# RELATIONSHIPS BETWEEN AVIAN DIVERSITY AND AGRICULTURAL LANDSCAPE HETEROGENEITY

Şengül Aksan[2*]

[1] Received on 12.03.2022 accepted for publication on 16.11.2022.
[2] Isparta University of Applied Sciences, Department of Wildife Ecology and Managament, Isparta - Turkiye. E-mail: <sengulaksan@isparta.edu.tr>.
*Corresponding author.

ABSTRACT – Studies on birds and their habitats are usually conducted in natural areas (protected areas, forests, wetlands, etc.). In this study, the relationship between agricultural landscape diversity and the species diversity of birds was investigated in an agricultural zone surrounded by natural and forested areas. Observations were carried out in 60 sample grid squares. Presence/absence data for birds and cultivated plants at each sample site were recorded. The Shannon-Wiener diversity index for bird species and landscape metrics for agricultural areas were used in the sample site. A multiple linear regression analysis was performed to explain the correlation between agricultural landscape diversity and bird species diversity. According to the results, the area-weighted mean shape index (AWMSI) and the number of patches (NP) were found to be particularly effective at predicting bird species diversity (R2 = 0.66). In addition, as the patch number and patch shape ratio increased in a sample area, the diversity of bird species (R = 0.83) expanded. It can be concluded that agricultural zones consisting of small, different patches are rich areas for bird species diversity. Bird species diversity is lessened in agricultural areas with uniform or similar landscape structures consisting of large patches. If the NP in the area is high, but not distributed in a mosaic pattern, then the diversity of bird species is considered weak. Despite the increasing NP and patch types, bird species diversity declines if there is intense human activity in the area.

Keywords: Agricultural area; Avian diversity; landscape metrics.

# *RELAÇÕES ENTRE DIVERSIDADE AVIÁRIA E HETEROGENEIDADE DA PAISAGEM AGRÍCOLA*

*RESUMO – Estudos sobre aves e seus habitats são geralmente realizados em áreas naturais (áreas protegidas, florestas, áreas úmidas, etc.). Neste estudo, a relação entre a diversidade da paisagem agrícola e a diversidade de espécies de aves foi investigada em uma zona agrícola cercada por áreas naturais e florestais. As observações foram realizadas em 60 quadrados de grade de amostra. Dados de presença/ausência de pássaros e plantas cultivadas em cada local de amostragem foram registrados. O índice de diversidade de Shannon-Wiener para espécies de aves e métricas de paisagem para áreas agrícolas foram usados no local de amostragem. Uma análise de regressão linear múltipla foi realizada para explicar a correlação entre a diversidade da paisagem agrícola e a diversidade de espécies de aves. De acordo com os resultados, o índice de forma média ponderada por área (AWMSI) e o número de manchas (NP) foram considerados particularmente eficazes na previsão da diversidade de espécies de aves (R2 = 0,66). Além disso, à medida que o número de manchas e a proporção da forma de manchas aumentavam em uma área de amostragem, a diversidade de espécies de aves (R = 0,83) aumentava. Pode-se concluir que as zonas agrícolas constituídas por pequenas manchas diferentes são áreas ricas em diversidade de espécies de aves. A diversidade de espécies de aves é reduzida em áreas agrícolas com estruturas de paisagem uniformes ou semelhantes, consistindo em grandes manchas. Se o NP na área for alto, mas não distribuído em um padrão de mosaico, então a diversidade de espécies de aves é considerada fraca.*

*Apesar do aumento dos tipos de NP e manchas, a diversidade de espécies de aves diminui se houver intensa atividade humana na área.*

*Palavras-Chave:* Área agrícola; Diversidade aviária; Métricas de paisagem.

## 1. INTRODUCTION

Agricultural areas have great importance in terrestrial ecosystems. Depending on the increase in the human population, the process of converting natural areas to agricultural zones is still in progress. It is known that this transformation negatively affects biodiversity in tropical and temperate regions (Donald et al., 2001; Flynn et al., 2009). On the other hand, the irrigable areas opened for agriculture in arid regions ensure the diversification of the land structure and therefore offer new habitat opportunities for many living species (Selmi and Boulinier, 2003). For successful biodiversity management, it is important to understand the relationships between landscape diversity and wild animals in traditional farming areas (Benton et al., 2003; Aksan, 2018). If the relationship between flora and fauna diversity in the field is determined, various land design and application studies can be conducted to enhance biodiversity.

The importance of conserving biodiversity in agricultural areas is increasing (Kleijn et al., 2006). Fahring et al. (2011) claim in their study that “the value of agricultural land for conservation has been recognized formally in Europe through some agri-environment schemes, but these are not organized to produce particular levels or types of heterogeneity at the landscape scale.” Both local and global authorities are unanimous in determining agricultural policies in a way that preserves biodiversity (Toledo and Burlingame, 2006). The most practical way to promote biodiversity in agricultural areas is to develop landscape diversity, which is expressed as the composition and configuration of different land plots. It is thought that the habitat needs of many wild animals in agricultural zones can be met by increasing product variety (Aksan and Akbay, 2018).

The impact of agricultural product variety on bird species is less known (Fahrig et al., 2011). Some studies have shown that natural edge vegetation, forest land, natural grasslands, and non-cultivated habitats that are located near farmland increase bird species richness and bird density in agricultural areas (Benton et al., 2002; Heikkinen et al., 2004; McMahon et al., 2008; Smith et al., 2010). These studies were mainly carried out in the temperate zone, in areas where forests were converted for agriculture. On the other hand, there are fewer studies on lands that were not forested in the past but were used for dry farming and later opened to irrigated farming (Norfolk et al., 2015). Dry farming lands are transformed into irrigated agricultural zones with dams and ponds in semi-arid regions in some countries, such as Turkey. For proper planning, there is an urgent need for research on how this transformation affects the environment, especially biodiversity.

In the Turkish town of Atabey and agricultural areas that have been converted into irrigated agriculture by human hands, the spatial landscape structure is shaped according to farmers’ agricultural activities (Selmi and Boulinier, 2003). The natural vegetation and planted tree species that grow along the boundaries create an edge density between patches and make the land heterogeneous (Haslem and Bennett, 2008; Tryjanowski et al., 2011; Aksan, 2018). In addition, uncultivated and fallow farmland, native grass, and shrub species offer renaturation habitats for wild animals (Kisel et al., 2011; Morelli et al., 2013). Old fruit trees in abandoned orchards serve wildlife with their fruits, cavities, and other habitat features. Furthermore, many fruits from shrub species that can grow around irrigation canals are an important food source for wild animals. Consequently, landscape diversity expands, and different habitats for bird species develop in small-scale agricultural areas (Pino et al., 2000).

Agricultural products diversified with the establishment of the irrigation system in semi-arid regions in Atabey. It is hypothesized that this situation positively affects biodiversity. For successful biological management, this hypothesis needs to be corroborated by fieldwork (Tryjanowski et al., 2011). The main purpose of this study is to reveal the relationships between agricultural landscape diversity and bird species diversity in an area where irrigated farming is carried out, located in the semi-arid transition zone between the Mediterranean and steppe climates in the western Mediterranean region.

## 2. MATERIAL AND METHODS

### 2.1 Study area

The Atabey Plain is located in Isparta, Turkey 30º 27' 43"- 30º 39' 02" eastern longitudes and 37º 50' 32"- 37º 58' 19" northern latitudes) and covers an area of 20,217 ha (Figure 1), where the continental climate is dominant. According to meteorological records between 2014–2017, the annual average temperature was 12.0ºC, with the highest temperatures reaching 22.3ºC (July) and the lowest temperatures being 2.0ºC (January). The annual precipitation measured was 560 mm (Climate-Data, 2017). The Atabey Plain is an area where dry and irrigated agriculture are combined, and a wide variety of agricultural products are grown. Traditional and classical farming methods are applied in the field. There is natural herbaceous and woody vegetation, as well as forested areas around the site.

### 2.2. Sample collection and statistical analyses

The research area was divided into 2,741 squares of 300 m x 300 m (9 ha). Inventory work was carried out in 60 sample sites randomly selected from these squares. Presence/absence data for bird species and agricultural crops/vegetation were recorded at each sample site. Plant species of sample sites were identified. A direct observation technique was applied for birds in the sample sites, and visible and vocalizations were counted in 10-minute intervals (Bibby et al., 1998; Gregory et al., 2004). Observations were carried out from 06:00 A.M. to 07:00 P.M. (Shiu and Lee, 2003). Field studies were conducted in the form of repeated observations in the same areas every month between 2016–2017. Species were identified according to Porter et al., (2009).

Source: Author.
Fonte: Autor.

**Figure 1 –** Location of the plots in study area, plots/cell ID and land use/cover type.
***Figura 1*** *– Localização das parcelas na área de estudo, identificação das parcelas/células e tipo de uso/cobertura do solo.*

The images of the area were downloaded from Google Earth and geo-referenced by using ground checkpoints. After that, a 300-meter fishnet vector map was generated and overlapped with the boundary map of the study area. Each cell of the fishnet vector map possesses a unique ID. Finally, the overlaid vector map of land use/cover was drawn in the fishnet vector map. This was done by aggregating converted areas in each 300-meter grid identified by cell IDs of the vector map. All patches were then drawn in the delineated grid and identified based on land use/cover type (Figure 1).

The AWMSI and NP landscape-level metrics (Eq.1 and Eq.2) were calculated using the vector version of FRAGSTATS (McGarigal and Marks, 1995) employing ArcGIS 10.6 software.

$$\text{AWMSI} = \sum_{j=1}^{n}\left[\left(\frac{0.25\,p_{ij}}{\sqrt{a_{ij}}}\right)\left(\frac{a_{ij}}{\sum_{j=1}^{n}}\right)\right] \quad \text{Eq.1}$$

$$\text{NP} = ni \quad \text{Eq.2}$$

**n** = number of patches in the landscape of patch type, **j** = 1, ..., n patches, $\mathbf{p_{ij}}$ = perimeter (m) of patch ij, $\mathbf{a_{ij}}$ = area (m$^2$) of patch ij, **ni** = number of patches in the landscape of patch type (class) **i**,

The Shannon-Wiener diversity index shown in Eq.3 was used to calculate bird species diversity (Shannon and Weaver, 1949).

$$\text{Shannon-Wiener}(H^1) = -\sum_{i}^{S}\frac{n_i}{N}\ln\frac{n_i}{N} \quad \text{Eq.3}$$

**ni** = frequency value for class i, **S** = Number of classes, **N** = total number of observations

Multiple linear regression analysis was applied to explain the relationships between land diversity and bird species diversity.

## 3. RESULTS

As a result of this research, 99 bird species from 33 families belonging to 16 orders were identified. Detailed information about the detected bird species can be found in the study of Aksan and Mert (2016).

The study area contained different vegetation types, dry and irrigated agricultural zones, fruit trees, cereal fields, rose gardens, vegetable gardens, fallow lands, coniferous forests, clearings, natural stony areas, shrubs, dams, and streams. This diversity in the field allowed the observation of different bird species.

**Table 1 –** Patch types and codes recorded in sample sites.
***Tabela 1*** *– Tipos de patches e códigos registrados em sites de amostra.*

| Codes | Patch type | Codes | Patch type | Codes | Patch type | Codes | Patch type |
|---|---|---|---|---|---|---|---|
| 1 | %100 *P. somniferum* L. | 21 | %70 Malus sp. %30 Vacant | 41 | %100 Broad-leaved trees | 61 | %30 *C. libani* A. Rich %70 Weed |
| 2 | %50 Pyrus sp. %50 Vacant | 22 | %90 Malus sp. %10 Vacant | 42 | %90 Broad-leaved trees %10 Shrub | 62 | %40 *C. libani* A. Rich %60 Weed |
| 3 | %100 *H. Vulgare* L. | 23 | %100 Malus sp. | 43 | %100 Broad-leaved trees, coniferous | 63 | %50 *C. libani* A. Rich %50 Weed |
| 4 | %10 *P. dulcis* Mill .%90 Vacant | 24 | %60 Prunus sp. %40 Vacant | 44 | %10 *Populus nigra* L.%90 Weed | 64 | %10 *P. persica*(L.) Batsch%90 Vacant |
| 5 | %10 *P. dulcis* Mill. %90 Weedt | 25 | %15 Tree nursery %85 Vacant | 45 | %40 *Populus nigra* L.%60 Weed | 65 | %50 *P. persica* (L.) Batsch%50 Vacant |
| 6 | %90 *P. dulcis* Mill. %10 Vacant | 26 | %100 *V. sativa* L. | 46 | %50 *Populus nigra* L.%50 Weed | 66 | %60 *P. persica* (L.) Batsch%40 Vacant |
| 7 | %90 Vitis sp. %10 Weed | 27 | %80 *R. damascena* Mill. %20 Vacant | 47 | %60 *Populus nigra* L.%40 Weed | 67 | %90 *P. persica* (L.) Batsch%10 Vacant |
| 8 | %100 *R. idaeus* L. | 28 | %10 *P. nigra* Arnold %90 Weed | 48 | %70 *Populus nigra* L.%30 Weed | 68 | %80 *C. sempervirens* L.%20 Weed |
| 9 | %100 *T. Aestivum* L. | 29 | %40 *P. nigra* Weed Arnold%60 | 49 | %80 *Populus nigra* L.%20 Weed | 69 | %90 *C. sempervirens* L.%10 Weed |
| 10 | %100 Pebble | 30 | %90 Coniferous %10 Vacant | 50 | %100 *Populus nigra* L. | 70 | %90 *S. alba* L. %10 Weed |
| 11 | %70 Juglans sp. %30 Vacant | 31 | %10 Mixed fruit trees %90 Vacant | 51 | %90 *Q. coccifera* L. %10 Weed | 71 | %100 *S. alba* L. |
| 12 | %80 Juglans sp. %20 Vacant | 32 | %10 Mixed fruit trees %90 Weed | 52 | %10 *P. avium* L.%90 Vacant | 72 | %100 Dam |
| 13 | %90 Juglans sp. %10 Vacant | 33 | %10 Mixed fruit trees %90 Vegetables | 53 | %30 *P. avium* L.%70 Vacant | 73 | %100 Stream |
| 14 | %100 Juglans sp. | 34 | %20 Mixed fruit trees %80 Vacant | 54 | %60 *P. avium* L.%40 Vacant | 74 | %100 Pool |
| 15 | %100 Weed | 35 | %25 Mixed fruit trees %75 Vacant | 55 | %80 *P. avium* L.%20 Vacant | 75 | %100 Water-trench |
| 16 | %100 Shrub | 36 | %30 Mixed fruit trees %70 Vacant | 56 | %90 *P. avium* L.%10 Vacant | 76 | %100 Ploughed field |
| 17 | %100 Natural rock, stone, weed | 37 | %40 Mixed fruit trees %60 Vacant | 57 | %100 *P. avium* L. | 77 | %80 *P. cerasus* L.%20 Vacant |
| 18 | %10 Malus sp. %90 Vacant | 38 | %80 Mixed fruit trees %20 Vacant | 58 | %100 Housing | 78 | %90 *P. cerasus* L.%10 Vacant |
| 19 | %30 Malus sp. %70 Vacant | 39 | %90 Mixed fruit trees %10 Vacant | 59 | %100 Gravel | 79 | %100 Road |
| 20 | %50 Malus sp. %50 Vacant | 40 | %100 Mixed fruit trees | 60 | %100 Laid fallow | 80 | %100 *M. Sativa* L. |

**Table 2 –** Landscape metrics (AWMSI, NP) and Shannon_H values in sample site.
***Tabela 2*** *– Métricas de paisagem (AWMSI, NP) e valores de Shannon_H no local de amostra.*

| Sample site no | Bird species | AWMSI | NP | Shannon H | Numberof patch types | Patch type codes |
|---|---|---|---|---|---|---|
| 1 | 18 | 1,987 | 2 | 3,045 | 2 | 28, 72 |
| 2 | 22 | 1,625 | 10 | 3,178 | 7 | 30, 40, 53, 58, 68, 69, 79 |
| 3 | 20 | 1,421 | 35 | 3,091 | 16 | 6, 9, 12, 15, 24, 38, 39, 46, 52, 53, 54, 55, 57, 64, 76, 79 |
| 4 | 22 | 2,147 | 30 | 3,258 | 14 | 9, 10, 28, 29, 30, 55,58, 60, 61, 62, 63, 69, 74, 79 |
| 5 | 13 | 1,468 | 15 | 2,708 | 8 | 3, 15, 18, 20, 34, 60, 76, 79 |
| 6 | 15 | 1,766 | 19 | 2,833 | 11 | 7, 15, 39, 50, 54, 55, 57, 60, 67, 76, 79 |
| 7 | 13 | 1,392 | 8 | 2,639 | 4 | 3, 9, 76, 79 |
| 8 | 23 | 1,675 | 21 | 3,258 | 15 | 4, 5, 8, 12, 28, 59, 60, 61, 62, 63, 70, 71, 72, 76, 79 |
| 9 | 19 | 1,521 | 5 | 2,996 | 3 | 44, 49,79 |
| 10 | 18 | 1,860 | 23 | 3,135 | 13 | 15, 16, 20, 21, 22, 38,42, 47, 49, 50, 71, 73, 79 |
| 11 | 21 | 1,435 | 31 | 3,258 | 17 | 3, 9, 15, 19, 20, 31, 36, 41, 52, 53, 54, 55, 56, 60, 65, 66, 67 |
| 12 | 6 | 1,246 | 6 | 1,792 | 5 | 9, 15, 26, 60, 76 |
| 13 | 16 | 1,326 | 20 | 2,833 | 7 | 3, 9, 15, 26, 60, 76, 79 |
| 14 | 15 | 1,602 | 35 | 2,944 | 14 | 3, 4, 9, 15, 27, 28, 31, 35, 36, 58, 60, 68, 77, 79 |
| 15 | 21 | 1,443 | 47 | 3,091 | 13 | 3, 4, 7, 9, 11, 15, 19, 27, 28, 31, 37,58, 79 |
| 16 | 17 | 1,391 | 21 | 2,89 | 13 | 3, 9, 15, 20, 27, 39, 52, 53, 56, 60, 76, 79, 80 |
| 17 | 23 | 1,549 | 30 | 3,296 | 14 | 4, 6, 9, 15, 20, 21, 22, 41, 42, 47, 49, 50, 70, 79 |
| 18 | 15 | 1,515 | 51 | 2,773 | 22 | 4, 9, 11, 15, 17, 18, 19, 20, 21, 23, 27, 34, 37, 38, 40, 50, 53, 54, 56, 57, 60, 79, |
| 19 | 19 | 1,282 | 7 | 3,091 | 7 | 15, 18, 19, 20, 21, 58, 79 |
| 20 | 18 | 1,162 | 4 | 2,996 | 3 | 15, 19, 60 |
| 21 | 12 | 1,760 | 10 | 2,639 | 6 | 18, 19, 20, 22, 24, 89 |
| 22 | 7 | 1,477 | 9 | 2,197 | 5 | 15, 28, 51, 73, 79 |
| 23 | 16 | 1,461 | 10 | 2,833 | 5 | 4, 15, 51, 54, 60 |
| 24 | 16 | 2,122 | 45 | 3,045 | 16 | 9, 10, 15, 16, 27, 30, 41, 42, 43, 44, 55, 58, 62, 63, 76, 79 |
| 25 | 24 | 1,425 | 39 | 3,434 | 21 | 33, 56, 35, 7, 15, 16, 20, 24, 27, 34, 36, 38, 41, 42, 54, 55, 56, 57, 76, 78, 79 |
| 26 | 19 | 1,681 | 18 | 3,135 | 12 | 4, 7, 15, 16, 27, 34, 41, 42, 46, 58, 75, 79 |
| 27 | 18 | 2,370 | 23 | 3,091 | 13 | 14, 15, 17, 30, 50, 51, 58, 59, 63, 71, 73, 74, 79 |
| 28 | 13 | 1,643 | 21 | 2,773 | 9 | 3, 9, 15, 20, 28, 58, 59, 60, 79 |
| 29 | 11 | 1,128 | 1 | 2,565 | 1 | 9 |
| 30 | 19 | 1,389 | 58 | 2,996 | 20 | 3, 4, 7, 9, 12, 15, 16, 22,36, 38, 39, 49, 53, 54, 55, 56, 58, 60, 76, 79 |
| 31 | 9 | 1,420 | 10 | 2,197 | 5 | 9, 54, 55, 60, 79 |
| 32 | 12 | 1,360 | 9 | 2,708 | 4 | 3, 9, 22, 79 |
| 33 | 25 | 1,583 | 39 | 3,296 | 12 | 3, 4, 9, 10, 15, 17, 27, 28, 59, 63, 76, 79 |
| 34 | 13 | 1,473 | 9 | 2,708 | 8 | 4, 9, 26, 55, 60, 76, 79, 80 |
| 35 | 20 | 1,988 | 27 | 3,135 | 18 | 3, 4, 9, 10,15, 16, 27, 28, 29, 30, 49, 51, 58, 63, 72, 73, 76, 79 |
| 36 | 20 | 1,618 | 21 | 3,135 | 13 | 7, 12, 13, 15, 31, 35, 40, 53, 55, 57, 60, 65, 79 |
| 37 | 10 | 1,370 | 8 | 2,485 | 5 | 9, 15, 22, 60, 79 |
| 38 | 15 | 1,407 | 9 | 2,773 | 5 | 5, 6, 9, 15, 79 |
| 39 | 13 | 1,331 | 22 | 2,773 | 15 | 1, 3, 4, 9, 15, 18, 19, 20, 21, 23, 27, 40, 50, 58, 79 |
| 40 | 13 | 1,192 | 3 | 2,708 | 3 | 15, 17, 79 |
| 41 | 22 | 1,411 | 8 | 3,178 | 5 | 27, 28, 29, 51, 79 |

**Continued ...**
***Continua...***

Table 2 ...
*Tabela 2 ...*

| | | | | | | |
|---|---|---|---|---|---|---|
| 42 | 16 | 1,510 | 22 | 2,833 | 11 | 3, 9, 15, 53, 54, 55, 60, 66, 76, 78, 79 |
| 43 | 10 | 1,322 | 11 | 2,485 | 7 | 2, 3, 9, 26, 60, 79, 80 |
| 44 | 15 | 1,445 | 22 | 2,944 | 11 | 15, 21, 32, 38, 55, 56, 57, 60, 77, 78, 79 |
| 45 | 24 | 1,617 | 16 | 3,332 | 10 | 9, 10, 15, 30, 37, 38, 48, 58, 69, 79 |
| 46 | 18 | 1,503 | 13 | 3,045 | 8 | 1, 3, 15, 31, 34, 42, 60, 73 |
| 47 | 13 | 1,440 | 42 | 2,89 | 15 | 1,9, 12, 13, 15, 31, 48, 49, 50, 55, 56, 57, 60, 76, 79 |
| 48 | 12 | 1,684 | 20 | 2,773 | 13 | 3, 7, 9, 12,15, 23, 32, 38, 53, 57, 64, 76, 79 |
| 49 | 17 | 1,612 | 8 | 2,996 | 5 | 4, 9, 54, 57, 76, |
| 50 | 11 | 1,128 | 1 | 2,485 | 1 | 9 |
| 51 | 20 | 1,589 | 9 | 3,135 | 8 | 5, 13, 32, 38, 40, 56, 75, 79 |
| 52 | 15 | 1,650 | 6 | 2,996 | 6 | 4, 9, 15, 33, 51, 76 |
| 53 | 26 | 1,604 | 24 | 3,466 | 13 | 1, 4, 9, 14, 15, 19, 31, 38, 57, 60, 76, 79, 80 |
| 54 | 22 | 1,426 | 19 | 3,178 | 10 | 3, 4, 9, 15, 17, 26, 27, 60, 76, 79 |
| 55 | 5 | 1,487 | 8 | 1,792 | 4 | 9, 60, 76, 79 |
| 56 | 12 | 1,339 | 15 | 2,639 | 9 | 4, 9, 15, 47, 50, 56, 57, 73, 79 |
| 57 | 9 | 1,128 | 1 | 2,398 | 1 | 9 |
| 58 | 12 | 1,498 | 9 | 2,565 | 4 | 30, 51, 63, 79 |
| 59 | 17 | 1,677 | 23 | 2,996 | 10 | 4, 15, 32, 34, 37, 54, 55, 56, 65, 79 |
| 60 | 14 | 1,313 | 14 | 2,773 | 9 | 3, 9, 15, 21, 49, 60, 70, 76, 79 |

Eighty different patch types were recorded in 60 sample sites. The characteristics of these patch types are depicted in Table 1.

A minimum of one and a maximum of 58 patches were drawn in a single sample site. Accordingly, a minimum of one and a maximum of 22 different patch types were recorded in a single sample site (Table 2).

Cultivated wheat, fallow lands, plowed lands, and roads were recorded in area 55, which is where five bird species were counted (the lowest number of bird species in the survey) (Table 2). Different flora elements, such as various fruit trees of different heights and ages, various grain fields, fallow, and empty patch species, were recorded in sample area 53, where the highest number of bird species was encountered (26 bird species) (Table 2).

For each sample site, the NP, patch types, patch type codes, landscape metrics, and Shannon H values are listed in Table 2.

According to the results of multiple linear regression analysis (Table 3) with habitat diversity values, the AWMSI and NP were found to be associated with bird species diversity at a rate of 66% (R 0.83).

The sample sites had different numbers of patches, so the values obtained for the NP varied between one and 58. A relationship was noted where low species diversity was found in sampling areas where the same types of patches were located side by side (not mosaic-like scattered), even when the NP in the sampling areas was high. (Figure 2 A and C).

For the AWMSI, it was determined that several large patches in the sample site were surrounded

**Table 3** – Results of multiple linear regression analysis.
***Tabela 3** – Resultados da análise de regressão linear múltipla.*

| Model Summary | | | | | | |
|---|---|---|---|---|---|---|
| Model | Unstandardized Coefficients | | R | R Square | Adjusted R Square | Std. Error of the Estimate |
| | B | Std. Error | | | | |
| (Constant) | 2,246 | ,087 | | | | |
| AWMSI | ,256 | ,056 | ,825 | 681 | ,664 | ,1711867 |
| NP | ,016 | ,003 | | | | |

Source: Author.
Fonte: Autor.

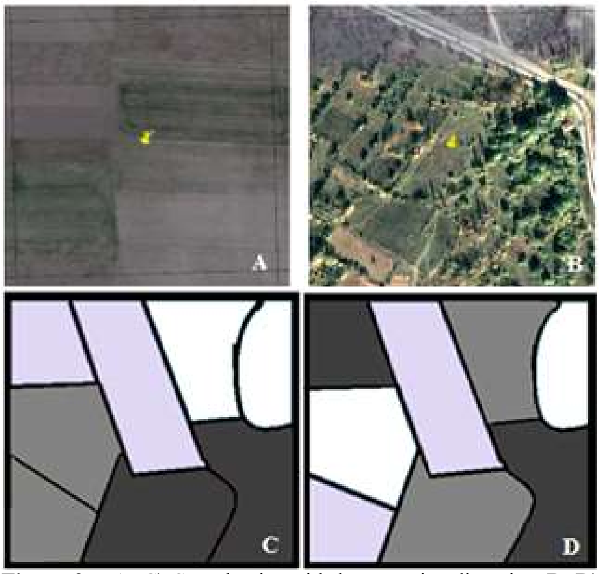


**Figure 2 –** A, C) Sample site with low species diversity: B, D) Sample site with rich species diversity .
***Figura 2*** *– A, C) Local de amostragem com baixa diversidade de espécies: B, D) Local de amostragem com rica diversidade de espécies.*

by small patches and that the locations where different agricultural plants found in these patches were important in terms of wildlife diversity. It was observed that wild animal species diversity flourished as the quantity of patch type increased (if these patches were distributed in a complex way) in the sample site (Figure 2 B and D). Changing patch numbers and their distribution in the sample site caused the values obtained for the AWMSI to vary from 1.1284 to 2.3701. The AWMSI was one when all patches were circular and this value incremented as the patches became more irregular. It was determined that the greater the increase in the weighted shape ratio of the patch number and patch sizes in a sample site, the higher the bird species diversity.

It was observed that the Shannon value varied between 1.792 and 3.466, explaining the diversity of bird species in the sampling areas. Table 2 shows that in areas that contain important the AWMSI and NP values for wildlife but appear to be inverse with species diversity, it is inversely proportional due to human-induced effects (various conditions, such as the presence of permanently used structures, excessive agricultural activity, and the proximity to heavily used road networks). It should not be forgotten that the study area was not a forest or a natural protection area but an agricultural plain where agricultural activities are carried out intensively, and the anthropological effect is an important ecological factor.

It was observed that there are various water sources, such as dams and streams, in the areas with the highest species diversity. The water sources (dam, stream, pool) located near the sample sites with low AWMSI and NP values attracted birds to these areas and generated a higher Shanonn H value.

## 4. DISCUSSION

According to the results of the regression analysis with habitat diversity values, the AWMSI and NP were found to be associated with bird species diversity at the rate of R2 = 0.66 (r = 0.83). It was determined that the greater the weighted ratio of the NP and patch number in a sample site, the higher the diversity of bird species. This result is consistent with the study of Haslem and Bennett (2008).

Corroborating other studies (Morelli et al., 2013; Aksan and Akbay, 2018; Liao et al., 2020), differences were observed in the size of the patches and edges that produce an edge effect between various agricultural zones, creating areas that respond to different habitat demands in terms of wild animals and especially birds. Similar to these study findings, Liao et al. (2020) decided that heterogeneity is important for bird diversity because the growth of edge density and the small patch size of cropland indicates a longer edge length.

Smith et al., (2010) reported that bird species feeding on invertebrates in organic farming areas are positively associated with increased habitat heterogeneity. In this study, it was observed that, although the areas consisting of large and uniform patches offered a more limited response to the habitat demands of wild animals, the distance from the center to the edges was favorable to some species for hiding. It is thought that bird species nesting in the trees on the edges prefer these areas in terms of reaching food within a safe, short distance.

In this study, it was observed that species such as *Emberiza calandra* (Pallas, 1776) and *Galerida* *cristata* (Linnaeus, 1758), which nest on the ground, generally prefer dry farming lands that cover large areas. In dry farming areas where no agricultural activity (hoeing, spraying, thinning, irrigation, etc.) has been carried out for a long time, birds feel safe and also benefit from food availability. Consequently, some bird species were seen more frequently in such areas. Ndang'ang'a et al. (2013) reported that fallow or cultivated agricultural lands have a positive effect on the diversity of grassland itself and grassland for granivore and omnivore species. Insectivorous and predatory bird species nesting in trees or bushes prefer more complex habitats to meet their needs and do not prefer uniform areas. Morelli et al. (2018) reported that associations between landscape metrics, diversity, and community metrics were strongest in arable lands, followed by mixed environments, while only poor correlations were found in forest environments.

Consistent with these study results, Belfrage et al., (2015) observed in their study that the diversity of butterfly and bird species developed in areas with small patches and different land structure diversity, while the diversity of species in question decreased in areas with large patches of uniform or similar terrain. In addition to their biological needs, birds prefer areas that provide nutrition and hiding while allowing easy access (flight distance to food and water) and safety (predators, pesticide, nest proximity, human influence). As the NP, patch type, and land structure diversity increase in the area, they respond to what birds require, resulting in more diversity in bird species and more individual birds that prefer these areas. The factors affecting species diversity in ecology should be evaluated separately for each area. Sample sites with a low AWMSI and NP are expected to have a proportionally low Shannon value. Contrary to expectations, it was found that the Shannon value was high in this sample site affected by water, natural areas, and complex patch types around it. Comments and evaluations should therefore be made considering all environmental factors together and separately, as well as the characteristics of the observed areas, so that the appropriate decisions can be made for the field and plans implemented.

Similar to these study results, Belfrage et al., (2015) found that small-scale agricultural areas provide more patch and land structure diversity than large-scale agricultural areas. According to Belfrage et al., (2015) and Liao et al., (2020), there was a higher number of nesting and breeding birds with more territorial ownership, depending on the diversity of the land structure. It has been determined that not only the NP and the diversity of land structure, but also the distribution of these patches relative to each other are important in the increase in species diversity. Rather than clustering the same type of patches and forming large areas, the dispersal of patches of different characters without forming a unity creates diversity in the area and encourages species diversity. Similarly, Haslem and Bennett (2008) reported that patch mosaic heterogeneity and the nature of the surrounding natural area promote species diversity.

In accordance with the results of this study, it has been reported in many studies that as the NP and heterogeneity increase in agricultural areas, bird species diversity expands (Atauri and Lucio, 2001; Devictor and Jiguet, 2007; Fahring et al., 2011; Belfrage et al., 2015; Liao et al., 2020) and the number of individual birds increases in direct proportion (Farina, 1997; Belfrage et al., 2005; McMahon et al., 2008; Smith et al., 2010).

## 5. CONCLUSIONS

The diversity and structural differences seen in traditional agricultural areas and small agricultural lands are higher in terms of bird species diversity, when compared to agricultural zones with a uniform structure, formed by growing a single product in large areas. It was observed that, as a result of agricultural activities carried out with a single product in large areas, fewer bird species are present. If biological richness that includes bird species and wildlife diversity is desired, diversification can be carried out in agricultural areas in line with these study results. Unfortunately, biodiversity is ignored in favor of consumption needs and the priorities of production policies. However, if modern agriculture is required in large areas, the continuity of bird species diversity can be ensured by meeting the biological needs of different species by allowing various crops, trees, shrubs, and weeds to grow in certain parts of the agricultural zone.

For the conservation of birds in farmlands, more consideration is necessary for increasing crop diversity in farmland and ensuring the appropriate, effective landscape size for bird use when managing farmland. For protection and improvement, further studies focusing on relationships between bird species and habitat components at breeding/non-breeding times as well as relationships between migratory and native birds in agricultural areas are needed.

## AUTHOR CONTRIBUTIONS

Şengül AKSAN was in charge of all text. Şengül AKSAN: experimental set up, data collection, analyse obtained and discussed the statistical, experimental, estimated data and she wrote the paper. Author read and approbed the final version of manusript.

## 6. REFERENCES


Aksan Ş. Relationship Between Some Wild Mammalian Species And Agricultural Crops. Biological Diversity and Conservation. 2018;11(2):65-70.

Aksan Ş, Akbay N. Effect of agricultural landscape diversity on mammalian wild animal species diversity: Case of Atabey plain. Turkish Journal of Forestry. 2018;19(2):176-184. doi: 10.18182/tjf.348834

Aksan Ş, Mert A. Ispart a Atabey Ovası'nın kuş türleri ve bollukları. Turkish Journal of Forestry. 2016;17(2):153-157. doi: 10.18182/t jf.61184

Atauri J A, De-Lucio J V, The role of landscape structure in species richness distribution of birds, amphibians, reptiles and lepidopterans in Mediterranean landscapes. Landscape Ecology. 2001;16(2): 147-159.

Belfrage K, Bjorklund J, Salomonsson L. The effects of farm size and organic farming on diversity of birds, pollinators, and plants in a Swedish landscape. AMBIO A Journal of the Human Environment. 2005;34(8):582–588.

Belfrage K, Björklund J, Salomonsson L. Effects of Farm Size and On-Farm Landscape Heterogeneity on Biodiversity—Case Study of Twelve Farms in a Swedish Landscape. Agroecology and Sustainable Food Systems. 2015;39(2):170-188.

Benton TG, Bryant DM, Cole L, Crick HQP. Linking agricultural practice to insect and bird populations: a historical study over three decades. Journal of Applied Ecology. 2002;39(4):673–687.

Benton TG, Vickery JA, Wilson JD. Farmland biodiversity: is habitat heterogeneity the key? Trends in Ecology and Evolution. 2003;18(4):182–188.

Bibby C J, Jones M, Marsden S. Expedition Field Techniques: Bird Surveys. London: Royal Geographical Society; 1998. 134 p.

Climate-Data. [cited 2017 December 08] Available https://tr.climate-data.org/ location/19359/.

Devictor V, Jiguet F. Community richness and stability in agricultural landscapes: The importance of surrounding habitats. Agriculture, Ecosystems and Environment. 2007;120(2-4):179–184.

Donald PF, Green RE, Heath MF. Agricultural intensification and the collapse of Europe's farmland bird populations. Proceedings of the Royal Society of London. Biological Sciences. 2001;268(1462):25-29.

Fahring L, Baudry J, Brotons L, Burel FG, Crist TO, Fuller RJ, Martin J L. Functional landscape heterogeneity and animal biodiversity in agricultural landscapes. Ecology letters. 2011;14(2):101-112.

Farina A. Landscape structure and breeding bird distribution in a sub-Mediterranean agro-ecosystem. Landscape Ecology. 1997;12(6):365-378.

Flynn DFB, Gogol-Prokurat M, Nogeire T, Molinari N, Richers BT, Lin BB, Simpson N, Mayfield MM, Declerck F. Loss of functional diversity under land use intensification across multiple taxa. Ecology letters. 2009;12(1):22-33.

Gregory RD, Gibbons DW, Donald PF. Bird census and survey techniques. Bird Ecology and Conservation. A Handbook of Techniques. Oxford: Oxford University Press; 2004;17-56 p. doi: 10.1093/acprof:oso/9780198520863.003.0002

Haslem A, Bennett AF. Birds in Agricultural Mosaics: The Influence of Landscape Pattern and Countryside Heterogeneity. Ecological Applications. 2008;18(1):185-196.

Heikkinen RK, Luoto M, Virkkala R, Rainio K. Effects of habitat cover, landscape structure and spatial variables on the abundance of birds in an agricultural–forest mosaic. Journal of Applied

Ecology. 2004;41(5):824-835.

Kisel Y, McInnes L, Toomey NH, Orme CDL. How diversification rates and diversity limits combine to create large-scale species—area relationships. Philosophical transactions of the Royal Society of London. Series B, Biological sciences. 2011;366(1577),2514–2525, http://dx.doi.org/10.1098/rstb.2011.0022

Kleijn D, Baquero RA, Clough Y, Di´Az M, Esteban J, Fernandez F. Mixed biodiversity benefits of agri-environment schemes in five European countries. Ecology letters. 2006;9(3):243–254.

Liao J, Liao T, He X, Zhang T, Li D, Luo X, Wu Y, Ran J. The effects of agricultural landscape composition and heterogeneity on bird diversity and community structure in the Chengdu Plain, China. Global Ecology and Conservation. 2020;24,e01191.

Morelli F, Pruscini F, Santolini R, Perna P, Benedetti Y, Sisti D. Landscape heterogeneity metrics as indicators of bird diversity: Determining the optimal spatial scales in different landscapes. Ecological Indicators. 2013;34:372-379.

Morelli F, Benedetti Y, Šímová P. Landscape metrics as indicators of avian diversity and community measures. Ecological Indicators. 2018;90:132-141.

McGarigal K, Marks BJ. Fragstats: Spatial Pattern Analysis Program for Quantifying Landscape Structure. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 1995; 122 p (General Technical Report PNW-GTR-351. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.)

McMahon BJ, Purvis G, Whelan J. The influence of habitat heterogeneity on bird diversity in Irish farmland. In Biology & Environment. 2008;108(1):1-8.

Ndang'Ang'a PK, Njoroge JB. Githiru, M. Vegetation composition and structure influences bird species community assemblages in the highland agricultural landscape of Nyandarua, Kenya, Ostrich. Journal of African Ornithology. 2013;84(3):171-179.

Norfolk O, Power A, Eichhorn MP, Gilbert, F. Migratory bird species benefit from traditional agricultural gardens in arid South Sinai. Journal of Arid Environments. 2015; 114:110-115.

Pino J, Rodà F, Ribas J, Pons X. Landscape structure and bird species richness: implications for conservation in rural areas between natural parks. Landscape Urban Plan. 2000;49(1–2);35–48.

Porter R F, Christensen S, Schiermacker-Hansen P. Türkiye ve Ortadoğunun Kuşları (Birds of Turkey and the Middle East). Dev Belgesel Yayınları (Giant Documentary Broadcasts); 2009. 455 p. ISBN-10: 6056048705

Selmi S, Boulinier T. Breeding bird communities in southern Tunisian oases: the importance of traditional agricultural practices for bird diversity in a semi-natural system. Biological conservation. 2003;110(2):285-294.

Shannon C E, Weaver W. The mathematical theory of com- munication. Urbana: Univ. Illinois Press; 1949.

Shiu HJ, Lee PF. Asessing avian point-count duration and sample size using species accumulation functions. Zoological Studies. 2003;42(2):357–367.

Smith HG, Dänhardt J, Lindström Å, Rundlöf M. Consequences of organic farming and landscape heterogeneity for species richness and abundance of farmland birds. Oecologia. 2010;162(4):1071-1079.

Tryjanowski P, Hartel T, Báldi A, Szymanski P, Tobolka M, Herzon I, et al. Conservation of farmland birds faces different challenges in Western and Central-Eastern Europe. Acta Ornithologica. 2011;46:1-12.

Toledo Á, Burlingame B. Biodiversity and nutrition: A common path toward global food security and sustainable development. Journal of Food Composition and Analysis. 2006;19(6):477-483.