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RESEARCH ARTICLE

# Assessment of Root-Shoot Ratio, Biomass, and Carbon Sequestration of Chestnut-leaved Oak Seedling (*Quercus castaneifolia* C. A. Mey)

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ABSTRACT

One of the most important ways to reduce atmospheric carbon is the carbon sequestration by trees. Chestnut-leaved oak (*Quercus castaneifolia* C. A. Mey) is one of the most important native oaks of Iran distributed in the Hyrcanian Forests. The pure and mixed stands of it cover about 6.5% of these forests. In this study, carbon sequestration of chestnut-leaved oak seedlings was evaluated by using some morphological characteristics of the root and shoot. For this purpose, one hundred seedlings were sampled by method of Systematic-Random from the sowing bed on March 2022 in the Pylambra nursery at Guilan province. Seedlings are divided to three grades small, medium and large according to Root Collar Diameter (RCD). The biomass and carbon sequestration of chestnut-leaved oak seedling were calculated according to the basic density of its root and shoot. The Pearson's correlation coefficient was used for correlation detection between variables. The one-way analysis variance test at the 95% confidence level was used to recognize difference among biomass and carbon sequestration of three group of the oak seedlings. The results of correlation analysis showed that the root collar diameter (RCD) had the strongest correlation with other morphological characteristics. The amount of the basic density for the root and shoot of the oak seedling was obtained about 0.57 g/cm$^3$ which is the same for both of them. The amount of the biomass and carbon sequestration of the root was obtained more than shoot at the small and medium seedlings, whereas in large seedling was the same. In general, by increasing the size of seedling the biomass and carbon sequestration increased.

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## 1. Introduction

Carbon is the most important of greenhouse gas that in recent decades increasing of it has been caused earth warming in the atmosphere. Warming has damaging effects on lives and was caused destruction of natural ecosystems, occurrence of drought, climatic and ecological imbalance. Carbon sequestration in plant biomass and soils under the biomass is the most simple and cheapest possible way to reduce levels of this atmospheric gas.

As part of the carbon cycle, trees transform carbon dioxide to biomass through photosynthesis (Equation 1) (Liu & Li, 2012).

$$Co_2 + H_2O \rightarrow BIOMASS + O_2 \quad (1)$$

This function is beneficial to humans because it counteracts emissions of carbon dioxide ($CO_2$), a greenhouse gas. Anthropogenic carbon emissions have caused a 40% increase in atmospheric $CO_2$ concentrations in the last century, a change which is known to be causing global warming (IPCC, 2013). Whole-plant biomass of juvenile trees will greatly improve the

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accuracy of current estimates of forest carbon stocks for proposed new areas of indigenous afforestation/reforestation (Marden et al., 2018). Carbon sequestration involves the removal of $CO_2$ from the atmosphere, aiming to reduce the greenhouse effect. Wood basic density is a direct part of this process Carbon dioxide ($CO_2$) gas, one of the compounds released into the atmosphere by man, is produced in all parts of the planet, mainly by burning petroleum-derived fuels and by producing cement (75% of total emissions). $CO_2$ is one of the greenhouse gases by the absorption of thermal infrared light. Carbon becomes available to living beings through plants by photosynthesis, and because carbon is stored, it is often called fixed carbon. *Quercus* is the largest genus in the family *Fagaceae* with about 300-600 species. This genus includes evergreen and deciduous shrubs and trees extending from cold latitudes to tropical Asia and Americas. Chestnut-leaved oak (*Quercus castaneifolia* C. A. Mey) is one of the most important species of Iran's native oaks, distributed in the Hyrcanian Forests (Panahi et al., 2011). The aim of this study is to: *i)* to develop a model explaining the shoot and root dry weight of the oak seedling according to variation of the root collar diameter ii) to understand the role of the oak seedling quality on carbon sequestration.

## 2. Materials and Methods

### *2.1.* Study Area

This study was done on the oak seedlings that grow in the Pylambra nursery. The location of the Pylambra nursery is Pareh Sar city in Guilan province, Iran (49° 4′ E, 37° 36′ N) (Figure 1).

According to the climatic data received from the meteorological station, the climate of the area is very humid; and the mean annual temperature is 16.5 °C and average precipitation is 2139.7 mm.

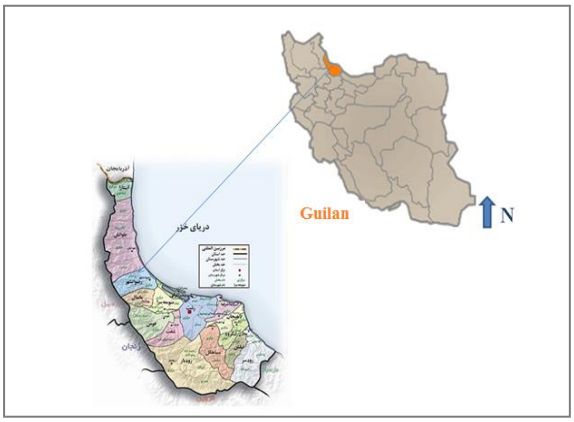


**Figure 1**. Locations of the study area in Guilan province, Iran.

### *2.2.* Sampling Method of Seedlings

Samples were taken from chestnut-leaved oak seedlings grown within frames measuring 0.3 m x 0.3 m by Systematic random sampling method (Figure 2). Sampling was done before the seedling transport to the planting fields on March 2022. More than 100 seedlings were sampled and then they transported to the forestry measuring lab in the faculty of natural resource at University of Guilan.

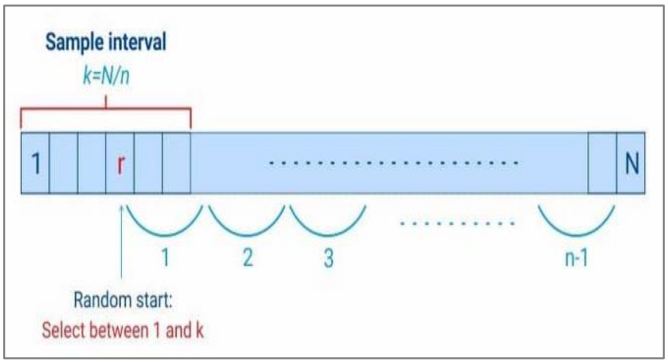


**Figure 2.** Systematic random sampling.

### *2.3.* Measurement of Morphological Attributes

The oak seedlings were divided to three grades as small (3-6 cm), medium (6-9 cm) and large (9-12 cm) according to Root Collar Diameter (RCD). Then their morphological attributes were measured. Seedlings were divided into two sections: Shoot and Roots. Shoot height (SH), root collar diameter (RCD) were measured with accuracies 1 mm and 0.01 mm, respectively. Number of the First Order lateral Roots (FOLR) and Root length (RL) were measured and Root Volume (RV) was determined by water displacement method (Taherzadeh et al., 2014).

### *2.4.* Measuring the Volume of Seedling Roots and Shoot

Seedling Roots have an irregularly shape. Therefore, using geometry is often difficult and complicated. The easiest way to measure root volume is using the water displacement method (Figure 3).

The volume of the oak seedlings was calculated by subtracting the volume of the water alone (V1) from the volume of the water plus the seedling roots (V2) (Equation 2).

$$V_{root} = V2 - V1 \quad (2)$$

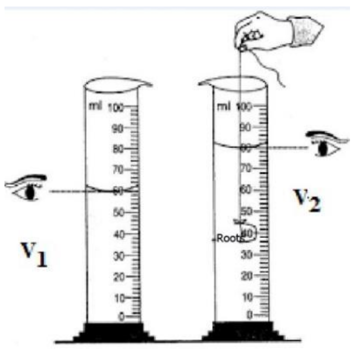


**Figure 3**. Measuring the volume of the seedling roots.

Unlike roots, the volume of each Seedling shoot was calculated according to the geometry Equation 3 (Kirby & Potvin, 2007).

$$V_{shoot} = \pi\,(RCD)^2/4 \times SH \times 0.5 \quad (3)$$

Where:

$V_{shoot}$ = Seedling Shoot Volume ($cm^3$)

RCD = Root Collar Diameter (cm)

SH = Shoot height (cm)

### *2.5.* Calculating Green Weight (GW) and Dry Weight (DW)

The green weight of a seedling is an estimate of the mass of the fresh seedling when it is alive.

Dry weight represents the mass of the wood in the seedling when dried in an oven, so the moisture is removed. For this purpose, at first the fresh weights of each part were measured. Then dry weight of them was measured after drying into Oven at 80 °C for 24 h (Taherzadeh et al., 2014).

### *2.6.* Calculating Basic Density and Biomass of the Seedling

Basic density is the relationship between absolutely dry mass and saturated volume of seedling.

Basic density was determined by the maximum moisture content method reported and calculated as (Peichl & Arain, 2006):

$$BD = DW / Vs \quad (4)$$

BD = Basic density ($g/cm^3$)

DW = Dry Weight (g)

Vs = Saturated volume ($cm^3$)

$$B = V \times BD \quad (5)$$

B = Seedling Biomass (g)

V = Seedling Volume ($cm^3$)

### *2.7.* Calculating Carbon Storage (C)

Carbon storage is the amount of carbon in the shoot and roots of the seedling. This is the total amount of carbon that is captured from the atmosphere during photosynthesis as well as the amount of carbon sequestered by the seedling. From experiments, scientists have found that about 50 per cent of biomass is carbon (Birdsey, 1992).

$$C = 0.50 \times B \quad (6)$$

C = Carbon storage of Seedling (g)

B = Biomass of Seedling (g)

$$CS = C \times 3.67 \quad (7)$$

CS = $CO_2$ Sequestration by a seedling (g)

### *2.8.* Statistical Analysis

Grading is done on the basis of Root Collar Diameter (RCD). The accuracy of the grading tested by the Discriminant analysis. Kolmogorov-Smirnov test was used to verify the normality of data distribution and the Levene's test was used to evaluate the homogeneity of variances. Differences between mean of morphological attributes in diameters grades were tested using analysis of variance (one-way ANOVA). Wherever grades means were significant, the Duncan's post hoc test was carried out to compare the means. These analyses were conducted with the SPSS software (Version 19).

## 3. Results and Discussion

The age of all the oak seedlings was similar at the time of studying, but there were initial and significant differences in the above-ground metrics among them. The diameter class distribution of the oak seedling in the Pylambra nursery exhibited a tendency towards a bell curve distribution (Figure 4). The classes with most abundant individuals were 6-9 cm (medium) and 9-12 cm (large) with respectively 50 and 30% of individuals. Table 1 shows the descriptive statistics of the morphological characteristics of the oak seedlings.

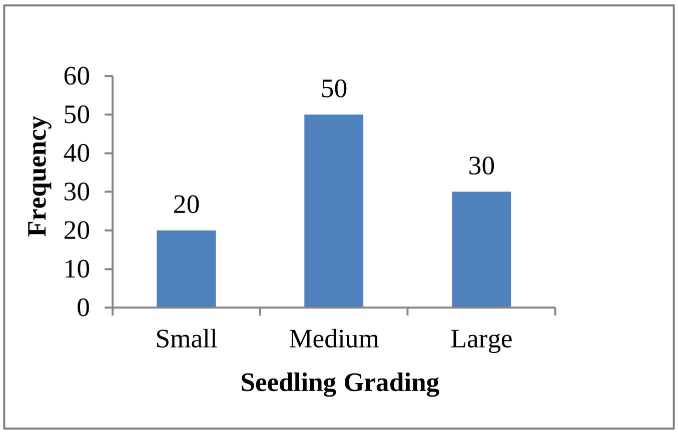


**Figure 4.** The diameter class distribution of the oak seedling in the Pylambra nursery.

**Table 1.** Descriptive statistics of the morphological characteristics of chestnut-leaved oak seedlings.

| Seedling attributes | Mean±sd | Minimum | Maximum |
|---|---|---|---|
| Root collar diameter (mm) | 7.3±0.4 | 3 | 14.8 |
| Shoot height (mm) | 556.09±20 | 66 | 1279 |
| Shoot dry weight (g) | 6.67±0.25 | 1 | 22.24 |
| Root length (mm) | 393±3 | 139 | 730 |
| Number of the first order lateral roots | 5.78±0.2 | 0 | 22 |
| Root volume ($cm^3$) | 10.25±0.5 | 2 | 65 |
| Root fresh weight (g) | 18.26±0.8 | 3.24 | 66.93 |
| Root dry weight (g) | 8.79±0.5 | 1.38 | 23.95 |

RCD is the base of the stem ends and the roots begin. Until recently, the standard minimum root collar diameter has been about 3.2 mm. Now, the industry standard is moving up. International Paper has increased its minimum standard to 3.8 mm or more in diameter. And the trend is in the direction of even larger seedlings sometimes up to 5.5 mm or more for special site conditions. The advantages of large-diameter loblolly pine seedlings are many, according to research on seedlings ranging in size from 3.8 mm to more than 7 mm (South, 1998). RCD was used instead of DBH in the analysis of seedling allometry because it was not expected to reach DBH height (1.3 m).

In this study, the RCD range for the oak seedling obtained between 3 mm and 12 mm. Results showed among the seedling characteristics, root collar diameter was most correlated with others, therefore it was a good indicator of the seedling quality. Therefore, the grading is done on basic of on morphological attributes associated with this factor. Attributes of less than mean was considered as small, more than mean + Standard deviation as large and between these two states were considered medium. Finally, seedlings were graded into three grades (small, medium, large) based on the root collar diameter. Checking the grading accuracy on basic discriminant analysis showed that in both stage of sampling the probability more 90% grading is done correctly in each sampling stages.

The correlation coefficient and significance level between Root collar diameter (RCD) and Shoot height (SH), Shoot fresh weight (SFW), Shoot dry weight (SDW), Root volume (RV), Root fresh weight (RFW) and Root dry weight (RDW) was analysis using the Pearson's correlation coefficient (Table 2).

**Table 2.** Pearson's correlation coefficient and significance level of chestnut-leaved oak seedlings.

| | RCD | SH | SFW | SDW | RV | RFW | RDW |
|---|---|---|---|---|---|---|---|
| **RCD** | 1 | | | | | | |
| **SH** | 0.595 ** | 1 | | | | | |
| **SFW** | 0.915 ** | 0.666 ** | 1 | | | | |
| **SDW** | 0.88 ** | 0.549 * | 0.954 ** | 1 | | | |
| **RV** | 0.837 ** | 0.593 * | 0.895 ** | 0.800 ** | 1 | | |
| **RFW** | 0.931 ** | 0.591 * | ** 0.918 | 0.873 ** | 0.949 ** | 1 | |
| **RDW** | 0.917 ** | 0.460 * | 0.898 ** | 0.904 ** | 0.890 ** | 0.978 ** | 1 |

** The significance level is 99%, * The significance level is 95%.

The most correlation obtained between RCD and weights of root and shoot of the oak seedling. A seedling with a large-diameter root collar can produce more wood in a shorter time than its average to smaller counterparts.

Comparison of carbon sequestration of shoot- and root biomass means were showed in three grades (Table 3).

The highest carbon sequestration of shoot- and root biomass were in Large Seedlings with the numerical values of 8.66 and 8.28 g, respectively. The results indicate that larger grades seedlings are more capable in the production and use of carbohydrates and in nutrient uptake, and had grown more in the nursery, therefore probably have better performance in the field (Singh et al., 2011).

Figures 5 and 6 illustrate the trend of the shoot and root dry weights with an increase in RCD.

**Table 3.** Calculated parameters for three diameter classes of chestnut-leaved oak seedlings.

| Parameters | Small Seedling (3-6 cm) | Medium Seedling (6-9 cm) | Large Seedling (9-12 cm) |
|---|---|---|---|
| **Shoot volume ($cm^3$)** | 3.96 | 11.07 | 28.14 |
| **Shoot biomass (g)** | 2.26 | 6.31 | 16.04 |
| **Shoot carbon (g)** | 1.22 | 3.41 | 8.66 |
| **Root volume ($cm^3$)** | 7.21 | 14.66 | 26.92 |
| **Root biomass (g)** | 4.11 | 8.35 | 15.34 |
| **Root carbon (g)** | 2.22 | 4.51 | 8.28 |
| **Seedling volume ($cm^3$)** | 11.17 | 25.72 | 55.06 |
| **Seedling biomass (g)** | 6.37 | 14.67 | 31.38 |
| **Shoot/Root biomass ratio** | 0.55 | 0.75 | 1.04 |
| **Seedling carbon (g)** | 3.18 | 7.92 | 16.95 |
| **$CO_2$ sequestration (g)** | 11.67 | 29.07 | 58.54 |

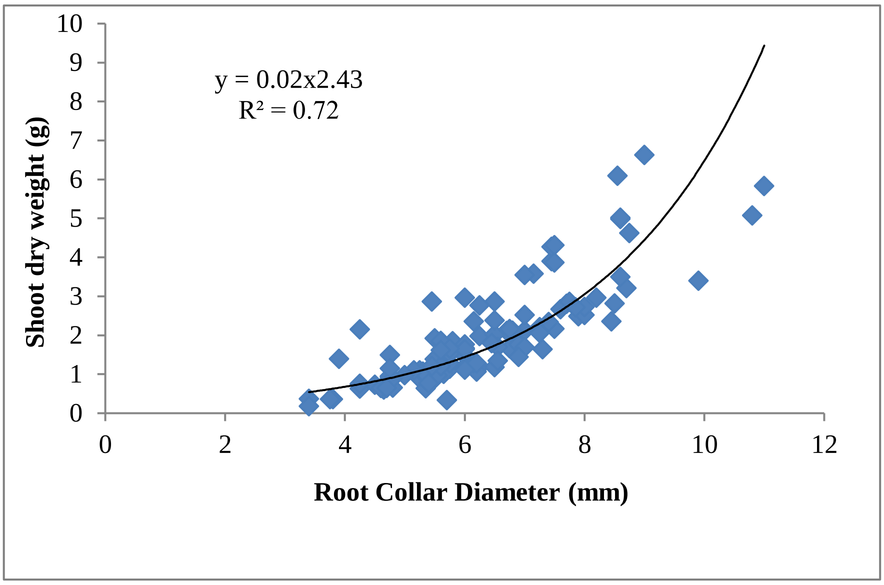


**Figure 5.** Power growth analysis of RCD and SDW.

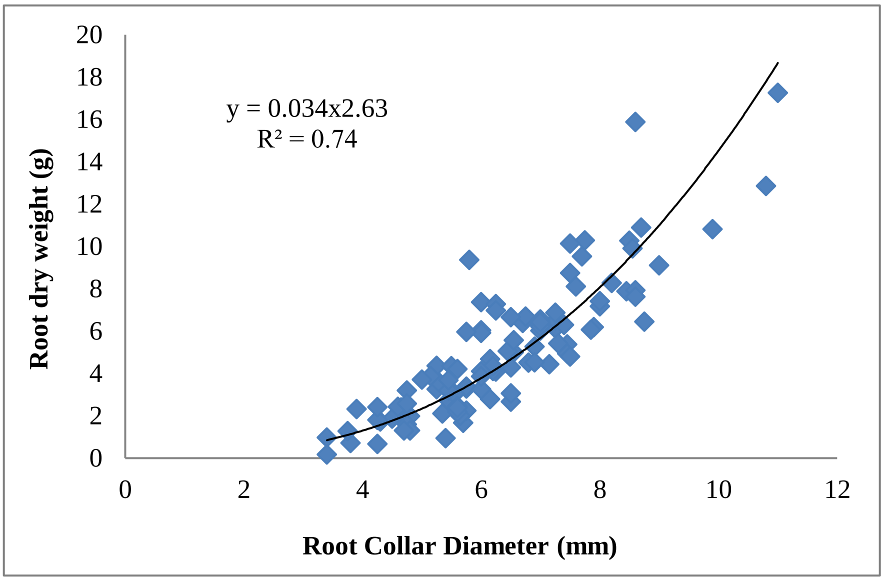


**Figure 6.** Power growth analysis of RCD and RDW.

The curves were plotted using the estimated shoot and root dry weight values in the power models. The curves have been obtained from estimated values of shoot and root dry weights.

Tree allometric equations are critical tools for determining tree volume, biomass and carbon stocks and have the potential to improve our understanding about carbon sequestration in woody vegetation to support the implementation of policies and mechanisms designed to mitigate climate change (Jara et al., 2014). The models for the prediction of biomass, though related to a specific case study are a tool of considerable utility for both ecological and silvicultural purposes (Marziliano et al., 2015).

Two-parameter power regression analysis was a good fit for the RCD and SDW data, with $R^2$=0.72 and also for the RCD and RDW data, with $R^2$=0.74.

## 4. Conclusion

Generally, in this study the RCD of chestnut-leaved oak seedling obtained more than the standard minimum root collar diameter at the same ages. The RCD detected a good indicator of the oak seedling quality and also has high correlation with other morphological attributes. The oak seedling was graded according to RCD into three grades (small, medium and large). The highest Carbon Sequestration of Shoot and Root biomass obtained in large seedlings. The power regression obtained a good fit model for the RCD and SDW data and also for RDW data.

## Declaration

An earlier version of this article was presented at the 3rd International Congress on Engineering and Life Science at Karadeniz Technical University, Trabzon on 20-22 September, 2023.

## Conflict of Interest

The authors declare that they have no conflict of interest.

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RESEARCH ARTICLE

# Criticism of the Effect of Green Cover Change on Air Quality with i-Tree Canopy (Bursa-Osmangazi Region Sample)

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**ABSTRACT**

Anything that reflects the ethnicity of a society that has aesthetic and visual textures transferred from past generations to the present day, that is universally accepted, that contains abstract and concrete concepts, and that is intended to be preserved and transferred to future generations is called "cultural heritage". Today's urbanism continues to develop around the settlements of ancient civilisations, which are accepted as cultural heritage. Today, migration from villages to cities has increased and population density in cities has shown a rapid upward trend. The destruction of green areas due to rapid urbanisation has increased visibly and has made smart cities with green areas obligatory. In smart urbanisation, practical methods are sought to quickly identify green areas and determine the benefits provided by these areas. The most widely used software for measuring tree canopy cover is i-Tree Canopy, which allows urban planners to quantify the ecosystem services and benefits of tree communities and forests at multiple scales, including pollution reduction, carbon sequestration and storage, and runoff reduction. Within the scope of the study, the changes on green areas such as urbanisation, industrialisation, increase in transportation networks brought about by population growth in the historical city centre of Bursa and the negative and positive effects of these changes were examined. In the study, the time-dependent changes of green areas in urban heritage and urban planning were determined with GIS (Geographical Information Systems) techniques, and suggestions were developed for existing and new green areas to be planned in the city.

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## 1. Introduction

The target of management plans for conservation and sustainability in cultural heritage sites is to protect and develop the outstanding universal value of the field for present and future generations, and to take actions to achieve this (Öksüz Kuşçuoğlu & Taş, 2017). Regarding the structure of the Smart City concept, there are different approaches in standard, maturity assessment model, index and architecture studies (Bilgem, 2021). Smart city definitions include six main components (Yiğitcanlar, 2015; Uçar et al., 2020), namely smart "governance, economy, people, mobility, life and environment" (Lombardi et al., 2012; Uçar et al., 2020) when evaluating the performance of smart cities.

Currently, changes such as urban sprawl, industrialisation and deforestation have led to various environmental problems (Kaplan et al., 2018; Ersoy Tonyaloğlu, 2019; Yaşlı et al., 2023). Depending on health, education, transport and employment opportunities, migration from villages to cities has increased, thus the population density in cities has exhibited a rapid upward trend. In order to meet the housing needs of the population concentrated in urban centres, an increase in housing has become a must. Due to rapid urbanisation, the destruction of green areas has visibly increased and adverse conditions such as increased air pollution in urban centres and

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flooding due to the increase in impervious areas have occurred. Urban forests improve air quality and provide clean air by absorbing marine pollutants such as $NO_2$, $SO_2$, $O_3$, VOC, PM2.5 and PM10 from the air (Zhao et al., 2023). The location, types, analysis, spatial distribution, capacity, functionality and adequacy of urban open and green spaces are considered to be the most important components of planning and design (Gül et al., 2020). "Liveable and Sustainable Cities that Add Value to Life" is set as the vision with the strategy that focuses on "Effective and Sustainable Smart City Governance" and "Competent and Productive Smart City Ecosystem" in the focus of smart urbanism in Turkey (Bilgem, 2021).

Cities and society have to change and city dwellers demand places to enjoy their living spaces (Nagode et al., 2023). Cultural heritage is the richness that tells the common past of the people in the same society, reveals their historical accumulation, and has meaning not only for the society and future generations but also for all humanity, both abstract and concrete (Öksüz Kuşçuoğlu & Taş, 2017). Green space is an integral part of the human history of heritage cities and the inherited culture for generations (Henderson, 2013; Campagnaro et al., 2020).

Heritage is defined as a stock of values characterised by stability, continuity and acceptance in society. According to many studies, by 2050, 68 per cent of the world's population is expected to live in cities due to the growth in developing countries (Li et al., 2021). Effective and efficient management of limited resources in the face of unlimited human needs and sustainable urbanisation processes will only be possible with innovative and smart solutions (Partigöç, 2023). Therefore; the concept of smart city has emerged in recent years (Campagnaro et al., 2020).

Smart cities represent the future on both an economic and social level and their main goal is to provide a digitalisation-friendly sustainable environment and promote learning. In smart urbanisation, practical methods are sought to quickly identify green areas and determine the benefits provided by these areas. The most widely used software for measuring tree canopy cover is i-Tree Canopy based on Google Maps (Konôpka et al., 2023). Through these innovative practices and tools, managers can demonstrate the ecosystem services and benefits of tree communities and forests at multiple scales, including pollution reduction, carbon sequestration and storage, and runoff reduction (Hirabayashi et al., 2011; Uçar et al., 2020).

Planning for green spaces in historic heritage sites is a humanitarian task, especially after the devastation caused by wars (Bradford & D'Amato, 2012). Increasing the quantity and quality of urban green spaces can provide many benefits, such as improving the liveability of cities and increasing their resilience to threats such as climate change (Kim & Lim, 2016; Speak & Salbitano, 2023).

The communications and information technology revolution has led to the adoption of the concept of smart cities, which has evolved over time from digital cities, knowledge cities and sustainable cities in the mid-twentieth century to the broader concept of smart cities (Batty, 2014). Many cities around the world are seeking to become smart cities due to the many benefits that the smart cities concept provides to the city and the citizens in these cities (Campagnaro et al., 2020).

Changes in green areas in the city centre of Bursa, a UNESCO cultural heritage city hosting areas rich in cultural heritage, and the negative and positive effects of these changes on air pollution were revealed in this study. In order to determine the role that smart cities approach can play in the protection of green areas, the time-dependent changes of green areas were determined with i-Tree software and GIS techniques and new suggestions were developed for the planning and protection of green areas in the city centre according to the results obtained. In this context, revealing the time-dependent green area change of city centres with historical value together with the reasons will contribute to the protection of these areas both local and areal in the future.

## 2. Materials and Methods

The 28 neighbourhoods of Osmangazi district of Bursa province were selected as the study area. The land cover change in the historical areas within the boundaries of the study area (Figure 1) was determined considering population change starting from 2023 for 2011 and 1997. In the study, the increase in the population and the changes occurring accordingly in the area of the historical change of the green areas of the city developing within the scope of today's smart urbanism were evaluated. In addition, the monetary contribution change with the removal of toxic gases (CO, $NO_2$), which have many negative effects on human health used in air pollution calculations, pesticides used in industry and agriculture and particulate matter (PM2.5, PM10) in secondary chemical reactions (PM2.5, PM10) over the years has also been examined.


**Figure 1.** Study area consisting of 28 neighbourhoods in Osmangazi District of Bursa Province.

Within the scope of the study, the neighbourhood boundaries obtained from Osmangazi Municipality were overlaid with Google Earth map in ArcGIS software and 28 neighbourhoods were determined as the study area. Old orthophotos of Bursa city centre obtained from Bursa Metropolitan Municipality were used as database in ArcGIS. Cover Class ((1) Grass/Herbaceous, (2) Impervious Buildings, (3) Impervious Other, (4) Impervious Road, (5) Soil/Bare Ground, (6) Tree/Shrub, (7) Water) created for the study area in i-Tree Canopy was converted to kml/kmz file.

For the year 2023, the land classification created by random point assignment with the help of i-Tree Canopy was converted to kml/kmz format and evaluated with the orthophoto of 2011 and the aerial photograph of 1997 obtained from local administrations, and the current and past cover classes were compared separately for each point in i-Tree Canopy. When making field determination on the points, 1/600 or 1/800 scale was used to avoid deviation in the position of the point. The changed points in the study were updated separately for 1997 and 2011 in i-Tree Canopy version.

As exemplified in Figure 2, the change of Osmangazi district of Bursa province, where the study was carried out, was determined at an eye distance by moving 200-300 m closer to each point with the help of Google Earth Pro.

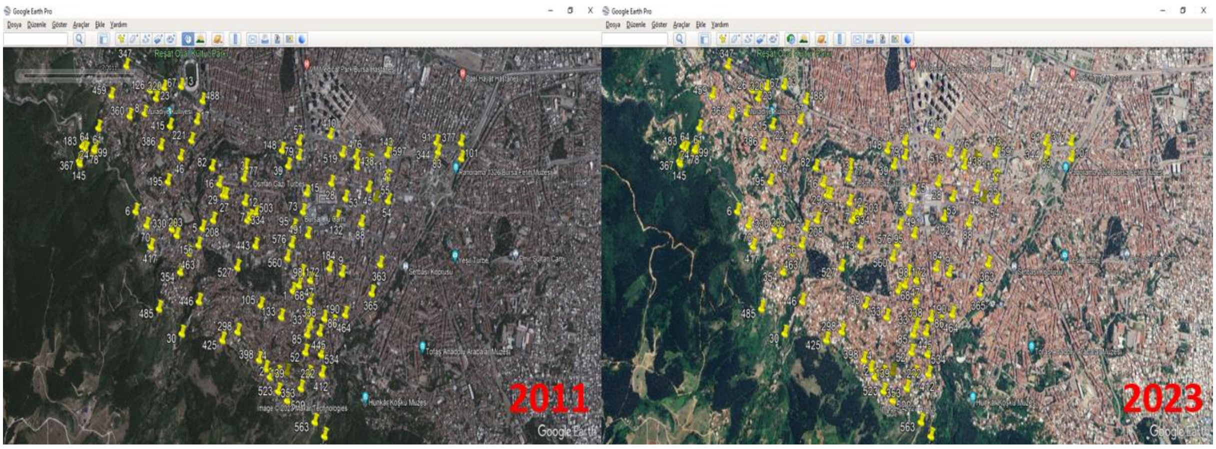


**Figure 2.** Representation of the sample areas on Google Earth.

i-Tree, used in the study, is a software package provided by the United States Department of Agriculture (USDA) that provides urban and rural forest area analysis and benefit assessment tools. i-Tree tools can help in planning the management of forest areas by measuring forest structure and the environmental benefits provided by trees. i-Tree software can link forest management activities with environmental quality and liveable areas according to the ecosystem cycle formed by wooded areas (URL-1).

the i-Tree Canopy program, firstly, the neighbourhood boundaries of Ulu Cami and its surroundings, which is one of the historical symbols of the city and located in Osmangazi district, obtained from Osmangazi Municipality, were transferred to the i-Tree program with ArcGIS software and the file was converted into shapefile and AutoCad shape format. The boundaries of the study area were uploaded to the i-Tree Canopy programme and the 600 points randomly assigned to the i-Tree Canopy programme were confirmed to which of the 7 different cover classes (Grass/Herbaceus, Impervious Buildings, Impervious Other, Impervious Road, Soil/Bare Ground, Tree/Shrub, Water) specified in the programme and the process was saved in kml/kmz file format. Afterwards, Cover Assessment and Tree Benefits Report was obtained from i-Tree Canopy. Which Cover Class the area selected in the report falls into, Tree Benefits: Air Pollution (metrix) values (CO, $NO_2$, PM2.5, PM10 in the air) were analysed in the software interface using the data obtained from the classes created according to the points randomly thrown by the program. In this analysis, it calculated the percentage error margins and gave the monetary values of the ecosystem. The Cover Assessment and Tree Area Report of the historical area covering the Ulu Mosque and its surroundings given by the i-Tree Canopy software was created separately for the dates 1997, 2011 and 2023, and the change of the factors in the report, the directions of change and the reasons for change were investigated and discussed.

## 3. Results and Discussion

### *3.1.* Population Change Effects

Bursa, which is home to areas rich in cultural heritage, is an industrial city while Osmangazi district, one of the historical centres of the city, continues to receive migration for this reason. In addition, after the civil war that broke out in 2011 due to the mobbing of the Syrian regime against the people, mass migration to our country took place; Osmangazi district also increased the population of the district by receiving migration. The requirements brought by this increase, urbanisation, industrialisation, construction of transportation networks, etc. of Osmangazi district have caused negative changes on green areas.

Erdem et al. (2023) concluded that the population density of Bursa is in Nilüfer, Osmangazi, Yıldırım districts which are close to industrial zones, environmental problems are seen in these districts, the silhouette of the city has changed due to intensive migration and problems such as unplanned urbanisation have emerged. Figure 3 shows the population growth graph from the 1990s to the present day. In this thirty-three year period, there is a 57% increase in population.

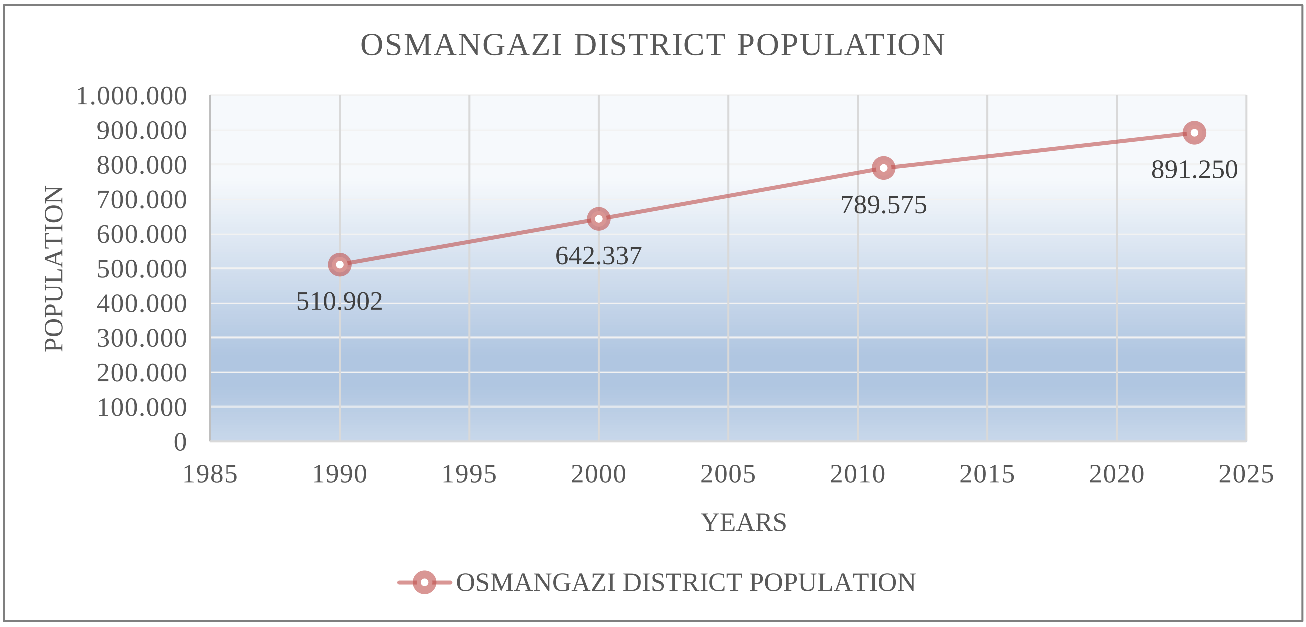


**Figure 3.** Population change graph of Osamangazi distict over the years (TUIK-2023).

In his study on migration, Küçükdağ (2023) revealed that mass migration does not only cause urbanisation problems, but also has intense effects on the awareness of urbanisation that requires adaptation to the city, and also emphasized that mass migration to the city brings along some environmental problems such as air, water, environmental pollution, traffic and noise.

In the study, it is clear that one of the important factors of the changes in the historical city area is the transformation of green areas into residential areas due to sudden and intense population growth.

### *3.2.* i-Tree Canopy Area Cover Class

In the study using i-Tree software, a total of 348 points were assigned to grass/harbecus and tree/shrub classes in 1997 from 600 randomly assigned points in an area of 4.02 $km^2$ including the Ulu Mosque and its surroundings, which is included in the UNESCO cultural heritage list in Osmangazi district. Grass/harbecus and tree/shrub classes were calculated to cover 58% of the whole area in 1997 with a standard error of 2.83% and this area corresponds to approximately 2.23 $km^2$.

In 2011, a total of 243 points were assigned to grass/harbecus and tree/shrub classes. Grass/harbecus and tree/shrub classes accounted for 40.5% of the whole area in 2011 and were calculated to be approximately 1.63 $km^2$ with a tolerance of 2.64%.

Finally, a total of 206 points were assigned to grass/harbecus and tree/shrub classes in 2023. Grass/harbecus and tree/shrub classes were calculated as 34.34% of the whole area for 2023, approximately 1.38 $km^2$ with a margin of error of 2.5%.

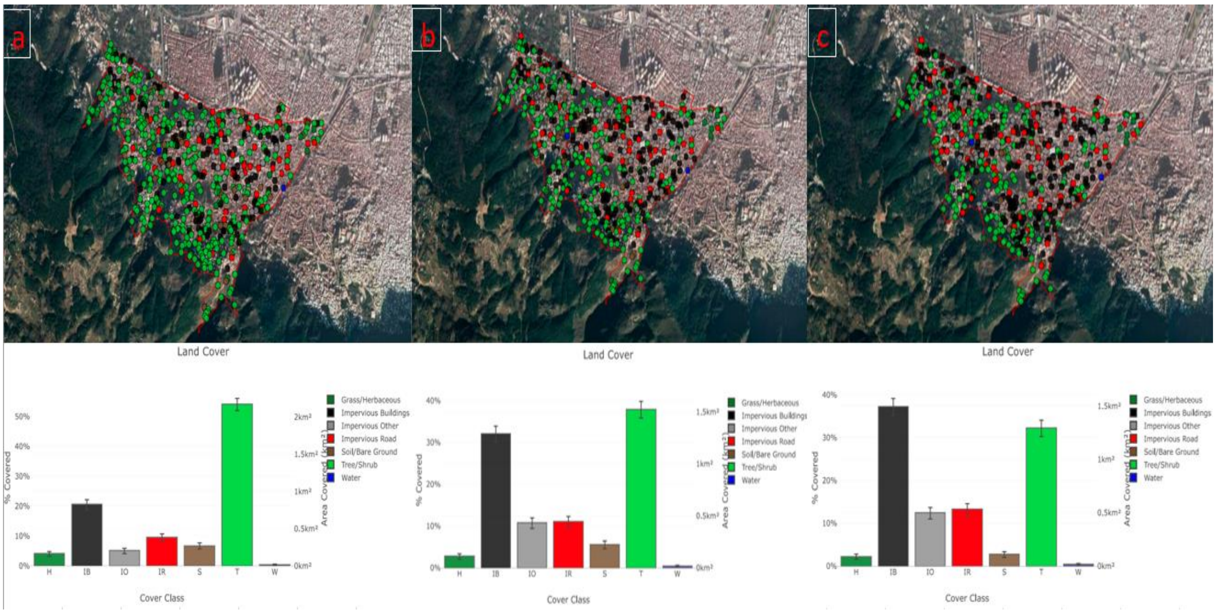


**Figure 4.** Change of cover classes according to years in i-Tree Canopy (a: 1997, b: 2011, c: 2023).

### *3.3.* Impact of Air Pollutant

The increase in population in urban centres has caused a decrease in urban forests over the years, so the removal of harmful gases (CO, $NO_2$) and particulate matter (PM2.5 and PM10) that reduce air quality in urban centres has been calculated through i-Tree Canopy. These gases and particles can be generated by natural factors such as volcanoes, forest fires, storms, etc., as well as anthropogenic sources such as industrial activities, burning of fossil fuels, biomass burning, vehicle emissions, agriculture, construction and mining activities (Öztürk, 2023). Tor (2023) stated in his study that many studies have mentioned the relationship between PM2.5 and PM10 exposure and lung cancer risk and cardiovascular diseases, the relationship between $NO_2$ lung and breast cancer and that these substances cause respiratory diseases. Yaşlı et al. (2023) stated that there is concrete evidence that trees, urban green spaces and wider green infrastructure can provide significant reductions in urban temperatures and prevent health problems caused by heat waves. Many studies emphasize the role of tall shrubs, urban trees and urban forests in reducing carbon emissions, carbon capture and storage in urban areas (Goodale et al., 2002; Ersoy Tonyaloğlu et al., 2021; Öztekin Kara, 2022).

In the study conducted around Ulu Camii and its surroundings, Figure 5 shows the annual removal of CO, $NO_2$ and PM values affecting the air quality depending on the change of green areas. Accordingly, the amount of CO removed in 1997 was 274.93 kg with a standard error of 10.36 kg, the amount of $NO_2$ was 1518.82 kg with a standard error of 57.23 kg, and the amount of PM was 3926.27 kg with a standard error of 148.05 kg; compared to 1997, the amount of CO removed in 2011 was 82.31 kg (192.62 kg with a standard error of 10.08 kg), $NO_2$ amount 454.71 kg (1064.11 kg with a standard error of 55.69 kg), PM amount 1173.37 kg (2752.92 kg with a standard error of 144.07 kg). When 2023 i-Tree Canopy data was compared with 1997, it was observed that the amount of CO removed decreased by 111.16 kg (163.77 kg with a standard error of 9.71 kg), $NO_2$ decreased by 614.09 kg (904.73 kg with a standard error of 53.64 kg), and PM decreased by 1585.68 kg (2340.59 kg with a standard error of 138.76 kg).

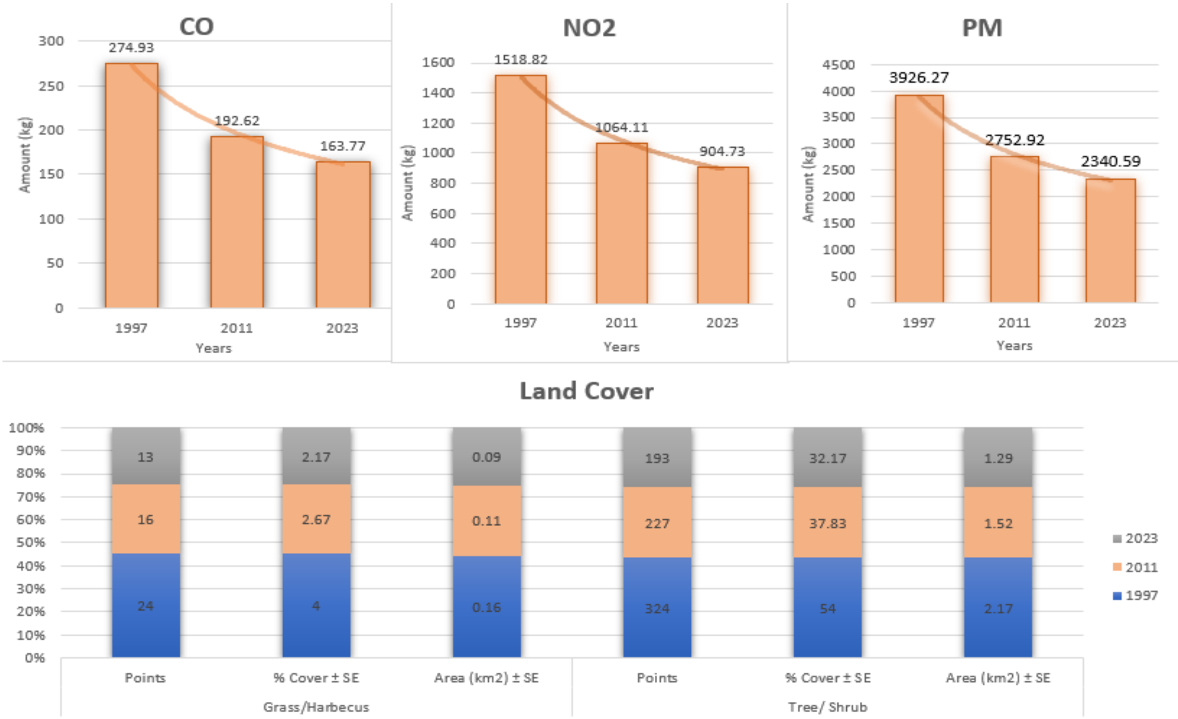


**Figure 5.** Graph of change in CO, $NO_2$, PM and green cover of Osmangazi district by years.

**Table 1.** 2023 Comparison of annual pollutant concentrations in Osmangazi District with Türkiye, European Union (EU) and World Health Organisation (WHO) limit values.

| (µg/m³) | Average | Max. Value | Average Annual Production | Türkiye | European Union | World Health Organization |
|---|---|---|---|---|---|---|
| **$PM_{10}$** | 43.34 | 300.47 | 520.08 | 40.00 | 40.00 | 20.00 |
| **$PM_{2.5}$** | 26.50 | 256.70 | 318.00 | - | 25.00 | 10.00 |
| **$NO_2$** | 30.91 | 163.01 | 370.92 | 40.00 | 40.00 | 40.00 |
| **CO** | - | - | - | 10.00 | 10.00 | 4.00 |

(Source: Air Quality Assessment and Management Regulation)

In Table 1, annual average pollutant concentrations in Osmangazi district were compared for Türkiye, EU and WHO limit values and PM10 and PM2.5 pollutants were found to be higher than the upper limit set by all three. These values are more than twice the WHO health organisation limit. $NO_2$ was below the averages given by Türkiye, EU and WHO. No measurement was made for CO.

**Table 2.** Air pollution value estimation of Osmangazi district by years.

| **Tree Benefit Estimates: Air Pollution (Value (USD))** | | | |
|---|---|---|---|
| | **1997** | **2011** | **2023** |
| **Description** | **Value (USD) ± SE** | **Value (USD) ± SE** | **Value (USD) ± SE** |
| Carbon Monoxide (CO) removed annually | $404 ± 15 | $283 ± 15 | $241 ± 14 |
| Nitrogen Dioxide ($NO_2$) removed annually | $732 ± 28 | $513 ± 27 | $436 ± 26 |
| Particulate Metter (PM) removed annually | $9.3345 ± 3.517 | $65.399 ± 3.423 | $55.604 ± 3.297 |
| **TOTAL** | **$94.481 ± 3.560** | **$66.195 ± 3.465** | **$56.281 ± 3.337** |

i-Tree Canopy has calculated a financial value according to the years studied in Table 2 in air pollution forecasts. According to this calculation, while the total amount of CO, $NO_2$ and PM removed annually for 1997 was 5720.02 ± 214.64 kg, the financial contribution value to our country was $94481 ± 3560; for 2011, 4009.65 ± 209.84 kg and the financial value it provided to our country ($66195 ± 3465) constituted a loss of $121 compared to 1997, while in 2023, the annual amounts removed were 3409.09 ± 202.11 kg and a financial loss of $37741 was revealed in the financial value ($56281 ± 3337) compared to 1997 data.

## 4. Conclusion

The study shows that the population of the Ulu Camii and the surrounding historic area has increased by 57% from the 1990s to the present day, and this increase has been accompanied by unplanned urbanisation. i-Tree Canopy land classification shows that the tree/shrub and grass/herbaceous plant classes, which covered 58% of the study area in 1997, decreased to 40.5% in 2011 and to 34.34% today. This situation has shown that green areas have been replaced by impervious buildings, roads and other impervious areas.

Due to the increase in population, the number of buildings and roads, the increase in the use of vehicles, the increase in the number of industrial zones have negatively affected the density of urban forests and green areas. Accordingly, in the years we have been working on Osmangazi district, the annual removal data of CO, $NO_2$ and PM from air pollutants in urban landscapes in Figure 5 and their environmental material values in Table 2 have been observed to be in a decreasing trend.

For all these reasons, in order to increase air quality within the scope of smart urbanism in Osmangazi district of Bursa city;

1. Campaigns and encouragements should be made to increase public awareness about the benefits of green areas,

2. The existing green areas should be protected by giving importance to their maintenance; afforestation works should be carried out around the roadside, refuges and industrial facilities,

3. Recreation areas should be combined with multifunctional areas such as recreation areas, children's playgrounds, sports areas and cultural performance areas,

4. Utilise technology and monitoring systems to monitor air quality, pedestrian traffic and maintenance needs of green spaces,

5. Bursa, which is an automotive city, should be encouraged to use today's technology electric vehicles, the use of renewable energy (solar, wind, geothermal energy) sources should be expanded, the integration of the arrangements of the infrastructure of industrial facilities such as drilling wells, the use of chimney filters, the use of underground resources, the establishment of treatment facilities should be integrated into smart technologies,

6. Be flexible in adapting green development strategies to changing urban and social dynamics, using continuous monitoring data and feedback from the community as a basis for measuring the relevance and success of initiatives,

7. Changes in vegetation cover, changes in air quality and their effects on tourism and the quality of life of the inhabitants should be regularly monitored and evaluated,

8. Distribution maps of existing green areas should be created, deficient areas should be identified and potential green areas should be planned together with local administrations.

With the implementation of these recommendations, the green areas of the historical centre of Bursa, which is a cultural heritage city, will be better planned within the scope of sustainability principles. In this way, both the historical texture of the city centre can be preserved and sustainable urban environments that will benefit the city residents and visitors can be created.

## Conflict of Interest

The authors declare that they have no conflict of interest.

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RESEARCH ARTICLE

# Stand Analysis and Distribution Areas of European Aspen (*Populus tremula* L.) Forests in Türkiye

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**ABSTRACT**

The aim of the study is to analyze the studies that have been done and need to be done on the general characteristics, distribution areas, and silviculture of European aspen stands naturally distributed in Türkiye. In the study, data obtained from the General Directorate of Forestry, Department of Forest Administration, and Planning for the year 2019 was used as the material. With these data, the spatial extent of European aspen stands in Türkiye was determined. Based on the obtained data, pure stands of European aspen, primarily in the regions where they have the most extensive spatial distribution, were examined on-site. Additionally, by evaluating the planning data in comparison with the current situation, European aspen stands were analyzed from a silvicultural perspective. The study determined that the total extent of European aspen forests in Türkiye is 278,013.7 hectares. Of the European aspen stands in Türkiye, 40.4% are in Elazığ, 17.3% in Erzurum, 15.7% in Trabzon, 11.4% in Kayseri, and 7.5% in Giresun Regional Directorates of Forestry. Furthermore, 92.3% of European aspen stands are located within these five regional directorates. Moreover, in Türkiye, 34,916.6 hectares of pure aspen stands and 13,745.6 hectares of stands dominated by aspen exhibit degraded qualities. Depending on the developmental stages, the largest spatial distribution in both pure stands (8,886.3 ha) and stands dominated by aspen (6,071.3 ha) has been identified in the ab developmental stages. When examining the developmental stages of European aspen in Türkiye, it's generally observed that young European aspen stands prevail. The management objective of same-aged pure and mixed aspen forests should be redefined according to both the succession stages and habitat conditions. In stands with ecological functions, protection and moderate interventions must be made, and in stands with production functions, necessary tending interventions must be made on time and sustainability must be ensured.

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## 1. Introduction

In Turkish forestry, the European aspen species is known to be one of the pioneering tree species, and therefore, there is a lack of silvicultural studies both in scientific research and technical applications. Indeed, according to recent data on plans, the increasing distribution areas of aspen species in both pure and mixed stands, along with the functions they undertake, are remarkable. Especially in extreme regions, its ability to form pure or mixed stands is important not only as a pioneering species but also due to its diverse functions (economic, ecological, and socio-cultural). Emerging as a crucial tree species that comes to the rescue of ecosystems in forest gaps, abandoned agricultural lands, and areas of forests disrupted by biotic and abiotic damages. Indeed, the European aspen species, through anthropogenic impacts, reaches areas devoid of vegetation (such as clear-cutting, fire, pests, fungi, etc.), often establishing temporary, sometimes permanent stands and preparing suitable climate and soil conditions for succeeding tree species while contributing to a wide range of ecological

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functions. Due to the species being considered a pioneer and secondary species in Turkish forestry, there hasn't been much research conducted by both the forestry organization and universities and research institutions on this species until now. However, Saatçioğlu (1976) included the European aspen species under the heading "High Economic Value Mass Tree Species (Primary Species)" in his book "Biological Foundations and Principles of Silviculture" stating that the European aspen is a considerably large tree in Türkiye, regarded as one of the primary tree species.

European aspen (*Populus tremula* L.) is a species belonging to the genus *Populus* in the Salicaceae family of the order Salicales within Angiosperms, divided into five main sections. The European aspen is situated within the Trepidae sub-section of the Leuce section (Kayacık, 1981; Jobling, 1990). The European aspen forests, with a wide distribution, especially in the Northern Hemisphere encompassing Europe and Asia, are naturally found throughout Europe as a whole, North Africa, Central and Northern Asia, Siberia, Northern Korea, Northern Japan, Türkiye, and the Caucasus (Yaltırık, 1993). Therefore, this species is naturally distributed across a vast geography, both globally and within Türkiye. The extensive natural range of the species is a consequence of its ability to adapt to extreme environmental conditions.

In Türkiye, it is noted that the species thrives exceptionally well in Western Thrace, Western Anatolia, and the Black Sea region. It's found individually, in clumps, or in groups across all forest regions except for the Southeast and the steppe regions of Central Anatolia. Particularly, it occupies areas along streams, rivers, and within forest clearings (Saatçioğlu, 1976; Yaltırık, 1993). Although literature on the species' distribution areas in Türkiye often states its absence in the Southeast and the steppe regions of Central Anatolia, natural occurrences have been identified through field surveys and incorporated into management plans in regions such as Kayseri, Sivas, Bitlis, Bingöl, Van, Siirt, and Hakkari within the Inner and Eastern Anatolian territories, where it forms extensive stands. This situation has been reported in studies conducted by Atalay (2019), Atalay et al. (2021), Turna et al. (2021), and Turna and Atar (2022). Özel et al. (2018), in a study conducted in the Erzurum-Pasinler region, found that aspen trees in this region are the second closest tree species to the tree line after Scots pine, which are found in the subalpine and war zones. In addition, as a result of this study, it has been found out that this species, notwithstanding its natural area of occupancy across Türkiye, could thrive up to 2,460 m in altitude and extent of occurrence.

Although the forest management plans provide the extent of areas where European aspen forests naturally occur, there's an inadequacy in terms of information regarding the management methods, stand characteristics and silvicultural treatments. It's evident from current forest management plans that European aspen forests are increasingly spreading over considerably vast areas compared to previous plans. Nevertheless, field personnel from the General Directorate of Forestry have indicated the existence of European aspen stands that are yet to be reflected in the plans. Technical field surveys and observations conducted by us have revealed the presence of European aspen forests that are not recorded in the forest management plans. Indeed, in a study conducted by Turna et al. (2021), it was found that despite the absence of European aspen areas in the forest management plans of the Horasan Forestry Directorate, the renewed plan in 2021 identified 9,541.4 hectares of forest area designated for aspen management. The aim of this study is to analyze the general characteristics, extent of distribution, and silviculture of naturally occurring European aspen stands in Türkiye, as well as to assess the studies conducted and the necessary research that needs to be undertaken in this field.

## 2. Materials and Methods

In the study, the data obtained from the General Directorate of Forestry, Department of Forest Administration, and Planning for the year 2019 was used as the material. These data were utilized to determine the spatial extent of pure and mixed European aspen stands in Türkiye. The forest stands types, developmental stages (Table 1), and status of pure and mixed stands related to silvicultural interventions were evaluated concerning the Regional Forest Directorates (RFDs). Consequently, based on the data acquired, on-site examinations of European aspen stands, particularly the pure stands in the Regional Directorates with the highest spatial distribution of European aspen stands, were conducted. Additionally, plan data was assessed in comparison with the current status to analyze aspen stands from a silvicultural perspective. Throughout this process, the growing conditions of aspen forests were considered, and recommendations were provided regarding silvicultural intervention methods based on stand establishment characteristics.

**Table 1.** Classification of developmental stages.

| Developmental stages | Criteria (average diameter at breast height) |
|---|---|
| a (regenerated) | <8.0 cm |
| b (young) | 8.0 – 19.9 cm |
| c (mature) | 20.0 – 35.9 cm |
| d (over-mature) | >36.0 cm |

## 3. Results and Discussion

### *3.1.* The Distribution Area of European Aspen Stands

The spatial distribution of European aspen stands in Türkiye based on 2019 data concerning pure aspen stands, stands dominated by aspen, and mixed stands involving aspen with other species is presented in Table 2.

**Table 2.** The distribution area of European aspen stands (2019).

| Sequence No | Regional Forest Directorates | Pure Aspen (ha) | Aspen + Other (ha) | Other + Aspen (ha) | Total (ha) |
|---|---|---|---|---|---|
| 1 | **Amasya** | 1205.8 | 443.7 | 1176.0 | 2825.5 |
| 2 | **Ankara** | 2593.4 | 617.4 | 5220.9 | 8431.7 |
| 3 | **Artvin** | 436.0 | 0.0 | 13.8 | 449.8 |
| 4 | **Balıkesir** | 0.0 | 0.0 | 4.1 | 4.1 |
| 5 | **Bursa** | 94.2 | 0.0 | 223.0 | 317.2 |
| 6 | **Çanakkale** | 236.0 | 0.0 | 45.2 | 281.2 |
| 7 | **Denizli** | 25.3 | 0.0 | 152.9 | 178.2 |
| 8 | **Elazığ** | 13010.2 | 5983.0 | 93149.8 | 112243.0 |
| 9 | **Erzurum** | 21360.8 | 10147.8 | 16475.8 | 47984.5 |
| 10 | **Eskişehir** | 3.0 | 0.0 | 882.2 | 885.2 |
| 11 | **Giresun** | 5227.1 | 2752.7 | 12911.7 | 20891.5 |
| 12 | **Isparta** | 12.7 | 0.0 | 0.0 | 12.7 |
| 13 | **İstanbul** | 693.2 | 443.8 | 406.2 | 1541.2 |
| 14 | **İzmir** | 3.6 | 0.0 | 0.0 | 3.6 |
| 15 | **Kahramanmaraş** | 103.2 | 0.0 | 0.0 | 103.2 |
| 16 | **Kastamonu** | 372.9 | 390.8 | 3191.6 | 3953.3 |
| 17 | **Kayseri** | 5945.1 | 5991.6 | 19826.3 | 31763.0 |
| 18 | **Konya** | 9.9 | 83.9 | 44.4 | 138.2 |
| 19 | **Kütahya** | 92.6 | 183.2 | 1737.7 | 2013.5 |
| 20 | **Muğla** | 0.0 | 12.3 | 172.6 | 184.9 |
| 21 | **Sakarya** | 62.3 | 51.2 | 140.4 | 253.9 |
| 22 | **Trabzon** | 6975.1 | 5106.4 | 31657.7 | 43739.2 |
| 23 | **Zonguldak** | 0.0 | 5.4 | 90.9 | 96.3 |
| **Total** | | | | | 278013.7 |

European aspen forests in Türkiye cover a total area of 278,013.7 hectares (Table 2). According to the 'National Poplar Commission Country Development Report 2016-2019' prepared by Velioğlu et al. (2020), they are found across approximately 287,005.5 hectares, with 152,408.8 hectares classified as productive stands, while the remaining 134,596.7 hectares are reported to be degraded stands. Additionally, the wood production volume in European aspen forests for the year 2019 is stated to be 132,134 $m^3$. In Türkiye, European aspen forests, either in pure or mixed stands, are present within 23 out of 30 Regional Directorates of Forestry. In this study, the five Regional Directorates with the highest distribution of European aspen stands within these 23 Regional Directorates were evaluated from a silvicultural perspective. The ranking of spatial distribution by Regional Directorates is as follows: Elazığ (112,243.0 ha), Erzurum (47,984.5 ha), Trabzon (43,739.0 ha), Kayseri (31,763.0 ha), and Giresun (20,891.5 ha) RFDs. Accordingly, in Türkiye, 40.4% of European aspen forests are located in Elazığ, 17.3% in Erzurum, 15.7% in Trabzon, 11.4% in Kayseri, and 7.5% in Giresun RFDs. Furthermore, 92.3% of European aspen stands are found within these five Regional Directorates (Figure 1).

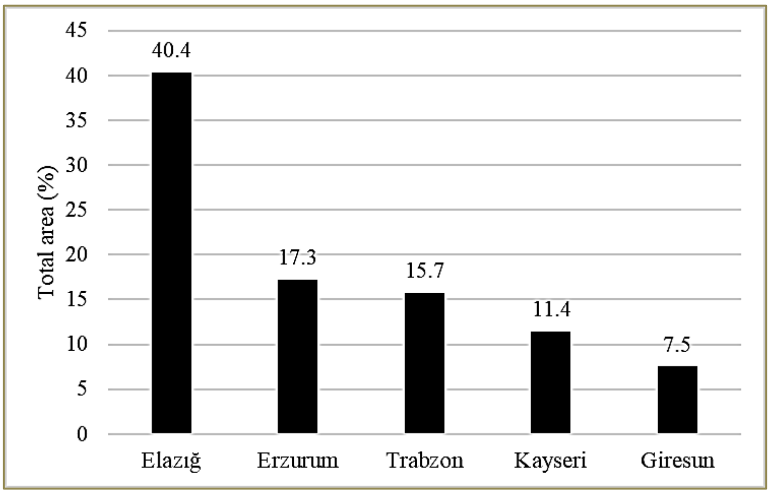



**Figure 1.** The area of European aspen stands in the top five regional directorates with the largest spread area.

The distribution of pure European aspen stands is as follows: Erzurum (21,360.8 ha), Elazığ (13,010 ha), Trabzon (6,975.1 ha), Kayseri (5,945.1 ha), and Giresun (5,227.1 ha). Stands where European aspen is mixed should be considered separately, categorizing them as either European aspen-dominated or dominated by other species (such as oak, Scots pine, black pine, etc.). Silvicultural interventions in mixed stands dominated by other species and those in stands dominated by European aspen may vary, indicating the need for distinct approaches. Especially considering the mixture ratio and form of stands, it is necessary to determine whether European aspen exhibits a pioneer species characteristic. For instance, in mixed stands where oak or Scots pine dominates, aspen may gradually retreat from the area. However, in mixed stands dominated by aspen (especially aspen+oak mixtures), aspen can entirely take over the dominant position over time. Accordingly, the spread area of mixed stands dominated by aspen is listed as Erzurum (10,147.8 ha), Kayseri (5,991.6 ha), Elazığ (5,983.0 ha), Trabzon (5,106.4 ha), and Giresun (2,752.7 ha). When considering the spread area of both pure and aspen-dominated stands, the importance of the species becomes evident (Figure 2).

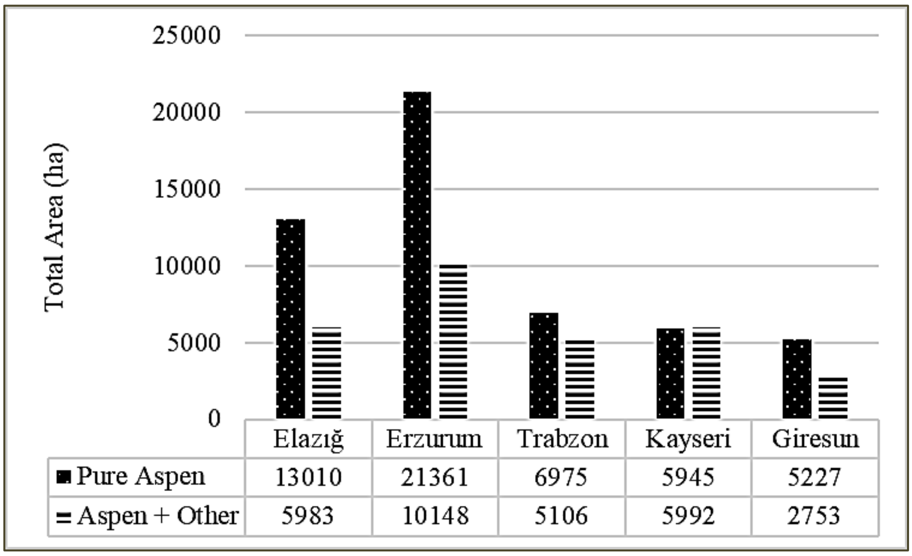



**Figure 2.** The top five regional directorates with the highest spread area of pure aspen and aspen-dominated stands.

Elazığ RFDs, ranking first in total area, naturally comprises extensive areas of European aspen, both in pure stands and mixed stands, due to its vast geographic expanse. Similarly, a significant portion of the aspen areas in the region (88.4%) are mixed with oak, while the remaining 11.6% consist of pure stands. The area covered by oak+aspen mixed stands is 92,969.2 hectares, while the area covered by aspen+oak mixed stands is 5,500.1 hectares. Both pure and mixed stands predominantly belong to the young and mature developmental stages in terms of developmental stages. Overall, 54.4% of aspen stands in the region are degraded, while 45.6% have a normal structure. Additionally, it has been noted that both pure and mixed stands are distributed not as contiguous units (e.g., 5-10-20 hectares) but rather as smaller areas (1-2 hectares). Furthermore, due to the region's topographic and other characteristics, it seems less conducive for comprehensive studies.

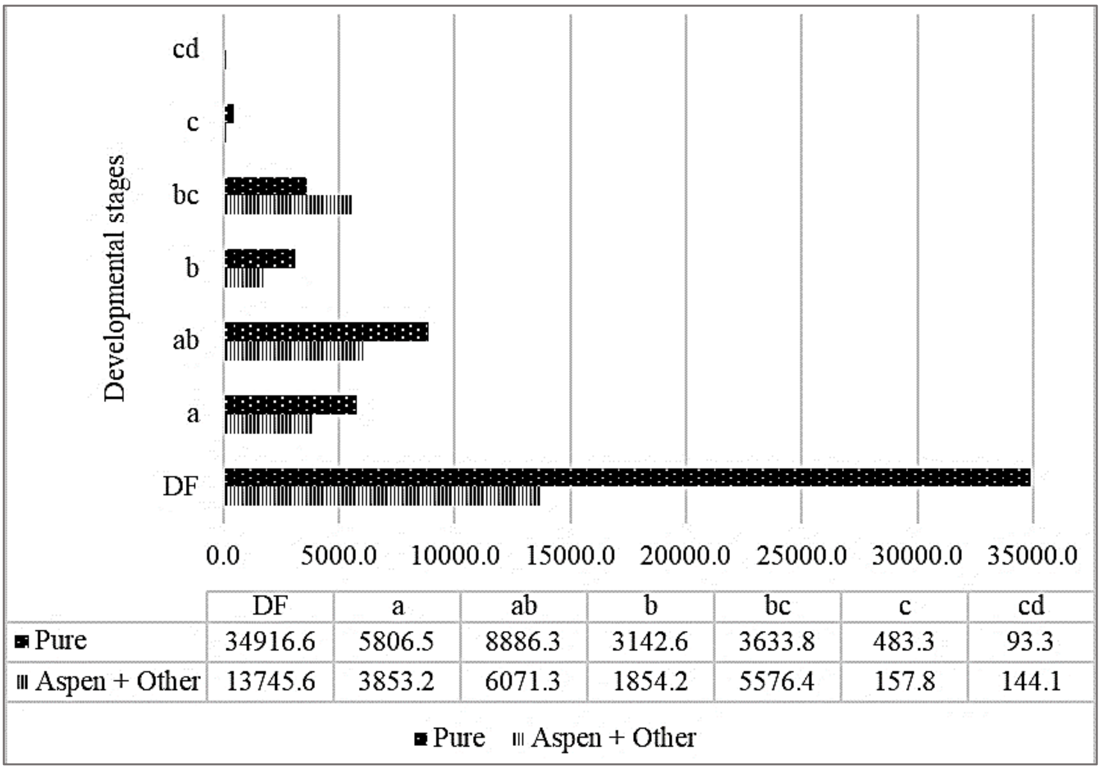
The Erzurum RFDs, ranking second in terms of spread area, comprise 45% (20,798.3 ha) of pure aspen stands, with 22.3% (4,637.5 ha) of this being in the first thinning stage. A significant portion of mixed stands dominated by aspen includes aspen+other deciduous species. Additionally, stands with aspen+oak and aspen+Scots pine are also quite prevalent. Despite Erzurum RFDs being known for Scots pine forests, the spread area of Scots pine+aspen stands is only 2,180.3 hectares. When examining the stand structure of aspen forests throughout the regional directorate, 78.2% (36,194.3 ha) are found to have degraded, while 21.8% (10,102.6 ha) exhibit normal structure. This emphasizes the significance of managing productive aspen forests from a silvicultural perspective. During the examinations conducted in aspen forests, it was found that in the current state, aspen+oak mixtures generally appear as pure stands of European aspen, with oak being beneath the crown closure of aspen during its youth stage. Evaluating the tree species involved in the mix, it's evident that the region is dominated by climax species like oak and Scots pine. Additionally, in the Ardahan Posof region, increasing instances were noted where aspen mixed with other deciduous species, along with findings showing mixtures with oriental spruce during on-site examinations.

In Trabzon RFDs, encompassing a spread area of 43,739 hectares for aspen, 66% of this species lies within Gümüşhane and 44% within the boundaries of the Torul Forest Management Directorate. Among the European aspen stands in the region, 16% are pure stands, while 12% exhibit aspen dominance in mixed stands. Areas where aspen mixes with other species like

Scots pine, oak, and oriental spruce constitute 72% of the total. According to the planning data, it's understood that 69.2% of the existing areas have a normal structure.

In Kayseri RFDs, the 31,763 hectares of aspen stands are in 15,467.7 hectares (49%) degraded and 16,295.3 hectares (51%) normal structure. Pure stands dominate within the Kayseri and Sivas Forest Management Directorate boundaries. In the foothills of Mount Erciyes, since 2019, thinning interventions have been conducted annually, and wood has been produced. The 20,891.5 hectares of aspen forests located in Giresun RFDs are situated in the regions of Şebinkarahisar, Suşehri, and Koyulhisar. 85% of the existing aspen forests are of normal structure, while 15% are degraded. In mixed forests, the dominant species are Scots pine+aspen and oak+aspen.

The spatial distribution of stands dominated by pure and European aspen in Türkiye, according to their developmental stages, is illustrated in Figure 3. Accordingly, 34,916.6 hectares of pure European aspen stands and 13,745.6 hectares of stands dominated by European aspen are of degraded structure. Based on their developmental stages, the highest spatial distribution in both pure (8,886.3 ha) and European aspen-dominated (6,071.3 ha) stands is identified in the ab stage.




| | DF | a | ab | b | bc | c | cd |
|---|---|---|---|---|---|---|---|
| Pure | 34916.6 | 5806.5 | 8886.3 | 3142.6 | 3633.8 | 483.3 | 93.3 |
| Aspen + Other | 13745.6 | 3853.2 | 6071.3 | 1854.2 | 5576.4 | 157.8 | 144.1 |

**Figure 3.** Distribution area (ha) of pure and aspen-dominated stands in Türkiye based on their developmental stages (DF: Degraded forest).

### *3.2.* Ecological Features

**Climate:** When examining the climatic characteristics of European aspen in their natural habitats worldwide, including Türkiye, they are found to thrive in areas ranging from humid and oceanic climates to moist cold continental regions. Therefore, the species extends its distribution towards humid-cold areas in Eurasia and North America, reaching as far as the northern polar circle. Accordingly, in terms of climate requirements, it is not a highly selective species. It prefers temperate and cool climates while being adaptable to various climatic conditions. The European aspen is modest in its requirements for both rainfall and temperature, exhibiting resilience against frost. It holds significant importance in high-mountain forestry (Atalay, 2019; Velioğlu et al., 2023). Atalay (2019) mentions that in Türkiye, European aspen demonstrates a wide distribution from semi-arid to semi-humid continental, humid temperate, and moist to semi-moist cold climates, where relative humidity ranges between 60 and 70% and annual average rainfall exceeds 450 mm up to over 1000 mm. There's a linear relationship between days covered with snow and the optimal distribution of European aspen. It's been observed that European aspen proliferates and site increase in locations with over 100 days of snow cover. Velioğlu et al. (2023) report an annual average rainfall of 604 mm in the European aspen areas of Mount Erciyes. In the areas where European aspen spreads, the annual average temperature ranges between -30 °C and 12 °C. However, in optimal distribution areas, these values range between 8 °C and 30 °C (Atalay, 2019). Accordingly, it appears that European aspen forests are not resistant to high temperatures; rather, they thrive in locations with cold winters and cool summers. Indeed, examinations and observations conducted in its natural habitats indicate its ability to thrive in almost every climate type. It has low temperature requirements and is resilient against frost.

**Soil:** European aspens spread on soils that belong to zonal, azonal, and intrazonal groups, especially on soils resembling andosols found on basalt-andesites and high mountain-meadow soils (Atalay, 2019). It favors soils that are fresh, permeable, and have good drainage, showing a preference for sandy loam and loamy soils while disliking very dry and heavy clay soils. It also spreads over rocky slopes with substantial physiological depth, gravelly slopes, and loose rockslides. Atalay et al. (2021) indicated that in the vicinity of Mount Erciyes, the pH values of the soil and parent materials range between 6.14-6.44, the lime content varies from 1.15% to 26.47%, and the organic matter content ranges from 0.2% to 4.8%. These values suggest that European aspen forests are not highly selective in terms of soil properties. Indeed, research conducted by Meier et al. (2012) in the Alps concluded that soil properties do not significantly impact the natural distribution of European aspen, as it can thrive in almost any soil type.

**Topographic Features:** The elevation, aspect, slope, and hillside shapes are influential in the distribution and stand structure of the species. Throughout Türkiye, the natural habitats of the species are found in various aspect groups and at different elevation levels. The European aspen extends from sea level to the upper limit of the forest, but its main distribution occurs above 1800 meters.

In the Black Sea region, it ranges from 30-50 meters above sea level to as high as 2000 meters. Due to the humid climate in these areas, the distribution appears as individual-tree mixture or group rather than in stands. Beyond the Black Sea region and in the Inner Anatolia, the lower limit for forest stands is generally around 1100-1400 meters, particularly around Mount Erciyes, Gümüşhane, Elazığ, and Sivas. European aspen forests have been observed at elevations of 2537 meters in Mount Yıldız, Sivas. Throughout Türkiye, it reaches up to the upper forest limit. Depending on geographical regions, it extends from 2000-2600 meters on Mount Erciyes to 2400-2500 meters in the Northeast Anatolia region (Turna & Atar, 2019; 2022). Additionally, Velioğlu et al. (2020) report that the European aspen species in Türkiye exists within the natural forests within the altitude range of 0-2900 meters, sometimes appearing as pure forest stands, but primarily as groups or individual trees, often as the initial form of forest communities.

It is understood that the European aspen spreads across nearly all aspect groups in terms of individual-tree or stand structure. Especially in shaded aspect groups, it establishes higher-quality stands; however, both pure and mixed stands are found across all aspect groups. As water availability increases, the best stands are typically found on north, west, south, and east-facing aspects. According to Bilgili (2007), a yield study conducted in the Erzurum and Şebinkarahisar regions indicated that among European aspen stands, 33% were on the northern, 28% on the eastern, 26% on the southern, and 13% on the western aspects. Additionally, Dinca and Vechiu (2020) reported that in their study, 32% were southeast, 26% northeast, 13% west, 14% north, and 14% east-facing aspects.

The European aspen is a light-demanding species with no tolerance for shade. Its youth cannot develop under its own crown closure (Turna & Atar, 2022). These characteristics are crucial in silvicultural interventions. Indeed, one of the reasons for the European aspen's natural growth in forest gaps, disturbed or vacant areas, and abandoned agricultural fields is this requirement. When evaluating the natural distribution areas of the European aspen in Türkiye, it has been observed that it forms stands across all slope categories. Particularly in the natural pure European aspen stands within the boundaries of Giresun, Trabzon, Erzurum, and Kayseri RFDs, our examinations and observations revealed its growth in areas with higher slopes that are less accessible. Additionally, it has been determined that it establishes pure, clump, or group stands in low-slope areas such as abandoned agricultural lands.

### *3.3.* Stand Structures and Silvicultural Technique

The characteristics of stand structure are important indicators in making decisions regarding silvicultural interventions. Based on various site inspections conducted by us at different times, along with the existing forest management plan data, it has been observed that European aspen forests exhibit development under significantly different ecological conditions.

The seeds of European aspen are capable of being dispersed over extensive distances via wind and subsequently germinating in favorable habitats. Particularly in areas left bare due to various causes such as deforestation, wildfires, abandoned agricultural lands, or rocky terrain unsuitable for other plant species, the germination of European aspen seeds leads to the emergence of distinct young populations. Subsequently, owing to robust root suckers production, European aspen gradually proliferates, forming clumps, groups, and extensive stands of trees (Figure 4). The area covered, supported by interconnected root suckers, varies between 500 and 1200 square meters, contingent upon ecological circumstances. The merging of young populations arising from shared root suckers results in the formation of groups or extensive stands constituting European aspen stands.

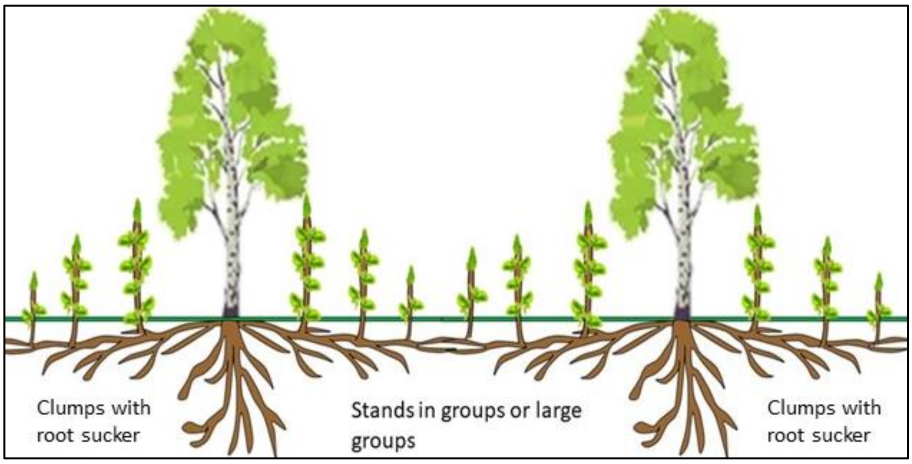



**Figure 4.** Clumps or groups of European aspen originating from root suckers.

When considering the development of European aspen stands in Türkiye, it's understood that they initially expand through seeds (generative) and then continue to grow through vegetative means (root suckers). Due to the formation of European aspen stands through both seed and root sucker-originated individuals, in terms of silviculture techniques, they can be defined as coppice with standards. However, considering the wood preferred for use in industry, they can be classified as high forests. Indeed, in the natural forests situated in both shaded and sunny exposures around Mount Erciyes, investigations conducted by Turna and Atar (2022) determined that aspen seeds, falling among the rocky patches on the slopes, germinate and spread by producing root suckers within the fissured and cracked soil structure containing sand, silt, and fine gravel. These areas, as indicated in numerous literature sources, are not a result of anthropogenic effects (such as the removal of climax species like oak or Scots pine from the area). Instead, they are naturally occurring forests that have been abandoned or have grown due to a decrease in livestock and agricultural activities. This situation leads aspen forests to initially start as small clumps or groups in pure form and later transition into mixed stands with some elements of the natural flora blending in. For instance, the majority of aspen forests on Mount Erciyes in Kayseri consist of pure stands, while in regions like Erzurum and Gümüşhane, some are pure and others are mixed stands.

When examining the developmental stages of stands, in the same area, stands in stages a, b, and c are observed, appearing in clumps, groups, and larger groups. European aspen forests, which have a high demand for light, form single-storied as crown closure occurs. As one moves away from the central focal point, stands in stages c, b, and a are encountered. Therefore, the age of the forest, whether individual, clumped, or grouped, varies based on the location within the area, ranging from 1 to 170 years, and after 40-50 years, they are susceptible to internal decay. Hence, for forests intended for production, the rotation age could be related to operational goals but is recommended to be between 40 and 50 years old due to the onset of internal decay.

In European aspen stands, the storied structure varies depending on whether they are pure or mixed stands. For instance, in pure European aspen forests or those mixed with light-demanding tree species like aspen + oak or aspen + Scots pine, a single-storied is observed. However, in mixtures such as aspen + fir or aspen + spruce, rare instances of multi-storied can be seen. Crown closure generally exhibits horizontal density, encompassing various levels such as dense, regular, loose, and open. European aspen, naturally distributed across a wide geographical area in Türkiye, naturally blends with a diverse range of tree species. Therefore, apart from the mixture type, determining the storied structure and crown closure according to local conditions is crucial during silvicultural decision-making. Dinca and Vechiu (2020) conducted a study in European aspen forests in the Carpathian Mountains of Romania, where they found that 47% were individual, 48% were in clumps, and 5% were in groups in terms of mixture type.

European aspen develops a taproot in its youth. During later developmental stages, it develops a permanent root system. Moreover, due to the species developing very strong and long lateral roots, it is not heavily affected by storms in its natural distribution areas. Its ability to produce strong root suckers and being a thrifty species is important for soil conservation and ecosystem improvement. The lateral root spread is more directed towards open areas. Gifford (1966) mentions that the horizontal root spread of *Populus tremuloides* can exceed 30 meters, while the vertical distance reaches 2.7 meters, and the species has a very dense network of fine roots.

Planned forestry requires that any silvicultural interventions in a forest stand be applied according to silvicultural plans in harmony with forest management plans. Therefore, in European aspen stands, where a significant portion is designated for high mountain ecosystem function and another part is allocated for soil and nature conservation within the forest management plans, it is crucial to meticulously examine them, especially pure stands. The management objective should be determined accordingly.

In order to determine silvicultural interventions to be applied in European aspen forests, it is crucial to have a good understanding of the species' stand structures, management objectives, yield tables (determining relationships between site productivity and growth for identifying optimal stand structures), and the biology of the species. Apart from the general ecological and stand structure characteristics mentioned above, the functions of European aspen stands should be identified to commence silvicultural interventions accordingly. It's important to note that silvicultural interventions should be determined based on the succession stages of the species and, particularly, the growing conditions of the environment, ensuring interventions are aligned with these stages and management objectives. It is a known fact in terms of forestry techniques that silvicultural interventions in an ecologically functional forest will differ from those in a production forest. However, the sustainability of stands that have reached the end of their rotation age can only be achieved through the regeneration of these stands.

#### *3.3.1. Regeneration*

In Türkiye, there hasn't been any scientific or applied work for regeneration purposes in European aspen forests. One reason is that existing management plans prioritize ecological functions over timber production. Another reason is the perception of European aspen as a pioneer species. The regeneration process of European aspen occurs either through seed-based generative methods or vegetative methods from shoots, similar to other tree species. European aspen has a high light requirement, especially in open areas (clear-cutting or fire-affected), making it feasible to regenerate through seeds under highly suitable conditions (where the soil is open and warm, devoid of live ground cover, including root and stem shoots). As European aspen's seed properties enable them to travel long distances and germinate well under ample light, they can be regenerated through seeds in such areas. Young stands unaffected by frost create pure forest stands.

According to preliminary information obtained from our field inspections and project studies, it appears that the young stands arriving in the area are predominantly root-sprout-based natural stands. For mature European aspen stands, the regeneration method in small areas could potentially rely on a natural regeneration method based on clear-cut. Indeed, Worrell (1995) suggests that although seed-based regeneration is possible due to seed production capacity and ecological compatibility, there are practical difficulties. Most research has focused on vegetative production. Through root suckers, multiple sprouts emerge from the same root, and in subsequent years (around 20-30 years old), the number of individuals in the stand ranges from 2500 to 3700 per hectare, depending on light competition. Therefore, it is stated that the regeneration method in pure European aspen stands is based on clear-cut. It is noted that a single-parent European aspen tree can produce hundreds of root suckers. Börset (1985) emphasizes that, as a result of clear-cutting a mature stand, the number of sprouts per hectare can exceed 50,000 to 100,000. Krasny and Johnson (1992) stated that 98% of the young sprouts that emerge in the clear-cutting area occur during the first vegetation period following cutting.

Boydak and Çalışkan (2014) define regeneration through root, stem, and trunk sprouts as vegetative natural regeneration. In European aspens, particularly due to the high potential for root sucker formation and the ability of their seeds to travel long distances, forests can form in nature through both seed and sprout sources. (Latva-Karjanmaa et al., 2003) mention that although both *Populus tremula* and *Populus tremuloides* species have high seed yield potential, seed-based regeneration practices are rarely observed. Instead, the primary mode of reproduction is stated to be asexual (vegetative) production based on root suckers.

According to our research conducted on pure European aspen stands in Türkiye, the most suitable method for species regeneration is the vegetative natural regeneration method, which focuses on sprout development. The equivalent term for this practice in silviculture literature is the clear-cutting method. However, large-scale clear-cutting operations can harm the ecological functions associated with European aspen, particularly causing negative impacts on wildlife, and thus, they should not be preferred. Therefore, regeneration methods should be implemented in small areas (clumps or groups). Clear-cut in clumps might often be insufficient. Maintaining an open crown closure is desired to meet the light requirements. Renewal of the area is ensured through clear-cutting in groups or large clumps, resulting in the emergence of new stands primarily through root suckers. For instance, Crouch (1981) conducted a study in Northwest Colorado on the effects of the clear-cutting method on regeneration in *Populus tremuloide*s (70 years old stand). Within the first three years after the removal, the condition of the newly emerged stands was assessed. The number of individuals per hectare in the experimental area was 1327, with total basal area of 13600 $cm^2$/ha. Approximately half of the trees had a diameter at breast height greater than 14 cm. The stand had a normal density, with 62 dead trees per ha and crowded individuals. The average diameter was 15-16 cm, with a few individual pine trees within the area. At the beginning of vegetation after cutting (July), a few sprouts were observed, which decreased from 18120 to 3280 by September.

After tending interventions carried out in pure European aspen stands in the Sakarciftligi region of Mount Erciyes in Kayseri, the dense young growth originating from root suckers in the ground cover will gain independence following subsequent cuttings (either tending or clear-cuttings for regeneration purposes). Preliminary research data from a tending worked 40-45-year-old pure European aspen stand in the area indicate that the number of root suckers at 3-4 years old ranges between 100,000 and 200,000, with average heights of 0.5-1.5 meters and root collar diameters between 2 and 8 mm (Turna & Atar, 2022). Therefore, the abundance of young sprouts obtained after the final tending interventions in pure aspen stands indicates that sprout-originated regeneration is a suitable method for aspen stands (Figure 5).

**Figure 5.** The youth formed from root suckers after tending interventions.

In the regeneration of mixed stands of aspen+Scots pine or aspen+black pine, it's crucial to ensure the preservation of the primary species. Aspen cuttings in favor of pine species within the scope of tending interventions in stands aspen+Scots pine or Scots pine+aspen encourage root sucker development in aspens. This phenomenon has been observed in mixed stands of Scots pine and aspen managed by the Sivas Forest Management Directorate (Figure 6). Therefore, after tending interventions aimed at preserving the climax species in mixed stands of aspen+Scots pine, aspen+black pine, Scots pine+aspen, or black pine+aspen, young aspen growth coming into the area should be treated as an ground cover and removed from the site. The successful regeneration of primary species should be the primary consideration here.

**Figure 6.** The dominance of young European aspen growth in the area following tending interventions against aspen in mixed stands of Scots pine and European aspen (Sivas).

### *3.3.2. Tending*

In Türkiye, there are intensely pure and mixed stands of Euroepan aspen found in developmental stages a, ab, b, and bc. However, the management objectives for these stands have not been clearly stated or they have only been included for ecological functions in plans. Therefore, no explanation has been provided regarding the silvicultural interventions that should be applied to stands subject to tending interventions. However, as highlighted in Worrell (1995)'s study in Scotland, in forests managed for timber production, the rotation length ranges between 40 and 60 years. For the production of small-diameter materials, it is recommended to conduct maintenance at age intervals of 8-15 years, with average heights of 6-10 meters, thinning interventions spacing at 2x3 meters. It is also suggested to conduct thinnings at intervals of 5 years between ages 15 and 30, followed by intervals of 7-8 years in subsequent years, reducing the number of individuals per hectare to 300-400 at the final harvest stage. These data emphasize the importance of defining management objectives in determining the intensity of tending interventions.

There is no scientific study conducted regarding tending interventions in European aspen stands naturally distributed in Türkiye based on stand development stages. In recent times, tending works aimed at enhancing stability and establishing healthy stands against biotic and abiotic factors have been addressed both by forest managers and scientific studies, especially in stands at the "b" developmental stage.

***Juvenile stage:*** The implementation of protective measures and the thinning of naturally occurring youth are crucial tending practices, depending on the development of the youth when applying measures for youth care. In European aspen stands in Türkiye, due to the lack of suitable natural or artificial regeneration studies, there is no specific work related to youth tending. However, thinning the youth originating from sprouts, particularly due to anthropogenic effects like fire or land degradation, should be considered, especially considering variations in water scarcity and temperature degrees. Moreover, regulating the mixture, removing diseased individuals from the area, and, most importantly, implementing protective measures can enable healthier youth development in the area. Perala et al. (1999) mentioned that in the same-aged pure Euroepean aspen stands over a rotation period of 50 years, if the number of individuals per hectare decreases below 1,000 due to natural competition, maintenance cuttings, or events like fire, the number of youth coming from root suckers could range between 10,000 and 100,000 per hectare.

***Thicket stage:*** Pre-commercial thinning interventions during the thicket stage are crucial for the future of European aspen stands. Particularly in uniformly aged, single-storied pure European aspen stands, having extensive areas subject to pre-commercial thinning interventions is crucial based on management objectives. Natural pruning and stem dissociation occur rapidly in aspen stands with high light requirements. There is no completed study on pre-commercial thinning in European aspen stands in Türkiye. However, within the scope of the "Effects of Thinning Interventions on the Development of European Aspen (*Populus tremula* L.) Stands (Erciyes Example)" project initiated in 2023 under the Central Anatolia Forestry Research Directorate, the silvicultural interventions that should be applied to European aspen stands are examined. In a study investigating the silviculture of Kayseri-Erciyes European aspen stands (Turna & Atar, 2022), it was determined that in stands at the thicket stage, diameter values ranged from 2.80 cm to 12.30 cm, with an average diameter of 7.42 cm, and the number of live trees per hectare was 7500. The number of standing dead individuals (45%) was reported at 6150 per hectare.

In stands intended for paper production, a density of 1100 individuals per hectare is considered adequate for growth, production, and quality. However, for high-quality log production, more intense interventions (550 individuals/ha) through pre-commercial thinning are recommended. For bioenergy production facilities, it is stated that no thinning interventions are necessary (6000 individuals per hectare) or only light thinning interventions with a count of 3000 individuals/ha are sufficient (Ha, 2018). Therefore, the intensity of interventions in European aspen stands subject to pre-commercial thinning varies according to the management objectives. Measurements conducted in European aspen stands by the Gümüşhane Forest Management Directorate revealed an average of 15,000 individuals per hectare and an average height of 5 meters during the thicket stage. This indicates severe natural pruning and stem dissociation in European aspen stands in full crown closure. A before-and-after comparison of a pure European aspen stand subject to pre-commercial thinning conducted by the Sivas Forest Management Directorate in 2007 is presented in Figure 7. It was determined that silvicultural interventions were carried out under the guise of rehabilitation.

**Figure 7.** Before and after pre-commercial thinning intervention in a pure European aspen stand.

***Sapling, Pole and Wood Stage:*** Thinning interventions are carried out as part of tending works during the young, mature, and over-mature development stages. In the Erciyes region under the Kayseri Forest Management Directorate, initial thinning interventions in European aspen stands commenced in 2020 and 2021, while in the Develi region, they began in 2020. The total timber volumes obtained from these initial thinning interventions were determined. Accordingly, within the scope of the thinning interventions in Erciyes, 2505 $m^3$ was harvested from 29.1 hectares in 2020, and in 2021, 3194 $m^3$ was obtained from a 51.1-hectare area. In Develi, a total of 4482 stere of wood chips were obtained, equivalent to an average of 42 $m^3$ per hectare (Turna & Atar, 2022). Jones and Shepperd (1985) indicated in their study that if a stand is to be thinned once, it is advisable to wait until dominant individuals reach a height of 8 m and a diameter of 5-8 cm. They suggested thinning to leave 1730 individuals per hectare with a spacing of 2.5 × 2.5 m. Additionally, they recommended thinning at a spacing of 4.6 × 4.6 m when dominant and codominant individuals reach a height of 11 meters, aiming for 494 individuals per hectare. On the other hand, Börset (1976) generally suggested that thinning should commence when the crown of the top tree exceeds 40-50% of the tree height in European aspen. They advocated for thinning to occur only 2-3 times, with an initial thinning leaving 700-1000 individuals per hectare, a second thinning when the trees reach 16-17 m in height, resulting in 350-700 individuals, and a third thinning when the average height is 20-23 m, with 350-400 individuals per hectare.

Thinning interventions related to European aspen are performed in line with the demands of the industry, aiming for well-formed materials for short-term management, including quality pole and timber production for telegraph poles and mine props. For industries such as paper and oriented strand board, where the evaluation of thin material is essential, the focus lies more on volume than wood quality. Therefore, silvicultural interventions aimed at maximizing production within short rotation age are preferred over thinning practices (Hamilton, 1976).

## 4. Conclusion

Rather than solely considering the European aspen species as a pioneer species and therefore not envisioning any silvicultural intervention, it would be more appropriate to reconsider the functions attributed to this species, taking into account its significant spatial expansion and the increasing prevalence of pure stands in Türkiye. Reassessing the functions attributed to the species and determining the most suitable functions would be pertinent. In line with the determined function and management objectives, silvicultural interventions related to the species must be implemented without interruption.

The biological, ecological, and socio-cultural characteristics of the species should be thoroughly analyzed alongside silvicultural techniques, and appropriate interventions should be implemented accordingly. Particularly in pure stands, tending works will not only enhance the resilience of existing European aspen forests against biotic and abiotic stressors but will also ensure more productive and sustainable forests through interventions favoring superior-quality individuals.

In mixed stands where European aspen is part of the mix, delicate management is necessary to ensure both the continuity of climax species and the preservation of biodiversity. It would be better to choose interventions against European aspen in such stands. However, if creating gaps within the stand, leaving European aspen individuals in the area is advised, while individuals located at the edges of the forest stand and within streamside vegetation should not be removed from the area.

In summary, it is essential to redefine management objective for same-aged pure and mixed European aspen forests based on both succession stages and growing conditions, ensuring timely interventions in line with silvicultural needs. It is a known fact in terms of forestry techniques that protective and moderate interventions are different in ecological function areas compared to production function areas, varying based on research outcomes. European aspen forests play crucial roles within the ecosystem. Therefore, abandoned or potentially inhabitable areas, initially populated and then improving within the habitat conditions, should be ecologically planned and managed to serve various functions.

Managing European aspen forests in line with the requirements of silviculture according to their developmental stages is necessary for ensuring sustainability. Identifying superior stands for improvement efforts, conducting genetic conservation, and establishing seed orchards are essential in the context of breeding programs and conserving genetic resources.

In mixed forests, interventions favoring the dominant species are recommended until research outcomes are obtained. Specifically, in European aspen stands mixed with pine, interventions against European aspen should be conducted.

## Conflict of Interest

The authors declare that they have no conflict of interest.

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REVIEW ARTICLE

# Ecosystemic Alienation from the Perspective of Paraecology

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**ABSTRACT**

Individual alienation, which began in the previous century with the industrialization revolution, has now progressed to the level of ecosystem alienation. Catastrophic destruction that occurs with the disruption of natural ecosystem functions proceeds insidiously. The main objective of this study is to make paraecological approaches more understandable, and aid efforts to make nature conservation and environmental ethics a way of life in the solution of environmental problems caused by ecosystemic alienation. With the magic of hedonism, an alienated person becomes lonely and robotic. Today, modernity is the main activator of alienation. Weak living things, which constitute the basic paradigm of modernity, must constantly feed this system. However, maintaining modernity tends to destroy the system by exploiting it. Ecological destruction, such as climate change, drought, and desertification have reached a global threat level. Living things are unaware that they are preparing to perish under the threat of alienation, along with their systems. Ecosystemic alienation, a latent virus that has existed for over a century, is the highest level of alienation. Selling or bartering these functions by calculating the financial value of the services and functions of natural ecosystems is another indicator of alienation. The solution is not to destroy the alienated humans (aliens) responsible for the degradation of ecosystems, but to push them to the limits and neutralize them. Efforts to create virtuous people who will solve ecological problems and adopt living as a part of nature cannot be realized with utopian principles. Adoption of global nature conservation ethics is possible with lifelong education for all ages.

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## 1. Introduction

### *1.1.* Some Ecological Aspects on Nature and Human Relationship

Human beings, who are in a consumer position in the relationship between nature and humans, have always exploited nature. Unplanned use of natural resources has exceeded the carrying capacity of ecosystems, and ultimately endangered the sustainability of nature. Global climate change is one such danger (Çepel, 2006). To date, many ecological approaches have been proposed to control these negativities, which cause human-centered and environmental disasters. These approaches form the basis of ecological planning. For example; Arne Naess (1986) advocated the "deep ecological" view; While he evaluated nature as an entity with a unique life value like human beings, he stated that nature is seen as a tool for people in the ecological view he called "Shallow" (Ferry, 2000). With a nature-oriented environmental understanding (Tamkoç, 1994), mysticism is located in the main axis of philosophies dominated by the "deep ecological" view (Elkins, 1994). Deep ecological philosophy: This consists of a set of cultural and life chains fed by Buddhist, Christian, and secular philosophers. In this axis, it is emphasized that the existence comes from the same source, even though they are outwardly different. Therefore, humans are only one of the other beings. On the other hand, in Pantheist beliefs, holiness is attributed to all beings (Lynn, 2003). The fact that deep ecologists see human beings as responsible for ecological destruction has

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caused them to be influenced by philosophies called "Ecosophy", which use teachings such as Taoism and Buddhism (Wagner, 2013). The essence of Taoist philosophy is a rhythm in which nothing is treated as an object and everything is interconnected (Elgin, 1994). In Buddhism teaching on this subject, "Patticasamuppada" is responsible for the creation of everything and everything is interdependent (Anonymous, 2013). All these teachings have found a place in the "Deep Ecological’ approach to consider oneself as a part of the universe with a spiritual consciousness (Capra, 1994). One of the basic elements of the systems theory of deep ecology is that all beings on Earth are in a chain of relations with each other (Zimmerman, 1989).

In the "Biocentric" understanding of deep ecology, all beings are considered equal. The anthropocentric view was completely rejected (Mellor, 1993; İdem, 2002). In fact, it can be said that the basis of the biocentric view is inspired by a very old approach to bequeathing the world to future generations (Bari, 2003). Man's destiny in the world is determined not by dominating nature, but by using his will in line with his thoughts. The value of all assets is essential. Humans have no superiority over other beings (Metzner, 1994). According to deep ecologists, it is unacceptable to consider humans as leading roles and other living things as extras in natural scenes (Laçiner, 1998). According to ecofeminists, the dominance of men over women is similar to that of nature. Men are the main source of destruction in nature. Merchant has seen and identified woman and nature side by side as two entities that are oppressed and dominated against man (Ünder, 2005). In social ecology, people's domination has led to the domination and exploitation of nature (İdem, 2002). Roszak (1992) combines psychology and ecology with the concept of ecopsychology, and argues that people who isolate themselves from nature are spiritually unhappy and ultimately harm themselves.

The ecopsychological approach aims to reconcile today's people with nature will be possible by revealing the instinct of living together and respecting it, which is inherent in nature. Erzurumlu İbrahim Hakkı (1756), on the other hand, talked about a multidimensional teaching on the creation of beings and the relationship between nature and human; “He first created the universal soul from essence. He then created the spirits of angels, plants, and nature. For these souls, certain authorities were appointed according to their rank and each class went to their own stations. Every soul found its own kind, formed communities, and every community remained in its place.” He states that plants and humans souls in nature. This approach shows that man will never be domineering in his relations with nature and can only be a ruler on the condition of observing the rights of all creatures.

Although humans are mostly in a dominant position in the rapid destruction of nature in the relationship between humans and nature, habitat conditions (soil, climate, physiography, etc.) in some regions can be more decisive in these disasters. In the face of a society that constantly consumes resources unilaterally in developed countries, anthropocentric shallow ecology has a worldview that sees all kinds of desires and demands legitimate in its relationship with nature and that the whole earth belongs to humans (Önder, 2003). However, he considered it a duty to make efforts to prevent the depletion of natural resources (Keleş & Hamamcı, 2002). According to deep ecology, the Earth does not belong to humans. Every being has the right to life (Naess, 1995). The creator of all ecosystems has appointed man as a will-powered being on earth, and this role of trustees also includes the management of sensitive and valuable relics, such as nature. Managing trust is an important part of a man's test on Earth. Humans have the will to choose ways such as planning the earth, rehabilitating it, correcting or destroying it, aggravating it, and confusing the world by spreading corruption (Mevdudi & Kayani, 1996; Bursevi, 1997). Öztürk (2002) considers the deterioration of nature (pollution of nature, ozone depletion, etc.) to change the original creation, to be under the control of the devil. It is aimed at being very sensitive about the protection and improvement of nature and to prevent the irresponsible use of unlimited nature (Nasr, 1988; Gürsel, 1995; Özdemir & Yükselmiş, 1995).

In the concept of principles advocated by deep ecology argues that anthropocentric thinking is the only source of ecological problems and that the solution must undergo an ideological, economic, cultural and technological restructuring. Deep ecologists do not take a stance in favor humans in the relationships within the nutrient cycle in ecosystems (Des Jardins, 2006). The alienation of humans from the center of life brings human and non-human creatures to the forefront (Önder, 2003). In this view, where integration with nature and equality are at the forefront, people's ethnic, political, religious, and other ties should not be in front of ecosystem dependency (Ünder, 1996; Pepper, 1999). As a result, deep ecological thinking is important in terms of bringing ecological thoughts that teach not to think and act in a human-oriented manner (Tamkoç, 1994).

Mellor (1993), who states that Naess's ecosophy is to become conscious of being one with the planet, also criticizes the idea that all living things are equal in the philosophy of deep ecology, and that man sees it as a being who exploits nature. Another criticism is that Kovel (2005) focused on the decentralization of humanity within nature through deep ecology. Plumwood (2004) criticized deep ecology for not giving importance to social structure by emphasizing personal transformation. These criticisms of deep ecology appear as a result of anti-humanism and nature-centrism. Seeing people at the center of all problems and seeing all technologies as harmful is a mistake in itself (Bookchin, 1994; Ata, 2002; Kovel, 2005). While nature gains meaning only within society, the relationship between them depends on the society's perception of nature (Elkins, 1994). Deep Ecologists have significantly narrowed down humanistic morality's concept of duty and responsibility (Ferry, 2000). Deep ecology movement in world class, race, gender, etc. This consists of an ambiguous, amorphous, and baseless assumption that insults humanity by ignoring differences (Porrit, 1994).

The philosophy of society's relations with nature will not only shape these ecological relations but will also form the basis of ecological planning for a sustainable nature. These approaches bring to the fore an understanding of ecology, in which the uniqueness of assets is reflected at the ecosystem scale; Paraecology, This understanding of ecology; It is based on the transfer of the purpose of creation of beings to life as a whole.

Paraecological approach: Reducing threats to ecosystems and including environmental destruction in the rehabilitation process as a part of the rehabilitation process of human beings sociologically, psychologically, and philosophically. The aim here is to enable the person, who is the basis of the problem, to take an active role in the solution process. Paraecological approaches are flexible ways of thinking that help individuals internalize accepted or planned ethical concepts in their lives, especially in understanding and utilizing the relationships between ecology and psychology, sociology, and philosophy. Understanding and internalizing the relationships between ecology and psychology, sociology, and philosophy can help individuals become more environmentally aware and adopt ethical values. These approaches can encourage people to act responsibly towards their environment and work towards sustainability.For human beings who insist on solving environmental problems on a global scale, "*The real danger is the alienation of people who cannot make ecological planning and implementation in parallel with active changes and developments in the world. First of all, these problems must be identified and then overcome*" (Dindaroğlu, 2014a; Dindaroğlu, 2021).

Some prominent Paraecological approaches (Dindaroğlu, 2014a);

• All assets in nature have values both for themselves and others, and this value forms part of the ecological cycle. The purpose of creating the universe was for man. However, this situation does not give man the right to dominate other beings. Other beings are like the limbs of man. Their point of view is their own heart, hand, leg, and so on, which should be similar to their relationship with their organs.

• Plants are one of the most important components of the ecological cycle. There are no insignificant entities that do not play a role in the ecosystem cycle.

• Stopping pollution should not hinder economic development. Simultaneously, pollution must be stopped and economic development must be achieved. With industrial development, technologies that can eliminate pollution without affecting the ecosystem cycle should be developed. Humans are well equipped to ensure economic development and protect ecosystems. However, this world is a field for increasing the level of intelligence, ability, and knowledge of human beings. Therefore, the relationship between man and nature is one of the stages of positive or negative conclusions for this purpose.

• What is really dangerous is the problem of "alienation of man from himself", which cannot make ecological planning and implementation in parallel with the active changes and developments in the world. The basis of man's problems with nature lies in man's forgetting of his purpose of existence and alienation from himself. First of all, this problem should be determined and then it should be overcome. All these constitute an important part of the world's wisdom. The person who is alienated from himself or herself deviates from the purpose of existence. However, humans are sufficiently strong to overcome this problem. In this context, before our plans, we should equip society with active, sustainable ecological and environmental ethics, and plan our natural resources with this perspective. Human beings are at the center of the management and responsibility of these processes.

• Living standards should progress in synchrony with ecological balance. It does not make sense to have a luxury villa in an area where everything is covered by garbage and chemical waste.

• "Existence" must fulfill its duty within the ecological cycle, completely and in accordance with its purpose of existence. Otherwise, the system is disrupted.

Nature and humans are not cruel. Both must maintain a balance in ecological relations. Here, it is a man's duty to preserve the natural balance he is dependent on.

• The main goal of ecological relations is to fully and completely maintain ecosystem functions. If the relations continue for or against one side, the entire ecosystem will suffer.

Therefore, while rehabilitation work is being planned, people living in the region should manage natural resources with the awareness that they do not have the right to rule over nature unconditionally in accordance with their purpose of existence, but that they have the right to live in other beings like themselves. Additionally, people with low-income levels should be supported by social and economic projects, and their income levels should be increased. It is necessary to develop an environmental sensitivity that does not sacrifice humans or nature and provides the perception that both are indispensable values for this ecosystem.

"*It is easy to make people love the natural beauties and make them feel pity for the destruction of nature. However, it is very difficult to convince people that they are constantly destroying nature for a more civilized and modern life and that* *this action is equivalent to the destruction of the foundations of life. In this context, these seemingly small tasks to be done individually should not be underestimated*” (Çepel, 2005).

### *1.2.* Origin of the Word "Alienation"

In the dictionary of the Turkish Language Association, the word "Wild" is expressed as a desolate place where no people live. This is a word of Persian origin. It is also used in the sense of wild, untamed creature, foreign, unfamiliar. On the other hand, the word alienation is used in the meanings of not knowing, becoming ignorant, being a foreigner, being ignorant, not getting used to it, being strange, being foreign (TDK, 2016).

It is called 'Entfremdung' in German, and 'alienation' in French and English. In English, the word 'Alien' is a foreign noun and the verb form is 'alienate'. It is used to differentiate, deprive, change or alter. However, according to Geyer, in the 1980s, the concept of alienation was emptied, ambiguous and sometimes full of contradictions. To the extent that the basis of problems in many branches of science has been tried to be explained by alienation, schizophrenia, loneliness in old age, perversion, assimilation problems, etc. (Schacht, 2015).

### *1.3.* Alienation with Different Perspectives

In the dualism of man and nature, Hegel and Marx's alienation problematic naturally emerges. By focusing more on people, Mevlana focuses on the alienation of man from himself. According to Mevlana, the main problem stems from the inability of a man to be in harmony with himself and his environment. Feuerbach; expressing it as causing people to form an intermediate stage that leads them to seek their own essence, and draws attention to the positive side of alienation (Tekin, 2010).

Feuerbach, rejecting Hegel's point of view of alienation between nature and the absolute spirit, puts forward the alienated human form of God as the criterion of alienation (Erdost, 2010). The center of alienation, which Hegel focused on theology, became closer to anthropology in Feuerbach's views. Human; With the development of technology and industry, he moved away from his material and moral values, and he was forced to do the work given to him for a certain fee, without knowing what the product he produced was. In a way, the robotization of man is the result of alienation (Marx, 2014). According to Marx, it can occur in the form of alienation of the worker to the product produced by the worker, to the work processes, to nature, and to the self (Demirer & Özbudun, 1999). Albert Camus defines history, religion, customs and traditions as the alienation of a person from himself and his reason for being. According to Duhm, human beings live in a world in which capitalism breeds alienation and is surrounded by the principles of competition and success. Likewise, Pappenheim gives loneliness in modern societies, the egoistic and objectifying understanding of life, as typical examples of alienation (Çelik, 2001).

Durkheim and Weber also discussed the concept of alienation in sociological currents of thought. Durkheim argued that alienation occurs in societies where solidarity and division of labor weaken and industrialization increases. According to Weber, modern people, who have serious problems with trust, tend to strengthen bureaucracy while minimizing personal relationships. An individual's loss of personality or routinization of charisma occurs as a result of rationality and causes the process of mechanization (Weber, 1996). Weber describes this event using the metaphor of the "Iron Cage.” Weber and Marx presented the mechanization of the individual and the commodification of labor as two important causes of alienation (Löwith, 1982). Marx argued that poverty, while Durheim argued that wealth is effective in alienation. Horney, on the other hand, views alienation (neurosis) as a mental disorder and argues that the perpetrator is the individual and society (Douglas, 1989). Marcuse (1997) described alienation as a figure in which individuals move away from the human essence, lose their creative qualities, and technology plunges people into a one-dimensional vortex.

### *1.4.* Could Ecosystem-Specific Alienation Be Possible?

When the origin of the word alienation is examined, we can see that the word "Wild,” which is the origin of the word, is used for inanimate objects, although it is described for human beings. Being called "Geist" in its inner stages of the Hegelian dialectic has been cut off from its own essence for self-realization, has become someone else and is now alienated from itself. It is nature that provides space for contingency in Geist's self-knowledge in order to reach evolution, and in his passing through this alienation process, in his objectification (Copleston, 1985). Living things find opportunities to live in natural places; thus, nature is also a site for living and non-living things. So, nature is also a site for living or none-living things. In this context, there is a close relationship between space and society. Space forms the basis of social structure and change (Alver, 2006).

In this study, the space that includes living and non-living things and where mutual relations occur will be called the "Ecosystem" ecosystem. Ecosystems consist of non-living organisms (inorganic and organic materials), primary producers (green plants), consumers (who eat plant and animal materials), and decomposers (bacteria and fungi) (Çepel, 1998).

Within the scope of the relationship between change and alienation in ecosystems, the following questions arise:

• Do creatures living in changing habitat conditions in ecosystems live a passive life?

• To what extent can changing habitat conditions in ecosystems change living things?

• To what extent do changes in habitat characteristics alienate living organisms?

• Is alienation in favor of or against living things?

Finding answers to such questions can help us understand the basic facts in the solution to change and the alienation that comes with it.

Natural ecosystems are not like bureaucratic systems created by humans. Bureaucratic systems are strictly prescriptive, formally organized, closed to the outside, non-interactive, and have concrete goals (Wallace & Wolf, 2004). However, natural ecosystems are open systems that have a wide tolerance range in which many living things can live together, and that can be designed and affected by the living things in which they live. Alienation is influenced by changes and transformations that progress over time. Change is the sum of the changes over time. In biology, the “variation” is expressed in mathematics as “a quantity taking separate values from each other or the distinction between two such values” (TDK, 2016). Alienation occurs as a result of transformation (Afşar, 1992).

Living and non-living things integrate with their environment through various adaptations to maintain their existence optimally in the ecosystems in which they interact. This situation differentiates and changes living things, and ultimately provides genetic, species, and ecosystem diversity, which is expressed as biodiversity (Çepel, 1998; Gökmen, 2011). In adaptation processes, living things, especially human beings, can change both themselves and their environment for the continuity of life (Mengüşoğlu, 1971). Habitats, where living creatures live in ecosystems, play an active role in regulating the behavior, personality, and responsibilities of living things. For example, living things symbiotically due to changing habitat conditions can help their host adapt to changing ecological conditions, as well as cause the death of the host and itself in parasitic relationships.

Ecosystems are places of feeding, reproduction, and socialization because they form habitats in which living things live. The stability of species and populations in ecosystems is directly related to their habitat characteristics. Growth environments are the main factors affecting changes and transformations in individual and social scales. In general, nature and man have been evaluated by scientists using a dualist approach. In other words, nature is the source of alienation for humans. However, this point of view is criticized from the ecological perspective, which Arne Naess (1986) refers to as "Shallow", in which nature is seen as a tool for humans. In Arne Naess's "deep ecological" view, he considers nature an entity with a unique life value, like human beings (Ferry, 2000). However, the evaluation of man as a part of nature causes alienation to differentiate.

Each ecosystem aims to reach a natural balance within itself and with other ecosystems. With the deterioration of the balance in ecosystems, a new and different ecosystem emerges, and this process is called succession. In ecosystems, factors such as living things, natural events, diseases, fires, climate change, changes in soil quality, wind, and insect damage are among the causes of ecological success. Human beings are sometimes in a position of dominating succession and are sometimes affected (Çepel, 1995).

Negative alienation specific to ecosystems can be expressed as a situation that occurs as a result of the change, change, or dysfunction of habitat conditions in such a way that ecosystems cannot fulfill their specific niches. Due to changing conditions, it is no longer possible for living organisms to survive in this habitat to realize their optimal growth. It must change and adapt in order to survive. These changes in the alienated ecosystem, called adaptation, form a part of its biodiversity. Ecosystemic alienation has a significant potential to cause changes in species composition in the habitat.

Succession forms the basis of ecosystem alienation. Although they play an important role in the development, maturation, and diversity of ecosystems, they can also cause deterioration of ecosystem health, which cannot be recovered. The main task of the ecological factors that make up the ecosystem is to ensure the sustainability of total efficiency/productivity. If a change in habitat conditions in ecosystems does not prevent the sustainability of this basic task, it can be considered a positive result of alienation. This is because high adaptation to changing conditions is only possible in the presence of organisms with high ecological tolerance. In terms of spatial change, the birth of a baby, the falling of a fruit, and a leaf from its branch are also alienations. The decomposition of organic matter can also be regarded as an alienation. The yellowing of chlorophyll in the leaves due to the decomposition of changing ecological conditions is the first symptom of this (anatomical chemical weathering). In the second stage, the organic materials that accumulated on the soil surface were mechanically decomposed. Organic tissues that undergo anatomical decomposition in soil creatures are mixed with the inorganic part of the soil. With this process, the spatial alienation increases. It is now on the verge of an advanced transformation. The third level is the humusification and mineralization processes. Microorganisms decompose organic tissue into their constituent elements. In an environment in which alienating spaces and transformers play an active role, new products are synthesized. However, this alienation is necessary and positive alienation that ensures the sustainability of matter cycles in ecosystems (Dindaroğlu, 2021). The term "disenchantment" used by Weber (1993) for social alienation would not be wrong to be used for the disruption of the natural balance in the miraculous matter cycles that ensure the sustainability of ecosystems.

Some deformations or further death may occur in living beings in ecosystems in which optimal living conditions disappear. Survival is the new and only role for living beings, which are within tolerance limits, trying to adapt to changing ecological conditions. Bauman (2016) also sees alienation among people and the existence of strangers as a necessity in modern life.

## 2. Aliens in Ecosystems

Ecosystems are interconnected in natural balance through complex relationships. Any break in the coordination between them or the inability to fulfill their requirements causes the alienation process to begin. Thus, an environment was provided for foreigners to settle. This is the initial stage of the process in which the negative consequences of alienation can be seen. Alien species begin to settle under changing habitat conditions. The extent to which alien species settle in their habitats and whether they form a social space is related to both the changing ecological conditions and genetics of the aliens. The main problem is that alienation in ecosystems has become constant. Spatial alienation, especially that starting with soil degradation, is accepted as the beginning of the desertification process. The main purpose of the fight against global climate change and desertification is to push aliens into the ecosystem. Complete extermination of aliens was not possible. This is because alienation and strangers also have duties in the ecosystem (Dindaroğlu, 2021).

Ecosystems (wild land) where alienation creates a permanent and spatial occupation create an uninterrupted resistance to spatial rehabilitation (Dindaroğlu, 2014b). Breaking this resistance is easier with the improvement of the factors that make up the growing environment (especially the soil). Especially in the analysis of the sites in forest ecosystems, climax species and accompanying plant species together form living units in undisturbed areas. The associations between plants were analyzed in habitat studies. For example; beech-fir association (79.5%), Scots pine association (12%) and *Dactylis glomerata-Crataegus tanacetifolia* association (8%), *Sparganiumerectum-Epilobium hirsutum* association (0.5%) in a forest ecosystem (Günay & Küçük, 2007) was determined. In this habitat, climax species and accompanying plant associations are present. All these species are native and established species. The alienation process that occurred in this growing environment developed in a positive way. As another example, when the habitat conditions (physical spatial alienation) changed by forest fires dominate the area, Sistus spp. shrubs form. Populus tremula then entered the area. These two species were alien species that later came to an alienated environment. However, since they form part of the succession steps, they are useful aliens that prepare the habitat for climax species. These aliens also provide genetic, species, and ecosystem diversity, together with habitat (space). Habitats, which are places where living and non-living organisms live in ecosystems, are living spaces where a living species adapts, and biotopes are the living spaces of communities. Their habitats mainly consist of primary producers (green plants with chlorophyll), primary level producers (herbivores), secondary consumers (carnivores), and decomposers (bacteria and fungi). Ecosystems operate with a variable energy flow that occurs between matter cycles and food chains.

Native species in an ecosystem can coexist with alien species. However, many vital relationships can affect this situation. Living in the same ecosystem also leads to the development of relationships between species. These relationships, starting from the necessity of surviving life, vary according to levels in the food chain. Relationships at different nutritional levels often require a subordinate level to nurture predators. Those with the same nutritional level often compete for the same food source. This situation creates both intraspecific and interspecific competitions. In addition, special forms of dependence, such as parasitism, symbiosis, and communalism, can be observed among species. Living with foreign species continues with the most appropriate of the above-mentioned types of relationships. Bauman (2016) describes the environment in which strangers live in a wild region and sees cities as important sites of false encounters. In fact, there is competition here too. He attributes the most basic condition of living with strangers to the mysterious art of fake welcome. While interspecies interaction constitutes the main theme in alien relationships in ecosystems, the basis of living with strangers in human societies is to be pushed beyond the social space without creating an interaction space with foreigners. Thus, a suitable living environment is provided by suppressing foreigners and making them ineffective (Simmel, 1969). Similar to alien species that have settled in degraded habitats in ecosystems that are confined to a limited area, the system can restrict the movements of aliens in order to protect themselves in the defense of social spaces.

Each species has a tolerance range that allows it to adapt to the changing ecological conditions. Even if invasive alien species dominate the environment, they remain alien. For example; Although exotic species are adapted to culture or seem to have adapted to changing conditions for years, that species is an alien species for that habitat. In subsequent processes, they have the potential to move away from the environment.

Both the affirmation of alienation as the dynamics of the ecosystem and the fact that it is held responsible for the deterioration of ecosystems increase the role of ecosystemic alienation and the depth of the occurring paradox, as in social alienation. As a matter of fact, Bauman (2016) uses the expressions “*Need and threat are the mainstay of existence in the perception of foreignness and it is the disaster that prepares its end*”. The end of the struggle for life in natural ecosystems, accompanied by their internal dynamics and ecological conditions, is part of the extinction process. However, these extinction processes have paved the way for different species.

### *2.1.* Alienation, Niche and Tolerance Relationship in Ecosystem

Living things in ecosystems are constantly in reactive, co-actional, and actional interactions with other living and non-living beings sharing the same environment (Gökmen, 2011). Every living thing has to fulfill certain duties and responsibilities in the ecosystem to survive. While this necessity is vital for living things, it also fulfills important functions for the sustainability of the ecosystem. However, many living organisms continue their lives without realizing the importance of their functions in the ecosystem.

Tolerance is a response to the degree of adaptability of living things to changing ecological conditions. Tolerance is closely related to different living species and their genetic structures. However, changing ecological conditions can also change species and genetic diversity. In the previous section, if the change in habitat conditions in ecosystems negatively affected the sustainability of a basic task, it was considered a negative alienation for living or non-living things. In fact, the perception of alienation has always been negatively handled. However, if harmony, which is the inevitable result of change and transformation from an ecosystem point of view, does not change the ecological niche and maintains its sustainability within tolerance limits, it can be considered as positive alienation (Dindaroğlu, 2021).

### *2.2.* Alienation and Habit Relationship in Ecosystem

From the perspective of ecology and sociology, one of the most important effects of ecosystem alienation in living life is habits, which are an important part of the ability to adapt to change. In this case, habit gains a character. If it ensures continuity of the niche, it is good; if it harms it, it is bad. Alienation can lead to the acquisition of new habits, which can also become a camouflage of alienation (Dindaroğlu, 2021).

Every being tends to preserve its existence to survive. Habits, on the other hand, are changes that occur in the quality and internal characteristics of beings. Since there is no individuality in a homogeneous inanimate world, habits cannot be mentioned. However, individuality begins with a heterogeneous unity of space and time in nature, where it creates a single and indivisible living world. The law of habit is that the living beings in this world are in constant change and repetition, which is a pattern caused by consciousness (Ravaisson, 2015).

Habit; it means being used to something, temperament, ability, familiarity (TDK, 2018). Habit corresponds to an adaptation of the science of ecology. For example, the ability of plants to adapt to changing ecological conditions is considered a habit. The realization of habit in the science of ecology depends on the realization of succession (sustainable change). Similar to such habits, it can generate tendencies toward survival and functioning.

Beings that want to protect and continue their lives create resistance to negative changes. Maine de Biran states that what provides resistance is the being's remembering of the principles of action and therefore thinking (Maity, 2014). Action, on the other hand, is the two main roots that create effort and passion. The opposing development of action and passion creates consciousness. What strengthens consciousness is the continuity of action, which weakens it as the ordinarisation of passion. At the same time, with the continuity of action, pain and intensity lose their effectiveness. If there is no work of effort and passion in the formation of the action, it loses its continuity and effectiveness. Even if the habits of humans are harmful, they can become a prerequisite for life (Ravaisson, 2015). Similar to the habits of humans, in biocenosis, adaptive traits acquired later can never replace genetically inherited traits. Living things can adapt to changing conditions in various ways. However, the features gained through adaptation can change vital metabolic or physiological features and lead to serious problems in the absence of adaptations.

### *2.3.* Causes of Spatial (Ecosystemic) Alienation in the Forest Ecosystem

The main ecological problems, such as rapid population growth, poverty, pollution, and climate change, which cannot be effectively solved on a global scale, also constitute sources of spatial alienation. The reasons for ecosystem alienation are as follows (Dindaroglu, 2017):

1-The formation of physical and morphological changes caused by young individuals, whose optimal habitat conditions are changing and trying to adapt to new ecological conditions, in order to survive. Individuals in this situation cannot mature in a healthy manner. Let's evaluate this situation in terms of forest ecosystems; we can say that clear-cut applications in large areas constitute one of the main reasons for negative spatial (ecosystemic) alienation. Reducing operating costs and eliminating some rejuvenation problems. Therefore, clear-cutting methods are preferred. However, Clear-cut applications eliminate optimal local site conditions. If the clear-cut method is to be applied, it can be applied in limited small areas, taking into account the potential of the habitat (Odabaşı & Özalp, 1994; Akdemir & Özdemir, 2015). Clear-cut applications in large areas significantly eliminate the ecosystem services offered by forest ecosystems to society. In such forest ecosystems, which are at risk of spatial (ecosystemic) alienation, unsuccessful regeneration or adverse effects on potential habitat productivity and biodiversity can occur.

2- Formation of new living conditions by mutual interaction between ancient relict endemic species and new species trying to adapt to deteriorated habitat conditions.

3- The removal of young individuals belonging to species that are forced to adapt to changes in habitat conditions and the settlement of new species in their place.

4- Loss of ability to compete within or between species.

5- Loss of habitat conditions and the necessity of living alone as an individual.

6- Incorrect and excessive human intervention in natural ecosystems.

## 3. Approaches to Combating the Problem of Alienation

Marx stated that the international ideas of Hegel and Feuerbach on alienation, which were a great source of inspiration for him, did not have a chance to be applied in practice (Hyppolite, 2010). Feuerbach focused on the alienation of an abstract person devoid of history and class, whereas Hegel focused on the alienation process that he saw as necessary for people to reach their own consciousness (Marx, 2014). Marx argued that the solution to alienation can come about through the coordinated movement of sovereign people (Marx, 2013).

Duhm states that capitalism is the biggest obstacle in overcoming alienation. However, the inability to find an evaluation of why the analyses they put forward for the alienation problem did not work led to the search for other solutions. In this context, Althusser drew attention to the ambiguity of the concept of alienation and suggested focusing on the exploitation of these workers and class struggle (Çelik, 2001). According to Kierkegaard and Heidegger, the only solution to alienation is to turn to God. According to atheist existentialists such as Sartre and Camus, after accepting the meaninglessness of life in order to overcome alienation, it is necessary to recreate itself with free choices. Mevlâna defined the birth of man as the main source of alienation and described alienation as a break from the whole. Mevlana's analysis against alienation is based on not forgetting the essence and purpose of human creation. According to Mevlana, alienation is everything that will weaken or break one’s relationship with the creator, and to the extent that man gets closer to the creator, he is freed from alienation. In this regard, Mevlana suggested concentrating on the purpose of creation, staying away from worldly passions that distract human beings from the purpose of existence, staying away from deflecting foci for the soul to gain peace, and finding this by turning to their own inner worlds (Tekin, 2010).

On the other hand, Marx analyzed alienation as the separation of humans from nature. According to Marx, religion is seen as an alienating element that enters human nature and reduces human natural and creative characteristics to a passive state (Swingewood, 1991). According to Porrit (1994), people see alienation from the awareness that the nature in which they live is their home, as a problem of alienation. The man’s ability to overcome alienation is part of his test in this world. This is under their own control. According to Bayraktar (1992), on the other hand, human beings have stated that the nature they live in should be purified so that they can evaluate the nature as a sacred entity and design their relationships. According to Freud; It is possible for a person to overcome alienation by becoming aware of the forces that have imprisoned him, expanding the area of freedom and becoming a conscious human being (Dindaroğlu, 2017). Identifying the reality of alienation, which is considered a human-specific phenomenon, with Marxism or other movements can be considered as a reflection that limits the definition and solution of alienation.

Bauman (2016) states that ways to eliminate social strangers are only possible with phagic (inclusive) and emic (exclusionary) strategies. Let's evaluate this approach at the ecosystem scale; alien species either adapt (inclusive) by using the characteristics of the ecosystem and itself, or they have to move away from the environment (exclusive).

Bauman (2016) states that it is necessary to create a physical, cognitive and moral space at the social level in order for the society to get rid of alienation and foreigners. Since humans are living beings in an ecosystem, we can say that this approach also constitutes an important part of ecosystem alienation.

In order to prevent ecosystem alienation or to push strangers into the background, habitat improvement (spatial improvement), as well as the creation of socially improved cognitive and moral spaces. In fact, this approach forms the basis of the "Paraecological" approach. It is a waste of time that human beings tend to isolate themselves from the improvement of environmental disasters caused by them (Dindaroğlu, 2014a).

With today's rapidly developing and transforming modernity, it is not possible to cope with moral experiences left to us from the past (Jonas, 1974). It is understood that the framework and content cannot be determined without establishing effective ethical principles in the future without creating a cognitive and moral space that society will accept. "Forest Engineering" is one of the most important professional disciplines that undertakes important tasks such as preventing ecosystemic alienation in the past and present, controlling foreigners and pushing them into the background. The preservation and development of this professional discipline can provide a more systematic and professional solution to the problem of ecosystemic alienation spreading on a global scale (Dindaroğlu, 2017).

The paraecological approach proposes a solution based on education and the adoption of the problem of "alienation from oneself" in the solution of ecological problems in ecosystems. Paraecological parameters contain flexible solution strategies that can differ for each ecological unit. Some of the prominent parameters in education, especially for the prevention of alienation, are as follows; (1) In the first stage of education, first of all, the tragic consequences of environmental problems are introduced and then their causes are understood, (2) Various teaching techniques should be used in the education process (quantum technique, experiential teaching, gradualism, thinking techniques, etc.). (3) In this process, non-governmental organizations and role models should encourage an ecological lifestyle. (4) They should play an important role in transforming the solutions produced against environmental problems into a lifestyle and internalizing them by using the unique lifestyles, habits, cultures, religious belief tendencies, symbols, rituals, and myths of societies. In order for these solutions to be applied in daily life, they should be supported by psychological approaches, subliminal messages, and their effects should be expanded by being encouraged by legal regulations (Dindaroğlu, 2015).

### *3.1.* Aporia of Alienation in Ecosystem

Beck (2014) stated that the source and solution of the problems faced by modern humanity today pass through technology. This is also a reflection of the doom and indispensability of technology. The dangers posed by modernization are similar to those occurring in ecosystems. Neither was immediately recognizable. Projections of the possible effects may be too long. This is similar to alienation. Alienation may have become a culture and perhaps a habit. Even if this situation is understood, it is much more difficult to take precautions or change lifestyles.

Restoration of deteriorated habitats in natural ecosystems, that is, eliminating alienation, is difficult. Nature takes advantage of its internal dynamics to re-establish disturbed balances. These dynamics gradually begin to repair parts individually, thus transforming the environment. However, these processes are complex interrelationships that affect each other. Despite its complexity, nature has always acted justly. Ecosystems act to achieve or maintain the equilibrium. For example, a large tree will not steal the nutrients of a small sapling because it is very strong. In particular, as forest trees age, the use of plant nutrients does not increase according to their age. Small saplings that require more growth receive more nutrients (Çepel, 1998). However, under competitive conditions, the situation may differ in terms of the environmental effects. Ecosystems can sometimes show a very strong resistance to change. For example, reclaiming an area that has been invaded by invasive species. Sometimes this change happens much more easily. Therefore, it is very important to protect natural ecosystems for self-reference when necessary.

Today, modern society has transitioned from an industrial society to a risky society. Understanding and eliminating threats or reducing their effects depend on the identification of risks and success in risk management. Therefore, more budget and time will need to be allocated for the management of risks in the future. Such predictions can be revealed using mathematical probabilities (Beck, 2014). Antony Giddens states that risk surveillance will form an important basis for the colonization of the future. Despite the fact that the indispensable means of transportation in daily life exploit natural resources and the damage caused by the polluting gases it spreads to the environment, we also witness that the contraction in automobile sales is considered a disaster in many countries. In the end, the excess common interests of the chains of causes that prepare the results that cause the disaster of the people makes the solution even more difficult. Therefore, risk creates an equalizing effect, threatening everyone (Bauman, 2016). Every link that constitutes the chain is alienated. I wonder whether the alienation of mankind is due to the fact that he thinks that the world was created for him. Alienated ecosystems are in a real struggle and war, with their ability to heal and adapt. Again, Bauman (2016) argued that science and technology, which are the other soldiers of the war in the fight against risks, only ensure the sustainability of risks.

One of the most important factors in meeting risks is to evaluate the effects of the action well. Basic features, such as the definition of the impact, its temporal and spatial variation, frequency, and magnitude, should be revealed. Understanding the main characteristics of the impacts that can be caused by natural intervention and developing measures to reduce these impacts can prevent negative ecosystem alienation.

The phenomenon of self-alienation, which is getting increasingly deeper day by day with modernity, can turn into a vicious circle in which it has to use the values it produces even to fight itself. How likely is it that the resources to be used to rehabilitate a deteriorated ecosystem will not increase the pressure on other natural resources? Bauman (2016) continues by stating that the systems that feed modernity will eventually kill their host by constantly exploiting them; "*Growth, imperialism and inflation; It is suicidal in terms of its long-term consequences… What we call economic growth is not the global rise of order, but the process of usurpation of order… More modernity is needed to remove the effects of the wounds inflicted by modernity. It cannot be said with certainty when the tail ends and the snake begin to eat itself. Unfortunately, the snake itself will never have a chance to learn that this point has been passed*."

### *3.2.* The Motives of Nature and the Globalization of Alienation

The main purpose of preserving natural balance is to ensure continuity in substance cycles. This purpose is a source of perfection in nature. The food web is also part of this cycle. In detail, it is actually the world of the strong who survive thanks to the weak victims. Actions, reactions and co-actions feeding each other. Therefore, the existence instincts of nature forced living things to survive. Basic paradigm: Although the weak are chosen as victims, they are built upon the fact that they never perish. Thus, the system must be constantly fed. The strange thing is that none of the living things that make up the system know or understand that they are the victims of the feeding relationship. Every living thing is conditioned to live. The abnormal pattern of events that occurs when the balance is disturbed initiates selection processes and eliminates stability in populations. Now that the weak have lost their lives, the strong will become proportionally more involved in the environment. The abundance of powerful organisms in the environment is a result of ecosystem alienation.

According to Karl Marx, a man's relationship with nature reflects a reflection of individual life. As a result of the disappearance of feudal society and the development of the bourgeoisie, the alienated person left nothing but a callous, self-seeking, and monetary exchange. Modern states function as committees dedicated to the services of the bourgeoisie. Those in the servant class have to sacrifice some of them so that they are not completely destroyed. It cannot be exchanged or sold among people; conscience, virtue, competence, honor, dignity, and so on, are now marketable. The modern world bourgeois and alienated nature use similar arguments. Both were unaware that they were preparing their own ends under the grip of alienation. In this environment, interests are at the forefront and they fight for their interests. Money, the god of man alienated from his own nature, reigns at the last point of interest. The desire to live luxury is the shallowest manifestation of alienation.

Ecosystem services are defined as the products and services provided to all beings on earth. These services can be listed under general headings, such as regulatory, procurement, cultural, and supportive (MEA, 2005). Modern states now demand the monetary equivalents of ecosystem services to be determined and ignore them, taking advantage of the fact that these services cannot be fully compensated because of their multidimensional interactions. This behavior is precisely the result of alienated systems. The necessity of calculating the monetary values of the breath taken, the clean water that is drunk, the soil formed over thousands of years, the comfortable climate, and a landscape with high aesthetic value; then, the sale or exchange of these values, that is, bringing them to the market, is an indicator of the highest level of alienation on a universal scale (Dindaroğlu, 2021).

### *3.3.* Relation of Natural Selection and Alienation

Karl Marx states that in interest-oriented relationships, the person himself does not have value. In the 20$^{th}$ century, society expressed discomfort with degenerating relations, but people who feed on corruption are also afraid of being a part of it. He feels obliged to maintain order to survive as an individual and to continue his comfortable life. Instead of solving problems, a human profile that covers them and moves away has been created. It was thought that a society fed with hypocrisy would be happier in this way. A thousand and one types of hypocrisy, hypocritical morality, hypocritical religion, hypocritical education, hypocritical trade, hypocritical marriages, etc., adopted and finally reached the hypocritical one in happiness.

The digitalized world not only facilitates access to everything but also tends to consume and devalue everything that can be accessed quickly and easily. When the pragmatic thought that he sometimes hides behind him evolves into an opportunistic one, everyone who finds the opportunity starts to take advantage of this situation. What is eroded is actually nothing but self-value judgment. Although the masks were designed by the Venetians to hide themselves and act more freely in history-liberated people at that time, it was understood centuries later that the moral collapse faced by society, which was deprived of identity, could not be solved by talking behind the mask. As a result, the alienation of humans is a basic requirement for the new world order.

Species selection is inevitable in ecosystems that become wild over time. The most dramatic effect of selection is that it destroys species with the narrowest tolerance range. Darwin, surviving species; “Not because they are strong, but because they are best adapted to changing conditions and can act together against common threats.” he describes. Here, the adaptation abilities of living things and their ability to act together come to the forefront.

Living organisms that use different speciation mechanisms to survive in changing conditions with ecosystem alienation manage to survive. Although it must use different mechanisms of speciation, its physiology or morphology changes as a result. Metamorphosis must be completely different. Thus, the basic building blocks were completely modified. If his passions have turned into habits and weaknesses in habits, the human being is fighting to survive alone in an ecosystem that is alienated again without realizing that he is alienated or depersonalized. This struggle is part of the selection process. Those who survive at the end of this period are subject to physical, mental, or spiritual changes without realizing it. These changes not only change and develop people but also leave traces of alienation.

### *3.4.* Paraecology Approach in Education

The sustainability of the solution to ecological problems brings up efforts to create a virtuous person (Curry, 2011). However, ecological movements have been criticized for adopting principles that cannot be applied in real life. Combat against environmental problems reaching a global scale can only be achieved by adopting a global moral understanding (Colucci-Gray et al., 2006). However, ecological views cannot be successful without support from political forces (Brzezinski, 1994). For this, environmental education should be provided starting at a young age.

It is only possible for environmental education to reach the expected goals in society when supported by different disciplines (Atasoy & Ertürk, 2008). Environmental education should also be designed to raise a well-equipped human being who has the ability to direct human behavior and respect nature (Geray, 1995; Ayvaz, 1998). However, rote environmental education is not very effective for people (Yücel & Morgil, 1998; Haktanır & Çabuk, 2000). For this reason, different teaching strategies that make students think, comprehend, analyze, synthesize, evaluate, and apply knowledge should be used (Ben-Peretz et al., 2003). However, modeling is also required to establish the relationship between fields with different impact factors, such as environmental education. To organize human life as a sustainable solution to environmental problems, seven basic elements (myths, symbols, goals, organizational order, control system, rituals, routines, and paradigm) in the culture network were used in Johnson (1998)'s organizational theory.

Dindaroglu (2015) determined some parameters suitable for paraecological approaches that highlight the psychological, sociological, and philosophical values that can help people fight ecological problems, especially in providing eco-ethical improvement, and to examine their potential for use in environmental education. Impact matrices were created using the main components of the methodology created in the "Malik Sensitivity Model" (Vester, 2007) with the parameters determined in accordance with the paraecological approaches (Dindaroğlu, 2015) to combat environmental problems. The effects of the parameters, according to the active and passive values, were determined by the participants and experts (Table 1). Prominent paraecological parameters; understanding of environmental problems; teaching strategies; cultural approach; symbols; rituals; myths; lifestyle; habits; belief tendencies; psychological support; political influence; legal regulations; communication, thinking, metaphors, incrementalism, quantum techniques, civil society organizations, multimedia, materials, field experiences, and role models (Figure 1).

**Table 1.** Paraecological parameters (mean values) matrix in the education of combating environmental problems (Dindaroğlu, 2015).

| | **Parameters** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | Passice Total (PT) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Understanding environmental problems | | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 3 | 2 | **58** |
| 2 | Instructional strategies | 3 | | 2 | 2 | 2 | 1 | 2 | 3 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 1 | 3 | 3 | **55** |
| 3 | Cultural approach | 3 | 3 | | 3 | 3 | 3 | 3 | 3 | 3 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | **42** |
| 4 | Symbols | 2 | 2 | 3 | | 3 | 3 | 3 | 1 | 3 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 2 | **42** |
| 5 | Rituals | 2 | 2 | 3 | 3 | | 3 | 3 | 1 | 3 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 2 | **42** |
| 6 | Myths | 2 | 2 | 3 | 3 | 3 | | 3 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 2 | **41** |
| 7 | Life style | 3 | 3 | 3 | 2 | 2 | 2 | | 3 | 3 | 2 | 1 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 1 | 3 | **55** |
| 8 | Habits | 3 | 3 | 3 | 2 | 2 | 2 | 3 | | 3 | 2 | 1 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 3 | **56** |
| 9 | Religious trends | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | | 2 | 2 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 0 | 3 | **58** |
| 10 | Psychological support | 3 | 3 | 3 | 1 | 1 | 1 | 3 | 3 | 2 | | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 1 | 1 | 3 | **52** |
| 11 | Political influence | 3 | 3 | 3 | 1 | 1 | 1 | 3 | 3 | 0 | 3 | | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | **47** |
| 12 | Legal regulations | 3 | 3 | 3 | 1 | 1 | 1 | 3 | 3 | 0 | 3 | 3 | | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | **47** |
| 13 | Communication | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | **66** |
| 14 | Thinking | 3 | 3 | 2 | 2 | 1 | 1 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | **58** |
| 15 | Metaphors | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | **56** |
| 16 | Incrementalizm | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 3 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | | 3 | 3 | 3 | 3 | 3 | 3 | 3 | **52** |
| 17 | Quantum technique | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 3 | | 3 | 3 | 2 | 2 | 2 | 2 | **52** |
| 18 | Civil society organizations | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | | 3 | 3 | 2 | 1 | 2 | **41** |
| 19 | Organizations | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | 1 | 1 | 2 | **36** |
| 20 | Multimedia | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | | 3 | 1 | 3 | **44** |
| 21 | Materials | 2 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 1 | 1 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 2 | | 1 | 2 | **39** |
| 22 | Field experiences | 3 | 3 | 3 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | **33** |
| 23 | Role models | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 3 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | | **51** |
| | Active Total (AT) | **61** | **62** | **54** | **41** | **36** | **35** | **47** | **50** | **45** | **46** | **37** | **38** | **55** | **54** | **55** | **54** | **52** | **54** | **54** | **55** | **48** | **36** | **54** | |

According to the matrix values of the paraecological parameters; understanding of environmental problems, teaching strategies, cultural approach, lifestyle, habits, belief tendencies, psychological support, communication, thinking, metaphors, incrementalism, quantum technique, civil society organizations, multimedia, role models were included in the critical region of the matrix. Symbols, rituals, myths, political influence, legal regulations, organizations, materials, and field experiences were included in the non-critical but important area (Figures 1 and 2).

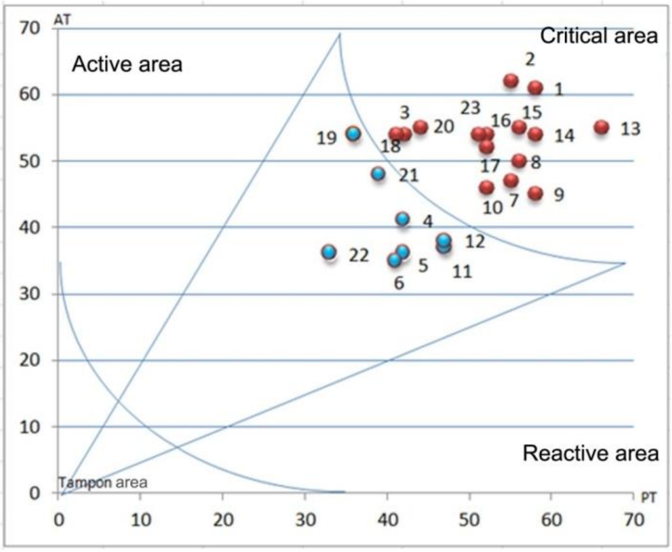


**Figure 1.** Consensus matrix results (Dindaroğlu, 2015).

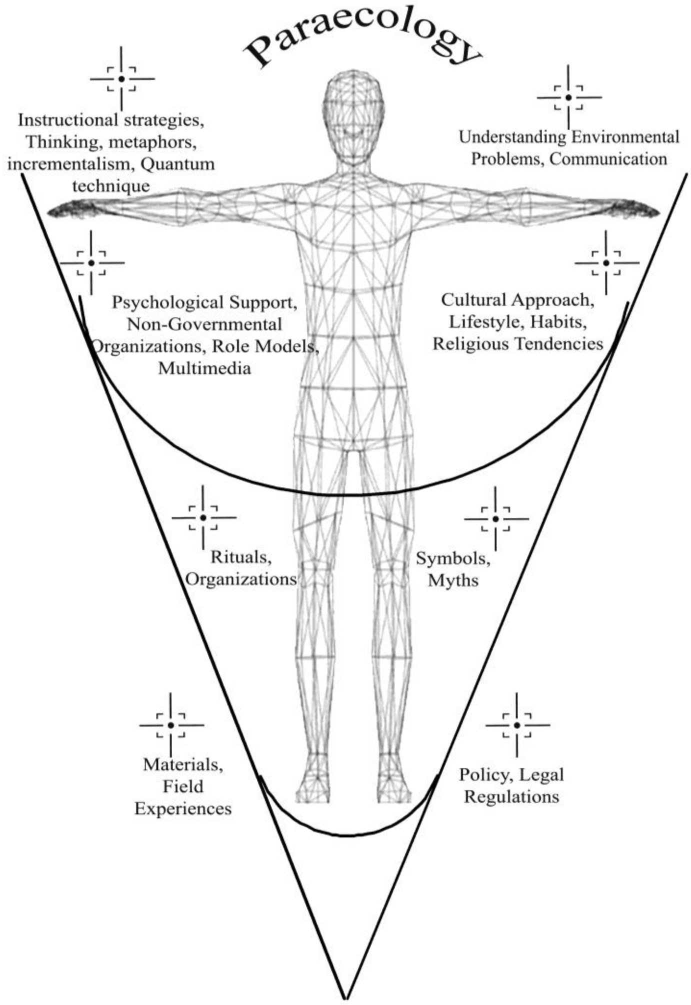


**Figure 2.** Illustration of paraecological parameters and consensus matrix in education (Dindaroğlu, 2015).

## 4. Conclusion

For ecosystems to perform their functions efficiently, the structural and functional properties of the entities composing them must not be impaired. For this, the characteristics of the habitat and food web must not change, and the natural balance must not be disturbed for any reason. In fact, it is accepted by everyone that "balance" ensures the continuity of these cycles. However, the balance of the ecosystem is closely related to the balance of the human beings who are dependent on it. Ensuring the multidimensional balance of humans (social, economic, cultural, spiritual, etc.) primarily depends on the provision of ecological balance.

The creation and maintenance of optimal conditions for living organisms can only be achieved through ecosystem services and cycles. For example; Plants that lose their optimal living environments as a result of global climate change or due to unconscious use migrate over time and disappear completely if change or pressure continues. In terms of ecosystem diversity, losses in gene diversity can also cause losses in species diversity. Losses in species diversity are a result of ecosystem alienation. The alienation processes in ecosystems that cannot fulfill their natural functions have a large share of anthropogenic pressures. However, the ecosystem, which has become alienated by the deterioration of natural balance, will no longer be a safe harbor for human beings. The alienation process, like balance, is a multidimensional phenomenon and has the potential to constantly change its role and shape under the influence of active and passive processes, such as actional, reactionary, and co-actional.

As a result, while the problem of "self-alienation of human beings" is generally based on ecological problems, the present century creates a time period in which the ecosystems are alienated and abandon their functional services, and the aliens in the ecosystem begin to create continuity by creating a social space.

From the perspective of paraecology, alienation accepts this century's pandemic-level latent virus as an ecosystem alienation. Individual human alienation, which started with the industrialization revolution in the past century, has reached the scale of ecosystem alienation by leveling up in this century. Mankind's struggle with alienation became even more difficult in this century. An ecosystem with impaired functions is the background source of never-ending mutations in alienated humans.

Loss of ecological diversity causes disruptions in the food chain at different trophic levels. With the loss of living spaces of plants, which are important raw materials for the pharmaceutical industry as well as food supply, it will pass to a stage that cannot be fed healthily and cannot find the medicine to cure when sick or can be reached at a high cost. As habitat degradation forces plants to migrate, it is not difficult to predict the direction of migration movements of humans, who are more mobile than plants. Weak communities, whose natural resources are plundered by imperial powers, suffer the most from environmental disasters. Protection of natural ecosystems and ensuring their sustainability are among the most important tasks to be addressed in this century. Optimal land use should be planned and anthropogenic-induced land degradation should be prevented. In nature, deserts should remain as deserts, and forests should remain in forests. Each natural ecosystem has important duties in protecting its natural balance, and sustainability can only be achieved by their planned operation and protection with strict rules. One natural ecosystem should not be favored over another.

Efforts to create virtuous people to solve ecological problems to be sustainable cannot be realized by adopting principles that cannot be realized in real life. Combating environmental problems that have reached a global scale can only be possible with the adoption of global nature conservation morality. To create environmental ethics, many parameters that can affect every stage of education can be used: understanding of environmental problems, teaching strategies, cultural approach, symbols, rituals, myths, lifestyle, habits, belief tendencies, psychological support, political influence, legal regulations, communication, thinking, metaphors, incrementalism, quantum techniques, non-governmental organizations, multimedia, materials, field experiences, role models, etc.

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## Conflict of Interest

The author has no conflict of interest to declare.

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REVIEW ARTICLE

# The Role of Artificial Intelligence and Remote Sensing Technologies in Forest Ecosystems and Their Importance in Determining Carbon Capture Potential

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**ABSTRACT**

Climate change and global warming are among the most pressing environmental issues requiring urgent and adequate global action to protect future generations worldwide. One of the key approaches used to reduce $CO_2$ emissions and mitigate the worst effects of climate change is carbon capture technologies. Carbon capture technologies have the potential to capture carbon from the atmosphere and convert it into fuels that can be used in environmentally friendly energy production. Innovative technologies can enhance carbon capture potential, which can play a significant role in combating climate change. Better understanding of mechanisms for capturing, storing, and releasing carbon from the atmosphere allows for more accurate assessments of carbon capture potentials. Scientists, industries, and policymakers are making significant efforts to explore new technologies to reduce greenhouse gas emissions and achieve net-zero emission goals. Development of new technologies involves complex processes and requires a digital system to optimize big data forecasting and reduce production time. Mathematical and statistical approaches play a crucial role in solving research problems, providing fast results and cost-effective tools for predicting large datasets. Effective policies for carbon capture and international cooperation can enhance carbon capture potential. New policies and collaboration models can incentivize investment in carbon capture projects, thereby increasing their potential. These new approaches can be used to better understand carbon capture potential and develop effective solutions to combat climate change. However, research in this field is still ongoing, and further research and development will be needed in the future.

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## 1. Introduction

Ecosystems are defined as complex structures formed by the interaction of living and non-living components. This interaction occurs around three fundamental functions: energy transfer, chemical cycles, and population controls (Odum, 1989). Energy transfer initiates with the utilization of sunlight by plants through photosynthesis and continues by being transferred among organisms in food chains. Chemical cycles involve the transformation of elements through biological, geochemical, and atmospheric processes. Population controls regulate the growth and decline of populations because of interactions between species. Each element within the ecosystem has specific functions and maintains equilibrium with other elements while fulfilling these functions. For instance, plants absorb $CO_2$ from the atmosphere through photosynthesis, while animals consume oxygen and produce $CO_2$. This equilibrium preserves the functionality of the ecosystem. However, disturbances to this balance can lead to disruptions in the functioning of the entire system, threatening its existence.

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Carbon (C) is a ubiquitous and fundamental element found in nature, shared by all living organisms. Carbon is crucial as a building block of biological molecules and is present in both living and non-living structures, ranging from the glucose produced in photosynthesis to various organic and inorganic compounds. Particularly, carbon in the form of $CO_2$ in the atmosphere has contributed to environmental issues such as global warming and climate change with its increasing levels over the past century. Carbon exhibits a high affinity for bonding compared to many other elements and can be found in nature both in its elemental form and in compounds. Carbon present in organic compounds forms the structure of living organisms, while it can also be found in inorganic compounds such as carbonates (Mirici & Berberoğlu, 2020).

The carbon cycle is the process of recycling carbon atoms in nature, and in this process, plants in terrestrial ecosystems play a significant role. Plants absorb carbon dioxide from the atmosphere through photosynthesis, particularly in large areas such as forests, creating a significant carbon sink (Pan et al., 2011). Additionally, plants contribute to the carbon cycle by transferring $CO_2$ to the soil through their roots and fallen leaves (Felzer et al., 2005; Sitch et al., 2007; Ainsworth et al., 2012). However, carbon can be released back into the atmosphere from plants through the emission of volatile organic compounds from their leaves and the decomposition of soil organic matter and plant litter (Guenther et al., 2012; Krishna & Mohan, 2017; Chen & Chen, 2018). Factors such as climate and environmental conditions affecting plant physiology, as well as factors like global warming and changes in atmospheric composition, can significantly impact the carbon cycle, crop productivity, and biological diversity in a concerning manner (Feng et al., 2019, 2022; Agathokleous et al., 2020; Chaudhry & Sidhu, 2022).

The efforts to achieve post-industrial economic growth targets, coupled with the unrestricted use of products within ecosystems as natural resources and flawed land use policies, result in high levels of $CO_2$ emissions from terrestrial ecosystems to atmospheric systems. Throughout the process of retaining the generated carbon dioxide in the atmosphere, it can be stored in various parts of woody and herbaceous plants, ranging from root and stem structures to leaf and bark contents. Therefore, green areas serve as significant regions that absorb a high amount of freely circulating carbon gas on Earth. The retained carbon gases are stored in the genetic structures of all plants within forest ecology in different manners (Ataf, 2017).

The increase in $CO_2$ levels in the Earth's atmosphere, along with other greenhouse gases, leads to global climate change and temperature rise. Research indicates that global climate change is attributed to $CO_2$ effects ranging from 55% to 80%. Plants absorb atmospheric $CO_2$ through photosynthesis to produce organic matter. Forests, having the highest leaf area compared to other plant communities, are where $CO_2$ is predominantly consumed. Hence, the preservation and expansion of forested areas on Earth's surface through afforestation are recommended as the most effective methods to delay global climate change.

Forests are the largest sink areas and significant reservoirs where carbon gases are sequestered. With their structural features and both above and below-ground components, forests containing annual and perennial herbaceous and woody plants facilitate the absorption of free carbon gas. Therefore, areas with dense populations of photosynthetic organisms are observed to sequester more carbon gas. The forest ecosystem, which contains 76-78% of the carbon gas sequestered in terrestrial areas, plays a crucial role in combating global warming (Kahyaoğlu et al., 2019).

Greenhouse gas emissions led to severe global climate change, and urgent reductions in $CO_2$ emissions are necessary. Carbon capture and storage represent highly reliable technologies for reducing carbon emissions and hold potential for reducing the greenhouse effect in the future. Machine learning (ML) is one of the fastest-growing areas of intelligent technology today, regarded as a significant tool for performing demand forecasting based on computer science and data statistics.

Machine learning is applied in the development of prediction systems, particularly in highly complex systems where modeling with deterministic methods is challenging, using past experiences. These techniques provide a closed-form input-output relationship that automatically generates and manages computational models based on existing data, maximizing a performance criterion depending on the problem.

Recently developed machine learning methods show promising progress due to their ability to effectively integrate remote sensing products with ground observation data. Data-driven machine learning methods can preserve the effective information of remote sensing products and sample observation data, extract complex nonlinear relationships between input and output variables, and achieve the goal of merging different data scales, providing high flexibility and data adaptability. Data-driven approaches based on machine learning can extract new information from data and develop insights about new mechanisms. Research also indicates that machine learning methods are more successful in predicting ecosystem carbon sinks compared to traditional statistical methods. In this context, using machine learning methods as a bridge to integrate remote sensing products with ground observation data offers an effective solution to reduce prediction uncertainty.

The impacts of global climate change are increasingly evident, with the rise in greenhouse gas concentrations in the atmosphere accelerating this process. Therefore, the preservation and restoration of ecosystems with high carbon capture capacity are of paramount importance. Forests play a critical role in the carbon cycle and biological diversity worldwide, making the determination of carbon capture potentials a significant research topic. In this study, we will explore novel approaches beyond traditional methods, utilizing machine learning to determine the carbon capture potential in forests.

## 2. Determination of Carbon Capture Potentials of Forests through Traditional Methods

The carbon capture potentials of forests are typically determined through traditional methods such as long-term data collection, field measurements, and statistical analyses. These methods involve a detailed analysis process that considers biological and physical characteristics of forests as well as soil, climate, and other environmental factors. Environmental factors are given in Table 1.

**Table 1.** Environmental factors.

| Soil properties | Climate conditions | Vegetation and biodiversity | Topography |
|---|---|---|---|
| Soil form | Rainfall regime | Species diversity | Land slope |
| Organic matter content | Heat | Growth rates of trees | Height |
| pH | Moisture | Ages | Water drainage |
| Depth | Wind speed | Densities | Aspect |

### *2.1.* Field Measurements and Statistical Analyses

The process of determining carbon capture potentials in forests begins with field measurements. These measurements typically encompass factors determining forest structure such as tree species, age, diameter, height, and density, as well as soil properties like organic matter content. The collected data is processed through statistical analyses and utilized to estimate the carbon storage capacity of forests. These analyses are crucial for understanding the quantity and distribution of carbon stocks in forests.

### *2.2.* Biophysical Models

Another traditional method used to determine the carbon capture potentials of forests is the use of biophysical models. These models simulate the carbon cycle of forest ecosystems and assess the impacts of various factors (e.g., climate change, soil properties, plant species, etc.) on carbon storage. These models typically rely on processes such as tree growth rates, photosynthetic activity, organic matter decomposition, and use mathematical formulas to predict carbon capture potentials.

### *2.3.* Soil Analyses

Since soil is a crucial component of carbon storage, soil analyses are also important in determining the carbon capture potentials in forests. These analyses typically involve determining the physical and chemical properties of soil samples. Factors such as soil organic carbon content, soil texture, pH, and nutrient elements influence the carbon storage capacity of forest soil. These data are used to evaluate the carbon storage potentials of forests in the soil.

Overall, the determination of carbon capture potentials of forests is a complex process involving various data collection and analysis methods. Traditional methods typically rely on direct field studies, while the use of modern technologies enables broader coverage and more precise predictions. These methods play a crucial role in the sustainable management of forest resources and in combating climate change.

## 3. New Approaches and Technologies

Determining the carbon capture potential of forests is crucial for environmental conservation and combating climate change. In addition to traditional methods, evolving technologies and advanced analysis techniques provide new and effective approaches for assessing this potential. Next-generation remote sensing technologies, such as high-resolution imagery and laser scanning tools, offer the opportunity to analyze the structural characteristics of forests in detail. These technologies can be utilized to determine the biophysical properties of forests, tree density, species diversity, and age distribution. Furthermore, advanced analysis methods like machine learning and artificial intelligence play a significant role in predicting carbon storage potential in forests by processing large amounts of data. These methods can model the complex relationships between forest structural characteristics and carbon stocks and forecast future changes. However, it is essential to consider environmental factors such as local climate data and soil properties. These data are crucial for understanding the effects of forest ecosystems on the carbon cycle and identifying potential carbon storage areas. Evolving technologies and advanced analysis methods offer new and effective approaches for determining carbon capture potential in forests. These approaches could be a significant step for environmental conservation and combating climate change, contributing significantly to the sustainable management of forests.

### *3.1.* Remote Sensing Methods

In recent years, remote sensing methods have become a significant research area for determining the carbon capture potential of forests. Remote sensing enables the analysis of the structural and biophysical characteristics of forests through technologies such as high-resolution images and laser scanning collected from satellites and aircraft (Zhang et al., 2019). With these technologies, important features of forests such as tree density, species diversity, age distribution, tree height, and total carbon stock can be directly measured.

Remote sensing is a technique used to determine the properties of objects using data collected by remote sensors and devices. Remote sensing techniques can be used to estimate carbon stock in forest cover through aerial and satellite imaging systems. High-resolution satellite data allows for the development of models that identify relationships between plant biomass and carbon stock. Additionally, the use of artificial intelligence algorithms and computer vision analyses enhances the potential for automatically identifying trees and predicting carbon stocks.

Remote sensing data can be collected over larger areas and more rapidly compared to traditional field measurements, allowing for the creation of more comprehensive carbon inventories. Furthermore, remote sensing techniques can be used to monitor forest dynamics over time and understand changes in carbon storage potential. Therefore, remote sensing methods are considered an important tool for determining the carbon capture potential of forests and developing sustainable forest management strategies.

### *3.2.* Artificial Intelligence Methods

Climate change stands out as a prominent environmental threat on a global scale, and determining the carbon capture potential of natural ecosystems is a crucial step in combating this threat. Experts in the field of forestry are working in various research areas to better understand and enhance the carbon capture capacity of natural forests. In this context, artificial intelligence (AI) methods emerge as advanced analytical tools.

Artificial intelligence methods such as machine learning are effectively utilized in complex processes such as analyzing large datasets, identifying carbon capture properties, and predicting carbon emissions from forest ecosystems. Machine learning algorithms are particularly important in determining the carbon capture potential of forests. These algorithms process large datasets to identify factors associated with carbon capture in forests and use these factors to predict carbon storage capacity. Additionally, machine learning methods use learning algorithms to identify plant species and other ecosystem components in forests and predict their carbon capture capacities.

In this context, artificial intelligence methods emerge as effective tools in forestry for carbon management and combating climate change. The use of artificial intelligence techniques in determining the carbon capture potential of natural forest ecosystems can contribute to the development of forestry policies and the creation of sustainable forest management strategies.

### *3.3.* Machine Learning (ML) Methods

Determining the carbon capture potential of forests is of critical importance for environmental conservation and combating climate change. In this context, machine learning (ML) methods play a significant role in analyzing large datasets and deciphering complex relationships (Mitchell, 2014; Yan et al., 2021). ML methods can provide faster and more accurate results compared to traditional methods in predicting the carbon capture potential of forest ecosystems.

Machine learning can identify factors associated with carbon capture by analyzing large datasets and use these factors to predict the carbon capture potential of forest ecosystems. These methods can be effective in identifying plant species and other ecosystem components in forests, predicting carbon storage capacity, and monitoring changes in the carbon cycle.

ML methods offer various approaches in determining the carbon capture potential of forests. Among these approaches are various algorithms such as support vector machines, decision trees, random forests, and deep learning. These algorithms can be used to analyze factors influencing carbon storage capacity in forests and predict the carbon capture potential of forest ecosystems.

#### *3.3.1. Decision tree (DT)*

Decision trees are a popular machine learning algorithm used for both classification and regression tasks. They work by recursively partitioning the data into subsets based on the values of input features, maximizing the homogeneity of resulting subsets at each split. This process continues until a stopping criterion, such as reaching maximum tree depth or minimum number of samples in a node, is met.

One of the most significant advantages of decision trees is their interpretability. The resulting tree structure is easy to understand and can be visualized, facilitating explanation of the logic behind predictions. Additionally, decision trees can handle both numerical and categorical data and are robust to outliers and missing values. However, decision trees tend to overfit, especially when allowed to grow very deep. Techniques such as pruning and adjusting maximum tree depth or minimum samples per node can be used to mitigate this issue. Additionally, ensemble methods like random forests and gradient boosting can be employed to combine multiple decision trees for enhanced performance.

In summary, decision trees are versatile and interpretable models widely used in various machine learning applications. While they have limitations such as overfitting, these can be alleviated with proper tuning and ensemble techniques, making decision trees a valuable tool in predictive modeling.

#### *3.3.1.1. determining carbon capture potential of forests: decision trees*

Determining the carbon capture potential of forests is crucial for forestry management and climate change strategies. In this context, machine learning methods such as decision trees can be effective tools for predicting the carbon storage capacity of forest ecosystems (Işık et al., 2024).

Decision trees are modeling techniques that represent complex relationships in the dataset as simple decision rules. When decision trees are used to determine the carbon capture potential of forests, the impact of various factors (such as plant species, soil properties, climate data) on carbon storage capacity can be examined. Decision trees offer several advantages. Firstly, they are easy to explain and interpret since the tree structure is represented in a human-understandable format. Additionally, decision trees can tolerate missing values in the dataset and can work with both categorical and numerical data.

When using decision trees in the process of determining the carbon capture potential of forests, careful preparation of the dataset and proper training of the model are important. Selecting the right features and avoiding overfitting can improve the accuracy of predictions. Decision trees are an effective machine learning method that can be used in the process of determining the carbon capture potential of forests. This method can support decision-making processes in forestry and contribute to the development of sustainable forest management strategies.

### *3.3.2. Random forest (RF)*

Random Forest (RF) is a powerful ensemble learning method used for both classification and regression tasks. It is based on the concept of decision trees but enhances them by reducing overfitting and improving prediction accuracy.

In the Random Forest model, multiple decision trees are independently trained on random subsets of the training data and random subsets of features. During training, each tree is constructed by selecting a random subset (with replacement) of the training data and considering only a random subset of features at each split. This randomness helps reduce overfitting by decorrelating individual trees. To make predictions, each tree in the forest independently predicts the target variable, and the final prediction is determined by aggregating the predictions of all trees. For regression tasks, this aggregation is typically done by taking the average of individual tree predictions, while for classification tasks, it can be done by taking the majority vote.

Random Forests offer various advantages over single decision trees. They are resilient to overfitting and handle high-dimensional data well. Additionally, they provide estimates of feature importance that can be useful for feature selection and interpretation. Moreover, the implementation of Random Forests is relatively straightforward, and they can handle both numerical and categorical data without requiring preprocessing. Overall, Random Forest is a versatile and powerful machine learning algorithm widely used in practice due to its high performance, robustness, and ease of use.

#### *3.3.2.1 determining forest carbon capture potential: random forest (RF)*

Ensemble learning methods like Random Forests have become significant research avenues in recent years for determining the carbon capture potential of forests (Gozukara et al., 2023). Random Forests rely on the principle of training each tree on a random subset of the data using multiple decision trees to make predictions. This way, each tree constructs its unique learning model, and then these models are aggregated to obtain a stronger and more stable predictive model.

When Random Forests are used to determine the carbon capture potential of forests, various input features (e.g., plant species, soil composition, climate data) are considered, and the impact of these features on carbon storage capacity is analyzed. Each decision tree predicts carbon storage potential using different combinations of these features. Then, predictions obtained from all trees are aggregated to make a collective prediction.

The success of Random Forests in determining forest carbon capture potential can be evaluated from multiple perspectives. Firstly, this method provides higher prediction accuracy compared to a single tree because predictions from multiple trees are combined. Additionally, Random Forests enable feature selection to assess the importance of each feature and build the most effective predictive model.

In conclusion, ensemble learning methods like Random Forests offer an effective and reliable approach for determining the carbon capture potential of forests. These methods support decision-making processes in forestry and contribute to the development of sustainable forest management strategies.

### *3.3.3. Artificial neural networks (ANNs)*

Artificial Neural Networks (ANNs) are a form of artificial intelligence technology that encompasses mathematical models and algorithms inspired by the functioning of biological neural networks. ANNs are used to describe complex data relationships, discover patterns, and make predictions. They consist of interconnected artificial neurons or units called neurons. Each neuron receives input data, multiplies these inputs by weights, passes them through an activation function, and then produces an output. The overall output of the network is obtained by appropriately combining the outputs of each neuron (Sazli, 2006).

ANNs have a wide range of applications. For instance, ANNs used in classification problems are successfully employed in various fields such as image recognition, text classification, and medical diagnosis. Additionally, ANNs used in regression problems are effective in areas such as stock price prediction, weather forecasting, and market demand prediction.

The training of ANNs is typically an iterative process carried out with real data. The data set is fed into the network, the network's predictions are compared with the actual values, and then the model parameters (weights and biases) are updated to reduce errors. This process is repeated to enable the network to make accurate predictions, and the overall performance of the network improves.

Artificial Neural Networks are considered powerful and flexible tools for identifying patterns and making predictions in complex data sets. However, training and computation processes of the network can be time-consuming, especially when working with large data sets, and may encounter some issues like overfitting. Therefore, careful design and training of ANNs are crucial.

#### *3.3.3.1. determining forest carbon sequestration potential: artificial neural networks*

Artificial Neural Networks (ANNs) are machine learning models with the ability to learn from complex datasets. The use of ANNs in determining the carbon sequestration potential of forests may involve analyzing information from various data sources and creating models to predict carbon sequestration potential in forests (Nandy et al., 2017). Here are some general approaches where ANNs could be used in this process:

Data Collection and Preparation: The first step in utilizing ANNs typically involves appropriate data collection and preparation. Various factors such as climate data, soil properties, plant species, and forest structure can be among the data used to determine the carbon sequestration potential in forests. ANNs can process and analyze this data.

Model Development and Training: ANNs can learn complex relationships from such data and develop models to predict the carbon sequestration potential in forests. These models can be trained to predict the carbon storage capacity in a particular forest ecosystem.

Validation and Adjustments: It is important to evaluate the accuracy of the models created by ANNs and adjust as necessary. This process may involve various validation techniques to determine how well the model performs on real-world data.

Application and Prediction: The developed models by ANNs can be used to predict the carbon sequestration potential in a specific forest ecosystem. These predictions can play a significant role in the formulation of forestry policies and strategies such as carbon trading.

Continuous Updating and Improvement: Forest ecosystems change over time, so it is important to continuously update and improve the models used by ANNs. This may involve adding new data and ensuring that the model adapts to changing conditions.

The use of ANNs in determining the carbon sequestration potential of forests can contribute to the sustainable management of natural resources and play a significant role in combating climate change. This approach can assist in making informed and efficient decisions in forest management (Tsai & Kuo, 2013).

### *3.3.4. Convolutional neural networks (CNNs)*

Convolutional Neural Networks (CNNs) are deep learning models that have been particularly successful in areas such as image processing and recognition. They are designed to process unstructured and high-dimensional datasets, especially visual data, and have a structure that is optimized for image processing (Taye, 2023).

The fundamental components of CNNs include convolutional layers, activation functions, pooling layers, and fully connected layers. Convolutional layers learn different features of an input image by moving filters (kernels) over the input image. Activation functions enhance the learning ability of the network by activating the outputs at each layer. Pooling layers reduce the output size, thereby reducing computational costs and improving the network's generalization ability. Fully connected layers combine all feature maps to obtain the output of the network."

CNNs have achieved significant success in many applications, particularly in image classification, object detection, facial recognition, land classification, and medical image processing. Especially in competitions conducted on large datasets such as ImageNet, they have shown significantly better performance compared to traditional methods.

The key to the success of CNNs lies in the use of learnable filters and shared weights between layers. These features enhance the network's ability to generalize overall features and learn specific characteristics.

#### *3.3.4.1. determining forest carbon sequestration potential: convolutional neural networks*

An advanced approach for determining the carbon sequestration potential of forests involves the use of Convolutional Neural Networks (CNNs). CNNs are one of the widely used deep learning methods, particularly in the field of image processing. However, the success of this model in determining the carbon sequestration potential in forests depends on the quality of the dataset and, especially, the proper selection of input data.

The working principle of CNNs is like ANN in terms of determining the carbon capture potential in forests.

The use of CNNs in determining the carbon capture potential in forests can be a valuable tool for the sustainable management of these valuable natural resources. However, careful data collection, preprocessing, and model training are required for the accuracy and reliability of the model.

There are many advantages and disadvantages between traditional machine learning methods and deep learning (such as CNN). The main advantages and disadvantages of these two approaches are given in the table below (Table 2).

**Table 2.** Key advantages and disadvantages between traditional machine learning methods and deep learning (such as CNN).

| **Traditional Machine Learning Methods (Random Forest, Decision Trees)** | | **Deep Learning (CNN)** | |
|---|---|---|---|
| **Advantages** | **Disadvantages** | **Advantages** | **Disadvantages** |
| High interpretability | May be inadequate to model complex relationships | Automatic feature extraction | High computing power requirement |
| Less computational complexity | May have difficulty modeling nonlinear relationships | Modeling complex relationships | Large data sets requirement |
| Less dependence on data | Tendency to overfitting | Superior performance on large data sets | Interpretability challenge |

The advantages and disadvantages of both approaches may vary depending on their specific requirements and the amount of data available. Therefore, it is important to consider your problem area and available resources when choosing the most appropriate method.

## 4. Conclusion

Determining the carbon capture potential of forests with new methods emerges as a significant step in forestry and climate change mitigation. The utilization of innovative technologies such as artificial intelligence and data science, alongside traditional methods, enables us to achieve more accurate and comprehensive results. Through these new methods, it becomes possible to better understand the interaction of various factors, predict carbon capture capacity, and identify potential areas for improvement. Therefore, the adoption of new methods to determine the carbon capture potential of forests can contribute to the more effective development and implementation of forestry policies and carbon trading strategies. This, in turn, can promote sustainable forestry practices and facilitate the discovery of more effective solutions in combating climate change.


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## Declaration

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## Conflict of Interest

The author has no conflict of interest to declare.

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## AIMS & SCOPE

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• Research articles: original full-length research papers which have not been published previously and should not exceed 7500 words or 25 manuscript pages (including tables and figures)

• Review articles: on topical subjects and up to 10000 words or 25 manuscript pages (including tables and figures)

• Short communications: describing work that may be of a preliminary nature or a case report; preferably no more than 3000 words or 10 manuscript pages (including tables and figures)

• Letters to the Editor: should be included on matters of topical interest and not exceeding 2000 words or 10 manuscript pages (including tables and figures)

**Page Charges**

This journal has no page charges.

**Preparation of Manuscripts**

Papers must be written in English. Prepare your text using a word-processing software and save in ".doc" or ".docx" formats. Manuscripts must be structured in the following order:

- ***Title Page File***
  - Title (Concise and informative. Avoid abbreviations and formulae)
  - Author names and affiliation addresses (Full names should be given, no abbreviations. The corresponding author should be identified with an asterisk. Each affiliation address should include institution, faculty/school, department, city, and country)
  - ORCID numbers for all authors.
  - Corresponding author's e-mail, telephone number, and address
  - Acknowledgements (if applicable. Keep these to the absolute minimum)
  - Compliance with Ethical Standards
    - Conflict of Interest Statement
    - Statement on the Welfare of Animals (if applicable)
    - Statement of Human Rights (if applicable)
- ***Main File***
  - Title
  - Abstract (Should be between 200 and 250 words. References and abbreviations should be avoided)
  - Keywords (Minimum 4, Maximum 6 keywords)
  - Introduction
  - Materials and Methods
  - Results
  - Discussion (Can be combined with Results section if appropriate)
  - Conclusion (Can be combined with Discussion section if appropriate)
  - References
  - Table(s) with caption(s) (on appropriate location in the text)
  - Figure(s) with caption(s) (on appropriate location in the text)
  - and appendices (if any)

**Manuscript Formatting**

Use a 12-point Times New Roman font, including the references, table headings and figure captions, double-spaced and with 25 mm margins on all sides of A4 size paper throughout the manuscript. The text should be in single-column format.

• Each page must be numbered with Arabic numerals, and lines must be continuously numbered from the start to the end of the manuscript.
• Use italics for emphasis.
• Use only SI (international system) units.
• Use "dot" for decimal points.
• Use italics for species name.

**References**

*SilvaWorld* uses APA style (7th edition). Accordingly, authors must format their references as per the guidelines below. Please ensure that each reference cited in the text is also presented in the reference list. Authors should always supply DOI or URL of the work cited if available.

***In-text citation (Narrative):***

…The results of Ayan (2022) support…
…Ayan and Yer (2020) indicated that…
…According to the method of Ayan et al. (2021)…

***In-text citation (In parenthesis):***

…It was found to be isometric (Ayan, 2018)…
…is highly susceptible to diseases (Ayan & Kara, 2019)…
…have been studied (Yer et al., 2020)…

***Two or more works in the same parenthesis:***

…extremely toxic for the environment (Ayan, 2018, 2019; Sönmez et al., 2020a; Ayan & Turgut, 2021)…

***Citation in the reference list:***

References should be listed first alphabetically and then further sorted chronologically at the end of the article. The citation of all references should conform to the following examples:

***Article:***

Lastname, N., Lastname, M., & Lastname, O. (Year). Title of the work. *Title of the Journal*, *Volume*(Issue), Page numbers. DOI

Ayan, S. (1998). Tüplü sarıçam *Pinus silvestris* L. fidanı üretiminde yavaş yarayışlı gübrelerin etkileri. *Developmental & Comparative Immunology*, *35*(12), 1366-1375. https://doi.org/10.1016/j.dci.2011.07.002

Öztürk, S., & Ayan, S. (2015). Management alternatives in national park areas: The case of Ilgaz Mountain National Park. *Eco Mont-Journal on Protected Mountain Areas Research*, *4*(4), 37-44. https://doi.org/10.1046/j.1467-2979.2003.00121.x

Yer Çelik, E. N., Baloğlu, M. C., & Ayan, S. (2021). Gene expression profiles of Hsp family members in different poplar taxa under cadmium stress. *Turkish Journal of Agriculture and Forestry*, *45*(10), 102-110. https://doi.org/10.1111/jfd.13229

***Article by DOI (early access):***

Ayan, S., Çalışkan, E., Özel, H. B., Yer Çelik, E. N., Yılmaz, E., Gülseven, O., & Akın, S. S. (2022). The influence of effective microorganisms on physiological characteristics of containerized Taurus Cedar (*Cedrus libani* A. Rich.) seedlings. *Cerne*. https://doi.org/10.1590/01047760202228013018

***Book:***

Lastname, N., Lastname, M., & Lastname, O. (Year). *Title of the work*. Publisher.

Oidtmann, K., Xao, Q., & Lloyd, A. S. (2018). *The food need by the year 2050*. Elsevier.

***Book Chapter:***

Lastname, N., Lastname, M., & Lastname, O. (Year). Title of the chapter. In N. N. Lastname, A. Lastname & B. Lastname (Eds.), *Title of the book* (pp. Page numbers). Publisher.

Barbati, A., Mugnozza, G. S., Ayan, S., Blasi, E., Calama, R., Cicatiello, C., Canaveira, P., Collalti, A., Corona, P., Rio, M. del R., Ducci, F., & Perugini, L. (2018). Adaptation and mitigation. In G. A. E. Gall & H. Chen (Eds.), *State of Mediterranean forests* (pp. 51-63). Elsevier. https://doi.org/10.1016/b978-0-444-81527-9.50010-5

***Dissertation or Thesis:***

Lastname, N. (Year). *Title of dissertation/thesis* (Doctoral dissertation/Master's thesis, Name of Institution).

Ayan, S. (1990). *Determination of the characteristics of growing media and production technique for containerized oriental spruce (Picea orientalis (L.) link.) seedlings* (Doctoral dissertation, Karadeniz Technical University).

Ayan, S. (1988). *Appreciation on height growth of ten years of age of norway spruce (Picea abies (L.) karst.) origins in Eastern Black Sea region* (Master's thesis, Karadeniz Technical University).

***Conference Proceedings:***

Lastname, N., Lastname, M., & Lastname, O. (Year). *Title of the work*. Title of the Conference. City.

Ayan, S., Ayan, Ö., Altunel, T., & Yer, E. N. (2014). *Honey forests as an example agroforestry practices in Turkey*. World Congress of Agroforestry. New Delhi.

***Institution Publication:***

Institution name. (Year). *Title of the work*. URL

FAO. (2020). *Forestry statistics 2018*. http://www.fao.org/3/cb1213t/CB1213T.pdf

***Internet Source:***

Lastname, N. (Year). *Title of the work*. Retrieved May 15, 2020, from URL

Ayan, S. (2019). *Utilization of Zeolite as plant growing media*. Retrieved Jan 12, 2021, from https://earsiv.kastamonu.edu.tr/

**Table(s)**

Tables, numbered in Arabic, should be in separate pages with a short descriptive title at the top. Place footnotes to tables below the table body and indicate them with superscript lowercase letters (or asterisks for significance values and other statistical data).

**Figure(s)**

All illustrations should be labelled as 'Figure' and numbered in consecutive Arabic numbers, Figure 1, Figure 2 etc. in the text. If panels of a figure are labelled (a, b, etc.) use the same case when referring to these panels in the text. Figures are recommended to be in electronic formats such as PNG, JPEG, TIFF (min. 300 dpi). All figures or tables should be presented in the body of the text.

**Online Manuscript Submission**

Authors are requested to submit manuscripts via the journal's online submission system at https://prensipjournals.com/ojs/index.php/silva/login

**Submission Checklist**

- Author Guidelines of the journal has been read and adhered
  - **Title Page File**
    - Title
    - Full names, e-mails, and affiliation addresses of all authors
    - ORCID numbers of all authors
    - Corresponding author's e-mail, telephone number, and address
    - Ethical statements
  - **Main File**
    - Continuous page numbers
    - Continuous line numbers
    - Blinded document (no personal information is present)
    - Title
    - Abstract (200-250 words)
    - Keywords (4-6 keywords)
    - All figures and tables are numbered and cited in order in text
    - Completeness and accuracy of the references have been checked
    - References have been edited as per the Journal guidelines

**Publication Frequency**

The journal includes original scientific articles on a variety of different subjects in English and is being published twice a year in June and December.

**Publication Fees**

*SilvaWorld* is an open access journal. No submission or publication charges are collected. All authors and readers have free access to all papers.

## PUBLICATION ETHICS

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## OPEN ACCESS POLICY

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## REVIEW PROCESS

**Double-Blind Review and Evaluation Process**

Double-Blind Review is a method applied for publishing scientific publications with the highest quality. This method forms the basis of an objective evaluation of scientific studies and is preferred by many scientific journals.

The views of referees have a decisive place in the publication quality of a Journal. *SilvaWorld* uses the double-blind review method, which means that both the reviewer and author identities are concealed from the reviewers, and vice versa, throughout the review process, in the evaluation process of all studies. For this reason, the authors are asked to blind their manuscripts before submitting. All the studies submitted to *SilvaWorld* are evaluated by double-blind review method according to the following steps.

***1. Initial Evaluation Process***

The studies submitted to *SilvaWorld* are first evaluated by the editor. At this stage, studies that are not in line with the aim and scope of the journal, are weak in terms of language and narrative rules in English, contain scientifically critical mistakes, are not original worthy, and cannot meet publication policies are rejected. Authors of rejected studies will be notified within one month at the latest from the date of submission. Eligible studies are sent to the field editor to which the study is relevant for pre-evaluation.

***2. Pre-Evaluation Process***

In the pre-evaluation process, the field editors examine the studies, introduction and literature, methods, findings, results, evaluation and discussion sections in detail in terms of journal publication policies, scope and authenticity of study. Study which is not suitable as a result of this examination is returned to the author with the field editor's evaluation report within four weeks at the latest. The studies which are suitable for the journal are passed to the referee process.

***3. Referee Process***

The studies are sent to the referees according to their content and the expertise of the referees. The field editor examining the study may propose at least two referees from the pool of *SilvaWorld* Advisory Board or referee pool according to their field of expertise or may propose a new referee appropriate to the field of study. The editors evaluate the referee's suggestions coming from the field editor and the studies are submitted to the referees. Referees are obliged to guarantee that they will not share any process or document about the study they are evaluating.

***4. Referee Evaluation Process***

The period given to the referee for the evaluation process is 15 days. Proposals for corrections from referees or editors must be completed by the authors within 1 month according to the "correction instruction". Referees can decide on the suitability of the study by reviewing the corrections and may also request multiple corrections if necessary.

**Referee Reports**
Referee evaluations are based in general on the originality of the studies, the method used, and the conformity with the ethical rules, the consistent presentation of the findings and results, and the examination of the literature.

This review is based on the following elements:

*1. Introduction and Literature:* The evaluation report contains the presentation and purpose of the problem addressed in the study, the importance of the topic, the scope of the relevant literature, the timeliness and the originality of the study.

*2. Methodology:* The evaluation report includes information on the suitability of the method used, the choice and characteristics of the research group, validity and reliability, as well as on the data collection and analysis process.

*3. Findings:* The evaluation report includes opinions on the presentation of the findings obtained in the frame of the method, the correctness of the analysis methods, the aims of the research and the consistency of the findings, the presentation of the required tables, figures and images and the conceptual evaluation of the tests used.

*4. Evaluation and discussion:* The evaluation report includes the opinion on the subject based on findings, relevance to research questions and hypotheses, generalizability and applicability.

*5. Conclusion and suggestions:* The evaluation report contains the opinion on the contributions to the literature, future studies and recommendations for the applications in the area.

*6. Style and narration:* The evaluation report includes compatibility of the title with the content, appropriate use of English in the study, refers and references in accordance with the language of the study and APA rules.

*7. Overall evaluation:* The evaluation report contains opinion on the authenticity of the study as a whole, its contribution to the educational literature and the applications in the area. The journal considers that scientists should avoid research which kills or damages any species of animal which, using IUCN criteria, is regarded as threatened or is listed as such in a Red Data Book appropriate for the geographic area concerned. In accordance with this view, papers based on such research will not be accepted by the Journal, unless the work had clear conservation objectives.

**Plagiarism Detection**
In agreement with publishing policies of *SilvaWorld*, plagiarism check is required for each study that has undergone the "Review Process". The Turnitin plagiarism checker software is used for plagiarism detection.

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Proof documents will be sent to the corresponding authors via e-mail. Proofs should be checked immediately and responses should be returned back within 15 working days. It is the responsibility of the authors to check carefully the proofs. No changes will be allowed after this stage.

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