üzerindeki etkisi.

| Sample plot no<br>Örnek alan no | Oriental spruce<br>Ladin | Oriental beech<br>Kayın | Shannon-Weaner | Simpson | McArthur | Pielou Regularity |
|---|---|---|---|---|---|---|
| | Ratio of basal area<br>(Göğüs yüzeyi oranı) | | | | | |
| 243 | 0.46 | 0.54 | 0.69 | 0.50 | 1.99 | 0.99 |
| 495 | 0.90 | 0.10 | 0.33 | 0.18 | 1.22 | 0.47 |

Table 12. Average values of biodiversity indices regard to number of species.
Çizelge 12. Biyoçeşitlilik indekslerinin tür sayısına göre ortalama değerleri.

| Number of Species<br>Tür Sayısı | Shannon-Weaner | Simpson | MacArthur | Pielou Regularity | Number of sample plots<br>Örnek alan sayısı |
|---|---|---|---|---|---|
| 2 | 0.64 | 0.45 | 1.84 | 0.92 | 14 |
| 3 | 0.80 | 0.49 | 2.01 | 0.73 | 22 |
| 4 | 1.22 | 0.67 | 3.10 | 0.88 | 3 |
| 5 | 1.05 | 0.52 | 2.08 | 0.65 | 1 |

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