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Land use alteration strategy to improve forest landscape structural quality in Radhanagar forest range under Bankura District

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Abstract

In a forest landscape, landuse pattern is changing due to intrusion of anthropogenic activities. Such kind of human necessities restructured the existing landscape pattern which brings imbalance in regional biodiversity. Radhanagar Forest Range (RFR) in Bankura district has been faced same kind of activates since 1960. As a result, forest patch becomes isolated and structurally complex in nature which is an important cause for extinction of wild animal. To control this damage forest department increased forest area through several plantation schemes in vacant or barren land. But plantation areas were not appropriate in the question of structural forest quality in this region. The present study seems that forest structural quality is a vital consideration for balancing biodiversity, in concern of several ecological processes like species movement, connectivity, colonization and edge contrast. Suitable forest patch structure may possible when appropriate areas i.e. forest encroached areas will be select for plantation. To prove this statement, study considers two types of landuse alteration into forest land i) all barren land altered into forest and ii) selected encroached areas altered into forest land in RFR. ArcGIS 10.3 version software is used for technical map editing and preparing these spatial alteration maps. After that several landscape ecological indexes like Total Core Area Index (TCAI), Mean Core Area (MCA) at 300 m specified edge depth, Total Edge (TE), Edge Density (ED), Area Weighted Mean Shape Index (AWMSI), Area Weighted Mean Patch Fractal Dimension (AWMPFD) and Mean Patch Size (MPS) are calculated using FragStat 4.2 version software to compare both spatial alteration forest qualities. Comparison analysis explains that encroached areas alteration into forest land is qualitative to improve forest structural quality. It is interesting to know that less area will be planted in encroached area to get utmost forest structural qualities.

Keywords: Landuse pattern, Biodiversity, Extinction, Plantation, Spatial alteration, Forest landscape

Introduction

The landscape in Bankura and adjoining districts tremendously modified and transformed by several development activities like unscientific clear cutting of forest and forest regeneration, agricultural and settlement expansion, industrial establishment, road network development, mining activities etc. (Kulandaivel, 2010, DasChoudhury, *et. al.* 2013). For this reason, landscape becomes more heterogeneous and biological diversity is just extreme case (Chatterjee, 2016). Some indigenous species get extinct due to landscape alteration specially clearing of forest cover (O' Malley, 1908; DasGupta, 1989; Singh, 2006,). Haphazard and frequent movement of existing animal species due to unscientific land alteration causes conflict in this region (Mandal, 2018, Desai, *et. al.* 2010). Behind such circumstances forest landscape qualities are responsible (Sukumar, 2003). Qualities in concern of forest habitat size, connectedness, connectivity, proximity and plant species diversity determine several animal ecological processes (Li, 2007; Joshi, *et. al.* 2010; Forman, 1995; Fahrig, 2003; Rybicki, 2013). All these processes control by forest shape, core or interior, amount of edge and gap distance. According to many landscape ecologists, habitat shape is very essential consideration to manage forest landscape (McGarigal *et.al* 2005; Forman, 2009; Ewers & Didham, 2006). Therefore habitat is the leading component of landscape for ecological conservation. Ecological problems are also related to landscape mosaic pattern. Such patterns are habitat fragmentation, habitat encroachment and disturbance. Habitat fragmentation now becomes a special issue in ecological conservation (Cushman, *et. al.* 2010, Forman, 2014) and it is one of the most important problems which imbalance ecosystem in a region (Farina, 2006).

RFR forests shape is very much fragmented due to agricultural encroachment. It makes disturbance through the penetration of anthropogenic activities inside the forest core (Kumar, *et. al.* 2010; McGarigal *et.al.* 2009). It is one of the most important causes of frequent expose of wild animal (Sukumar, 2003; Desai, *et. al.* 2010). Similar movement pattern is also found in this region. In spite of any kind of measures are not taken to protect forest fragmentation in RFR as well as in this district. Yet forest cover has been increased through Joint Forest Management (JFM) by plantation in barren land since 1980 (Sudhakar and Raha, 1994). All initiatives or land alteration encourage or discourage forest cover without consider fragmentation and forest shape structure. Therefore, plantations in vacant or barren land are commonly found in this region (Mandal, *et. al.* 2014) and forest encroachment rate due to agricultural expansion are mostly common (Singh, 2006, Mandal, 2018). These programs are gradually prompt forest isolation greater than before. As a result wildlife activity in this region becomes an extreme issue especially elephant movement and conflict.

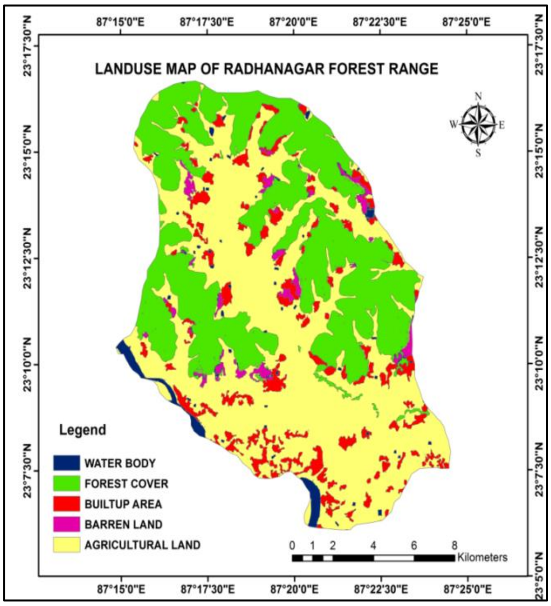
Habitat structural composition factors control many ecological activities. Poor habitat structure such high fragmentation, less core area, lower effective connectivity doesn't create balance ecology. In a human altered landscape, an appropriate landuse alteration is always meaningful to manage or increase habitat structural quality (Fernando, *et. al.* 2008). Generally, in a forest landscape plantation in vacant land is the process to develop forest qualities. Similar procedure is taken in RFR. But the question is that this land alteration strategy is scientific in the question of forest structural qualities? Therefore, the present study searches the appropriate areas or land for plantation into forest land which may scientific. This present research also tries to find which lands are to be taken for plantation to improve forest habitat quality. That enhance amount of forest core, forest area and lowers the edge effect, edge complexity as well as fragmentation which makes balances in regional biodiversity.

Materials and Methods

Study area

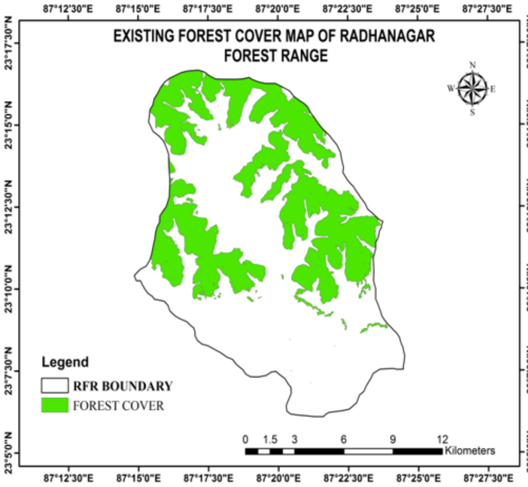
Radhanagar forest range in Bankura North Forest Division is ecologically an important region. Forest cover of this range is the second largest dominant land cover (Fig-1) after agriculture land use. Due to forest regeneration after 1980 forest cover increased (Sudhakar and Raha, 1994; Forest Report, 2017) and it's become a suitable ecological area for many migratory animal species (Singh, 2006). But forest becomes extremely patchy and structurally fragmented (Chatterjee, *et. al.* 2014; Mandal, 2018). Agricultural land expansion, animal husbandry, small scale industrial setup and housing establishment are the major causes of it (Singh, 2006; Kulandaivel, 2010). Therefore landscape alteration is very urgent to manage and control this type of complex structure.

Figure 1: Land use land cover map of RFR, IRS P6 LISS –III satellite image 2016.



Methods

The present study theoretically taken two types of land for plantation and alter into forest in map to compare which land is appropriate for plantation. These are all Barren Land (fig-1) and some specific Encroached Areas (fig-4). Generally forest covers increased through alteration of barren land by forest plantation. But forest plantation is not a meaningful concept to increase forest habitat quality until considering habitat structural factors. Habitat quality depends on maximum forest core, minimum edge effect, less fragmented patch and undisturbed activities like road in a forest patch. All these factors related to habitat structure but not in amount of forest.



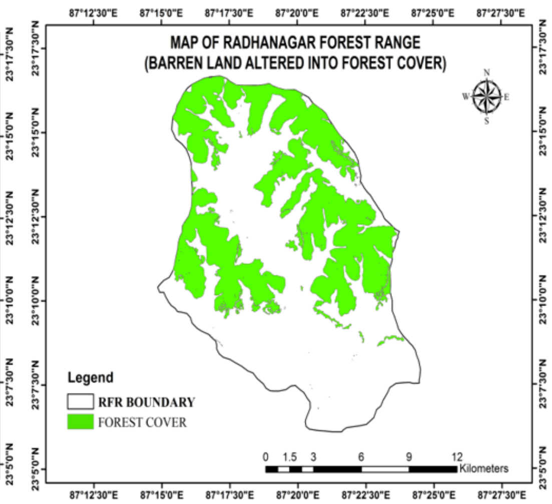
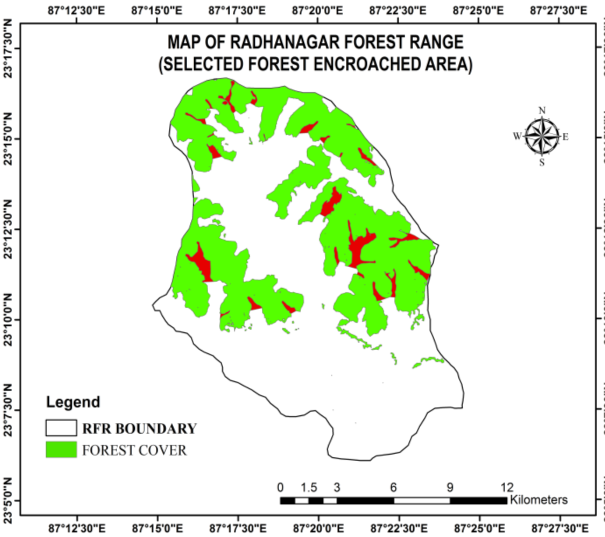


Figure 2: Existing forest landscape under RFR.

Figure 3: All barren land altered into to forest cover under RFR by reclassify method.

To get the actual scenario of the forest patches structure a classified categorical map has been prepared for that particular forest range (fig-2). In this map, work at first altered total barren land to forest (fig-

3) then altered some selected encroached areas (Fig-4) into the forest habitat separately through ArcGIS-10.3 version software. After preparation of these three map several ecological indices calculated to get the value of indices like Total Core Area Index (TCAI), Mean Core Area (MCA) at 300 m specified edge depth, Total Edge (TE), Edge Density (ED), Area Weighted Mean Shape Index (AWMSI), Area Weighted Mean Patch Fractal Dimension (AWMPFD) and Mean Patch Size (MPS) are measured through FragStat 4.2 software. After that study compares these indices values to understand which type of alteration will more ecologically important to enrich forest qualities?



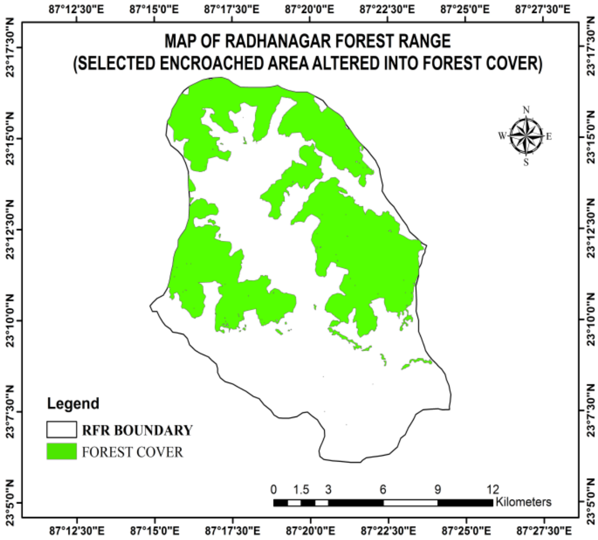
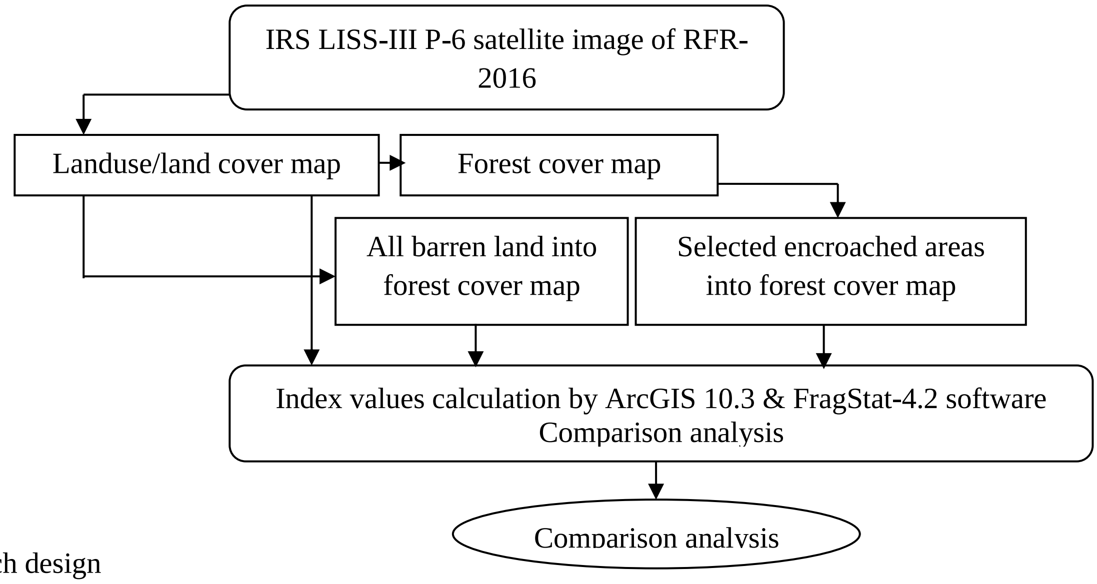


Figure 4: Selected areas (red marked) altered into forest land by shape editing.

Figure 5: Forest cover map after altered specific encroached area in RFR



Research design

Table 1: Used methods their description and unit after McGarigal and Marks 1995

Index	Method	Description	Unit
MCA	$MCA = \frac{\sum_{j=1}^{n} a_{ij}^{c}}{n_1}\left(\frac{1}{10,000}\right)$	$\mathbf{a_{ij}^{c}}$= core area (m^2) of patch ij based on specified- edge depth (300m). n_1=number of patches in the landscape of patch type (class) i	Hectares
TCAI	$TCAI=\sum \frac{a_{ij}^{c}}{a_{ij}}(100)$	$\mathbf{a_{ij}^{c}}$= core area (m^2) of patch ij based on specified- edge depth (300m). $\mathbf{a_{ij}}$= area (m^2) of patch ij	%
TE	Sum of perimeter of all corresponding patches		m
ED	$ED=\frac{\sum_{k=1}^{m} e_{ik}}{A}(10,000)$	e_{ik} = total length (m) of edge in the landscape involving patch type (class) i A= total landscape area (m^2)	m/ha
AWMSI	$AWMSI = \sum_{j=1}^{n}\left[\left(\frac{.25p_{ij}}{\sqrt{a_{ij}}}\right)\left(\frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}}\right)\right]$	p_{ij}= perimeter (m) of patch ij a_{ij}=area (m^2) of patch ij n_i= number of patches in the landscape of patch type (class) i.	None
AWMPFD	$AWMPFD=\sum_{j=1}^{n}\left[\left(\frac{2\ln .25p_{ij}}{\ln a_{ij}}\right)\left(\frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}}\right)\right]$	a_{ij}=area (m^2) of patch ij p_{ij}= perimeter (m) of patch ij n=number of patches in the landscape of patch type (class) i.	None
MPS	$MPS = \frac{\sum_{j=1}^{n} a_{ij}}{n_1}\left(\frac{1}{10,000}\right)$	a_{ij} = area (m^2) of patch ij class n_i= total number of patches in ij class	Hectares

The present study accepts these indices because ecological significance of landscape will be quantified by these indices. These measures are commonly used in landscape configuration assessment for management purpose. To understand the patch dominance MPS index is very useful method. It represents mean patch area in corresponding class. Higher value indicates better quality in a landscape (McGarigal, *et. al.* 2009). Structural shape of the landscape will be understood by AWMSI and AWMPFD. The index value when increased it shows increase shape complexity. High shape complexity is related to more structural fragments which are not qualitative in ecological manner (Flather and Bevers 2002; Haila 2002; Cushman 2006; Forman, 2010; Fahrig 2003). Patch core is another consideration to understand landscape qualities. A specific edge depth is very essential to demarcate core area. The present study considers 300 m edge buffer or distance depending on forest patch size in RFR to calculate core area matrix. The accepted indices MCA and TCAI high values indicate better forest qualities because it offers large amount of core and high percentage of core area in a landscape.

Results and Discussion

The Existing Forest Cover (EFC) is 7340.75 ha and number of forest patch is 23 in RFR. Forest cover increases in both alterations from existing situation i.e. 377.5 ha in case of Barren Land Alteration (BLA) to forest and 630.25 ha in case of Encroached Area Alteration (EAA) to forest. Normally, MPS will must rises in both cases due to increases of forest cover. Positive trend is found in EAA. MPS increase to 27.41 ha from EFC (Fig-6). But in BLA the trend is negative -77.96 ha due to increase patch number i.e. 23 to 32. Extend number of patch increases edge in the landscape (Dramstad, *et. al* 1996; McGarigal, *et. al.* 2002; Fahrig, 2013). Similar result is found in BLA. TE length is 352200 m which enlarged 66300 m from EFC and it also promote ED because landscape area is same. In case of EAA both TE and ED values are decrease from EFC (Fig-6). These results predict that forest habitat qualities will better in the question of edge contrast and patch dominancy in case of EAA than BLA and also EFC.

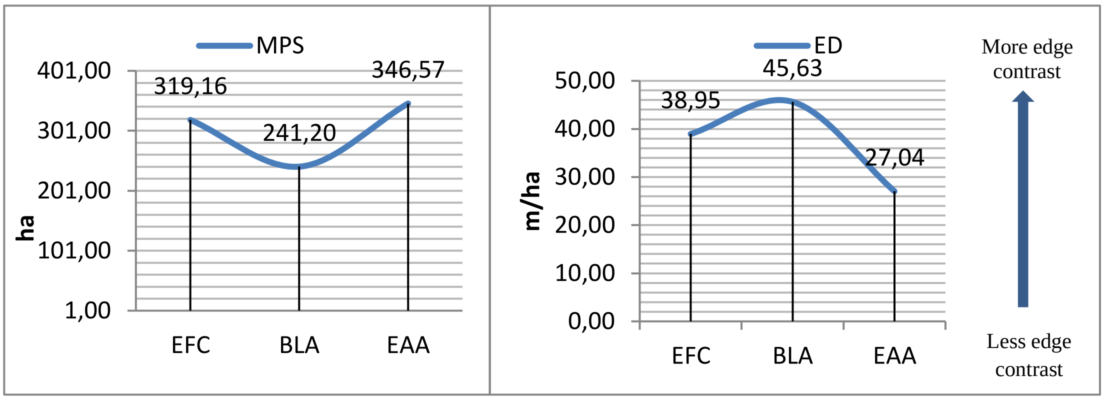


Figure 6: Graphical presentation of MPS and ED values of same three conditions

Forest patch structural character is another consideration to understand both forest condition qualities in RFR. AWMSI and AWMPFD are taken to compare forest shape structure qualities in between three conditions. It is seamed that shape complexity is high in BLA than EFC. Rather shape complexity decreases (Fig-7) in EAA which is 3.19 from 4.54 AWMSI of EFC. Similar trend also found in AWMPFD.

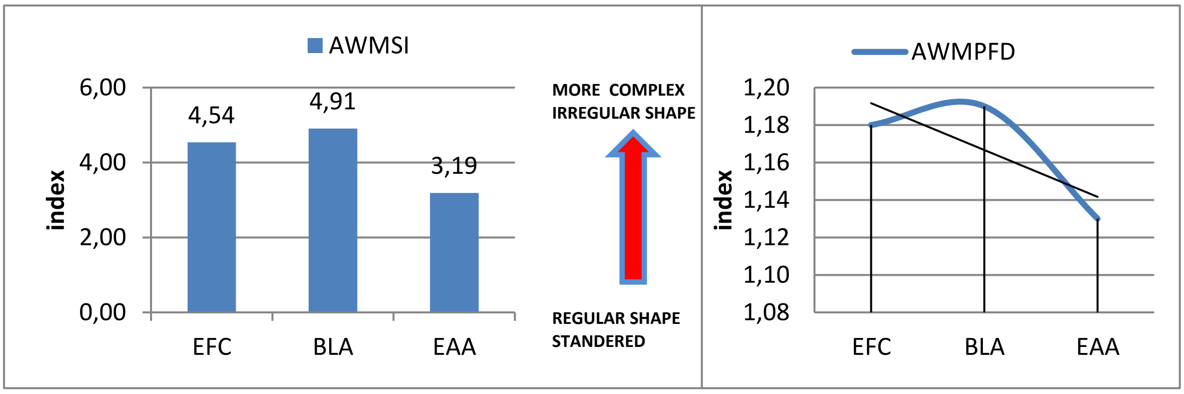


Figure 7: Graphical presentation of AWMSI and trend of AWMPFD values of same three conditions

Another component is core or interior of the forest habitat which is a significant ecological factor to support animal for their colonization (Couvillion, 2005; Li, *et. al.* 2007 Mandal, 2018). Forest core development and conservation is one of the sound full objectives in forest management strategy (Schmiegelow, *et. al.* 2002; McGarigal, *et. al.* 2005). To determine core area and its characteristics

MCA and TCAI are used at 300 m edge depth for both maps in RFR. The comparison measures show that MCA value rises (Fig-8) in EAA from both cases due to similar patch number with existing landscape and forest area enlargement. But MCA value declines in case of BLA though enlarge of forest area because number of forest patches increased by scatter alteration. Percentage of core area (TCAI) also increased in EAA 68.51 % from both maps i.e. 53.98% in EFC and 51.07% in BLA. The core amount is losing (-2.91%) in case of BLA due to increase structural shape from EFC.

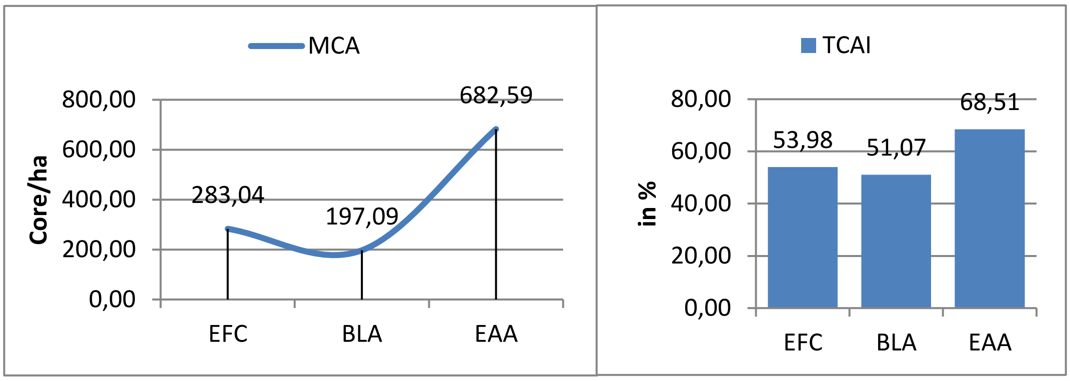


Figure 8: Represents the nature of core area indices in three condition in RFR

All graphical representation of landscape indices signifies that forest plantation is strongly appropriate in encroached areas. The present work proves that forest plantation in isolated point only increases forest areas but it raise several ecological demerits. This landuse alteration process is also responsible for more geographical and structural fragmentation which causes wildlife extinction (Lande, 1988; Sjögren-Gulve, 1994; Leakey and Lewin, 1995), decolonization (Crooks, 2002), decolonization leads human animal conflict (Carr and Fahrig 2001; Cushman 2006; Carr *et al.* 2002) and ultimately make ecosystem imbalance. Few amount of agricultural areas inside the forest i.e. encroached areas when altered in forest land it may qualitative than all barren land converted into forest in RFR. It has been found that not only forest shape structure but other ecological factors like forest habitat dependency (larger core area), dominancy (individual large patch area) and gap (inter patch distance) between forest habitat patches also qualitative through such type of EAA into forest in RFR. This spatial alteration into forest raises forest core, decreases forest isolation, edge influence, and increases amount of forest area. To balance forest ecosystem in a region these are very sensitive characters (Forman, 2014; Drohan, *et. al.* 2012) in a forest landscape. Therefore, it should be keep in mind that appropriate land must be select for plantation to improve or manage forest habitat quality (Banks, *et. al.* 2005).

Conclusion

Map is the simplest form of model of real earth (Farina, 2006; Forman 2010; Cushman, *et. al*. 2010). The study uses landuse and land cover map to prepare a simplest model of habitat conservation by proper spatial alteration. A minor but appropriate landuse change in forest how increase habitat quality that shows this work by comparing habitat structural ecological indices. Social forestry, Joint Forest Management, Forest Protection Committee, society for specific animal protection etc. are so many well organisations have to improve habitat quality through the proper instruction and landuse alteration in forest land for habitat structural management.

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Floristic characteristics of Mt. Nemrut National Park and its surroundings (Adıyaman)

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Abstract
Floristic characteristics of Mt. Nemrut National Park and its surroundings and the list of vascular plant species growing there are documented. Mt. Nemrut National Park is situated on the Southeast Taurus mountain range and is in the Iran-Turanian phytogeographical region. The research was carried out between 2010 and 2013. Two thousand five hundred plant specimens were collected from the area. At the end of the study, 777 vascular plant species and 403 genera belonging to 88 families were identified: 118 taxa (15,19%) are endemic to Turkey. The phytogeographic elements are represented in the study area as follows: Irano-Turanian 271 (34,9%), Mediterranean 52 (6,7%), E. Mediterranenen 44 (5,7%), Euro-Siberian 22 (2,8%), Euxin 2 (0,3%) and Unknown 386 (49,7%).

Key words: Adiyaman, Flora, Mt. Nemrut National Park, Vascular plants.

Özet
Bu araştırmada, Nemrut dağı milli parkı ve yakın çevresinin floristik özellikleri ve burada yetiştiği saptanan damarlı bitki taksonlarının listesi verilmiştir. Nemrut Dağı Milli Parkı, Güneydoğu Toros dağ silsilesi üzerinde yer almakta ve İran-Turan bitkicoğrafyası bölgesinde bulunmaktadır. Araştırma 2010-2013 yılları arasında yapılmıştır. Araştırma alanında 2500 bitki örneği toplanmıştır. Araştırma sonucu 88 familya'ya ait 403 cins'e bağlı 777 vasküler bitki türü saptanmıştır. Taksonlardan 118'i (%15,19) Türkiye için endemiktir. Araştırma alanındaki fitocoğrafik elementlerin dağılımı ise şöyledir: Iran-Turan 271 (%34,9), Akdeniz 52 (%6,7), Doğu Akdeniz 44 (%5,7), Avrupa-Sibirya 22 (%2,8), Öksin 2 (%0,3) ve Flora bölgesi bilinmeyen 386 (%49,7) 'dir.

Anahtar sözcükler: Adıyaman, Flora, Nemrut Dağı Milli Parkı, Vasküler bitkiler.

Introduction

Protected areas, which also contribute to economic and social development through the protection of natural-cultural resource values, are an indispensable tool of conservation and resource utilization policies. The primary function of conservation is to ensure the continuity of biodiversity in protected areas, including national parks which are the most important centers where sustainable development can take place. However, the biggest problem encountered in ecological planning studies in our country is the lack of sufficient biological and ecological inventories. Therefore, it is of great importance that the accurate and precise inventory of the biological asset is presented in detail.

In the inventory studies, it provides detailed information about the structure and functioning of the landscape since plants find everywhere at the same time as well as it creats different parts of the landscape visually and it is the great importance for other living on presence of vegetation organisms and it is related to habitats and environmental factors. Therefore, priority is given to vegetation analysis which is a basic step for (ecological) planning while setting out the management plans, conservation objectives and strategies of protected areas. However, it is necessary to know the flora to successfully be investigated vegetation.

Although flora studies have been carried out in many areas in our country, a limited number of studies have been conducted in and around Mount Nemrut and 80 taxa have been recorded from this area in Flora of Turkey (Davis, 1965-1988).

A systematic list of 175 taxa was presented by Uzun et al (2001) including Davis (1965-1988)'s records compiled flora of the National Park. Of the taxa in this list, 95 taxa were stated as new records during field observations and endemic species were given together with their localities. Tel (2001) identified 250 vascular plant species and 149 genera belonging to 44 families. Çakan et al. (2004) and Tuluhan et al. (2004) stated to be represent by 513 taxa in the area but they did not present a systematic list.

In spite of all these new studies, since the flora and vegetation structure of the area, which was declared a national park in 1989, could not be fully revealed, the targeted conservation strategies could not be reached. It is essential to determine the conservation priorities immediately by investigatig the endemic, rare and endangered species that have indicative in detail to create sustainable conservation strategies at the national park.

In order to reach the conservation strategies targeted at the LTDP (long-term development plan) in the Nemrut Mountain National Park, the floristic inventory was the initial stage of the work due to the most important ecological resource revealing the ecological characteristics of national park and included the distribution areas of taxa in this inventory, whether they are endemic or not and the hazard categories.

The floristic inventory at the end of study is a reference for researchers in ecological studies on Mount Nemrut and its surroundings on the Southeastern Taurus Mountains that is one of the many areas that Davis described as floristically middle, little or no work and suggested that studies should be conducted at the local level and in detail. As well as it should also be considered as a contribution to the flora studies of our country.

Materials and methods

Characteristics of the work area

The study area is Nemrut Mount National Park and its geograpic location, geo-morphologic, geologic, soil, climate, hydrologic and vegetation characteristics are given below.

Geographical situation

Nemrut Mount National Park is situated on a strategic area that is 37° 51' 30" 38° 00' 30" north latitude 38° 34' 30"- 38° 48' 30" east longitude, which provides access to the Euphrates and Taurus passages from Syria and Upper Mesopotamia to the Anatolian plateau in northern end of the area of called Fertile Crescent between the Euphrates, Tigris and the Nile rivers. The study area that is the national park area (13850 ha) and its surroundings is almost 20,000 hectares (Figure 1).

Topographic and Geomorphological Characteristics

Nemrut Mount National Park and its surroundings that situated between the Adıyaman-Kahta plateau and the Southeastern Taurus Mountains that were rised on these two main morphological structures have taken their present form as a result of young tectonic movements folding and fracturing of geomorphological units rather than paleotectonic movements. In the neotectonic (young tectonic movements) period, the mountainous areas corresponding to the anticlines were rised by cutting faults, a series of small synclines between their by merging basin floors were descended. Kahta Stream that is the most important water in the region was buried in the bed and formed deep gorges and valleys (Atalay et al. 2002; Sunkar and Karataş, 2014).

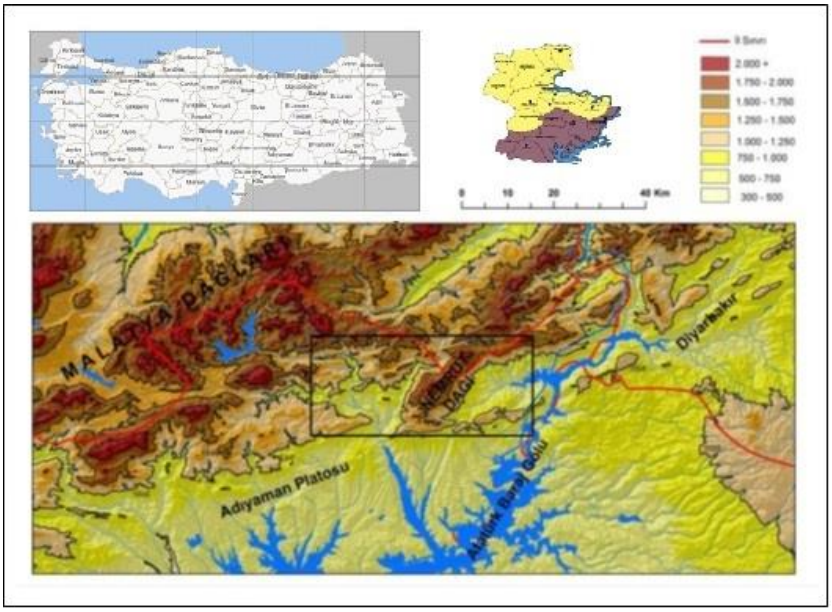


Figure 1. Locality of the study area (changed from Bozdağ, 2015).

The orographic structure of the region constitutes the highest part of the area which is mountainous areas extending in three series parallel to each other in the NE-SW direction, which Mount Nemrut (2206 m) is in the east of the valley Kâhta, Mount Halof (1400 m) is the west and Sincik Kekdan mountain (1121 m) is the north. Kahta river valley floor (550 m) that divides the area into three parts constitutes the lowest part of the area (Figure 2).

Figure 2. A view of Mount Nemrut National Park.

Geological Characteristics

The Nemrut Mountain National Park and its surroundings is to lie structurally between the transition zone in the Southeast Anatolian Miocene basin and in the Paleozoic metamorphic Bitlis massif in the north.

The geologic structure constitutes Mesozoic ophiolite series (peridotite, serpentine, limestone, radiolarite) and Lower Eocene clayey limestones is at the bottom and fractured Limestones lie over their. Şelmo formation, which represent Upper Miocene and settled correlator depots is on both sides of Kâhta stream and Plio-Quaternary fillings in the form of islets are on the Şelmo formation (Atalay et al., 2002, Karadogan, 2005).

Soil Properties

In the study area, Brown Forest Soils on lime-rich bedrock are in south and north. Lime-free Brown Forest Soils that are the widest distribution are in the northwest, east and western ends. Brown Soils are in the east and south, Lime-free Brown Soils are on the summit of Mount Nemrut and in Belli plateaus and Reddish Brown Soils are around the bed of Kâhta Stream.

The Reddish Mediterranean Soils are generally observed in the karstic areas. Due to the characteristics of the karstic area the soil is not on the surface but between the cracks and the layers of the limestones in the sloped area. Vertisols are observed in the pits (dolin) in karstic areas. There are Red Soils with high physiological depths on and between the gravel deposits on the slopes of the steep facing the Kahta stream of the Nemrut Mountain and on some slopes.

There are mass of sand and gravel on the large floodplain formed by Kahta river and alluvial (Quaternary) rich soils in places where Gedik stream and Kâhta river and its branches are (Atalay et al., 2002).

Climate Characteristics

In the study area, the continental mountain climate, which is long winters with heavy snow and limited number of sunny days prevails in the highlands. The low slopes of the mountains facing south and around the Kahta stream are dominated by mild climate conditions which can be expressed as a distorted Mediterranean climate (Atalay et al., 2002).

Regarding the temperature regime, there is a 4-month summer season between June and September, and a winter season of approximately 4.5 months from mid-November to the end of March and spring and fall seasons with a duration of 1.5-2 months. According to the meteorological data of the districts close to the research area (Kahta and Pütürge), the average annual temperature is 12-17 ºC, the average rainfall is 53-43 mm, the average annual relative humidity varies between 47-52% (http://www.mgm.gov.tr).

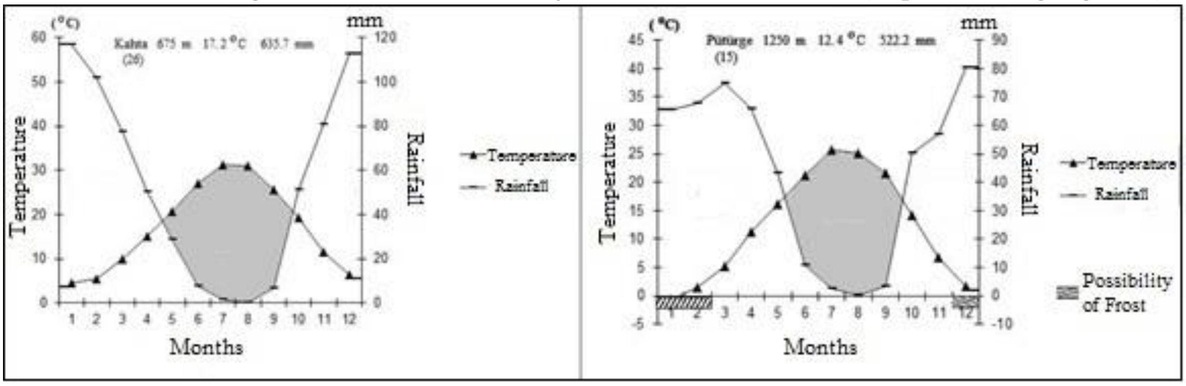


Figure 3: Kâhta and Pütürge districts climate diagram

Hydrological characteristic

The Kahta river and its branch which are an important river situated the northern and western and the Gedik stream (Kan stream) is in the southern and southeastern in the study area. The streams other than Kâhta river and Kan stream are generally temporary streams.

Vegetation

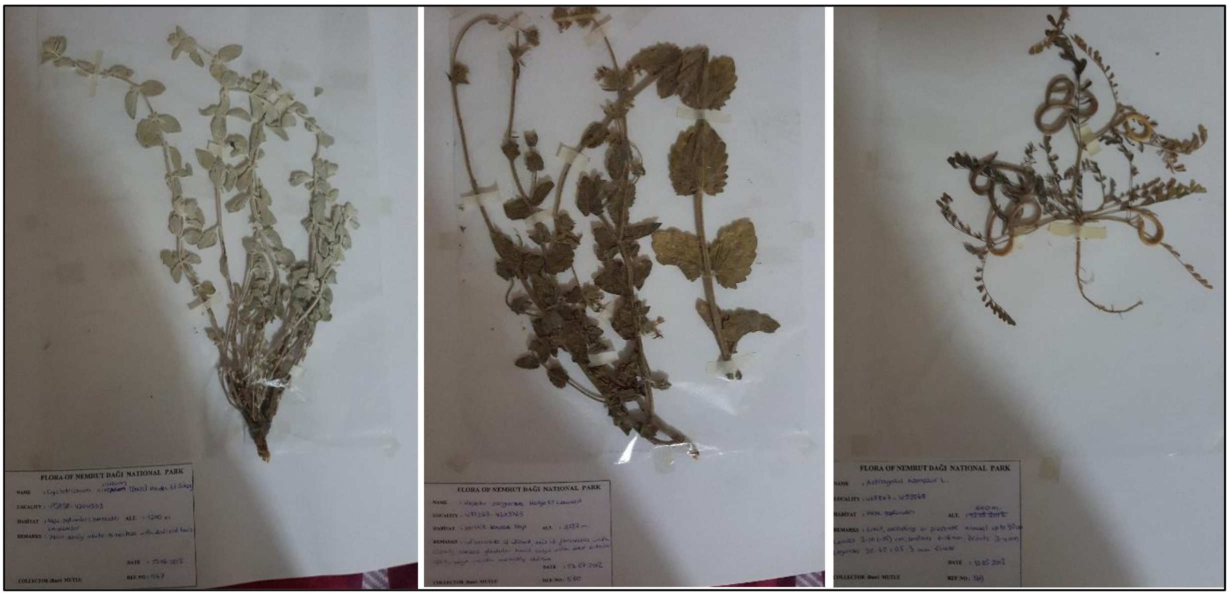
According to Davis (1971), the study area is located the C7 square in the Mesopotamian sub-region of the Iranian-Turanian floristic region characterized by a high proportion of dwarf shrubs, grasses and meadow although the tree species are relatively a small number (Davis, 1965-1985). According to Walter (1956), the zonal vegetation of the research area in this climate zone is "Step Humid Step Forest Zone", and Zohary's (1973) classification of plant regions is "Iranian xerophile *Quercus brantii* forest".

These dry forests which generally consist of pure oak communities, are described as free-standing trees steppe which are the continuation of oak-juniper forests spreading on the slopes of the Western and Central Taurus Mountains and were spread on steppe's side (Louis, 1939, Mayer and Aksoy, 1998).

Collection, preparation and identification of plant material

The materials of this study are 2500 vascular plant specimens collected from Nemrut Mount National Park and its surroundings in different vegetation formation between 2010 and 2013. Efforts were made to collect both flowering and fruiting specimens. When the specimens were identified the color slides and photographs taken during the field studies were utilized. The specimens were prepared according to established herbarium techniques.

The Flora of Turkey (Davis, 1965-1985, Davis et al.,1988, Güner et al., 2000), were used for identification of the specimens. Specimens belonging to genera which were difficult to determine were sent to specialists to minimise errors. Apiaceae members were determined by Karakuş, *Astragalus* specimens were determined by Aytaç, Brasicaceae members were determined by Mutlu, *Centaurea*, *Cyanus* and *Psephellus* specimens were determined by Kaya, some Fabaceae members were determined by Akan, some Lamiceae members were determined by İlçim, *Onosma* specimens were determined by Binzet and some Poaceae and Asterceae members by Arabacı, Rosaceae members by Ok and some species were compared to the Herbarium of İnönü University (Malatya) (Figure 4).



Şekil 4. Herbarium materials

The floristic lists were written in the same order as in the Flora of Turkey by checking on the IUCN website and the locality collected, habitat, altitude, coordinate, registration number, phytogeographic region, whether endemic and IUCN hazard categories (EN: Endangered / Endangered, VU: Vulnerable (NT: Near Threatened, LC: Least Concern). Authors of plant names are written according to authors of Plant Names (Brummitt et al., 1992).

Herbarium materials are partly stored in Istanbul University, Faculty of Forestry, Department of Landscape Architecture and partly stored in my personal archive.

Results and Discussion

At the end of the studies of the 2500 vascular plant specimens collected study area, 777 species 403 genera belonging to 88 families were established between in 2010-2013. Floristik list is given apendix 1.

118 of these taxa are endemic to Turkey and the rate of endemism is 15.19%. This ratio is quite high when compared to the studies conducted near the research area. Due to the fact that the research area is located on the Southeast Taurus Mountains and at the intersection of two phytogeographic regions and has the different climatic characteristics, soil structure, geographic status, geological and habitat characteristics.

8 (eight) species, *Erysimum nemrutdaghense* Mutlu, *Heldreichia atalayi* Kit & Tan, *Allium nemrutdaghensis* Kit & Tan, *Nepeta sorgerae* Hedge and Lamond, *Nepeta aristata* Boiss. & Kotschy ex Boiss., *Silene nemrutensis* K.Yıldız, *Minuartia tchihatchewii* (Boiss.) Hand-Mazz., *Gladiolus humilis* Stapf are endemic to Mt. Nemrut and known only from the type localities. The first 8 species were collected for the second time from the type localities in the study area. However, some taxa recorded previously in study area could not collected from it, because of the narrowness of the distribution areas. These taxa are as follows: *Astragalus commagenius* (Kotschy & Boiss.) Chamb., *Arenaria antitaurica* McNeill ve *Taraxacum microcephaloides* Soest.

According to the IUCN categories 7 species are in the EN (Endangered), 9 species are in the NT (Near threatened), 14 species are in the VU (Vulnerable) and 12 species are in the DD (Data Deficient) category (IUCN, 2019). *Cicer bijugum* Rech. fil. is a non-endemic but rare species. The taxa in the EN and VU categories are at high risk and require protection. Special attention should be given to the plants in the DD category since their status in nature cannot be clearly demonstrated (Ekim et al., 2000). The majority of taxa are in the LC (Lower Concerning) and LR (Lower Risk) category.

According to IUCN categories; *Allium nemrutdaghense*, *Erysimum nemrutdaghense*, *Papaver arachnoideum* Kadereit, *Cicer bijugum*, *Johrenia dichotoma* DC subsp. *sintenisii* Bornm., *Gladiolus humilis* Stapf, *Blysmus compressus* (L.) Panz. ex Link are in the EN (Endangered) category (IUCN, 2019).

Figure 5: Endemic *Allium nemrutdaghense* on the left and *Gypsophila pinifolia* on the right

Figure 6: Endemic *Erysimum nemrutdaghense* on the left and *Silene nemrutensis* on the right

When it comes to distribution of known species of phytogeographical region in the study area, Irano-Turanian elements comprise 271 (34,9%) taxa, Mediterranean elements consist of 52 (6,7%) taxa, E. Mediterranean elements are 44 (5,7%), Euro-Siberian elements are 22 (2,8%), and Euxin elements are only 2 (0,3%) and the phytogeographic unknown are 386 (49.7%).
Distribution number of taxa according to the phytogeographic are given in Table 1.

Table 1. Number of taxa according to the phytogeographic region

Number of taxa	**The phytogeographic region**
271	Irano-Turanian
52	Mediterranean
44	East Mediterranean
22	Euro-Siberian
2	Euxin
386	Unknown

In terms of number of taxa known the phytogeographic region, Irano-Turanian elements and Mediterranean (Mediterranean + East Mediterranean) elements rank first and second respectively on Mt. Nemrut National Park and its surroundings. Irano-Turanian elements are the highest because the study area locates the Iranian-Turanian floristic region and compose mainly of calcareous and steppic areas. Mediterranean elements are second, as the climate affecting on study area is not uniform and as well as on the Mediterranean Transition Biosome. Euro-Siberian elements that mostly adapted to meadow and wetland habitats are the small number, since the study area is distant to this phytogeographic region and has a dry climate.
The distribution of the majority of the taxa and the numbers of species which belong to these families in the research area are listed in Table 2.
Twenty families comprise 614 species of the 777 taxa established in the study area. In other words 79.2% of the flora of national park and its surounding consists of species that belong to 20 families. For these reasons, the species belonging to the 20 families listed in Table 2 are dominant in the steppic vegetation. The remaining 68 families, comprising 163 species, are represented by one or a few species in the area and constitute 20.98% of the flora of Nemrut Mountain National Park.

Table 2: Families with the highest taxa

Families	Taxa number	%	Families	Taxa number	%
ASTERACEAE	96	12.3	RANUNCULACEAE	20	2.6
FABACEAE	85	10.9	PLANTAGINACEAE	19	2.4
LAMIACEAE	57	7.3	EUPHORBIACEAE	12	1.5
BRASSICACEAE	57	7.3	PAPAVERACEAE	11	1.4
POACEAE	51	6.6	ASPARAGACEAE	11	1.4
CARYOPHYLLACEAE	43	5.5	POLYGONACEAE	11	1.4
APIACEAE	40	5.2	AMARYLLIDACEAE	11	1.4
ROSACEAE	29	3.7	HYPERICACEAE	9	1.2
BORAGINACEAE	26	3.4	CAMPANULACEAE	8	1.0
RUBIACEAE	22	2.8	ORCHIDACEAE	7	0.9

In terms of the number of taxa, Asteracea family and Fabaceae family rank first and second respectively as in Turkey's flora. The reason why the Asteraceae family is in the first row can be explained due to more tolerant to ecological factors, the ability to easily distribute the fruits and grow up mainly of calcareous and steppic areas. That the Fabaceae family is in the second row can be deduced that the research area provides a suitable ecological environment for the growth of these taxa. In terms of the number of genera and its families are listed in Table 3.

Table 3. Species totals of the major genera

Genera/Families	Species Number	Genera/Families	Species Number
Astragalus (Fabaceae)	20	*Centaurea* (Asteraceae)	10
Silene (Caryophyllaceae)	16	*Allium* (Liliaceae)	10
Prunus (Rosaceae)	13	*Ranunculus* (Ranunculaceae)	9
Salvia (Lamiaceae	11	*Hypericum* (Hypericaceae)	9
Alyssum (Brassicaceae)	11	*Trifolium* (Fabaceae)	8
Medicago (Fabaceae)	11	*Erysimum* (Brasicaceae)	8
Galium (Rubiaceae)	11	*Minuartia* (Caryophyllaceae)	7
Vicia (Fabaceae)	10	*Scorzonera* (Asteraceae)	7
Veronica (Scrophulariaceae)	10	*Papaver* (Papaveraceae)	7
Euphorbia (Euphorbiaceae)	10	*Aethionema* (Brasicaceae)	7

As can be seen from Table 3, the *Astragalus* L. species are dominant in the study area. Because as stated previously, calcareous and steppic areas are common in the study area and *Astragalus* is a mainly steppic genus as well as one of the largest genera of flowering plants that has approximately 2500 species world wide. The estimated number of species in Turkey, which are mainly Irano-Turanian elements, is around 400. Likewise, *Silene* L., *Prunus* L., *Salvia* L., *Alyssum* L., *Vicia* L., *Veronica* L., *Euphorbia* L., *Centaurea* L. and *Allium* L. are mainly steppic genera and these comprise relatively more species. *Trifolium* L., *Vicia* and *Euphorbia* as well as *Prunus* are quite widespread in forest areas.

Conclusion

Nemrut Mountain National Park was declared a national park in 1989 for the protection of its historical and archaeological values. However, since the flora and vegetation structure of the national park area could not be revealed exactly, the biological diversity of the area has not been investigated sufficiently too. In this study, it is determined that the area is very rich in florstic and the rate of endemism is quite high. When the ratio of known species of phytogeographic region is examined, that the Iranian-Turanian element is high, since the area is located in this phytogeographic region. However, the presence of other elements in the region shows that the site has rich and varied habitats due to its geomorphological structure.

The floristic inventory studies conducted showed that the study area has a rich biodiversity as well as archaeological values. Therefore it can be separated as a biosphere reserve with its relatively untouched natural features besides being a national park with its cultural features. In particularly, the areas where are karstic shaped, where have endemic plants, where are high mountain steppe, where are forest and where have archaeological remains are potential for biological reserv.

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Appendix 1. The list of the identified plant taxa from Nemrut Mountain National Park and Its Surroundings

EQUISETAACEAE
Equisetum variegatum Schleich. ex Web.&Mohr., Stream bed; 475718-4209163, 850 m., LC (VU)
Equisetum arvensis, Kahta river bed; 466514-4191226, 558-850 m., LC (VU)
ASPLENİACEAE
Asplenium aureum Cav., Quercus Forest; 464470-4198051, 900-1100 m., LC
DRYOPTERİDACEAE
Cystopteris fragilis (L.) Bernh., Quercus forest, 464470-4198051; 900 m.
PINACEAE
Cedrus libani A. Rich, Afforesttation area; 464737, 4215115, Medit., VU
Pinus brutia Ten., Afforesttation area, 468854-4194645, E. Medit., LC
CUPRESSACEAE
Juniperus oxycedrus L. subsp. ***oxycedrus,*** Shrubs; 468523-4199286, 620-1735 m., LC
Juniperus excelsa Bieb., Quercus Forest; 474513-4199773, 1520 m., LC
RANUNCULACEAE
Eranthis hyemalis (L.) Salisb., Step area; 477451-4202120, 1650 m.
Nigella oxytpetala Boiss., Shrubs; 477274-4207600, 1475 m.
Garidella unguicularis Poir., Shrubs; 468637-4199302, 620 m.
Delphinium peregrinum L., Quercus Forest; 469285-4198844, 655 m.
Delphinium kurdicum Boiss. & Hohen., Quercus Forest; 477125-4203387, 2000 m., Ir.-Tur
Consolida tomentosa (Auch. ex Boiss.) Schröd. subsp. ***oligantha*** (Boiss.) Davis, Shrubs; 471259-4201281, 900 m., Ir.-Tur.
Clematis vitalba L., Kahta river side; 466514-4191226, 558 m., Medit.
Adonis aestevilis L. subsp. ***aestivalis,*** Quercus Forest; 469759-4199803, 880 m.
Ranunculus sericeus Banks & Sol., Kahta river bed; 482430-4197400, 840 m., Ir.-Tur.
Ranunculus nivalis subsp. nivalis, Quercus Forest; 463801-4197457, 1100 m.
Ranunculus aucheri Boiss., Meadow; 480244-4206017, 1920 m.
Ranunculus asiaticus L., Calcerous area; 479533-4195519, 1040 m.
Ranunculus macrorhynchus Boiss. subsp. ***macrorhynchus***, Step area; 479133-4200341, 1430 m., Ir.-Tur.
Ranunculus millefolius Banks & Sol. subsp. ***millefolius***, Step area; 463801-4191552, 926 m.
Ranunculus ungui-catus Davis, Shrubs; 477555-4202517, 1740 m., End.
Ranunculus cornutus DC., Meadow; 479471-4201298, 1598 m., LC
Ranunculus arvensis L., Fields; 464663-4193142, 655 m.
Ficaria verna L., subsp. ***verna***, Step area; 477451-4202120, 1650 m.
Ceratocephalus falcatus (L.) Pers., Step area; 463801-4191552, 926 m.
Thalictrum minus L. var. ***minus***, Step area; 479793-420549, 1500 m.
BERBERIDACEAE
Bongardia chrysogonum (L.) Spach., Shrubs; 468961-4194447, 1000 m., Ir.-Tur.
PAPAVERACEAE
Roemeria hybrida** (L.) DC* subsp. ***hybrida, Step area; 463801-4191552, 926 m.
Papaver persicum Lindl. subsp. ***persicum***, Calcerous area; 468410-4193904, 1100 m.
Papaver persicum Lindl. subsp. ***fulvum*** Kit Tan & Sorger, Calcerous area; 477543-4203169, 1600 m., LC
Papaver persicum subsp. ***tauricola*** (Boiss.) J.W. Kadereit, Step area; 478832-4206509, 1642 m.
Papaver arachnoideum Kadereit, Quercus Forest; 479903-4200390, 1400 m., End., EN
Papaver syriacum Boiss. & Bl., Quercus Forest; 469285-4198844, 655 m.
Papaver clavatum Boiss. & Hausskn. ex Boiss., Step area; 462730-4191827, 893 m., End., LC
Papaver argemone L., Afforestation area; 67877-4193929, 915 m.
Hypecoum imberbe Sm., Fields; 480554-4195111, 890 m.
Corydalis oppositifolia DC. subsp. ***oppositifolia***, Step area; 477251-4203508, 2038 m., End.
Fumaria asepala Boiss., Fields; 463456-4191458, 879 m., Ir.-Tur.
BRASSICACEAE

Sinapis arvensis L., Fields; 463456-4191458, 879 m.
Hirschfeldia incana (L.) Lagr. Foss., Calceorus area; 479533-4195519, 1040 m.
Eruca vesicaria subsp. ***sativa*** (Mill.) Thell., Fields; 468414-4201008, 787 m.
Raphanus raphanistrum L., Fields; 480554-4195111, 892 m.
Crambe tatarica Sebeök var**.** ***tatarica***, Quercus Forest; 469759-4199803, 880 m.
Conringia clavata Boiss., Fields; 461952-4192084, 897 m.
Lepidium draba (L.) subsp. ***draba***, Fields; 483294-4197180, 856 m.
Isatis aucheri Boiss., Step area; 475919-4202634, 1800 m., End., Ir.-Tur., LC
Isatis corymbosa Boiss., Quercus Forest; 469872-4199703, 830 m., DD
Iberis carnosa Willd. subsp. ***carnosa***, Quercus Forest; 469334-4198579, 700 m., E. Medit.
Iberis odorata L., Stream bed; 468867-4199068, 603 m.
Heldreichia atalayi Kit Tan, Shrubs; 476891-4207827, 1300 m., End., Ir.-Tur.
Biscutella didyma L., Quercus Forest; 469759-4199803, 880 m.
Aethionema carneum (Banks & Sol.) B. Fedtsch., Shrubs; 476891-4207827, 1300 m., Ir.-Tur.
Aethionema arabicum (L.) Andrz. ex O.E. Schulz, Quercus Forest; 469285-4198844, 655 m., Step area; 463801-4191552, 926 m.
Aethionema eunomioides (Boiss.) Bornm., Step area; 477659-4201705, End., LR (LC)
Aethionema speciosum Boiss. & Huet, Quercus Forest; 477085-4207458, 1500 m., Ir.-Tur.
Aethionema iberideum (Boiss.) Boiss., Step area; 476494-4203909, 2000 m.
Aethionema capitatum Boiss. & Balansa, Step area 478510-4200215, 1520 m., End.
Aethionema armenum Boiss., Shrubs; 477543-4203169, 1900 m., Ir-Tur.
Thlaspi kotschyanum Boiss. & Hohen., Meadow; 475251-4203341, 1957 m.
Microthlaspi perfoliatum (L.) F.K. Mey., Quercus Forest; 482820-4196236, 860 m.
Capsella bursa-pastoris (L.) Medik., Fields; 480854-4198318, 1036 m.
Neslia paniculata subsp. ***thracica*** (Velen.) Bornm., Waste area; 463801-4191552, 926 m.
Ricotia aucheri (Boiss.) B.L. Burtt, Step area; 476533-4207288, 1600 m., Ir.-Tur., LC
Fibigia clypeata (L.) Medik., Quercus Forest; 469334-4198579, 700 m.
Fibigia macrocarpa (Boiss.) Boiss., Step area; 478510-4200215, 1520 m.
Fibigia eriocarpa (DC.) Boiss., Quercus Forest; 469334-4198579, 700 m.
Alyssum contemptum Schott & Kotschy, Step area; 474208-4198286, 1500 m., Ir.-Tur.
Alyssum szowitsianum Fisch. & Mey., Calcerous area; 468410-4193904, 1100 m.
Hormathophylla macrocarpa (DC.) P. Küpfer, Step area; 476066-4202860, 1905 m., End., Ir.-Tur., LC
Alyssum minus (L.) var. ***minus***, Quercus Forest; 482820-4196236, 860 m.
Alyssum strigosum Banks & Sol., Red pine afforestation; 467877-4193929, 915 m.
Alyssum xanthocarpum Boiss., Quercus Forest; 476612-4207396, 1539 m.
Alyssum bulbotrichum Hausskn. & Bornm., Shrub; 473498-4206188, 1020 m., End., CD
Alyssum trichocarpum T.R. Dudley & Hub.-Mor., Quercus Forest; 472391-4198266, 1400 m., End., Ir.-Tur., VU
Alyssum harputicum T.R. Dudley, Step area; 477683-4202962, 1800 m., End., Ir.-Tur., CD
Alyssum pateri Nyár. subsp. ***pateri***, Step area; 477528-4201732, 1700 m., End., Ir.-Tur., LC
Alyssum condensatum Boiss. & Hausskn. subsp. ***condensatum***, Step area; 475919-4202634, 1800 m.
Alyssum murale Waldst. & Kit. var. ***murale***; Meadow; 477491-4200767, 1604 m., End.
Clypeola jonthlaspi L., Quercus Forest; 482820-4196236, 860 m.
Clypeola aspera (Grauer) Turrill, Calcerous area; 474650-4198113, 1600 m.
Draba acaulis Boiss., Calcerous area; 475974-4203709, 2000 m., VU
Draba verna L. Shrubs; 463966-4197562, 1050 m.
Arabis alpina L. subsp. ***brevifolia*** (DC.) Greuter & Burdet, Calcerous area; 480414-4205506, 1990 m., E. Medit. (mt.)
Arabis nova Vill., Step area; 474208-4198286, 1500 m.
Hesperis pendula DC., Step area; 476494-4203909, 2000 m.
Erysimum nemrutdaghense Mutlu., 476494-4203909, 2030 m., End., EN
Erysimum pusillum Bory & Chaub, Step area; 476066-4202860, 1905 m., E. Medit., VU
Erysimum kotschyanum J. Gay, 477085-4207458, 1500 m., End., LC
Erysimum crassipes Fisch. & C.A. Mey., Step area; 477298-4204004, 2150 m.

Erysimum purpureum J. Gay, Step area; 477085-4207458, 1500 m., Ir.-Tur.
Erysimum smyrnaeum Boiss. & Balansa, Step area; 467599-4193501, 915 m.
Erysimum repandum L., Fields; 480854-4198318, 1036 m.
Erysimum kostkae Polatschek; Step area; 476822-4203764, 2013 m.
Goldbachia laevigata (M. Bieb.) DC., Step area; 474208-4198286, 1500 m.
Alliaria petiolata (Bieb.) Cavara & Grande, Quercus Forest; 471794-4198524, 1200 m.

CAPPARACEAE

Capparis spinosa var. ***canescens*** Coss., Calcerous; 465598-4198643, 615 m.
Cleome ornithopodioides L., Kahta river bed; 466514-4191226, 558 m.

RESEDACEAE

Reseda lutea L. var***. lutea***; Fields; 475438-4208615, 1054 m.

CISTACEAE

Helianthemum ledifolium (L.) Miller var. ***microcarpum*** Willk, Quercus Forest; 469334-4198579, 700 m.
Helianthemum salicifolium (L.) Miller, Step area; 462730-4191827, 893 m.
Fumana arabica (L.) Spach. var. ***arabica***, Quercus Forest; 468271-4199477, 685 m.

VIOLACEAE

Viola occulta Lehm., Red pine afforestation area; 467877-4193929, 915 m.

PORTULACACEAE

Portulaca oleracea L., Fields; 480554-4195111, 892 m.

CARYOPHYLLACEAE

Arenaria serpyllifolia L., Quercus Forest; 464470-4198051, 900 m.
Eremogone ledebouriana (Fenzl) Ikonn. var. ***parviflora*** Boiss., Quercus Forest; 471794-4198524, 1200 m., End., Ir.-Tur., LC
Eremogone drypidea (Boiss.) Ikonn., Step area; 477085-4207458, 1500 m., End., Ir.-Tur., LC
Eremogone minuartioides Dillenb. & Kadereit, Meadow; 477491-4200767, 1604 m.
Minuartia meyeri (Boiss.) Bornm., Waste place; 468061-4193613, 1000 m., Ir.-Tur.
Minuartia montana L. subsp. ***wiesneri*** (Stapf) McNeill, Waste place; 463801-4191552, 926 m., Ir.-Tur.
Minuartia decipiens (Fenzl) Bornm. subsp. ***decipiens***, Quercus Forest; 469334-4198579, 700 m.
Minuartia sclerantha (Fisch. & Mey.) Thell., Waste place; 463801-4191552, 926 m., Ir.-Tur.
Minuartia hamata (Hausskn. & Bornm.) Mattf., Waste place; 463801-4191552, 926 m.
Minuartia tchihatchewii (Boiss.) Hand.-Mazz., Step area; 475919-4202634, 1800 m., End.
Minuartia erythrosepala (Boiss.) Hand.-Mazz. var. ***cappadocica*** (Boiss.) McNeill, Step area; 475919-4202634, 1800 m., Ir.-Tur., End., LR (LC)
Sabulina mesogitana subsp. ***kotschyana*** (Boiss.) Dillenb. & Kadereit, Step area; 473899-4202082, 1800 m.
Stellaria media (L.) Vill. subsp. ***media***, Step area; 479906-4204727, 1950 m.
Cerastium dichotomum L., Step area; 479133-4200341, 1437 m.
Cerastium inflatum Link ex Gren., Step area; 474208-4198286, 1500 m.
Holosteum umbellatum L. var. ***umbellatum,*** Step area; 473283-4198165, 1500 m.
Telephium imperati L. subsp. ***orientale*** (Boiss.) Nyman, Quercus Forest; 469872-4199703, 830 m.
Dianthus strictus Banks & Sol. *var.* ***gracilior*** (Boiss.) Reeve, Quercus forest; 480121-4199088, 1200 m.
Dianthus masmenaeus Boiss., Step area; 475590-4203678, 2025 m., End., Ir.-Tur., LC
Dianthus brevicaulis Fenzl. subsp. ***brevicaulis***, Step area; 475590-4203678, 2025 m., End.
Petrorhagia cretica (L.) P. W. Ball & Heywood, Quercus Forest; 469334-4198579, 700 m.
Velezia rigida L., Quercus Forest; 463801-4191552, 926 m.
Saponaria viscosa C. A. Mey., Kahta river bed; 466514-4191226, 558 m., Ir.-Tur.
Gypsophila pinifolia Boiss. & Hausskn., 474650-4198113, 1600 m., End., Ir.-Tur.
Acanthophyllum verticillatum (Willd.) Hand.-Mazz., 468271-4199477, 685 m., Ir.-Tur.
Vaccaria hispanica (Miller) Rauschert, Fields; 468414-4201008, 787 m.
Silene longipetala Vent., Waste place; 474208-4198286, 1500 m., Ir.-Tur.
Silene marschallii C. A. Meyer, Step area; 474208-4198286, 1500 m., Ir.-Tur.
Silene capitellata Boiss., Quercus Forest; 480121-4199088, 1200, End., Ir.-Tur., LC

Silene chlorifolia Sm., Calceruos area; 477131-4201868, 1790 m., Ir.-Tur.
Silene swertiifolia Boiss., Quercus Forest; 469285-4198844, 655 m.
Silene stenobotrys Boiss. & Hausskn., Quercus Forest; 480121-4199088, 1200 m., Ir.-Tur.
Silene muradica Schischkin, Calceruos area; 477131-4201868, 1790 m., End., Ir.-Tur., LC
Silene arguta Fenzl., Step area; 475919-4202634, 1800 m. Ir.-Tur.
Silene nemrutensis K.Yıldız, 478832-4206509, 1642 m., End., Ir.-Tur.
Silene multifida (Adams) Rohrb., Shrubs; 463966-4197562, 1050 m.
Silene vulgaris (Moench) Garcke, Quercus Forest; 463801-4197457, 1100 m., LC
Atocion compactum (Fisch.) Oxelman, Kahta river bed; 466514-4191226, 558 m.
Silene chaetodonta Boiss., Waste place; 463801-4191552, 926 m., Ir.-Tur.
Silene crassipes Fenzl., Fields; 480554-4195111, 892 m.
Silene dichotoma Ehrh. subsp. ***dichotoma***, Quercus Forest; 472498-4197982, 1400 m.
Silene macrodonta Boiss., Kahta river bed; 466514-4191226, 558 m.
Silene conoidea L., Kahta river bed; 466514-4191226, 558 m.,

ILLECEBRACEAE

Herniaria hirsuta L., Quercus Forest; 480121-4199088, 1200 m.
Paronychia kurdica Boiss. subsp. ***kurdica*** var. ***kurdica***, Calcerous area; 465598-4198643, 615 m.
Scleranthus annuus L. subsp. ***annuus***, Waste place; 467943-4193371, 1100 m.

POLYGONACEAE

Atraphaxis billardieri Jaub. & Spach. var. ***billardieri***, Quercus Forest; 475260-4200450, 1685 m, İr-Tur.
Rheum ribes L., Meadow; 480244-4206017, 1923 m., Ir.-Tur.
Persicaria lapathifolia (L.) Delarbe, Stream bed; 465905-4196364, 586 m., LC
Polygonum setosum Jacq. subsp. ***luzuloides*** (Jaub. & Spach) Leblebici, Step area; 476533-4207288, 1600 m., Ir.-Tur.
Polygonum cognatum Meissn., Meadow; 476072-4204013, 1895 m.,
Polygonum aviculare L., Meadow; 477491-4200767, 1604 m.
Polygonum bellardii All., Steram bed; 482430-4197400, 840 m.
Rumex tuberosus L. subsp. ***horizontalis***, Quercus forest; 479056-4201492, 1700 m.
Rumex ponticus E. H. L. Krause, Meadov; 475251-4203341, 1957 m., End., Ir.-Tur., LC
Rumex pulcher L., Shrubs; 468961-4194447, 1000 m.
Rumex dentatus L. subsp. ***dentatus***, Calcerous area; 479533-4195519, 1040 m.

CHENOPODIACEAE

Dysphania botrys (L.) Mosyakin & Clemants, Stream bed; 466514-4191226, 558 m.
Blitum virgatum L. subsp. ***virgatum***, Step area; 477006-4203465, 2100 m.
Chenopodium vulvaria L., Fields; 461952-4192084, 897 m.
Noaea mucronata Aschers. & Schweinf subsp. ***mucronata,*** Step area; 473283-4198165, 1500 m.

TAMARICACEAE

Tamarix smyrnensis Bunge, Kahta river bed; 466514-4191226, 558 m., LC

GUTTIFERAE (HYPERICACEAE)

Hypericum spectabile Jaub. & Spach, Quercus Forest; 473838-4204903, 1200 m., End., Ir.-Tur.
Hypericum lydium Boiss., Step area; 475590-4203678, 2025 m.
Hypreicum* cf. *helianthemoides (Spach) Boiss., Red pine afforestation area; 468854-4194645, 900 m., Ir.-Tur.
Hypericum salsolifolium Hand.-Mazz., Quercus Forest; 468271-4199477, 685 m., End., Ir.-Tur.
Hypericum scabrum L., Calcerous area; 480414-4205506, 1990 m., Ir.-Tur.
Hypericum confertum Choisy subsp. ***stenobotrys*** (Boiss.) Holmboe, Quercus Forest; 472391-4198266, 1400 m.
Hypericum* cf. *olympicum L. subsp. ***olympicum***, Shrubs; 476053-4208097, 1190 m.
Hypericum perforatum L., Fields; 483294-4197180, 856 m.
Hypericum triquetrifolium Turra, Fields; 468414-4201008, 787 m.

MALVACEAE

Malva neglecta Wallr., Meadow; 475251-4203341, 1957 m.
Alcea striata (DC.) Alef. subsp. ***rufescens*** (Boiss.) Cullen, Calcerous area; 472612-4198410, 1455 m., Ir-Tur.

Alcea digitata (Boiss.) Alef., Calcerous area; 475552-4200487, 1760 m., Ir.-Tur.
Alcea apterocarpa (Fenzl) Boiss., Calcerous area; 479533-4195519, 1040 m., End., Ir.-Tur.
LINACEAE
Linum mucronatum Bertol. subsp. ***mucronatum***, Waste places; 462730-4191827, 893 m., Ir.-Tur.
Linum nodiflorum L., 462730-4191827, 893 m., Medit.
Linum strictum L., Quercus Forest; 469285-4198844, 655 m.
Linum pubescens Banks & Sol., Fields; 480554-4195111, 892 m., E. Medit.
GERANIACEAE
Biebersteinia multifida DC., Meadow; 478666-4201840, 1731 m., Ir.-Tur.
Geranium rotundifolium L., Step area; 468061-4193613, 1000 m.
Geranium tuberosum L., Step area; 463801-4191552, 926 m., Ir.-Tur.
Erodium gruinum L'Hér., Quercus Forest; 469872-4199703, 830 m., E. Medit.
Erodium cicutarium (L.) L'Hér. subsp. ***cicutarium***, Quercus Forest; 469872-4199703, 830 m.
Pelargonium endlicherianum Fenzl., Quercus Forest; 473515-4204797, 1100 m.
ZYGOPHYLLACEAE
Tribulus terrestris L., Fields; 480554-4195111, 892 m.
RUTACEAE
Haplophyllum myrtifolium Boiss., Quercus Forest; 479816-4200957, 1610 m. End., Ir.-Tur.
ACERACEAE
Acer monspessulanum subsp. ***assyriacum*** (Pojark.) Rech. fil., Calcerous area, 471937-4199251, 1100 m. Ir.-Tur.
Acer monspessulanum L. subsp. ***microphyllum*** (Boiss.) Bornm., Shrubs; 477555-4202517, 1740 m.
VITACEAE (Ampelidaceae)
Vitis vinifera L., Fields; 464663-4193142, 655 m., LC
RHAMNACEAE
Paliurus spina-christi Miller, Shrubs; 468523-4199286, 640 m.
ANACARDIACEAE
Cotinus coggygria Scop., Shrubs; 468523-4199286, 640 m., LC
Rhus coriaria L., Quercus Forest; 473515-4204797, 1100 m.
Pistacia khinjuk Stocks, Shrubs; 472109-4199696, 1050 m., Ir.-Tur., LC
Pistacia vera L., Fields; 471194-4201188, 847 m., Ir.-Tur., NT
Pistacia terebinthus L., Quercus Forest; 467516-4196064, 620 m.
LEGUMINOSAE (FABACEAE)
Prosopis farcta (Banks & Sol.) J.F.Macbr., Fields; 468414-4201008, 787 m.
Genista albida Willd., Step area; 477528-4201732, 1700 m.
Robinia pseudoacacia L., Red pine afforestation area; 467877-4193929, 915 m., LC
Colutea cilicica Boiss. & Balansa, Quercus Forest; 469285-4198844, 655 m.
Astragalus hamosus L., Quercus Forest; 468867-419068, 600 m.
Astragalus suberosus Banks & Sol. subsp. ***suberosus***, Step area; 478569-4201652, 1750 m.
Astragalus densifolius Lam. subsp. ***densifolius***, Step area; 476612-4207396, 1539 m., End., Ir.-Tur.
Astragalus cretaceus Boiss. & Kotschy, Step area; 479793-4200549, 1500 m., Ir.-Tur.
Astragalus oxytropifolius Boiss., Step area; 478510-4200215, 1520, End., Ir.-Tur.
Astragalus arnottianus (Gillies ex Hook. & Arn.) Speg., Calceours areas; 476815-4201236, 1750 m.
Astragalus aleppicus Boiss., Quercus fields; 471575-4199003, 1200 m., Ir.-Tur.
Astragalus altanii Hub.-Mor., Shrubs; 476891-4207827, 1300 m., End., Ir.-Tur.
Astragalus angustiflorus C. Koch subsp. ***anatolicus*** (Boiss.) Chamberlain, Calcerous area; 477131-4201868, 1790 m., End., E. Medit.
Astragalus barba-jovis DC., Meadov; 477491-4200767, 1604 m., End., Ir.-Tur.
Astragalus lamarckii Boiss., Quercus Forest; 471794-4198524, 1200 m., End., Ir.-Tur.
Astragalus kurdicus Boiss. var. ***kurdicus***, Step area; 475633-4197877, 1472 m., Ir.-Tur.
Astragalus kurdicus Boiss. var. ***muschianus*** (Kotschy & Boiss.) Chamberlain, Step area; 476066-4202860, 1905 m., End., Ir.-Tur.
Astragalus cephalotes Banks & Sol., Quercus area; 472681-4198130, 1507 m.
Astragalus macrocephalus Willd. subsp. ***finitimus*** (Bunge) Chamberlain, Step area; 476533-4207288, 1600 m., Ir.-Tur.

Astragalus lineatus Lam., Step area; 476066-4202860, 1905 m.,
Astragalus xylobasis Freyn & Bornm. var. ***xylobasis***, Quercus Forest; 469285-4198844, 655 m.
Astragalus elongatus Willd subsp. ***elongatus***, Step area; 477683-4202962, 1800 m.
Astragalus robustus Bunge, Quercus Forest; 469285-4198844, 655 m., Ir.-Tur.
Astragalus nitidissimus Greuter & Burdet, Step area; 476822-4203764, 2013 m., End., Ir.-Tur.
Glycyrrhiza glabra L., Fields; 468414-4201008, 787 m.
Bituminaria bituminosa (L.) C.H.Stirt., Fields; 468414-4201008, 787 m.
Psoralea jaubertina Fenzl., Fields; 475326-4208364, 1087 m., Ir.-Tur.
Cicer arietinum L., Fields; 463456-4191458, 879 m.
Cicer bijugum Rech. fil., Waste place; 463801-4191552, 926 m., Ir.-Tur., EN
Vicia tenuifolia subsp. ***elegans*** (Guss.) Nyman, Quercus Forest; 471794-4198524, 1200 m.
Vicia palaestina Boiss., Calcerous area; 479533-4195519, 1040 m., E. Medit.
Vicia assyriaca Boiss., Fields; 470636-4200696, 713 m., Ir.-Tur., DD
Vicia aintabensis Boiss., Waste place; 475633-4197877, 1472 m., Ir.-Tur.
Vicia peregrina L., Quercus Forest; 467516-4196064, 620 m. Ir.-Tur.
Vicia sericocarpa Fenzl var. ***sericocarpa***, Fields; 480554-4195111, 892 m., LC
Vicia hybrida L., Calcerous area; 479533-4195519, 1040 m., LC
Vicia sativa L. subsp. ***nigra*** (L.) Ehrh var. ***nigra***, Quercus Forest; 467516-4196064, 620 m.
Vicia sativa L. subsp. ***sativa***, Shrubs; 471259-4201281, 900 m.
Vicia narbonensis L. var. ***narbonensis***, Quercus Forest; 483329-4196499, 863 m., LC
Lens culinaris Medik. subsp. ***orientalis*** (Boiss.) Ponert, Quercus Forest; 469759-4199803, 880 m.
Lathyrus inconspicuus L. var. ***insconspicuus***, Step area; 475694-4208042, 1175 m.
Lathyrus cicera L., Quercus Forest; 482820-4196236, 860 m.
Lathyrus sativus L., Kahta river bed; 466514-4191226, 558 m.
Lathyrus aphaca L. var. ***biflorus*** Post, Quercus Forest; 469334-4198579, 700 m.
Pisum sativum L. subsp. ***elatius*** *(*Bieb.) Asch. & Graebn. var. ***elatius***, Quercus Forest; 464898-4198496, 800 m., Medit.
Ononis pubescens L., Stream bed; 475718-4209163, 850 m., Medit.
Ononis pusilla L., Quercus Forest; 470849-4199263, 1100 m., Medit.
Ononis spinosa L. subsp. ***leiosperma*** (Boiss.) Sirj., Step area; 475633-4197877, 1472 m.
Trifolium grandiflorum Schreb., Quercus Forest; 464177-4197845, 1000 m.
Trifolium boissieri Guss., Quercus Forest; 469285-4198844, 655 m., E. Medit.
Trifolium pratense L. var. ***pratense***, Quercus Forest; 482820-4196236, 860 m., LC
Trifolium stellatum L. var. ***stellatum***, Quercus Forest; 469334-4198579, 700 m.
Trifolium scabrum L., Waste place; 462730-4191827, 893 m., LC
Trifolium arvense L. var. ***arvense***, Quercus Forest; 463853-4191728, 867 m.
Trifolium purpureum Loisel var. ***purpureum***, Quercus Forest; 479957-4195451, 995 m.
Trifolium pilulare Boiss., Quercus Forest; 482820-4196236, 860 m.
Melilotus officinalis (L.) Desr., Quercus Forest; 469334-4198579, 700 m.
Medicago brachycarpa M.Bieb., Dry stream bed; 482962-4196167, 836 m., Ir.-Tur.
Trigonella spruneriana Boiss. var. ***spruneriana***, Quercus Forest; 464470-4198051, 900 m., Ir.-Tur.
Trigonella filipes Boiss., Quercus Forest; 469759-4199803, 880 m., Ir.-Tur.
Trigonella velutina Boiss., Stream bed; 471583-4196824, 969 m., Ir.-Tur.
Medicago rigida (Boiss. & Balansa) E.Small, Suphi stream dry bed; 466514-4191226, 558 m., End., E. Medit.
Medicago monantha (C.A.Mey.)Trautv. subsp. ***monantha,*** Quercus remain Forest; 480835-4198323, 1035 m., Ir.-Tur.
Medicago monspeliaca (L.)Trautv., Quercus Forest; 464470-4198051, 900 m., Medit.
Trigonella spicata Sm., Quercus Forest; 469334-4198579, 700 m, E. Medit.
Trigonella cariensis Boiss., Quercus Forest; 469872-4199703, 830 m., End., E. Medit.
Medicago radiata L., Quercus Forest; 468061-4193613, 1000 m., Ir.-Tur.
Medicago orbicularis (L.) Bartal., Shrubs; 468676-4194239, 1000 m.
Medicago sativa L. subsp. ***sativa***, Quercus Forest; 482820-4196236, 860 m.
Medicago coronata (L.) Bart., Quercus Forest; 482820-4196236, 860 m., Medit.
Medicago minima (L.) Bart. var. ***minima***, Step area; 468061-4193613, 1000 m.

Medicago scutellata L., Step area; 468061-4193613, 1000 m., Medit., LC
Medicago rigidula (L.) All. var. ***rigidula***, Step area; 467943-4193371, 1100 m., LC
Lotus gebelia Vent. var. ***hirsutissimus*** (Ledeb.) Dinsm., Quercus Forest; 482820-4196236, 860 m.
Hymenocarpos circinnatus (L.) Savi, Step area; 463267-4196102, 830 m., Medit.
Coronilla scorpioides (L.) Koch, Step area; 467943-4193371, 1100 m.
Securigera varia (L.) Lassen, Step area; 463801-4191552, 926 m.
Hippocrepis unisiliquosa L. subsp. ***unisiliquosa***, Quercus Forest; 468271-4199477, 685 m.
Scorpiurus muricatus L., Fields; 475326-4208364, 1087 m.
Hedysarum nuratense Popov, Calcerous area; 480118-4199142, 1220 m., End.
Onobrychis cornuta (L.) Desv., Step area; 475590-4203678, 2025 m., Ir.-Tur., LC
Onobrychis caput-galli (L.) Lam., Quercus Forest; 469285-4198844, 655 m., Medit.
Onobrychis aequidentata (Sm.) d'Urv, Quercus Forest; 469285-4198844, 655 m., Medit.
Onobrychis gracilis Besser, Quercus Forest; 469285-4198844, 655 m.,
Onobrychis galegifolia Boiss., Quercus Forest; 472452-4196785, 1100 m., Ir.-Tur.
ROSACEAE
Prunus spinosa L. subsp. ***dasyphylla*** (Schur) Domin, Quercus Forest; 476022-4207480, 1400 m.
Prunus domestica L., Fields; 483294-4197180, 856 m., DD
Prunus divaricata Ledeb. subsp. ***divaricata*** (Ledeb.) Schneider, Quercus Forest; 482820-4196236, 860 m.
Prunus prostrata Labill., Shrubs; 476053-4208097, 1190 m., LC
Prunus microcarpa C.A. Mey., Shrubs; 468637-4199302, 620 m., Ir.-Tur.
Prunus mahaleb *L. var.* ***alpina,*** Quercus Forest; 476612-4207396, 1539 m., VU
Prunus armeniaca L., Fields; 483294-4197180, 856 m.
Prunus dulcis (Mill.) D. A. Webb., Fields; 471194-4201188, 847 m.
Prunus trichamygdalus Hand.-Mazz. var. ***trichamygdalus***, Calcerous area; 477131-4201868, 1790 m., Ir.-Tur.
Prunus argentea (Lam.) Rehder, Shrubs; 464445-4192428, 800 m., Ir.-Tur., DD
Prunus arabica (Oliv.) Meikle, Shrubs; 465739-4199838, 682 m., Ir.-Tur.
Prunus lycioides (Spach) C. K. Schneider, Quercus Forest; 469759-4199803, 880 m.
Rubus sanctus Schreb., Stream sides; 466514-4191226, 558 m.
Potentilla meyeri Boiss., Meadow; 476072-4204013, 1895 m., Ir.-Tur.
Potentilla reptans L., Stream; 475718-4209163, 850 m.
Geum urbanum L., Fields; 483294-4197180, 856 m., Euro-Sib.
Agrimonia eupatoria L., Fields; 483294-4197180, 856 m.
Poterium sanguisorba subsp. ***sanguisorba*** L., Quercus Forest; 469334-4198579, 700 m., DD
Rosa pulverulenta M. Bieb., Calcerous area; 479687-4204945, 1945 m.
Rosa canina L., Stream bed; 465905-4196364, 586 m.
Rosa orientalis Dupont ex Ser., Calcerous area; 476274-4203947, 1925 m., Ir.-Tur.
Cotoneaster affinis Lindl., Shrubs; 473498-4206188, 1020 m.
Crataegus azurela var. ***aronia*** L., Quercus Forest; 483310-4196530, 850 m., End., LC
Crataegus monogyna Jacq. subsp. ***monogyna***, Shrubs; 463966-4197562, 1050 m.
Sorbus umbellata (Desf.) Fritsch var. ***umbellata***, Shrubs; 476891-4207827, 1300 m.
Sorbus torminalis (L.) Crantz var. ***torminalis***, Quercus remains; 476304-4207364, 1490 m., LC
Malus orientalis Uglitzk., Fields; 464663-4193142, 655 m., DD
Eriolobus trilobatus (Labill. ex Poir.) Roemer, Quercus Forest; 462723-4191860, 887 m.
Pyrus syriaca Boiss. subsp. ***syriaca***, Quercus Forest; 478964-4200204, 1400 m.
PUNİCACEAE
Punica granatum L., Fields; 464663-4193142, 655 m., LC
LYTHRACEAE
Lythrum salicaria L., Damp place; 465905-4196364, 586 m., Euro-Sib., LC
ONAGRACEAE
Epilobium minutiflorum Hausskn. Kahta river dry bed; 465666-4195807, 570 m., Ir.-Tur., LC
CUCURBİTACEAE
Bryonia multiflora Boiss. & Heldr., Quercus Forest; 469285-4198844, 655 m., Ir.-Tur.
DATİSCACEAE

Datisca cannabina L., Stream sides; 466514-4191226, 558 m.
CRASSULACEAE
Umbilicus horizontalis (Guss.) DC var. ***intermedius*** (Boiss.) Chamberlain, Calceruos area; 468410-4193904, 1100 m.
Rosularia sempervivum subsp. ***persica*** (Boissier) U. Eggli, Calceruos area; 475075-4198071, 1595 m., Ir.-Tur.
Sedum album L. subsp. ***album***, Calceruos area; 468410-4193904, 1100 m.
Petrosedum subulatum (C.A.Mey.) Afferni, Step area; 476533-4207285, 1600 m.
Sedum pallidum Bieb. var. ***pallidum***, Near stream; 466514-4191226, 558 m.
APIACEAE
Eryngium creticum Lam., Shrubs; 469285-4198844, 655 m., E. Medit.
Eryngium pyramidale Boiss. & Hausskn., Meadow; 479957-4195451, 995 m., Ir.-Tur.
Eryngium thyrsoideum Boiss., Shrubs; 476415-4202539, 1800 m., Ir.-Tur.
Eryngium glomeratum Lam. subsp. ***glomeratum***, Shrubs; 478964-4200204, 1400 m.
Eryngium billardieri Delar subsp. ***billardieri***, Calceruos area; 475075-4198071, 1595 m., Ir.-Tur.
Eryngium campestre L., Quercus Forest; 469285-4198844, 655 m.
Lagoecia cuminoides L., Quercus Forest; 469759-4199803, 880 m., Medit.
Echinophora tenuifolia L. subsp. ***sibthorpiana*** (Guss.) Tutin, Field; 462474-4193682, 890 m., Ir.-Tur.
Chaerophyllum nodosum (L.) Crantz, Quercus Forest; 473515-4204797, 1100 m., End., Ir.-Tur.
Rhabdosciadium microcalycinum Hand.-Mazz., Meadow; 477523-4202662, 1713 m, Ir.-Tur.
Grammosciadium macrodon Boiss., Step area; 476533-4207283, 1600 m., Ir.-Tur.
Scandix iberica M. Bieb., Quercus Forest; 479793-4200549, 1500 m.
Scandix pecten-veneris L., Waste place; 463801-4191552, 926 m.
Scandix australis L. subsp. ***grandiflora*** (L.) Thell., Step area; 474208-4198286, 1500 m.
Smyrnium cordifolium Boiss., Quercus Forest, 475458-4201703, 1550 m., Ir.-Tur.
Bunium paucifolium DC. var. ***brevipes*** (Freyn & Sint.) Hedge & Lamond., Waste place; 475694-4208042, 1175 m., End., Ir.-Tur., LC
Bunium microcarpum subsp. (Boiss.) Freyn ***microcarpum***, Fields; 483294-4197180, 856 m., E. Medit.
Pimpinella eriocarpa Banks & Sol., Calcerous area; 465598-4198643, 615 m., Ir.-Tur.
Pimpinella tragium Vill. subsp. ***lithophila*** (Schischkin) Tutin, Step area; 476066-4202860, 1907 m.
Kundmannia syriaca Boiss., Shrubs; 476415-4202539, 1800 m, End., E. Medit.
Lecokia cretica (Lam.) DC., Quercus Forest; 483329-4196499, 863 m.
Prangos pabularia Lindl. subsp. ***pabularia***, Step area; 480187-4205207, 1962 m., Ir.-Tur.
Heptaptera anisoptera (DC.) Tutin, Waste places; 475694-4208042, 1175 m.
Bupleurum aleppicum Boiss., Quercus Forest; 469285-4198844, 655 m., Ir.-Tur.
Bupleurum eginense (Wolff) Snogerup, Quercus Forest; 473838-4204903, 1200 m., Ir.-Tur., NT
Bupleurum gerardii All., Quercus Forest; 483310-4196530, 850 m.
Johrenia dichotoma DC subsp. ***sintenisii*** Bornm., Calcerous area; 476815-4201236, 1750 m., End., EN
Ferula rigidula DC., Step area; 479906-4204727, 1950 m.
Opopanax hispidus (Friv.) Griseb., Step area; 473899-4202082, 1800 m.
Trigonosciadium lasiocarpum (Boiss.) Alava, Step area; 475919-4202634, 1800 m., End., Ir.-Tur., LC
Leiotulus secacul subsp. ***secacul*** (Mill.) Pimenov & Ostr., Red pine afforestation area; 468854-4194645, 900 m.
Ormosciadium aucheri Boiss., Shrubs; 475453-4208974, 1000 m.
Tordylium cappadocicum Boiss., Quercus Forest; 483310-4196530, 850 m., End., Ir.-Tur., DD
Silphiodaucus hispidus (M.Bieb.) Spalik, Wojew., Banasiak, Piwczyiski & Reduron., Quercus Forest; 473838-4204903, 1200 m., Euro-Sib.
Torilis leptophylla (L.) Rchb. fil., Quercus Forest; 467516-4196064, 620 m.
Astrodaucus orientalis (L.) Drude, Quercus remain Forest; 475583-4209171, 880 m., Ir.-Tur.
Caucalis platycarpos L., Quercus Forest; 482820-4196236, 860 m.
Turgenia latifolia (L.) Hoffm., Shrubs; 468637-4199302, 620 m.
Daucus carota L., Fields; 468414-4201008, 787 m.
Artedia squamata L., Quercus Forest; 469285-4198844, 655 m.
ARALIACEAE

Hedera helix L., Stream side; 470259-4200348, 640 m.
CAPRIFOLIACEAE
Lonicera nummulariifolia Jaub. & Spach subsp. ***nummulariifolia***, Shrubs; 477828-4202719, 1750 m., LC
Lonicera etrusca G. Santi var. ***etrusca***, Quercus Forest; 471575-4199003, 1200 m., Medit.
VALERIANACEAE
Valeriana dioscoridis Sibth. & Sm., Quercus Forest; 483310-4196530, 850 m., E. Medit.
Centranthus longiflorus Stev. subsp. ***longiflorus***, Calcerous area; 480414-4205506, 1990 m, Ir.-Tur.
Valerianella coronata (L.) DC., Waste place; 462730-4191827, 893 m.
Valerianella vesicaria (L.) Moench, Quercus Forest; 469285-4198844, 655 m.
MORINACEAE
Morina persica L. var. ***persica***, Shrub; 473498-4206188, 1020 m., Ir.-Tur.
DIPSACACEAE
Cephalaria setosa Boiss. & Hohen., Quercus Forest; 469285-4198844, 655 m., Ir.-Tur.
Lomelosia argentea (L.) Greuter & Burdet, Quercus Forest; 469285-4198844, 655 m.
Lomelosia rotata (Bieb.) W. Greuter & Burdet, Kahta river bed; 471583-4196824, 969 m., Ir.-Tur.
Pterocephalus plumosus (L.) Coulter, Quercus Forest; 469759-4199803, 880 m.
COMPOSITAE (ASTERCEAE)
Xanthium strumarium L. subsp. ***strumarium***, Stream bed; 465905-4196364, 586 m.
Chrysophthalmum montanum (DC.) Boiss., Shrubs; 473498-4206188, 1020 m., Ir.-Tur.
Inula montbretiana DC., Meadow; 477523-4202662, 1713 m, Ir.-Tur.
Phagnalon rupestre (L.) DC. subsp. ***rupestre,*** Calcerous area; 465598-4198643, 615 m., Medit.
Helichrysum graveolens (M. Bieb.) Sw., Meadow; 477523-4202662, 1713 m.
Helichrysum plicatum DC. subsp. ***plicatum***, Step area; 477085-4207458, 1500 m., Ir.-Tur.
Helichrysum araxinum Takht. ex Kirpicz., Calcerous area; 468410-4193904, 1100 m.
Helichrysum arenarium (L.) Moench subsp. ***aucheri*** (Boiss.) Davis & Kupicha, Step area; 478510-4200215, 1520 m., End., Ir.-Tur.
Filago pyramidata L., Fields; 480554-4195111, 892 m.
Logfia davisii Holub ex Grierson, Step area; 474208-4198286, 1500 m.
Filago anatolica (Boiss. & Heldr.) Chrtek & Holub., 477491-4201298, 1604 m., Ir.-Tur.
Filago griffithii (A.Gray) Andrés-Sánchez & Galbany, Waste place; 462730-4191827, 893 m., Ir.-Tur.
Bellis perennis L., Shrubs; 464621-4193084, 656 m., Euro-Sib.
Turanecio eriospermus (DC.) Hamzaoglu var. ***eriospermus***, Step area; 476072-4204013, 1500 m.
Senecio vernalis Waldst. & Kit., Waste area; 473899-4202082,
Tussilago farfara L., Damp ground; 469475-4199989, 650 m., Euro-Sib.
Anthemis cretica L. subsp. ***anatolica*** (Boiss.) Grierson, Step area; 478510-4200215, 1520 m.
Cota tinctoria (L.) J.Gay ex Guss. var. ***tinctoria***, Quercus Forest; 483310-4196530, 850 m.
Cota wiedemanniana (Fisch. & C. A. Mey.) Holub., Step area; 462730-4191827, 893 m., End., LC
Anacyclus nigellifolius Boiss. subsp. ***orientalis*** (L.) Grierson, Calcerous area; 479533-4195519, 1040 m.
Achillea schischkinii D. Sosn., Shrubs; 476891-4207827, 1300 m., End., Ir.-Tur., LC
Achillea millefolium L. subsp. ***millefolium***, Step area; 1796 m., Euro-Sib., LC
Achillea nobilis L. subsp. ***kurdica*** Huber-Morath, Meadow; 477491-4200767, 1604 m, End., E. Medit., CD
Achillea arabica Kotschy., Quercus Forest;476891-4207827, 1300 m.
Tanacetum nitens (Boiss. & Not) Grierson, Calcerous area; 472612-4198410, 1455 m., End., LC
Tanacetum cadmeum (Boiss.) Heywood subsp. ***orientale*** Grierson, Meadow; 477491-4200767, 1604 m., End., Ir.-Tur., LC
Tanacetum densum (Lab.) Schultz Bip. subsp. ***amani*** Heywood, Step area; 475590-4203678, 2025 m., End., LC
Tanacetum argenteum (Lam.) Willd. subsp. ***argenteum***, Calcerous area; 1592 m., End., Ir.-Tur., LC
Tripleurospermum caucasicum (Willd.) Hayek, Waste places; 463801-4191552, 926 m.
Gundelia tournefortii L., Step area; 479133-4200341, 1437 m.
Cousinia foliosa Boiss. & Bal., Step area; 477085-4207458, 1500 m., End., Ir.-Tur., LC
Cousinia canescens DC., Step area; 474208-4198286, 1500 m., End., Ir.-Tur.

Silybum marianum (L.) Gaertn., Waste places; 468714-4193322, 852 m., Medit.
Cirsium echinus (M. Bieb.) Hand.-Mazz., Quercus Forest; 463801-4197457, 1100 m.
Cirsium strigosum (M. Bieb.) M. Bieb., Shrub; 477555-4202517, 1750 m.
Picnomon acarna (L.) Cass., Quercus Forest; 462723-4191860, 887 m., Medit.
Ptilostemon diacantha (Lab.) Greuter subsp. ***turcicus*** Greuter, Shrub; 465739-4199838, 682 m., E. Medit.
Notobasis syriaca (L.) Cass., Shrub; 468637-4199302, 620 m., Medit.
Carduus nutans L. subsp. ***nutans***, Quercus Forest; 483310-4196530, 850 m.
Carduus pycnocephalus L. subsp. ***albidus*** (M. Bieb.) Kazmi, Quercus Forest; 483310-4196530, 850 m.
Klasea cerinthifolia (Sm.) Greuter & Wagenitz, Calcerous area; 479533-4195519, 1040 m.
Klasea oligocephala (DC.) Greuter & Wagenitz, 468854-4194645, End., Ir.-Tur., LC
Centaurea virgata Lam. subsp***. virgata***, Waste places; 463801-4191552, 926 m.
Centaurea handelii Wagenitz, Shrub; 475431-4208349, 1100 m., Ir.-Tur., VU
Centaurea tomentella Hand.-Mazz., End., Ir.-Tur., NT
Centaurea behen L., Quercus remain; 468714-4193322, 852 m.
Centaurea solstitialis L. subsp. ***solstitialis***, Waste places; 468061-4193613, 1000 m.
Centaurea iberica Trev. ex Sprengel subsp. ***iberica***, Stream bed; 466514-4191226, 558 m.
Centaurea calcitrapa L. subsp. ***calcitrapa***, Meadow; 475572-4198084, 1536 m., Medit.
Centaurea urvillei DC. subsp. ***urvillei***, Calcerous area; 480118-4199142, 1220 m., E. Medit.
Centaurea urvillei DC. subsp. ***nimrodis*** (Boiss. & Hausskn.) Wagenitz, Calcerous area; 479533-4195519, 1040 m., LC
Psephellus mucronifer (DC.) G. Wagenitz, Calcerous area; 475974-4203709, 2000 m., End., Ir.-Tur.
Cyanus triumfettii (All.) Dostál Ex Á. Löve & D. Löve subsp. ***triumfettii***, Step area; 477298-4204004, 2150 m.
Crupina crupinastrum (Moris) Vis., Step area; 467943-4193371, 1100 m.
Cnicus benedictus L., Waste places; 463792-4191494, 973 m. DD
Carthamus lanatus L. subsp. ***lanatus***, Quercus Forest; 468271-4199477, 685 m.
Carthamus dentatus Vahl. subsp. ***dentatus***, Fallow; (468976-4195568, 780 m.
Xeranthemum annuum L., Step area; 468637-4199302, 620 m.
Xeranthemum longepapposum Fisch. & Mey., Quercus Forest; 469334-4198579, 700 m., Ir.-Tur.
Siebera nana (DC.) Bornm., Quercus Forest; 469872-4199703, 830 m., Ir.-Tur.
Chardinia orientalis (L.) O. Kuntze, Step area; 473899-4202082, 1800 m., Ir.-Tur.
Echinops pannosus Rech. fil., Waste places; 463801-4191552, 926 m., End., Ir.-Tur., DD
Scolymus hispanicus L subsp. ***hispanicus***, Quercus Forest; 469334-4198579, 700 m., Medit.
Cichorium intybus L. subsp. ***intybus***, River dry bed; 465905-4196364, 586 m.
Podospermum laciniatum subsp. ***laciniatum*** (L.) DC., Meadow; 477232-4207573, 1476 m.,
Scorzonera suberosa C. Koch subsp. ***suberosa***, Step area; 478569-4201652, 1750 m., End., Ir.-Tur.
Scorzonera phaeopappa (Boiss.) Boiss., Step area; 473283-4198165, 1500 m., Ir.-Tur.
Scorzonera semicana DC., Meadow; 477232-4207573, 1476 m., End., Ir.-Tur.
Scorzonera papposa DC., Quercus Forest; 473838-4204903, 1200 m., Ir.-Tur.
Scorzonera latifolia (Fisch. & C. A. Mey.) DC., Meadow; 476072-4204013, 1895 m., Ir.-Tur.
Scorzonera tomentosa L., Calcerous area; 477131-4201868, 1790 m., End., Ir.-Tur.
Scorzonera kotschyi Boiss., Quercus Forest; 469334-4198579, 700 m., Ir.-Tur.
Tragopogon coelesyriacus Boiss., Quercus Forest; 483310-4196530, 850 m.
Tragopogon pterocarpus DC., Calcerous area; 477131-4201868, 1750 m., Ir.-Tur.
Tragopogon buphthalmoides (DC.) Boiss., Step area; 473899-4202082, 1800 m.
Geropogon hybridus (L.) Sch. Bip., Quercus Forest; 467449-4193269, 839 m., Medit.
Leontodon biscutellifolius DC., Calcerous area; 475075-4198071, 1595 m.
Picris strigosa Bieb. var. ***strigosa***, Waste places; 462730-4191827, 893 m.
Urospermum picroides (L.) Scop. ex F. W. Schmidt, Quercus Forest; 464898-4198496, 800 m., Medit.
Hedypnois rhagadioloides (L.) F.W.Schmidt subsp. ***rhagadioloides***, Calcerous area; 465598-4198643, 615 m., Medit.
Rhagadiolus stellatus (L.) Gaertner var. ***stellatus***, Quercus Forest; 483310-4196530, 850 m.

Garhadiolus hedypnois (Fisch. & C. A. Mey.) Jaub. & Spach, Quercus Forest; 463801-4197457, 1100 m., Ir.-Tur.
Sonchus glaucescens Jord., Stream bed; 466514-4191226, 558 m.
Sonchus oleraceus L., Stream bed; 466514-4191226, 558 m.
Hieracium pannosum Boiss., Calcerous area; 476274-4203947, 1925 m., E. Medit.
Lactuca tuberosa Jacq., Calcerous area; 480118-4199142, 1220 m.
Lactuca serriola L., Quercus Forest; 467516-4196064, 620 m., Euro-Sib.
Lactuca viminea (L.) J. Presl & C. Presl subsp. ***viminea***, Calcerous area; 476008-4203333, 1900 m.
Taraxacum syriacum Boiss., Step area; 479133-4200341, 1437 m., Ir.-Tur.
Taraxacum sonchoides (D. Don) Sch. Bip., Quercus Forest; 474966-4200018, 1600 m., Ir.-Tur.
Chondrilla juncea L. var. ***juncea,*** Waste places; 468061-4193613, 1000 m.
Crepis alpina L., Shrub; 464445-4192428, 800 m.
Crepis foetida L. subsp. ***rhoeadifolia*** (M. Bieb.) Celak., Quercus Forest; 469759-4199803, 880 m.
Crepis commutata (Spreng.) W. Greuter, Waste area; 462730-4191827, 893 m.
Crepis sancta (L.) Babcock, Step area; 473899-4202082, 1800 m.
Crepis aspera L., Stream side; 471583-4196824, 969 m. DD

CAMPANULACEAE

Campanula involucrata Aucher ex A. DC., Step area; 477085-4207458, 1500 m., Ir.-Tur.
Campanula stricta L. var. ***stricta***, Step area; 476494-4203909, 2000 m., Ir.-Tur.
Campanula strigosa Banks &Sol., Quercus Forest; 472498-4197982, 1400 m., E. Medit.
Campanula saxonorum Gand., Fields; 478753-4199753, 1506 m., End., Ir.-Tur., LC
Asyneuma lobelioides (Willd.) Hand.-Mazz., Step area; 475593-4203683, 2025 m., Ir.-Tur.
Legousia falcata (Ten.) Fritsch ex Janch., Fields; 480554-4195111, 890 m., Medit.
Legousia hybrida (L.) Delarbre, Waste area; 926 m., Medit.
Legousia pentagonia (L.) Thell., 477274-4207600, 1475 m., E. Medit.

PRIMULACEAE

Androsace maxima L. subsp. ***maxima***, Shrubs; 476415-4202539, 1800 m.
Lysimachia arvensis subsp. ***arvensis***, (L.) U. Manns & Anderb., Fields; 461952-4192084, 897 m.
Lysimachia arvensis var. ***caerulea*** (L.) Turland & Bergmeier, Stream side; 482962-4196167, 836 m.
Lysimachia arvensis subsp. ***parviflora*** (Hoffmanns. & Link) Peruzzi., Quercus Forest; 464470-4198051, 900 m., Medit.

OLEACEAE

Chrysojasminum fruticans (L.) Banf, Quercus Forest; 469285-4198844, 655 m., Medit.
Fontanesia philliraeoides Labill. subsp. ***philliraeoides***, Quercus Forest; 469285-4198844, 655 m., E. Medit.
Fraxinus angustifolia Vahl subsp. ***angustifolia***, Quercus Forest; 473515-4204797, 1100 m.
Olea europa L. var. ***europaea*** Zhukovsky, Fields; 470680-4200704, 725 m.

APOCYNACEAE

Nerium oleander L., Stream dry bed; 466514-4191226, 558 m., Medit., LC
Vinca herbacea Waldst. & Kit., Quercus Forest, 470708-4199654,

ASCLEPIADACEAE

Periploca graeca L. var. ***graeca***, Stream side; 482962-4196167, 836 m., E. Medit.
Vincetoxicum canescens (Willd.) Decne. subsp. ***canescens***, Quercus Forest; 471575-4199003, 1200 m., Ir.-Tur.

GENTIANACEAE

Centaurium tenuiflorum (Hoffmanns.& Link) Fritsch subsp. ***acutiflorum*** (Schott) Zeltner, Quercus Forest; 483310-4196530, 850 m., Medit.
Gentiana olivieri Griseb., Quercus Forest; 483329-4196499, 900 m., Ir.-Tur.

CONVOLVULACEAE

Convolvulus dorycnium L. subsp. ***oxysepalus*** (Boiss.) Rech. fil., Waste area; 467943-4193371, 1100 m., E. Medit.
Convolvulus holosericeus Bieb. subsp. ***holosericeus***, Step area; 463801-4191552, 926 m.,
Convolvulus arvensis L., Fields; 464663-4193142, 655 m.
Convolvulus betonicifolius Miller, Step area; 463801-4191552, 926 m., Ir.-Tur.
Convolvulus scammonia L., Fields; 468414-4201008, 787 m., E. Medit.

CUSCUTACEAE
Cuscuta kurdica Engelmann, Quercus forest; 474966-4200018, 1600 m., Ir.-Tur.
BORAGINACEAE
Heliotropium circinatum Griseb., Fields; 471194-4201188, 847 m., Ir.-Tur.
Rochelia cancellata Boiss. & Bal., Quercus Forest; 463801-4197457, 1100 m., Ir.-Tur.
Rochelia disperma (L. fil.) C. Koch var. ***disperma***, Quercus Forest; 464177-4197845, 1000 m.
Asperugo procumbens L., Stream dry bed; 482430-4197400, 840 m., Euro-Sib.
Myosotis stricta Link ex Roem. & Schult., Calcerous area; 480414-4205506, 1990 m., Euro-Sib.
Myosotis refracta Boiss. subsp. ***refracta***, Quercus Forest; 463801-4197457, 1100 m., Medit.
Cynoglossum cristatum (Schreber) Boiss. subsp. ***cristatum***, Calcerous area; 476008-4203333, 1900 m., End., Ir.-Tur.
Cynoglossum lanatum Lam., Step area; 477298-4204804, 1750 m., Ir.-Tur.
Cynoglossum stamineum Desf., Meadow; 477523-4202662, 1713 m.
Cynoglossum montanum L., Calcerous area; 478900-4201827, 1727 m., Euro-Sib.
Arnebia densiflora (Ledeb.) Ledeb., Step area; 477528-4201732, 1700 m., Ir.-Tur.
Buglossoides arvensis (L.) I. M. Johnst., Waste place; 462730-4191827, 893 m.
Echium italicum L., Shrub; 470174-4200499, 670 m., Medit.
Onosma rechingeri H. Riedl., Shrub; 471259-4201281, 900 m., Ir.-Tur.
Onosma sericeum Willd., Quercus Forest; 483310-4196530, 850 m., Ir.-Tur.
Onosma mutabile Boiss. & Hausskn., Step area; 477085-4207458, 1500 m., End., LC (LC)
Onosma alboroseum Fisch. & C. A. Mey. subsp. ***albo-roseum*** var. ***albo-roseum***, Calcerous area; 480414-4205506, 1900 m. Ir.-Tur.
Onosma sorgerea Teppner var. ***subglabriflorum***, 479010-4201696, 1735 m., End., Ir.-Tur.
Cerinthe minor L. subsp. ***auriculata*** (Ten.) Domac, Meadow; 477529-4202662, 1713 m.
Anchusa azurea Mill. var. ***azurea***, Step area; 475633-4197877, 1472 m.
Phyllocara aucheri (DC.) Gusul**,** Step area; 463801-4191552, 926 m.
Nonea melanocarpa Boiss., Quercus Forest; 460368-4199650, 840 m., Ir.-Tur.
Nonea stenosolen Boiss. & Bal., Step area; 473899-4202082, 1800 m., End., Ir.-Tur., LC
Alkanna kotschyana DC., Step area; 478569-4201652, 1750 m., End., E. Medit., LC
Alkanna megacarpa DC., Meadow; 477491-4200767, 1604 m., End. Ir.-Tur.-LR (LC)
Trichodesma incanum Bunge, Shrubs; 468637-4199302, 620 m., Ir.-Tur.
SOLANACEAE
Hyoscyamus niger L., Step area; 476494-4203909, 2000 m.
Hyoscyamus aureus L., Calcerous area; 465598-4198643, 615 m., E. Medit.
SCROPHULARIACEAE
Verbascum diversifolium Hochst., Step area; 463801-4191552, 926 m., End., Ir.-Tur.
Verbascum varians Freyn & Sint, var. ***varians;*** Quercus forest, 480121-4199088, 1200 m,
Verbascum kotschyi Boiss. & Hohen., Shrubs; 473498-4206188, 1020 m., Ir.-Tur.
Scrophularia catariifolia Boiss. & Heldr., Dry stream side; 466514-4191226, 558 m., Ir.-Tur.
Scrophularia libanotica Boiss. subsp**. *armena*** R. Mill, Calcerous area; 472612-4198410, 1455 m., End., Ir.-Tur.-LR(nt)
Scrophularia xanthoglossa Boiss. var. ***decipiens*** (Boiss.& Kotschy) Boiss., Dry stream side; 466514-4191226, 558 m., Ir.-Tur.
Odontites aucheri Boiss., Step area; 476274-4203947, 1925 m., Ir.-Tur.
Odontites verna (Bellardi) Dumort. subsp. ***serotina*** (Dumort.) Corb., Step area; 478832-4206509, 1642 m., Euro-Sib.
Parentucellia latifolia (L.) Caruel, Quercus Forest; 469334-4198579, 700 m.
OROBANCHACEAE
Phelypaea coccinea (Bieb.) Poiret, Quercus Forest; 482820-4196236, 860 m., Ir.-Tur.
Orobanche oxyloba (Reuter) G. Beck, Step area; 473283-4198165, 1500 m.
ACANTHACEAE
Acanthus dioscoridis L. var. ***dioscoridis***, Red pine afforestation; 475431-4208349, 900 m.
VERBENACEAE
Vitex agnus-castus L., Stream dry bed; 482962-4196167, 836 m., Medit.
LABIATAE (LAMIACEAE)

Ajuga chamaepitys (L.) Schreber subsp. ***laevigata*** (Banks & Sol.) P.H. Davis, Shrub; 475453-4208974, 1000 m., Ir.-Tur.
Ajuga vestita Boiss., Quercus Forest; 478522-4206761, 1650 m.,, End., Ir.-Tur.
Teucrium multicaule Montbret & Aucher ex Bentham, Quercus Forest; 473498-4206188, 1020 m., Ir.-Tur.
Teucrium orientale L. var. ***puberulens*** T. Ekim, Quercus Forest; 463801-4197457, Ir.-Tur.
Teucrium chamaedrys L. subsp. ***tauricolum*** Rech. fil., Step area; 475633-4197877, 1472 m., End., E. Medit., LC
Teucrium polium L., Quercus Forest; 468271-4199477; 685 m.
Scutellaria rubicunda Hornem. subsp. ***subvelutina*** (Rech. fil.) Edmondson, Quercus Forest; 480121-4199088, 1200 m., E. Medit.
Scutellaria orientalis L. subsp. ***bicolor*** (Hochst.) Edmondson, Step area; 476533-4207288, 1600 m., End., Ir.-Tur.-LR (lc)
Phlomis rigida Labill., Meadow; 477491-4200767, 1604 m., Ir.-Tur.
Phlomis armeniaca Willd., Quercus Forest; 476891-4207827, 1300 m., End., Ir.-Tur., LC
Phlomis capitata Boiss., Step area; 477455-4202517, 1970 m., End., Ir.-Tur., LC
Phlomis kotshcyana Hub.-Mor., 475964-4207815, E. Medit.
Phlomis linearis Boiss. & Bal., Step area; 476822-4203764, 2013 m., End., Ir.-Tur., LC
Phlomis kurdica Rech. fil., Red pine afforestation area; 467877-4193929, 915 m., Ir.-Tur.
Lamium garganicum L. subsp. ***lasioclades*** (Stapf) R. Mill., Quercus Forest; 464898-4198496, 800 m., Ir.-Tur.
Lamium amplexicaule L., Quercus Forest; 483329-4196499, 863 m.
Lamium macrodon Boiss. & Huet, Ir.-Tur.
Ballota saxatilis Sieber ex J. & C. Presl subsp. ***saxatilis***, Calcerous area; 468061-4193613, 1000 m., E. Medit.
Marrubium parviflorum Fisch. & Mey. subsp. ***parviflorum***, Step area; 476022-4207480, 1400 m., Ir.-Tur.
Marrubium globosum Montbret & Aucher ex Bentham subsp. ***globosum***, Step area; 475260-4200450, 1687 m., End., Ir.-Tur., LC
Marrubium astracanicum Jacq. subsp. ***astracanicum***, Step area; 478832-4200509, 1642 m.
Sideritis libanotica Labill. subsp. ***kurdica*** (Bornm.) Hub.-Mor., Step area; 476822-4203764, 2013 m., Ir.-Tur.
Stachys cretica L. subsp. ***garana*** (Boiss.) Rech. fil., Quercus Forest; 472014-4198327, 1300 m., Ir.-Tur.
Stachys cataonica Bhattacharjee & Hub.-Mor., Quercus Forest; 464470-4198051, 900 m., End., Ir.-Tur., VU
Stachys lavandulifolia Vahl. var. ***lavandulifolia***, Calcerous area; 475075-4198071, 1600 m., Ir.-Tur.
Stachys munzurdagensis Bhattacharjee, Quercus shrub; 37 57 15 N-38 40 17 E, EN
Nepeta italica L. subsp. ***italica***, Quercus shrub; 483329-4196499, 863 m.
Nepeta nuda L. subsp. ***albiflora*** (Boiss.) Gams, Meadow; 475251-4203341, 1957 m.
Nepeta sorgerae Hedge & Lamond, Calcerous area; 477267-4203765, 2137 m., End., Ir.-Tur., CD
Nepeta aristata Boiss. & Kotschy ex Boiss., Quercus Forest; 479903-4200390, 1400, End., Ir.-Tur., NT
Lallemantia peltata Fisch. & Mey., Shrub; 477555-4202517, 1750 m., Ir.-Tur.
Lallemantia iberica (Bieb.) Fisch. & Mey., Quercus Forest; 467516-4196064, 620 m.
Primula vulgaris L., Fields; 483294-4197180, 856 m., Euro-Sib.
Satureja hortensis L., Stream sides; 482962-4196167, 836 m.
Clinopopodium vulgare L. subsp. ***arundanum*** (Boiss.) Nyman, Kahta river bed; 466590-4194857, 490 m.
Micromeria myrtifolia Boiss. & Hohen., Quercus Forest; 482820-4196236, 860 m., E. Medit.
Cyclotrichium niveum (Boiss.) Manden & Scheng., Quercus Forest; 473838-4204903, 1200 m., End., Ir.- Tur., VU
Thymus kotschyanus Boiss. & Hohen. var. ***glabrescens*** Boiss., Calcerous area; 477131-4201868, 1790 m., Ir.-Tur.

Thymus kotschyanus Boiss. & Hohen. var. ***kotschyanus***, Calcerous area; 477267-4203765, 2137 m., Ir.-Tur.
Thymus migricus Klokov & Des. Shost., Calcerous area; 477267-4203765, 2137 m., Ir.-Tur.
Thymus leucostomus Hausskn. & Velen. var. ***leucostomus***, Quercus Forest; 474966-4200018, 1600 m., E. Medit.
Thymbra spicata L. var. ***spicata***, Quercus Forest; 469285-4198844, 655 m.
Mentha pulegium L., Stream sides; 466514-4191226, 558 m.,
Mentha longifolia (L.) Hudson subsp. ***longifolia***, Stream sides; 466514-4191226, 558 m., Euxine
Ziziphora capitata L., Quercus Forest; 467516-4196064, 620 m.
Ziziphora tenuior L., Quercus Forest; 473498-4206186, 1100 m.
Salvia pilifera Montbret & Aucher ex Bentham, Quercus Forest; 484735-4207086, End., Ir.-Tur., LC
Salvia ballsiana (Rech. fil.) Hedge, Quercus Forest; 471794-4198524, 1200 m., End., Ir.-Tur., DD
Salvia multicaulis Vahl., Waste; 463801-4191552, 926 m., Ir.-Tur.
Salvia syriaca L., Waste area; 475694-4208042, 1175 m., Ir.-Tur.
Salvia viridis L., Step area; 463801-4191552, 926 m., Medit.
Salvia palestina Bentham, Calcerous area; 479533-4195519, 1040 m., Ir.-Tur.
Salvia aethiopis L., Step area; 476274-4203947, 1925 m.
Salvia ceratophylla L., Kahta river bed; , Ir.-Tur.
Salvia frigida Boiss., Quercus Forest; 479816-4200957, 1600 m., Ir.-Tur.
Salvia candidissima Vahl subsp. ***candidissima***, Quercus shrub; 465578-4204211, Ir.-Tur.
Salvia verticillata L. subsp. ***amasiaca*** (Freyn & Bornm.) Bornm., Quercus Forest; 478964-4200204, 1400 m., Ir.-Tur.
PLUMBAGINACEAE
Plumbago europaea L., Quercus Forest; 472452-4196785, 1100 m., Euro-Sib.
Acantholimon venestum Boiss. var. ***assyriacum*** (Boiss.) Boiss., Calcerous area; 476008-4203333, 1900 m,, End., Ir.-Tur.
Acantholimon acerosum (Willd.) Boiss. var. ***acerosum***, Step area; 478528-4201732, 1770 m., Ir.-Tur.
PLANTAGİNACEAE
Plantago lanceolata L., Stream bed; 466514-4191226, 558 m.
Plantago afra L., Stream bed; 482430-4197400, 840 m.
Kickxia lanigera (Desf.) Hand.-Mazz., Fields; 464663-4193142, 655 m., Medit.
Globularia trichosantha Fisch. & Mey subsp. ***trichosantha,*** Step area; 478832-4206509, 1642 m.
Linaria corifolia Desf., Meadow; 477232-4207573, 1476 m., End., Ir.-Tur., LC
Linaria chalepensis (L.) Miller var. ***chalepensis***, Step area; 463801-4191552, 926 m., E. Medit.
Linaria kurdica Boiss. & Hohen. subsp. ***kurdica***, Quercus Forest; 472010-4198327, 1300 m., Ir.-Tur.
Linaria simplex (Willd.) DC., Waste place; 469759-4199803, 880 m., Medit.
Anarrhinum orientale Bentham, Step area; 476533-4207288, 1600 m., Ir.-Tur.
Veronica reuterana Boiss., Meadow; 479471-4201298, 1598 m., Ir.-Tur.
Veronica biloba Schreber, Quercus remain; 476304-4207364; 1500 m., Ir.-Tur.
Veronica campylopoda Boiss., Quercus Forest; 478964-4200204, 1400 m., Ir.-Tur.
Veronica intercedens Bornm., Quercus remain; 476304-4207364, 1490 m., Ir.-Tur.
Veronica panormitana Tineo subsp. ***panormitana***, Quercus Forest; 482820-4196236, 860 m.
Veronica anagallis-aquatica L. subsp. ***lysimachioides***, Stream dry bed; 466514-4191226, 558 m.
Veronica scardica Griseb., Stream bed; 482430-4197400, 840 m.
Veronica cinerea Boiss. & Bal., Calcerous area; 479687-4204945, 1945 m., End., E. Medit., LC
Veronica macrostachya Vahl subsp. ***mardinensis*** (Bornm.) M. A. Fischer, Step area; 474208-4198286, 1500 m., End., Ir.-Tur.
Veronica orientalis Miller subsp. ***nimrodi*** (Richter ex Stapf) M. A. Fischer, Step area; 477125-4203387, 2000 m., End.
THYMELAEACEAE
Thymelaea gussonei Boreau, Quercus Forest; 469285-4198844, 655 m., Medit.
ELAEAGNACEAE
Elaeagnus angustifolia L., Stream sides; 466514-4191226, 558 m., LC
SANTALACEAE

Thesium tauricolum Boiss. & Hausskn., Quercus Forest; 472182-4198710, 1300 m., End., Ir.-Tur.-LR (NT)

ARİSTOLOCHİACEAE

Aristolochia bottae Jaub. & Sp., Quercus Forest; 483310-4196530, 850 m., Ir.-Tur.

EUPHORBIACEAE

Andrachne aspera Spreng., Quercus Forest; 464177-4197845, 1000 m.

Chrozophora tinctoria (L.) Rafin., Fields; 471194-4201188, 847 m., LC

Euphorbia petiolata Banks & Sol., Shrubs; 465739-4199838, 682 m., Ir.-Tur.

Euphorbia eriophora Boiss., Red pine area; 467877-4193929, 915 m., Ir.-Tur.

Euphorbia oxyodonta Boiss., Calcerous area; 479533-4195519, 1040 m., Medit., VU

Euphorbia aleppica L., Red pine area; 467877-4193929, 915 m.

Euphorbia szovitsii Fisch. & Mey. var. ***szovitsii***, Calcerous area; 479533-4195519, 1040 m., Ir.-Tur.

Euphorbia szovitsii Fisch. & Mey. var. ***kharputensis*** Aznav. ex M.S. Khan, Calcerous area; 475075-4198071, 1595 m., Ir.-Tur.

Euphorbia aulacosperma Boiss., Meadow; 479957-4195451, 995 m.

Euphorbia denticulata Lam., Quercus Forest; 479056-4201429, 1700 m., Ir.-Tur.

Euphorbia macroclada Boiss., Shrub; 465739-4199838, 682 m., Ir.-Tur.

Euphorbia cheiradenia Boiss. & Hohen, Step area; 475694-4208042, 1175 m., Ir.-Tur.

URTICACEAE

Parietaria officinalis L., Calcerous area; 479533-4195519, 1040 m.

MORACEAE

Morus alba L., Fields; 483294-4197180, 856 m.

Ficus carica L. subsp. ***carica*** (All.) Schinz & Thell., Fields; 464663-4193142, 655 m.

CANNABACEAE

Celtis tournefortii Lam., Calcerous area; 465598-4198643, 615 m., LC

JUGLANDACEAE

Juglans regia L., Fields; 464663-4193142, 655 m., LC

PLATANACEAE

Platanus orientalis L., Kan stream side; 470259-4200348, 640 m., VU

FAGACEAE

Quercus infectoria subsp**. *boissieri*** (Reut.) O. Schwarz, Quercus Forest; 467516-4196064, 620 m.

Quercus cerris L., Quercus Forest; 482820-4196236, 860 m., Medit., LC

Quercus brantii Lindley, Quercus Forest; 469872-4199703, 830 m., Ir.-Tur., LC

Quercus libani Olivier, Quercus Forest; 471794-4198524, 1200 m., Ir.-Tur., LC

SALİCACEAE

Salix bornmuelleri Hausskn., Kahta river sides; 465905-4196364, 586 m., Ir.-Tur.

Populus nigra L., Kahta river sides; 466514-4191226, 558 m, DD

RUBIACEAE

Plocama calabrica (L.f.) M.Backlund & Thulin, Quercus Forest; 474456-4197285, 1500 m., Medit.

Sherardia arvensis L., Quercus Forest; 464470-4198051, 900 m., Medit.

Crucianella gilanica Trin. subsp. ***kotschyi*** (Ehrend.) Ehrend., Meadow; 477523-4202662, 1713 m., Ir.-Tur.

Crucianella macrostachya Boiss., Step area; 463801-4191552, 926 m., E. Medit.

Crucianella angustifolia L., Shrubs; 468523-4199286, 640 m., Medit.

Asperula prostrata (Adams) K.Koch., Quercus Forest; 478522-420677-61, 1650 m., Euxine (mt.)

Asperula xylorrhiza Nâbelek, Quercus Forest; 476612-4207396, 540 m., Ir.-Tur.

Asperula orientalis Boiss. & Hohen., Quercus scrub; 464445-4192428, 800 m., Ir.-Tur.

Galium humifusum M. Bieb., Quercus Forest; 482820-4196236, 860 m.

Galium verum L. subsp. ***verum***, Step area; 477523-4202662, 1642 m., Euro-Sib.

Galium incanum Sm. subsp. ***elatius*** (Boiss.) Ehrend., Calcerous area; 477267-4203765, 2137 m., Ir.-Tur.

Galium lasiocarpum Boiss., Step area; 478569-4201652, 1750 m., End., Ir.-Tur., VU

Galium canum Req. ex DC. subsp. ***canum***, Quercus Forest; 464470-4198051, 900 m., E. Medit.

Galium setaceum Lam., Quercus Forest; 469285-4198844, 655 m.

Galium spurium L. subsp. ***ibicinum*** (Boiss. & Hausskn.) Ehrend, Quercus Forest; 483329-4196499, 863 m., Ir.-Tur.
Galium tricornutum Dandy, Quercus Forest; 467516-4196064, 620 m., Medit.
Galium nigricans Boiss., Step area; 475633-4197877, 1472 m., Ir.-Tur.
Galium runcinatum Ehrend. & Schönb.-Tem., Shrub; 464554-4192656, 740 m., End., Ir.-Tur. – VU (VU)
Galium verticillatum Danthoine ex Lam., Quercus Forest; 464898-4198496, 800 m., Medit.
Callipeltis cucullaris (L.) DC., Quercus Forest; 469285-4198844, 655 m., Ir.-Tur.
Cruciata taurica (Pall. ex Willd.) Ehrend., Step area; 477085-4207458, 1500 m., Ir.-Tur.
Rubia tenuifolia d'Urv. subsp. ***doniettii*** (Griseb.) Ehrend. & Schönb.-Tem., Quercus Forest; 469285-4198844, 655 m., E. Medit.

ARACEAE

Arum maculatum L., Calcerous area; 477455-4203339, 1970 m.
Dracunculus vulgaris Schott, Quercus Forest; 462723-4191860, 887 m., E. Medit., LC

ASPHODELACEAE

Eremurus spectabilis M. Bieb., Calcerous area; 479687-4204945, 1945 m., Ir.-Tur.
Asphodeline damascena (Boiss.) Baker subsp. ***gigantea*** E. Tuzlaci, Quercus Forest; 471794-4198524, 1200 m., End., Ir.-Tur.

LILIACEAE

Fritillaria pinardii Boiss., Step area; 477451-4202120, 1653 m., Ir.-Tur.
Tulipa armena Boiss. var. ***armena***, Calcerous area; 472612-4198410, 1455 m., Ir.-Tur.
Gagea gageoides (Zucc.) Vved., Calcerous area; 479687-4204945, 1945 m., Ir.-Tur.
Gagea chlorantha (Bieb.) Schult. & Schult. f., Calcerous area; 468410-4193904, 1100 m., Ir.-Tur.

ASPARAGACEAE

Scilla leepii Speta, Meadow; 478666-4201840, 1731 m., End., Ir.-Tur., NT
Puschkinia scilloides Adams, Calcerous area; 475552-4200487, 1760 m., Ir.-Tur.
Ornithogalum sphaerocarpum A. Kern, Quercus Forest; 480121-4199088, 1200 m.
Ornithogalum narbonense L., Quercus Forest; 469334-4198579, 700 m., Medit.
Ornithogalum oligophyllum E.D. Clarke, Meadow; 479133-4200341, 1437 m.
Ornithogalum neurostegium subsp. ***neurostegium*** Boiss. & Blanche, Field; 480554-4195111, 892 m.
Ornithogalum alpigenum Stapf, Shrub; 476053-4208097, 1190 m., End., E. Medit.
Leopoldia comosa (L.) Parl., Waste area; 463801-4191552, 926 m., Medit.
Hyacinthus orientalis L. subsp. ***chionophilus*** Wendelbo, Calcerous area; 475552-4200487, 1760 m., End., Ir.-Tur. -LR (nt)
Bellevalia longipes Post, Step area; 479133-4200341, 1437 m., Ir.-Tur.
Bellevalia malatiyensis UZUNH. & H.DUMAN, 469872-4199703, 830 m., End., Ir.-Tur.

COLCHİCACEAE

Colchicum paschei K.M. Perss., Meadow; 480292-4205453, 1972 m., End., Ir.-Tur.

AMARYLLİDACEAE

Sternbergia colchiciflora Waldst & Kit., Quercus Forest; 475458-4201703, 1550 m., LC
Allium borszczowii Regel, Calcerous area; 483310-4196530, 850 m., Ir.-Tur.
Allium paniculatum L, subsp. ***paniculatum***, Quercus Forest; 472014-4198327, 1300 m., Medit.
Allium opacum Rech. f., Quercus Forest; 469285-4198844, 655 m., E. Medit.
Allium flavum L. subsp. ***tauricum*** (Besser ex Rchb.) K.Richt. var. ***tauricum***, Step area; 468061-4193613, 1000 m., Medit.
Allium ampeloprasum L., Quercus Forest; 467516-4196064, 620 m., Medit., LC
Allium trachycoleum Wendelbo, Step area; 476822-4203764, 2013 m., Ir.-Tur.
Allium rotundum L., Quercus Forest; 483310-4196530, 850 m., Medit.
Allium calyptratum Boiss., Step area; 475633-4197877, 1472 m., E. Medit., LC
Allium asclepiadeum Bornm., Waste place; 468061-4193613, 1000 m., Ir.-Tur.
Allium nemrutdaghense Kit Tan & Sorger, Step area; 477298-4204004, 2150 m., End., Ir.-Tur.

IXOLIRIACEAE

Ixiolirion tataricum (Pallas) Herbert var. ***tataricum***, Meadow; 475572-4198084, 1536 m., Ir.-Tur.

IRIDACEAE

Iris sari Schott ex Baker, Calcerous area; 476815-4201236, 1750 m., End., Ir.-Tur. –LR (LC)

Iris persica L., Calcerous area; 475552-4200487, 1760 m., Ir.-Tur.
Crocus pseudonubigena (B.Mathew) Kernd., Pasche & Harpke, Calcerous area; 475552-4200487, 1760 m., End., Ir.-Tur.
Crocus damascenus Herb., Quercus Forest; 475458-4201703, 1550 m., Ir.-Tur.
Gladiolus humilis Stapf, Calcerous area; 477131-4201868, 1790 m., End., Ir.-Tur., EN
Gladiolus atroviolaceus Boiss., Quercus Forest; 482820-4196236, 860 m., Ir.-Tur.
ORCHİDACEAE
Cephalanthera kurdica Bornm. ex Kranzl., Quercus Forest; 469285-4198844, 655 m., Ir.-Tur.
Epipactis helleborine (L.) Crantz, Quercus Forest; 482820-4196236, 860 m., (LC) CR
Limodorum abortivum (L.) Swartz, Quercus Forest; 469872-4199703, 830 m., (LC) CR
Ophrys scolopax subsp. ***cornuta*** (Steven) E.G.Camus, Quercus Forest; 469334-4198579, 700 m., End., Ir.-Tur., LC
Orchis simia Lam., Quercus Forest; 469285-4198844, 655 m., Medit., LC
Orchis anatolica Boiss., Quercus Forest; 469285-4198844, 655 m., E. Medit., LC
Anacamptis palustris (Jacq.) R.M.Bateman, Pridgeon & M.W.Chase, Stream side; 482430-4197400, 840 m., LC
DIOSCOREACEAE
Tamus communis L. subsp. ***communis***, Quercus Forest; 483329-4196499, 863 m.
TYPHACEAE
Typha laxmannii Lepech., Kahta river bed: 465905-4196364, 586 m., Euro-Sib., LC
Typha domingensis Pers., Kahta river bed: 465905-4196364, 586 m., LC
JUNCACEAE
Juncus articulatus L., River bed; 482430-4197400, 840 m., Euro-Sib.
Luzula johnstonii Buchenau., Damp; 466514-4191226, 558 m., Euro-Sib., LC
CYPERACEAE
Schoenoplectus tabernaemontani (C.C.Gmel.) Palla, Stream sides; 482430-4197400, 840 m.
Bolboschoenus maritimus (L.) Palla var. ***maritimus***, Stream sides; 482430-4197400, 840 m.
Blysmus compressus (L.) Panz. ex Link; Stream near; 482962-4196167, 836 m., EN
Carex divisa Hudson, Stream; 482430-4197400, 840 m, Euro-Sib., LC
Cf. ***Carex pachystylis*** J. Gay, River bed; 466514-4191226, 558 m., Ir.-Tur., LC
GRAMINEAE (POACEAE)
Brachypodium pinnatum (L.) P. Beauv., Quercus Forest; 482820-4196236, 860 m., Euro-Sib.
Elymus erosiglumis Melderis, Shrub; 477555-4202517, 1740 m., End., Ir.-Tur., NT
Thinopyrum podperae (Nábelek) D.R.Dewey, Waste places; 467943-4193371, 1100 m., Ir.-Tur.
Crithopsis delileana (Schult.) Roshev., Quercus forest; 463801-4197457, 1100 m., Ir.-Tur.
Aegilops speltoides Tausch., Quercus Forest; 467449-4193269, 839 m., LC
Aegilops cylindrica Host, Step area; 478510-4200215, 1520 m., Ir.-Tur., LC
Aegilops umbellulata Zhukovsky subsp. ***umbellulata***, Waste places; 462730-4191827, 893 m., Ir.-Tur., LC
Aegilops triuncialis L., Waste places; 475694-4208042, 1175 m., LC
Aegilops biuncialis Vis., Quercus Forest; 483329-4196499, 863 m., LC
Aegilops columnaris Zhukovsky, Waste places; 468061-4193613, 1000 m., Ir.-Tur., LC
Triticum aestivum L., Fields; 461952-4192084, 897 m., DD
Hordeum murinum L. subsp. ***glaucum*** (Steud.) Tzvelev, Calcerous area; 479533-4195519, 1040 m.
Hordeum bulbosum L., Waste places; 462730-4191827, 893 m., LC
Taeniatherum caput-medusae (L.) Nevski, Quercus Forest; 469285-4198844, 655 m., Ir.-Tur.
Bromus japonicus Thunb. subsp. ***japonicus***, Waste places; 467943-4193371, 1100 m.
Bromus scoparius L., Quercus Forest; 464470-4198051, 900 m.
Bromus danthoniae Trin., Waste places; 467943-4193371, 1100 m.
Bromus tectorum L, Waste places; 467943-4193371, 1100 m.
Bromus sterilis L., Waste places; 462730-4191827, 893 m.
Bromus tomentellus Boiss., Step area; 475919-4202634, 1800 m., Ir.-Tur.
Avena eriantha Durieu, Waste places; 468061-4193613, 1000 m., LC
Avena sterilis L. subsp. ***ludoviciana*** (Durieu) Gillet et Magne, Waste places; 462730-4191827, 893 m., LC

Rostraria cristata (L.) Tzvelev, Quercus Forest; 472182-4198710, 1300 m.
Apera intermedia Hack., River side; 475718-4209163, 850 m., Ir.-Tur.
Alopecurus vaginatus (Willd.) Kunth, Quercus Forest; 483329-4196499, 863 m.
Alopecurus textilis Boiss. subsp. ***textilis***, Meadow; 479957-4195451, 995 m., Ir.-Tur.
Alopecurus myosuroides Huds. var. ***myosuroides***, River bed; 466514-4191226, 558 m.
Alopecurus utriculatus Sol. subsp. ***utriculatus***, Quercus Forest; 469334-4198579, 700 m., Ir.-Tur.
Phleum exaratum Griseb. subsp. ***exaratum***, Waste places; 462730-4191827, 893 m.
Festuca callieri (Hackel ex St.-Yves) F. Markgraf subsp. ***callieri***, Step area; 477298-4204004, 2150 m.
Festuca callieri (Hack. ex St.-Yves) Markgr., Step area; 477298-4204004, 2150 m., End., Ir.-Tur., LC
Festuca elwendiana Markgr.-Dann., Quercus Forest; 469334-4198579, 700 m.
Lolium rigidum Gaudin var. ***rigidum***, Waste places; 467516-4196064, 620 m., LC
Vulpia fasciculata (Forssk.) Samp., Step area; 475633-4197877, 1472 m., Medit.
Catapodium rigidum (L.) C.E. Hubbard ex Dony subsp. ***rigidum*** var. ***rigidum***, Quercus Forest; 464177-4197845, 1000 m.
Poa bulbosa L., Step area; 476494-4203909, 2000 m.
Eremopoa altaica (Trin.) Roshev., Stream side; 466514-4191226, 558 m., Ir.-Tur.
Dactylis glomerata L. subsp. **hispanica** (Roth) Nyman, Quercus Forest; 469285-4198844, 655 m., Euro-Sib.
Briza humilis M. Bieb., Quercus Forest; 469285-4198844, 655 m.
Parapholis incurva (L.) C.E. Hubb., Quercus Forest; 464470-4198051, 900 m.
Echinaria capitata (L.) Desf., Step area; 462730-4191827, 893 m.
Melica persica Kunth, Waste places; 468061-4193613, 1000 m.
Achnatherum bromoides (L.) P.Beauv., Quercus Forest; 482820-4196236, 860 m., Medit., LC
Stipa holosericea Trin., Field; 471194-4201188, 847 m., Ir.-Tur.
Stipa ehrenbergiana Trin. & Rupr., Shrub; 476071-4207791, 1300 m., Ir.-Tur.
Piptatherum coerulescens (Desf.) P.Beauv., Shrub; 477555-4202517, 1740 m.
Cynodon dactylon (L.) Pers., Fields; 468414-4201008, 787 m.
Echinochloa crus-galli (L.) P. Beauv., Fields; 480854-4198318, 1036 m., LC
Setaria viridis (L.) P. Beauv., Waste places; 467943-4193371, 1100 m.
Cenchrus orientalis (Rich.) Morrone, Stream sides; 471583-4196824, 969 m., Ir.-Tur., LC
Sorghum halepense (L.) Pers., Fields; 480554-4195111, 892 m.

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Tree species composition, structure and regeneration status in Munessa natural forest, Southeastern Ethiopia

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Abstract

Munessa forest is one of the undifferentiated afromontane forests in Ethiopia and that has threatened by deforestation, open grazing system and illegal logging operations. This study aimed to estimate the forest stand structure, tree species composition and diversity of tree species and regeneration status in Munessa natural forest. Vegetation data were collected from 54 plots of 20 m x 20 m for trees and 162 subplots of 5 m x 5 m for seedlings and saplings laid along six parallel transect lines. Floristic structure, basal area (BA), Importance value index (IVI) and species prioritization were analyzed using spreadsheet programs. Correlation coefficients, vegetation classification, Shannon diversity index and evenness were analyzed using RStudio 3.2.2. A total of 61 tree species (41 families) were recorded. Fabaceae was the most dominant family represented by four species followed by Oleaceae and Rutaceae, each having three species. The hierarchical cluster analysis revealed four community types, of which *Syzygium guineense* - *Croton macrostachyus* community type, exhibited the highest species diversity and evenness. The Shannon diversity and evenness index for the entire study area was 2.6 and 0.39 respectively. The correlation between elevation and species richness was negative and insignificant ($r = -0.545$, $p < 0.05$). The densities of seedlings, saplings and mature trees were 6,934, 1,686 and 481 individuals per ha respectively. This indicated that the regeneration status was significantly lower compared to other similar sites. The total BA of the forest was 91.75 m^2 per ha and its IVI ranged from 0.62 for *Calpurnia aurea* (Ait.) Benth. to 70.29 for *Podocarpus falcatus* (Thumb.) R.B.ex.Mirb. The estimated values of forest structure and regeneration status of the forest indicated that there was a huge disturbance induced by open grazing and illegal tree cutting. Therefore participatory forest management strategies need to be implemented to protect the forest sustainably.

Keywords: Basal area, Hierarchical cluster, Importance value index, Regeneration

INTRODUCTION

Biological diversity is often defined as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; This includes diversity within species, between species and of ecosystems" (Glowka et al., 1994). Forests in the tropical region constitute the most diverse plant communities on earth (Devi and Yadava 2006). However, the variety of tree species in the tropics is threatened partially by the introduction of exotic plant species and anthropogenic disturbances in the course of the last century (Paritsis and Aizen, 2008). The Ethiopian highland contributes more than 50 %

of the land area in Africa with afromontane vegetation (Abebe, 2008), of that the undifferentiated afromontane forests form the largest part. The undifferentiated afromontane forests are either mixed *Juniperus - Podocarpus* (gymnosperm genus) forests or predominantly *Podocarpus* forests, each with a component of broad-leaved species. They occur in both northwestern and southeastern highland at altitude ranges between 1500- 2700 m (Friis and Lawesson, 1993). About 35 % of the land area of Ethiopia was once covered with high forests but it reduced to 16 % in 1950s, 3.6% in 1980s, and to 2.3% in 2003(Tesfaye Hunde, 2007, Admassu et al., 2016). The flora of Ethiopia encompasses about 6,027 vascular plant species of which 10% are endemic (Kelbessa and Demissew, 2014). This distribution makes the country the fifth largest floral composition in tropical Africa (Didita et al., 2010). However, the rich biodiversity of the country is under serious threat due to deforestation, overgrazing, shifting cultivation, forest fire and poaching of forest reserves (IBC, 2009).

Munessa natural forest is one of the major timber supplier forests of the country and ironically puts the natural forest under severe pressure from illegal logging activities. In addition, the good transportation facilities between the forest and the timber market in the capital Addis Ababa favour smuggling of forest products and contribute to the degradation of the natural forest (Duriaux and Baudron, 2016). Moreover, grazing and encroachment due to agriculture activities has become increasingly affecting the area in recent years (Abebe, 2008). To secure the ecological equilibrium of the environment and attain the forest resource necessities, assessment of scientific data on the species composition, stand structure and distribution in the study areas become prime activity, where it has not been attained (Ayalew et al., 2006). Such study has rarely been investigated and their status is not well identified in the study area. Therefore, the objectives of this study was to explore the species structure, composition and regeneration status of trees and to identify the priority tree species for conservation and management interventions in the natural forest of Munessa.

METHODOLOGY

Study Site Description

This study was carried out in Munessa natural forest which is one among the three forest districts (Munessa, Gamboo and Shashemene districts) in Arsi forest enterprise. It is a protected forest that is owned by the state and controlled by Oromia Forest and Wildlife Enterprise (OFWE). It is located at 240 km south of Addis Ababa, Ethiopia (Figure 1) and bounded between 7°25´44´´N and 38°51´05´´E geographic coordinate along the eastern escarpment of the Rift Valley. It extends over an altitude ranges from 2100 m to 2450 m a.s.l. The total concession area of the enterprise is estimated as 21,384 ha, of which 6,230 ha is plantation forest and 15,154 ha is natural forest. According to the Ethiopian classification of climatic zones, Munessa forest can be classified as Dega (2300–3200 m a.s.l) zones. The area has a bimodal rainfall i.e. the main rainy season is from the end of June to September, and short rainy season is from February to April. The mean annual rainfall of the area is 1075 mm (18 year average) and the mean annual temperature is 15^0C (16 year average) (Duriaux and Baudron, 2016). Friis in 1992 described the vegetation of the area as “undifferentiated Afromontane Forest”, including varies upland forests with *Podocarpus*. Mixed broad-leaved deciduous and evergreen trees characterize the forest vegetation in Munessa natural forest. The dominant tree species are *Podocarpus falcatus* (Thumb.) R.B.ex. Mirb., *Prunus africana* (Hook.f.) Kalkm, *Croton macrostachyus* Del., *Maytenus addat* (Loes.) Sebsebe and *Nuxia congesta* R. Br. ex Fresen. The soil texture is predominately a slightly acidic and nutrient rich clay-loam that was evolved from volcanic parent material and it was classified as Mollic Nitisols (Fritzsche et al., 2007).

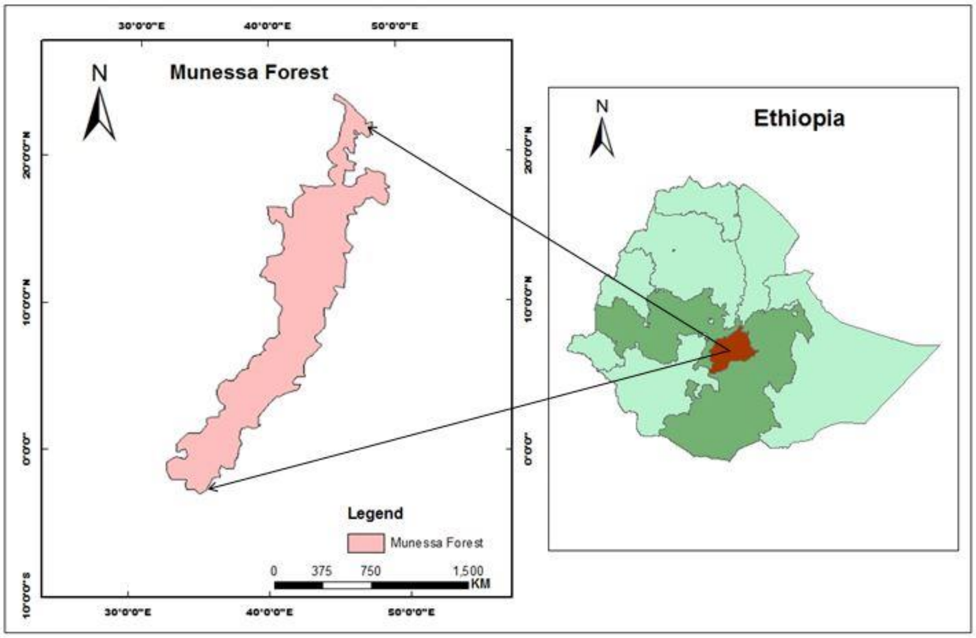

Figure 1. Location of the study area

Sampling design

Systematic sampling design was set to determine the tree species status of the study site. A 20 m x 20 m sample plots were laid along six parallel line transects (having a length of 800 m) along the altitudinal gradient at a distance of 100 m to cover representative samples of the forest. A total of 54 sample plots (9 at each transect) with an area of 2.16 ha each were plotted. The distance between adjacent transects was 250 m. In each plot, data on species name (vernacular and scientific nomenclature), abundance, dominance and evenness of each tree species were recorded. Diameter at breast height (DBH) with DBH $\geq$ 5 cm was measured using a tree caliper and diameter tape (Abate, 2003). The heights of all individuals of trees with a DBH $\geq$ 5 cm were measured with a hypsometer (Nikon Laser Rangefinder Forestry Pro). Local and scientific names and number of dead stumps were also recorded. In order to assess vegetation regeneration dynamics, seedlings and saplings counts were undertaken. Three subplots of 5 m x 5 m: two at the corners and one at the center nested within each 400 m^2 main plot (total area 75 m^2 per plot) were set to assess abundance and frequency of seedlings and saplings. A total of 162 subplots with total area of 0.40 ha were investigated.

Floristic data collection

All tree species in each plot were identified and their scientific and vernacular names were recorded on site. Representative plant specimens were collected, numbered and pressed to compile a complete list of species. Then specimens were identified and confirmed at the National Herbarium (ETH), at Addis Ababa University following Edwards et al. (1995, 1997), Tadesse (2004) and Hedberg et al. (2003, 2006, 2009a).

Forest composition and diversity

Species richness, Shannon–Wiener diversity index and evenness were computed following Maguran 1988 and Krebs 1999. Shannon–Wiener diversity index provides an account of both the abundance and evenness without disproportionately favoring any species as it counts all the species according to their frequency (Jost, 2007, Danoff-Burg and Xu, 2008). The value usually falls between 1.5 and 3.5, it rarely exceeding 4.5. To determine floristic similarity between the sample plots, Sørensen's similarity coefficient (SSC) was employed.

Vegetation structure

DBH, tree height, basal area, relative dominance, relative density, relative frequency and important value index were determined to describe the vegetation structure of the study area following Mueller-Dombois and Ellenberg (1974) and Martin (1995). The number of individuals within each DBH and height class was summed and histograms were constructed to determine the population structure and regeneration status of each woody species using Microsoft Excel.

Regeneration status of tree species

Floristic composition, number of seedlings, saplings and analysis of their densities in a forest has implications for regeneration and management of a natural forest. The density of seedlings and saplings is considered as a key indicator for determination of regeneration potential of a given forest (Dhaulkhandi et al., 2008). The total density of seedling, sapling and mature trees were determined and the ratio of seedlings and saplings to adult individuals of woody species, as well as the ratio of seedling to saplings were also computed to make a comparison.

Data analysis

In order to show the differences both in diversity and regeneration levels, further statistical analyses were done for the indices and species densities derived. Single-factor analysis of variance (one-way ANOVA) was determined to detect the significant difference in species evenness and diversity across altitudinal gradients. Simple Linear Correlation and Regression test was performed to investigate the relationships of tree species richness with elevation class. Where there is significant difference, mean separation was achieved through Tukey's B-test at $p < 0.05$ level of significance.

Plant community analysis

Hierarchical cluster analysis were made to classify plant communities based on the cover abundance data and floristic similarities (McCune et al., 2002) using the Cluster and Vegan packages in RStudio 3.2.2. The analysis was based on the abundance data of the species. A hierarchical agglomerative clustering technique was applied using Euclidean distance and Ward's method to classify plots that produced a dendrogram and cluster IDs. After identification of the major clusters, characteristic species of plant communities were identified by importing the cover abundance data matrix and cluster IDs into R software to produce a synoptic table. The plant communities were named after selecting the species with highest mean cover abundance value in each cluster (Oksanen et al., 2016).

RESULTS AND DISCUSSION

Tree species composition

A total of 61 tree species belonging to 41 families were identified of which seven families with nine species and more than ten numbers of individuals each constituted 80 % of total species richness. Having four species, Fabaceae is the most diverse family followed by Oleaceae and Rutaceae with three species each. Based on stand density Euphorbiaceae is the most dominant family with 125 individuals per ha followed by Ulmaceae with 100 individuals per ha. Top seven families having the highest number of individuals were depicted in Figure 2 below. The species richness of the study area varied from 3 to 12 species per plot with a mean of 8 species. From 61 species counted a wide variation in the number of individuals were shown that ranged from 1 individual of seven species to 98 individual of *Croton macrostachyus* Del. Furthermore the species-area curve showed an increase in species as the area of plot increases (Figure 3). This indicated that species richness and the area of plots are strongly positively correlated with $r = 1$, $p < 0.005$

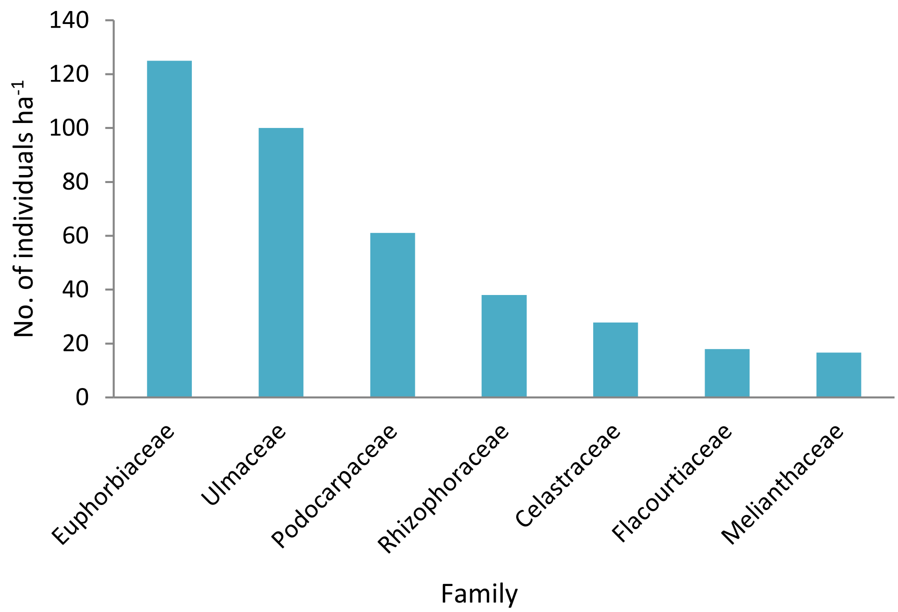

Figure 2. Species richness of dominant tree families in Munessa natural forest

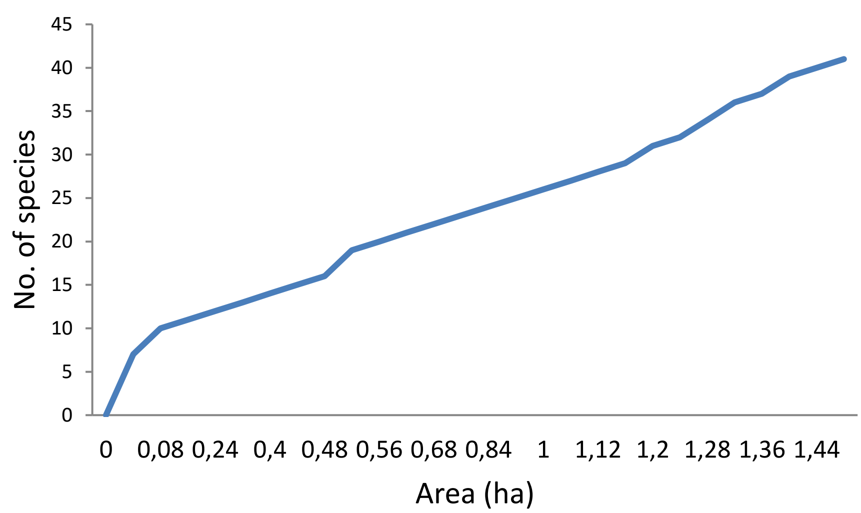

Figure 3. Species-area curve in Munessa natural forest

Based on the criteria established by Krishnamurthy et al. (2010) species were grouped into five categories such as predominant, dominant, common, rare and very rare species considering their density (per 2 ha) (Table 1). *Croton macrostachyus* with 244 individuals and *Celtis africana* Burm.f with 200 individuals are classified as predominant tree species and represented 5 % of species richness in the sample plot laid. This indicates 46 % of the species density. On the other hand *Podocarpus falcatus* with 122 individuals are categorized into dominant species and it represented 2 % of the species and 13 % of the stand density in the sample plot laid. Four species such as *Cassipourea malosana* (Baker) Alston, *Maytenus undata* (Thunb.) Blackelock, *Bersama abyssinica* Fresen. and *Dovyalis abyssinica* (A.Rich) Warb are classified as common species and accounted for 10 % of the species richness. 21 % of stand density represented this group. Twenty seven species including *Allophylus abyssinicus* (Hochst)Radlk, *Ekebergia capensis* Sparrm., and *Prunus africana* were under rare species category. They represented 66 % of the species and 20 % of stand density. Finally seven species including *Apodytes dimdiata* E. Mey. ex Arn, *Calpurnia aurea* and *Dombiya torrid* (J.F. Gmel.) P. Bampsare classified as very rare species and represented 17 % of the species richness and 1 % of tree density.

Table 1. Group of species based on the criteria established by Krishnamurthy et al. (2010)

Category	No of Individuals
Predominant species	≥ 200
Dominant species	100-199
Common species	25-99
Rare species	3-24
Very rare species	< 3

Vegetation classification

The vegetation classification at the 22 dissimilarity level from hierarchical cluster analysis resulted in four major tree species communities. Higher indicator value of a species was considered to name each community. The four community groups were *Celtis africana* - *Croton macrostachyus*, *Croton macrostachyus* - *Celtis africana*, *Celtis africana* - *Podocarpus falcatus* and *Syzygium guineense* - *Croton macrostachyus* (Table 2) and this are described as follows.

CI: *Celtis africana - Croton macrostachyus* Community

This community occurs in the altitudes between 2115 and 2159 m and comprises of 12 quadrates (about 0.49 ha). Two species, *Celtis africana* and *Croton macrostachyus* are found to be indicator species of the community as they display the highest indicator values. Some other tree species in the community includes *Podocarpus falcatus, Bersama abyssinica, Millettia ferruginea* (Hochst.) Bak. and *Albizia grandibracteata* Taub..

CII: *Croton macrostachyus - Celtis africana* Community

This community occurs between altitude ranges of 2169 and 2226 m. The two indicator species of this community are *Croton macrostachyus* and *Celtis africana* comprising of 12 quadrates (0.49 ha). A sizeable number of tree species in the community include *Podocarpus falcatus*, *Maytenus undata*, *Cassipourea malosana*, and *Ekebergia capensis*.

CIII: *Celtis africana - Podocarpus falcatus* Community

It occurs between 2208 and 2244 m altitude ranges. The two dominant species of this community are *Celtis africana* and *Podocarpus falcatus* and constitute of 11 quadrates (0.44 ha). It comprises of tree species including *Croton macrostachyus*, *Cassipourea malosana*, *Pouteria adolfi-friedericii* (Engl.) Baehni and *Allophylus abyssinicus*.

IV: *Syzygium guineense - Croton macrostachyus* Community

It occurs between altitudes ranges of 2246 and 2285 m. Dominant species of this community are *Syzygium guineense* (Willd.) DC. and *Croton macrostachyus* and it comprises of 19 quadrates (0.76 ha). Some of the tree species includes *Celtis africana*, *Podocarpus falcatus, Cassipourea malosana* and *Allophylus abyssinicus*.

Table 2. Synoptic cover abundance value for species reaching > 2% (CI = Community type 1, CII = Community type 2, CIII = Community type 3, and CIV = Community type 4)

Species	CI	CII	CIII	CIV
Albizia grandibracteata	3.8	0.0	0.0	0.0
Allophylus abyssinicus	0.0	0.0	2.8	2.0
Bersama abyssinica	5.7	3.7	4.6	2.0
Cassipourea malosana	5.7	5.2	12.7	6.4
Celtis africana	**35.7**	**21.5**	**26.3**	11.6
Croton macrostachyus	**24.4**	**39.2**	18.1	**17.2**
Ekebergia capensis	2.0	3.0	0.0	0.0
Fagaropsis angolensis	2.0	0.0	0.0	0.0
Ficus sycomorus	0.0	2.0	0.0	0.0
Galiniera saxifraga	0.0	0.0	2.8	0.0
Maytenus undata	2.0	6.7	3.7	6.0
Millettia ferruginea	5.6	0.0	0.0	0.0
Podocarpus falcatus	9.5	13.3	**21.8**	7.1
Pouteria adolfi-friedericii	0.0	0.0	3.6	0.0
Psydrax schimperiana	0.0	0.0	2.1	0.0
Syzygium guineense	0.0	0.0	0.0	**38.9**
Teclea simplicifolia	0.0	2.0	0.0	0.0
Vitex doniana	3.8	0.0	0.0	0.0

Species richness, diversity and evenness in the communities

The overall Shannon diversity index of Munessa natural forest was 2.6, which is lower than other evergreen afromontane forests in Ethiopia such as Zege forest (Alelign et al., 2007), Tara Gedam and Abebaye forests (Zegeye et al., 2011) and Zengena forest (Tadele et al., 2014) but it is higher than Menagesha Suba forest (Beche, 2011) and Kuandisha forest (Berhanu et al., 2016) (Table 3). This low diversity index in the study area is associated with high disturbance. The species evenness of the study area was 0.39 that was much lesser than 1 indicating uneven distribution of individuals within a species. This is due to the fact that anthropogenic impact, particularly free grazing and selective tree cutting, impairs the growth and survival rate of individuals of a species.

Table 3. Shannon diversity index of Munessa natural forest compared to other forests in Ethiopia

Forest Name	Shannon–Wiener index	Authors
Zege	3.72	Alelign et al., 2007
Tara Gedam and Abebaye	2.98	Zegeye et al., 2011
Zengena	2.74	Tadele et al., 2014
Munesa	2.6	**Present study**
Menagesha Suba	2.57	Beche, 2011
Kuandisha	2.5	Berhanu et al., 2016

The value of Shannon diversity index and species evenness is mainly affected by both the number of species and the number of stands in the community. Shannon diversity index is higher when the number of species and stands are higher as well as when the number of stands is evenly distributed. But species evenness is higher when the number of species is higher and the number of stands is evenly distributed throughout the species in the communities. Therefor the result of this study revealed that the species richness and Shannon diversity index in the communities is strongly positively correlated ($r = 0.92$, $p < 0.005$); the richer the species in the community is, the more diverse it becomes in that community. On the other hand, the correlation between Shannon diversity index and species evenness is negatively correlated ($r = -0.10$, $p < 0.005$); the more diverse a community is, the less evenly it is the distribution in that community (Table 4). The findings are not in line with reports elsewhere that suggest positive and strong correlations among species richness, diversity and evenness (Stirling and Wilsey, 2001). That is due to the reason behind the number of stands in the species are unevenly distributed while some species like *Croton macrostachyus and Celtis africana* shown higher number of individuals than other species in the communities and that may lead for the higher values of diversity. In terms of habitat, as it is shown in Table 4, community IV consisted of the highest species richness and diversity than other communities. Unlikely community II contained the highest evenness value than others.

Similarity of species composition among the communities

The computed Sorensen’s similarity coefficient of the three communities displayed community II and III share more species in common (44%) followed by community III and IV (41%), community I and III

(40%), community II and IV (39%), community I and IV (38%) and that of community I and II (35%) (Table 5).

Table 4. Species richness, Diversity and Evenness of the plant communities in Munessa natural forest

Communities	Altitude (m)	Species Richness	Diversity Index (H')	Hmax	Evenness (H'E)
I	2137	11	1.89	2.40	0.79
II	2198	15	1.87	2.71	0.69
III	2226	13	2.01	2.56	0.78
IV	2266	25	2.36	3.22	0.73

Table 5. Similarity index of tree species composition in three communities

Community Types	I	II	III	IV
I	-	0.35	0.4	0.38
II	-	-	0.44	0.39
III	-	-	-	0.41
IV	-	-	-	-

Vegetation structure

Tree density

The total density of individual trees of the natural forest of Munessa with DBH > 5 were 481 individuals per ha (Table 6). These density is lower compared to some other Afromontane forests in Ethiopia, such as, Kimphee forest (3059 stems per ha) (Senbeta and Teketay, 2003), Masha Anderacha forest (1709 stems per ha) (Yeshitela and Bekele, 2003), and Dindin forest (1750 stems per ha) (Shibru and Balcha, 2004). This could be due to variations in landscape topographic gradients as well as habitat qualities linked to ecological requirements of component tree species in the respective forests. Only two species had more or equals to 100 trees per ha. *Croton macrostachyus* had the highest density with 122 trees per ha followed by *Celtis africana* with 100 trees per ha, *Podocarpus falcatus* with 61 trees per ha, and *Maytenus undata* with 28 trees per ha. 95 % of the tree species, which were about 39 species, had a density of less than 100 stems per ha. The density of tree species with DBH greater than 20 cm was 356 trees per ha which accounts for 74 % of the total tree density. The corresponding tree density with DBH greater than 30 cm was 240 trees per ha which accounts for 50 % of the total tree density. The ratio of the overall density of tree species with DBH greater than 20 cm to those greater than 30 cm was 1.48. It indicated that the natural forest of Munessa was dominated by small sized trees. This predominance of small-sized trees was largely due to the high density of *Croton macrostachyus* and *Maytenus undata*. The major reason was due to selective cutting of medium and high sized trees for fire wood, local houses construction and furniture making. Similar conditions were reported from Dindin forest where *Olinia rochetiana* A.Juss. and *Myrsine africana* were dominant (Shibru and Balcha, 2004); and in Masha-Anderacha forest where *Cyathea manniana* Hook. was dominant (Yeshitela and Bekele, 2003).

Table 6. Density of tree species and their percentage coverage according to DBH class

DBH Class (cm)	Density (ha^{-1})	Percentage (%)
7-20	162	33.72
21-30	102	21.16
31-40	76	15.81
41-50	45	9.3
51-60	36	7.44
61-80	29	6.05
>=81	31	6.51
Total	481	100

Frequency

The frequency of tree species with DBH >=5 cm in the natural forest of Munessa ranged from 3 to 97 %. About 80 % of tree species belonging to frequency class A were absent in most of the plots laid (Figure 4). In contrast, tree species such as *Podocarpus falcatus, Croton macrostachyus,* and *Celtis africana* were most frequently appeared in many of the sample plots laid and they were belonging to frequency class E. From the figure it was depicted that high number of species were found in lower frequency classes and low number of species were found in higher frequency classes. This pattern shows the heterogeneity of tree species in the study area that implies uneven distribution of tree species in the natural forest of Munessa. The relative frequency of the species was ranged from 0.42 to 14.71 %. The highest relative frequency was documented for *Croton macrostachyus* with 14.71 %, followed by *Podocarpus falcatus* and *Celtis africana* with 13.45 % each. Generally, 7 % of the species had relative frequency above 10, 32 % of the species was between 1 and 10, and 61 % was below 1 %.

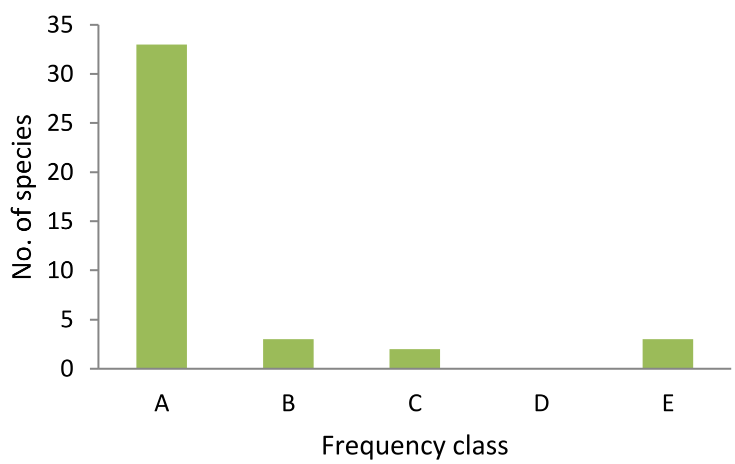

Figure 4. Number of species in each frequency class (A: 1–20 %, B: 21–40 %, C: 41–60 %, D: 61–80 %, E: 81–100 %)

Diameter and height class distribution

A total of 693 individuals of tree species whose DBH and height >=7 cm and >=2 m respectively were recorded from Munessa natural forest. DBH was classified into seven classes of 10 cm intervals (Class 1=7-20, Class 2=21-30, Class 3=31-40, Class 4=41-50, Class 5=51-60, Class 6=61-80, Class 7>=81) (Figure 5). Conversely, the height of trees was classified into nine classes of 5 m intervals (Class 1= 2–5 m, Class 2= 6–10 m, Class 3=11–15 m, Class 4=16–20 m, Class 5=21–25 m, Class 6=26–30 m, Class 7= 31-35m, Class 8= 36-40m, Class 9>=41 m) (Figure 6). The general pattern of tree distribution along DBH classes depicted an inverted J-shaped. These patterns of population distribution indicated a healthy regeneration status of the forests (Teketay, 1997). Similar results were reported for Kimphee forest (Senbeta and Teketay, 2003), Denkoro forest (Ayalew et al., 2006), Chato natural forest (Abdena, 2010) and Wof Washa natural forest (Fisaha et al., 2013). Podocurpus falcatus shows the highest DBH with 238 cm and Celtis africana shows the lowest DBH with 7.64 cm.

High density of tree species was concentrated in the first DBH class of the measured value i.e., from 7-20 cm and the lowest tree density was within the six DBH class i.e., from 61-80 cm. It was consistently declined from the lower DBH class to the higher DBH class except the 7^{th} class in which slight increment of individuals was seen. This pattern indicates that the majority of tree species had the highest number of individuals in lower DBH class which in turn shows the forest vegetation has good reproduction and recruitment potential. The distribution of tree species density with respect to height class was inclined and decline alternatively. This indicated that the height class distribution of the study area shows an irregular pattern. The second height class shows the highest tree density i.e., from 6-10 m and the lowest tree density was within the seventh class i.e., from 31-35 m. *Podocarpus falcatus* was the highest tree species in height reaching 65 m.

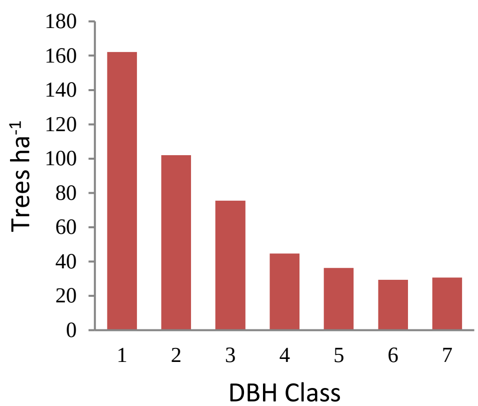

Figure 5. Distribution of tree density along DBH class

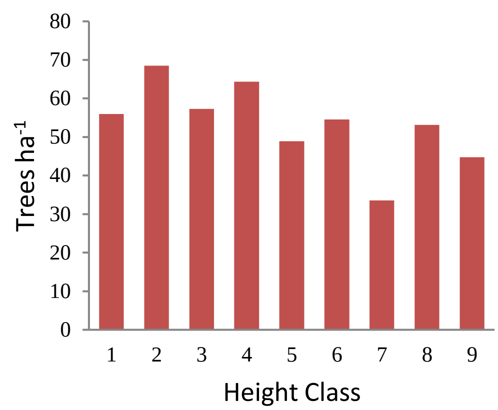

Figure 6. Distribution of tree density along height class

Basal area

Basal area (BA) is an important parameter for measuring relative importance of tree species in a forest (Bekele, 1994) than stem counts (Cain and Castro, 1960). Hence, plant species with larger basal area in a forest is considered as the most important species in that forest. The sum total BA of tree species with DBH >= 5 cm was 91.75 m^2 per ha. Eight species were contributed for 93% of BA in the study area. *Podocarpus falcatus* was the most important tree species of the forest with BA of 40.51 m^2 per ha which is about 44.15 %. The second most important tree species was *Celtis africana* with BA of 16.02 m^2 per ha which is 17.46 %. Others plant species were *Croton macrostachyus* with 15.08, *Pouteria adolfi-friedericii* with 5.35, *Ekebergia capensis* with 2.97, and *Bersama abyssinica* with 1.82, *Vitex doniana* with 1.60, *Cassipourea malosana* with 1.21 BA in m^2 per ha (Table 7). *Calpurnia aurea* contributed the least amount of BA, about 0.01 m^2 per ha, to the natural forest of Munessa.

Table 7. BA and relative BA of tree species in Munessa natural forest

Species	BA (m^2 ha^{-1})	Relative BA (%)
Podocarpus falcatus	40.51	44.15
Celtis africana	16.02	17.46
Croton macrostachyus	15.08	16.44
Pouteria adolfi-friedericii	5.35	5.83
Ekebergia capensis	2.97	3.24
Bersama abyssinica	1.82	1.99
Vitex doniana	1.60	1.74
Cassipourea malosana	1.21	1.32

From the total BA of twelve forests in Ethiopia, four of them, that are Menagesha Suba (158.68 m^2 per ha), Dodola (129 m^2 per ha), Kimphe Lafa (114.4 m^2 per ha) and Menna Angetu (94.22 m^2 per ha) shows the highest value than Munessa natural forest (91.75 m^2 per ha) and all the rest forests selected for comparison shows lower value. This is due to the presence of relatively larger DBH sized tree species in the study area (Table 8).

Importance value index (IVI)

The relative ecological significance and/or dominance of tree species in a forest ecosystem could best be unconcealed from the analysis of IVI values (Curtis and Mcintosh, 1950). The result from our analysis enabled us to identify the dominant tree species in Munessa natural forest. The IVI of tree species was ranged from 0.62 to 70.29. Three species depicted the IVI value of 20 and above. *Podocarpus falcatus* was relatively the dominant tree species with IVI value of 70.29, followed by *Croton macrostachyus* with 56.53, *Celtis africana* with 51.67 and *Maytenus undata* with 14.98 (Table 9). The first three species contributed 60 % of the IVI value and the rest 40 % was contributed by 38 species that had the IVI value less than 20. *Calpurnia aurea* contributed the least amount of IVI, about 0.62, in the Munessa natural forest.

Table 8. Comparison of BA of Munessa natural forest with other forests in Ethiopia in m^2 per ha

Forest Name	Basal Area (m^2 per ha)	Authors
Menagesha Suba	158.68	Beche, 2011
Dodola	129	Hundera, 2007
Kimphe Lafa	114.4	Aliyi *et al.*, 2015
Menna Angetu	94.22	Lulekal *et al.*, 2008
Munesa	**91.75**	**Present study**
Menagesha Amba Mariam	84.17	Tilahun, 2009
Masha Anderacha	81.9	Yeshitela and Bekele, 2003
Bibita	69.9	Denu, 2007
Magada	68.52	Bekele, 2005
Wof-Washa	64.32	Fisaha *et al.*, 2013
Dindin	49	Shibiru and Balcha, 2004
Denkoro	45	Ayalew *et al.*, 2006
Senka Meda	34.7	Bantiwalu, 2010

Table 9. IVI of top 10 tree species with their corresponding Relative Dominance (Rdo), Relative Frequency (Rfr), and Relative Density (Rde) in Munessa natural forest

Species	Family	R_{do} (%)	R_{fr} (%)	R_{de} (%)	IVI
Podocarpus falcatus	Podocarpaceae	44.15	13.45	12.69	70.29
Croton macrostachyus	Euphorbiaceae	16.44	14.71	25.38	56.53
Celtis africana	Ulmaceae	17.46	13.45	20.77	51.67
Maytenus undata	Celastraceae	0.80	8.40	5.77	14.98
Cassipourea malosana	Rhizophoraceae	1.32	5.04	7.88	14.25
Bersama abyssinica	Melianthaceae	1.99	6.72	3.46	12.17
Ekebergia capensis	Meliaceae	3.24	2.94	1.54	7.72
Pouteria adolfifriedericii	Sapotaceae	5.83	0.42	0.19	6.44
Allophylus abyssinicus	Sapindaceae	0.61	3.78	1.54	5.93
Aningeria adolfi-friedericii	Sapotaceae	0.67	2.10	1.54	4.31

The dominance of five species, such as *Podocarpus falcatus, Croton macrostachyus, Celtis africana, Maytenus undata and Cassipourea malosana* together contributed 73 % of the total stand density, 55 % of frequency, 80 % of total basal area and 69% of IVI, indicates that these species utilize the majority of forest space and resources in the study area. Of these five dominant species, *Podocarpus falcatus* is belongs to the Podocarpaceae family, *Croton macrostachyus* to the Euphorbiaceae, *Celtis africana* to the Ulmaceae, *Cassipourea malosana* to the Rhizophoraceae, and *Maytenus undata* to the Celastraceae.

Forest structure

The analysis of forest structures and examination of its patterns provide an estimate of the regeneration and recruitment status of tree species as well as to verify the viability status of the population that could further be employed for devising evidence based conservation and management strategies (Teketay, 2005a, Abiyu et al., 2006). Various patterns of population structures have been reported for different species in other Afromontane forests of the country by many authors including Teketay (2005a), Alelign et al. (2007), Yineger et al. (2008), Bantiwalu (2010), Beche (2011), Tadele et al. (2014) and Berhanu et al. (2015). In this study, the six tree species structure was determined considering their density at various DBH classes. As a result, four species population patterns were recognized (Figure 7). The first pattern is an inverted J-shape, which indicates the presence of large number of individuals at lower DBH classes with a gradual decreasing trend toward higher DBH classes. A few species including *Croton macrostachyus* had shown this patter, suggests good recruitment and regeneration. Similar pattern was reported by Teketay (1997) for 17 species at Gara Ades and 18 species at Menagesha dry Afromontane forests. The second pattern indicates the presence of abundant individuals at lower DBH classes and the absence of individuals at intermediate and higher DBH classes. Some species such as *Cassipourea malosana* and *Maytenus undat* were in this category. This pattern indicated heavy human pressure on higher DBH classes that leading to scarcity of mature individuals that can serve as seed sources. The third pattern revealed the presence of large number of individuals at the lower and higher DBH classes and the absence of individuals at the intermediate DBH classes. Some species such as *Podocarpus falcatus* and *Bersama abyssinica* had shown this patter. Similar results were reported by Teketay (2005a) in agreement with the second and third population patterns. The fourth pattern depicted the presence of large number of individuals at the intermediate DBH classes and small number of individuals at the lower and higher DBH classes. A few species including *Celtis africana* exhibited this patter. This pattern shows hampered regeneration, which could be attributed to poor recruitment coupled with selective cutting of individuals in the higher DBH classes. Feyera Senbeta and Demel Teketay (2003) reported similar population patterns in Kimphee forest.

Regeneration status

The total density of seedling, sapling and mature tree in Munessa natural forest was 6,934, 1,686, and 481 individuals per ha respectively (Figure 8). The density of seedlings obtained from the study area was less than the report made for Wof-Washa by Fisaha et al. (2013) and Kuandisha by Birhanu et al. (2016) which was 8,796.5 and 26,259 individuals per ha respectively. This could be due to the high exposure of the forest for grazing and other human impacts such as tree cutting for firewood, house construction and timber production. The density of seedlings and saplings was greater than mature trees. Conversely, the ratio of seedling to sapling was 4.11, seedling to mature tree was 14.4 and sapling to mature tree was 3.5. This result shows that the distribution of seedlings is much greater than saplings and mature trees and that of saplings is greater than mature trees. Accordingly, the number of seedlings and saplings being regenerated in the forest is about eighteen fold of the mature trees. Therefore, it is possible to say that the regeneration potential of the forest is relatively higher and its future floristic composition and diversity

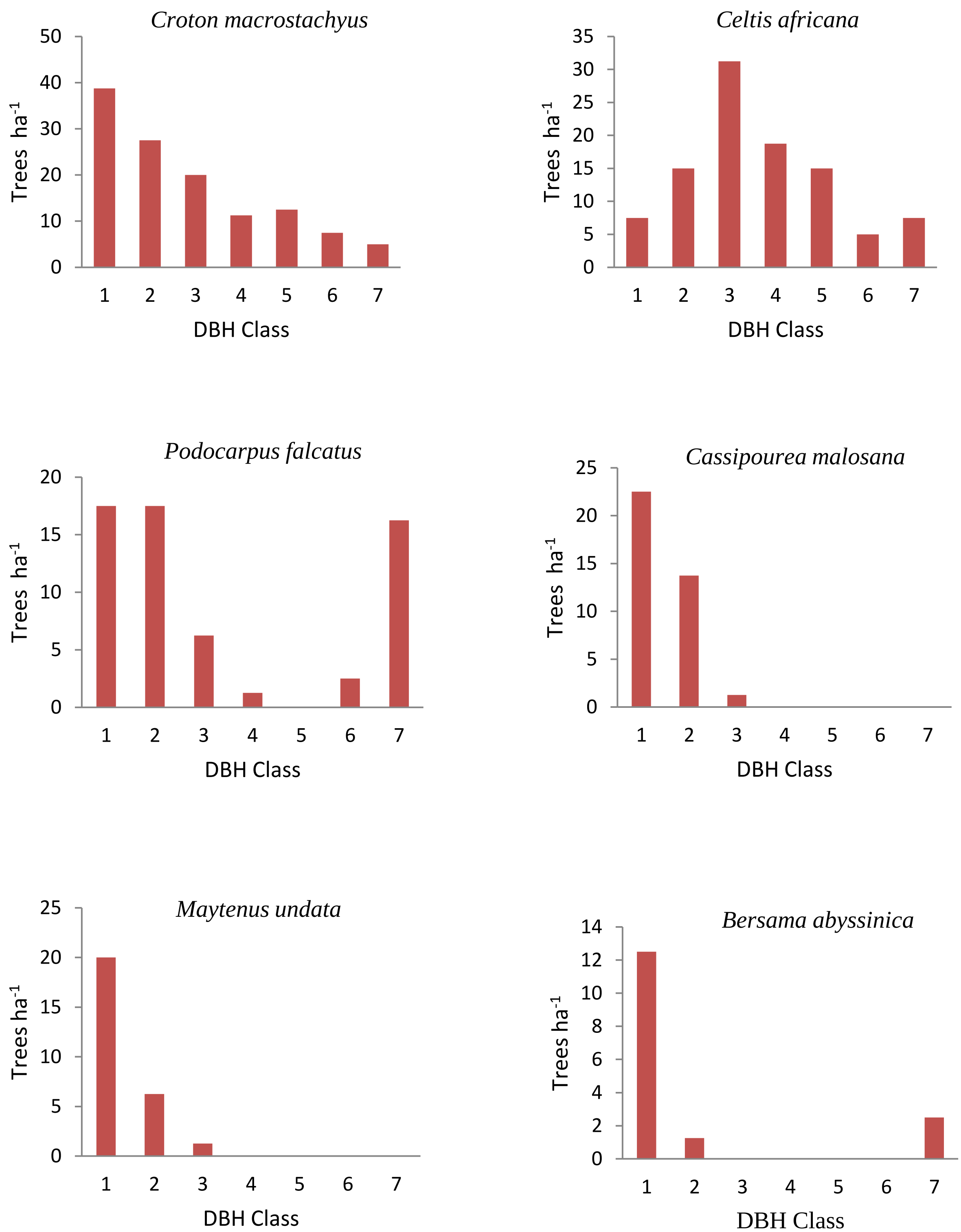

Figure 7. Population structure of representative tree species in DBH class (cm)

will be much better compared to the current situation. Seedling density was varied among species that ranges from 7 individuals per ha for *Erythrococca abyssinica* to 1826 individuals per ha for *Cassipourea malosana.* Generally, in the present study 71 % of the species had seedlings, whereas 29 % of the species lacked seedlings including *Albizia grandibracteata*, *Ficus sycomorus*, *Galiniera saxifrage* and *Hypericum revolutum*.

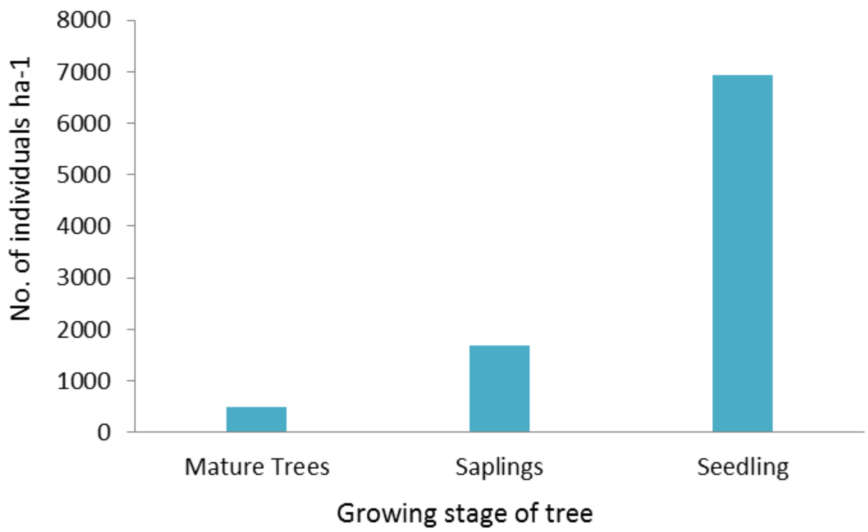

Figure 8. Density of seedlings, saplings and mature trees in Munessa natural forest

Levels of disturbance and species prioritization

Disturbances in the natural forests may include wind throw, natural and manmade fires, landslides, grazing, tree felling and clearing for cultivation (Teketay, 2005b). In the present study, free grazing and selective cutting of trees were the most disturbance factors observed during the assessment. Most commonly the species richness of trees and seedling density are negatively correlated with disturbance Økland (1990). Dead stumps, in the form of fallen and uprooted trees and standing dead trees were observed in most sample plots laid. This shows the severity of anthropogenic disturbance in the study area. Dead stumps of 14 species and dead standing trees of 11 species were recorded. *Croton macrostachyus* was the most disturbed tree species that were accounted for 18 % of disturbance followed by *Maytenus undata*, *Allophylus abyssinicus*, *Bersama abyssinica*, *Podocarpus falcatus*, *Prunus Africana* and *Calpurnia aurea*. Some characteristic species of the dry evergreen afromontane forest such as *Juniperus procera* were absent in the natural forest of Munesa. Regardless of the wide distributional range of *Juniperus procera* elsewhere in Ethiopia at altitudes 1500–3000 m a.s.l (Hedberg et al., 2009), the species is naturally absent in the study area. Seed predation has been noted to play its own role in reducing the seedling population of woody species such as *Juniperus procera* in the dry evergreen afromontane forests of Ethiopia (Teketay, 2005b). Species with lower IVI value were usually prioritized for conservation. Generally, 8 tree species with IVI value less than 2 were identified and received top priority status for conservation and management interventions in this study. Those tree species includes *Apodytes dimdiata, Calpurnia aurea, Dombiya torrida, Fagaropsis angolensis, Hypericum revolutum, Maesa lanceolata, Nuxia congesta,* and *Ochna holstii*.

CONCLUSION AND RECOMMENDATION

This study revealed that Munessa natural forest is more diverse in tree species compared to Menagesha Suba and Kuandisha forest. But it is less diverse compared with other afromontane forests such as Zege, Tara Gedam and Abebaye, and Zengena forest. This is due to the relatively higher disturbance level from grazing and selective logging by the local community. As a result, a significant number of woody species were either not regenerating or selectively removed for various purposes. For instance, even though the total BA of tree species was higher, the proportion of individuals with DBH was very high in lower DBH class compared with higher DBH class. Tree species richness generally showed an alternative decreasing and increasing trends from lower to higher elevations. Some species such as *Juniperus procera*, *Hagenia abyssinica* and *Olea europaea subsp. cuspidate,* which are characteristic species in the afromontane forests of Ethiopia, are naturally absent in the natural forest of Munessa.

Thus, we recommend conservation and management actions are mandatory for the priority species that shows low IVI and the entire forest as well. We suggest that free grazing and selective cutting of tree inside the forest should be abandoned. Moreover, bare land in the forest should be planted with prioritized species. The cut and carry system of grass from grazing areas can be another viable option to reduce the pressure from the forest. An investigation on soil seed banks should be conducted and receive top priority so that additional management interventions can be forwarded.

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Vulnerability analyses in forests using AHP in a GIS environment

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Abstract
Vulnerability, which is one of the criteria used in the preparation of the World Risk Index, is the measure of the damage and loss that a community or structure can suffer when a hazard occurs. In this research, a region with a high fire hazard was selected, and a model was created to determine the extent to which spatial objects (assets) could be damaged when the expected danger occurs in the selected region, using Analytic Hierarchy Process (AHP) in a Geographic Information System (GIS) environment. Since GIS-based AHP analysis is based on the comparison of different layers with each other and determining the weight values of the layers, the Terrestrial Measurement, Photogrammetry and Remote Sensing techniques, which are used as data sources in the evaluation of spatial data, are also discussed in the study.
Keywords: GIS, QGIS, AHP, photogrammetry, forestry, remote sensing.

Introduction

When Hazard and Risk are considered separately, they can be defined as following:

Hazard: Hazard can be defined as damage and potential for damage.

Risk: Risk can be defined as loss, injury or other consequences from the hazard. To define the overlap and separation between them, it can be evaluated that if an earthquake is the danger, it is the risk to buy a house from an earthquake zone. Again, one of the generally accepted definitions of risk is that 'risk is the combination of the probability of occurrence of an identified dangerous event and its consequences'. On the other hand, according to AS/NZS 4360:1999 Risk Management by Standards Australia (1999), risk can be defined as the likelihood of the occurrence of an event that has the potential to cause hazards, which can be measured in terms of outcomes and probability.

As can be understood from the definitions, risk is manageable and analyzable. Risk management regulates readiness before a risk takes place and enables efficient, fast, and accurate decision making in difficult situations. The determination of risk probability and risk effect is only performed by risk analysis.

The criteria used for ranking in the preparation of the World Risk Index are based on the most basic concepts such as Risk, Exposure, Vulnerability, Fragility, Coping, and Adaptation as mentioned in the Index for Risk Management or INFORM (Marin-Ferrer et al., 2017).

Vulnerability, which is one of the criteria mentioned above, is defined as the measure of the damage and damage that people, structures, or services may suffer when a hazard occurs. Hazard sources are divided into two main groups according to their reasons.

a) Natural Hazards (earthquakes, floods, landslides, avalanches, etc.)
b) Human Hazards (technological accidents, traffic accidents, fire, etc.)

According to the World Risk Report 2016, when evaluated in terms of Hazard (Human and Natural) and Exposure dimensions, Turkey ranks 12th in the world among the 12 highest scoring countries (Ersoy et al., 2017).

The presentation or preparation of the region where the risk analysis will be carried out in numerical data in a measurable, evaluable manner with all the details of the place directly affects the results of all evaluations to be made. Therefore, different methods can be followed in providing the data required for the type of hazard and the size of the impact area. However, in the case of regional or local hazards, the location and quality accuracy of all spatial details is very important for vulnerability analysis. In order to achieve this, it is useful to know different engineering measurements and data supply techniques.

Spatial data may require different engineering measurements depending on the hazard type. However, it should be noted that the first and most important data source is historical written data, records, and images related to the hazard of the place in question. In such analysis studies, the data in question is defined as existing data.

If measurement points related to hazard limits and hazard probability of the area defined as risk area are needed, a terrestrial measurement network is created from measurement points (control points) in the area. Nowadays, terrestrial measurements are carried out with highly sensitive measurement systems such as, total stations, global navigation satellite system receivers and terrestrial laser scanners (Ghilani & Wolf, 2011).

In the vulnerability assessment of an area, photogrammetry is a very important data source that provides all the natural or artificial details of the area, gathered in a three-dimensional, traceable, observable, and measurable manner. All spatial information of the region can be accessed by evaluating the overlapping and transverse overlapping (sidelap) aerial photographs taken with aircraft cameras (Lillesand et al., 2015). With the new generation of systems and sensors, such measurements can be made more accurately. Recordings and photos acquired with sensors placed in drones are examples of these (Yurtseven et al., 2019).

Obtaining reliable and measurable information about objects and/or areas without direct contact is called remote sensing. The demands of humanity to comprehend the environment, the earth and the universe brought up space studies and the perception of the earth from space, and thus temporal changes began to be monitored by periodic sensing of the ground surface. At the core of this technology are sensing systems and satellites to carry these systems into space, that is, carrier platforms. Today, satellite images (recordings) entered into our daily lives with the data presented to humanity and scientific studies (Campbell & Wynne, 2012). With the help of satellite data, the unknowns of the earth and the universe (with sensor systems directed to other planets) are being analyzed. Consequently, if spatial data is desired to be obtained in any region of the globe, it should be known that such data is readily available. However, understanding the remote sensing technology as a whole increases the sensitivity of the evaluations to be made.

The use of satellite data in temporal controls will help to control the dangers that await our world. The role of hardware and software required for the evaluation of satellite data will be recalled under the heading Geographic Information System (GIS).

Therefore, spatial data is the source of data for us, regardless of the method or system it is collected with, and each is defined as geographic information. The evaluation of the collected geographical information and the deduction of the results from the evaluations are realized with Geographic Information Systems (Showalter & Lu, 2009; van Oosterom et al., 2005).

Geographic Information System (GIS) is a combination of hardware, software, people, geographical data, and processes, which performs the functions of collecting, storing, processing, managing, spatial analysis, querying and presenting large volumes of data to assist users in location-based decision-making processes to solve complex social, economic, environmental, etc. problems around the world. Perhaps the data is the most important component of a GIS. Geographical data and related tabular data can be collected internally or purchased from a provider of commercial data. Most GIS use a Database Management System to create and maintain a database to assist in the organization and management of data.

The data model is a mathematical construct in GIS which represents geographic objects or surfaces as data. A GIS data model makes it possible for a computer to represent real geographical elements as graphical elements. There are 2 data models: Vector Data Model and Raster Data Model. Vector data is the positioning of spatial objects consisting of points, lines, and areas in a coordinate system. Raster data are formed by the combination of neighboring unit areas defined as pixels, which is the smallest unit that sensor systems can detect (Kennedy et al., 2013; Nghiem, Q. H.,2015; Kang et al., 2016).

Spatial data obtained by using the above mentioned techniques can be used in vulnerability studies. The use of GIS software in the management and analysis of spatial data can be considered as a necessity. In this study, spatial data obtained by using combination of such techniques were evaluated by using GIS and (Analytic Hierarchy Process) AHP techniques and the vulnerability of forest areas from wildfires was evaluated over a study area.

Material and Methods

Study Area

In this study, Bucak Forest Management Directorate which is a part of Isparta Forest Regional Directorate is selected as study area. As shown in Figure 1, an area of 100400 hectares (approximately 1004 square kilometers) covered with coniferous forests, which is 80% sensitive to fire, was selected as the research area. In this context, stand types data prepared for forest management by using photogrammetric, remote sensing and terrestrial techniques in GIS environment were used in the study.

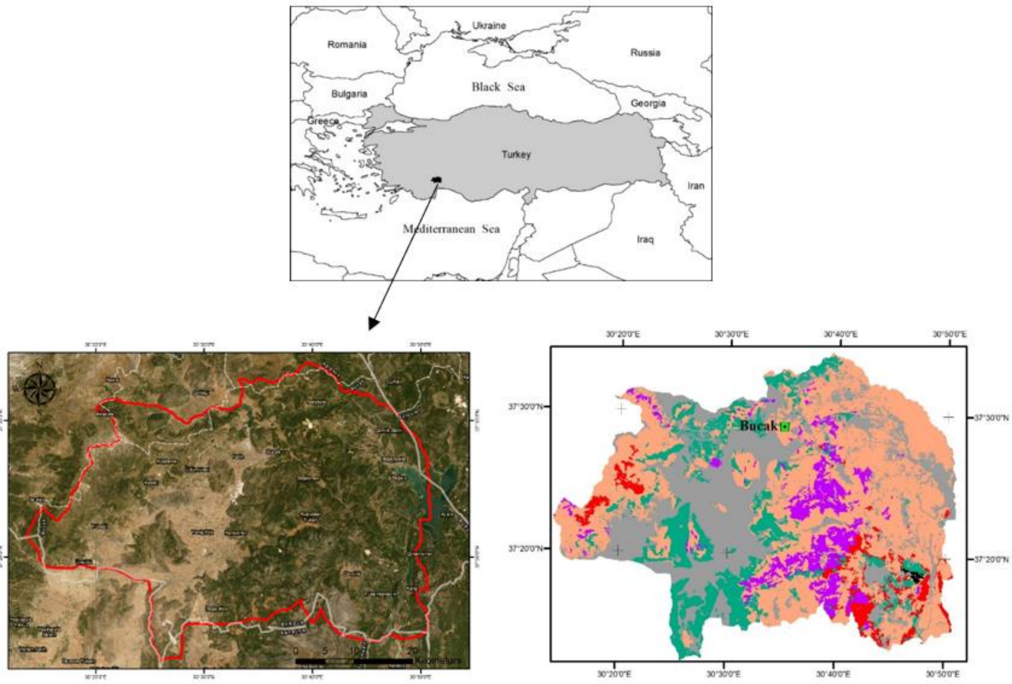

Figure 1. Research Area

GIS and AHP Analysis

As mentioned earlier components of GISs are listed as Hardware, Software, Data, Analysis, and Users. Hardware is the computer Geographic Information Systems operates in. In this context entire process and the analysis were conducted on a desktop computer with 2.6 Ghz processor, 16 GB of RAM and 64 bit Windows 10 Enterprise operating system.

GIS software provides the necessary functions and tools for processing, analyzing and displaying geographic data. Key software components of GISs are, Database Management System (DBMS), Tools (for the geographic information input and manipulation), and Graphical User Interface (GUI). There are several open source and commercial GIS software are presented to the users in the field of Geographic Information Systems. In this study, commercial ArcGIS (https://www.arcgis.com/) and open source QGIS (https://www.qgis.org/) software were used for data evaluations.

ArcGIS is a spatial data production, management, sharing and research tool for organizations. This software can be implemented on-location or in the cloud (e.g. Amazon, Azure, etc.) with ArcGIS Enterprise, or can be used as ArcGIS Online which is hosted and operated by Esri. Spatial analysis and spatial statistics it performs include one of the techniques that examine assets using topological, geometric or geographic features. ArcGIS v. 9.1 desktop (ArcReader, ArcView, ArcEditor, and ArcInfo), and extensions are used as GIS software in its structure.

Compared to other GIS software systems, QGIS allows similar users to create multi-layered maps using different map projections. Maps can be combined in different formats and for different uses. QGIS maps allow the creation of raster or vector layers. QGIS have many advantages such as flexibility, quality, security, performance, independence from a certain company, and compliance with open standards.

During the evaluations, firstly, data sources (e.g. remote sensing data [satellite data]) are evaluated with the ArcGIS software and appropriate hardware, and all details are classified. If there are specialized knowledge and symbols about spatial objects in the research area, they should be reached and descriptions should be international. Thus, the database of the research area is created in the GIS environment.

GIS software is generally commercial, and when it is cannot be obtained for economic reasons, the ease and free use of QGIS Open Source Software attracts researchers' attention. In order to perform QGIS-based AHP vulnerability analysis, a plug-in named Easy AHP is used in this study. The analysis is then performed by integrating it with the Weighted Linear Coupling. Further information can be found at https://github.com/MSBilgin/EasyAHP on how to perform this analysis.

Results and Discussion

Determination of Input Layers (Parameters)

Because GIS-based AHP analysis is based on determining the weight significance values of different layers, layer weights should be determined for AHP in the research area. This way, decision-makers define a hierarchy in the solution of complex problems and select the result that provides the suitability value.

Our research area includes forest areas, agricultural areas, settlements, and facilities that are sensitive to fire hazards. The parameters (input layers) that will be affected in case of an occurring fire hazard are as follows:

K1-Forest Areas, K2-Agricultural Areas, K3-Settlements, K4-Facilities

The comparison matrix of parameters (input layers) was created as shown in Table 1, in accordance with the recommendations of forest fire experts (Saaty, 1990).

Table 1. Comparison matrix of input layers (parameters)

	K1	K2	K3	K4
K1	1	5	8	8
K2	0.2	1	4	3
K3	0.125	0.25	1	2
K4	0.125	0.25	0.5	1
	1.45000	6.50000	13.50000	14.00000

According to this matrix, the importance weights of the criteria were calculated as shown in Table 2 and the consistency ratio (CR) was found to be less than 0.1.

Table 2. Calculation of importance weights of input layers (parameters)

K1	K2	K3	K4	Total	W	v	v/w
0.689655	0.769231	0.5925926	0.571429	2.6229071	0.655727	2.808143	4.28249
0.137931	0.153846	0.2962963	0.214286	0.8023592	0.20059	0.848185	4.228457
0.086207	0.038462	0.0740741	0.142857	0.3415997	0.0854	0.33408	3.91195
0.086207	0.038462	0.037037	0.071429	0.233134	0.058284	0.233097	3.99936
					1		16.42226
							4.105564

	Random Index (n= 4)	0.9	
Consistency Index	CI	0.035188	
Consistency Ratio	CR	0.039098	<0.1

After determining the importance weights of the input layers (parameters), the forest cover which has the highest significance weight (0,66) was represented by two sub-criteria (Vegetation type, Stand development stages) instead of the single weight value for all forest areas in line with the recommendation of forest fire experts, and again, they were evaluated with local weights (0.44 + 0.22) determined according to the evaluations of the experts (Table 3).

Table 3. Importance weights of input layers (parameters)

Criteria	Weight	Sub-Criteria	Local
Forest	0.66	Vegetation type	0.44
		Stand development stages	0.22
Agricultural Areas	0.20		0.20
Facilities	0.08		0.08
Settlements	0.06		0.06
	1.00		1.00

The stand data (Table 4 and Table 5) indicated by special symbols and definitions in the database created following the GIS basic principles for forest cover in the research area, for example, the meaning of the symbols used for stand development stages in Table 4, are defined as given in Table 6. The Values column shows the class values.

Table 4. Stand development stages

Stand development stages	Value
a, ab	10
b, bc	7
c, cd	5
d	3
e	1
Forest land (O, BP (black pine), S (spruce), etc.)	3
Other land (Bld., G, L, F, GP, etc.)	0

Table 5. Vegetation type classes

Vegetation type classes	Value
Pure / disordered coniferous	10
Pure / disordered – mixed coniferous	7
Pure / disordered – mixed coniferous – deciduous	5
Pure / disordered deciduous	3
Pure / disordered – mixed deciduous	3
Other lands (Bld., G, L, F, GP, etc.)	0

Table 6. 1.30 m diameters in terms of stand development stages

Diameter of Breast Height (d 1.30)	Stand Development	Stand Development Stage
0–7,9 cm	Youth	a
8–19,9 cm	Pole and Mast	b
20–35,9 cm	Thin Wood	c
36–51,9 cm	Middle Woodland	d
52 cm and over	Thick Wood	e

Proximity classes of agricultural areas to forest areas (m), Proximity classes of settlement areas to forest areas (m) and Proximity classes of facilities to forest areas (m) are given Table 7, Table 8 and Table 9.

Evaluation of Criterion Weights with Research Area Database

The criterion weights were recorded in the database of the forest units (stand) in the research area and using the ArcGIS Spatial Analyst module, the weight coefficients for each class were calculated by considering the class values determined for each type of vegetation and development age type, and the result values for the forest cover were obtained. Similar calculations were performed for the agricultural area, settlements, and facility areas, and a vulnerability map was obtained for the whole area (Figure 2).

Table 7. Proximity classes of agricultural areas to forest areas (m)

Proximity of Agricultural Areas to Forest Areas (m)	Value
0-100	10
100-200	7
200-300	5
300-400	3
400-500	1

Table 8. Proximity classes of settlement areas to forest areas (m)

Proximity Classes of Settlement Areas to Forest Areas (m)	Value
0-100	10
100-200	7
200-300	5
300-400	3
400-500	1

Table 9. Proximity classes of facilities to forest areas (m)

Proximity Classes of Facilities to Forest Areas (m)	Value
0-100	10
100-200	7
200-300	5
300-400	3
400-500	1

Conclusion

The research shows that in the face of any hazard, multidimensional and multi-staged studies should be conducted based on scientific approaches. Based on the fact that hazard and risk pair will always be together, it should be remembered that risk management before the hazard occurs and that risk analysis after the hazard occurs will be complementary. The studies that will be carried out before the damage occurs will allow researchers to determine the status of the available resources, risk factors, the measures that can be taken, and the duties of the society. The damage and losses that may occur in spite of all these measures can be calculated with the data obtained as a result of these previous studies, the things to be done to recover the losses can be determined, and the preventative measures can be renewed in order not to face similar situations again.

To be able to calculate the extent of damage and loss caused by every hazard, there is a need for very healthy, measurable, and computational spatial information about the hazard area (environment). Although open source GIS software has existed for a long time and is getting increasingly popular and progressing towards becoming mainstream, there may still be some concern about the quality of open-source software. Likewise, in the collection of the above-mentioned and indispensable data, it is likely that there are some hesitations in the minds of researchers about data quality.

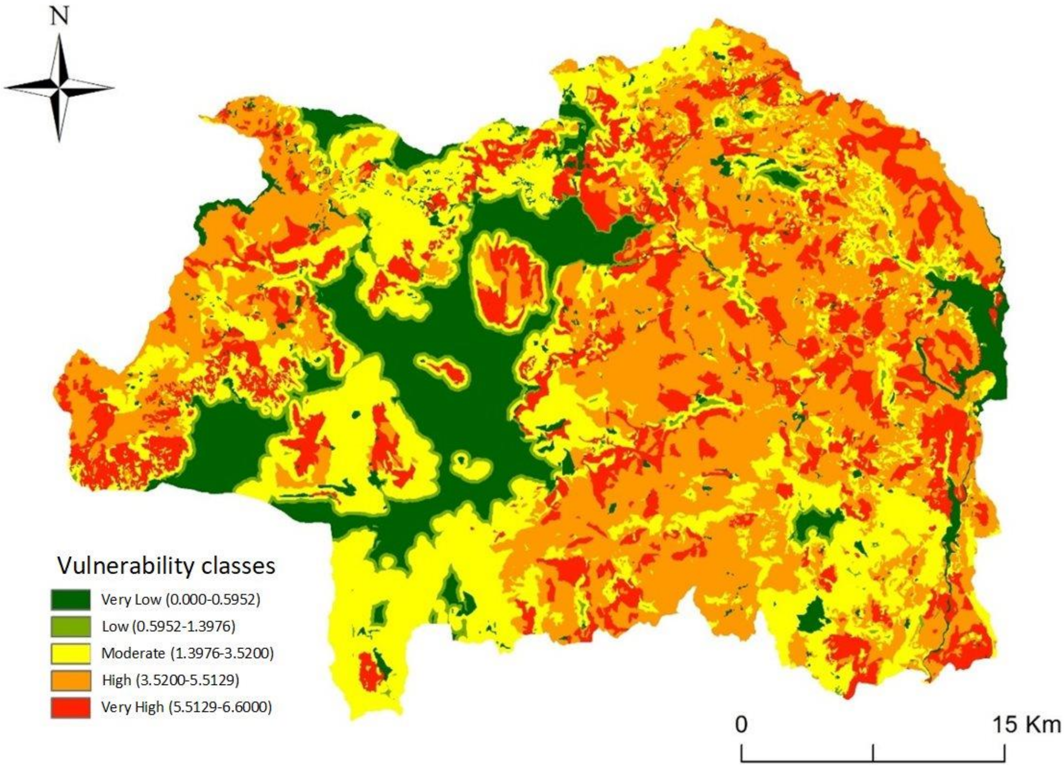

Figure 2. Vulnerability map of the research area.

The aim by demonstrating that QGIS, which is an open-source GIS software, can be used instead of commercial GIS to do the analysis of damage levels of spatial assets for the forest areas, agricultural areas, settlements, and facilities (which are intertwined in Turkey) with a GIS-based AHP analysis approach in the nature part selected as the model, is to pave the way for interested researchers.

The results of the vulnerability analysis invite people to take individual measures and to request measures to be taken by the administrations, taking into consideration the vulnerabilities before the hazard occurs, and invite the management to support the evaluation and research projects to be carried out in the hazard areas, and to produce public solutions according to the results. Thus, it will be possible to take the necessary precautions before the damages that may occur naturally. Researchers should do their part in this matter and publish their findings in publicly accessible environments. While doing this research, healthy data can be obtained not only with commercial software but also with open-source software. This way, researchers can use open-source software for determining risk indices, instead of waiting for resources to obtain commercial software.

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Evaluating spectral indices for estimating burned areas in the case of Izmir/Turkey

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Abstract

Mapping and determination of fire damaged areas in an accurate and prompt way is essential for identifying environmental losses caused by fires, post-fire management activities and planning strategies. In this context, this study aims to evaluate the performance spectral indices for discriminating burned and unburned areas in the immediate post-fire environment in the case of Gaziemir, Buca and Karabağlar districts of Izmir metropolitan city where one of the forest fires occurred in the 18rd August 2019. For this, whilst a Sentinel 2A (26th August 2019) was used to map burned / unburned areas as the reference dataset, two Landsat 8 satellite images (7th and 28th August 2019) were used for the calculation of spectral indices. The spectral indices of normalised difference vegetation index (NDVI), atmospherically resistant vegetation index (ARVI), two versions of normalised burn ratio (NBR and NBR2) and burnt area index (BAI) were calculated for the selected two dates as well as pre-fire and post-fire temporal differences in those indices. For the performance comparison of spectral indices, binary maps of burned and unburned areas were created and separability index (SI) was calculated for pre/post-fire differenced spectral indices. Our results suggest that NBR2, NDVI and ARVI had the highest potential for discriminating burned areas, respectively. Even though the value of separability indices was different from each other where NBR and BAI had the lowest values, that doesn't necessarily mean these indices cannot discriminate burned areas since the separation of burned and unburned areas highly depend on the spatio-temporal circumstances e.g. vegetation types and time lags between image acquisition dates.

Keywords: Remote sensing, spectral indices, burned area mapping, Landsat 8, Sentinel 2A.

Introduction

Forests, one of the most important natural elements of landscapes and one of the most species rich resources, provide a range of ecological, economic, social and cultural functions to all organisms as well as forming habitats to different species. Even though forests occupy almost one third of the Earth's land surface, they capture a higher proportion of solar energy, constitute large cooling islands, contain the largest concentrations of organic material, and act as carbon sinks compared to all other terrestrial and aquatic ecosystems (Gibbs et al. 2007; Chen et al. 2010; Curtis and Gough 2018). However, forests all over the world have been increasingly degraded / disappeared as a result of demand for natural resources, meeting the requirements of growing populations and natural hazards. Forest fires, one of the most important natural disasters in the globalising world, are one of the most prominent disturbance factors that cause the destruction of very large forest areas in a very short time unless necessary precautions are taken.

In Turkey, as in many parts of the world, one of the main factors endangering the future of our forests certainly is forest fires. Whilst forest fires are considered as one of the most important natural disasters, they cause many social, economic and environmental problems. Forest fires are one of the dominant disturbances, particularly in the Aegean and Mediterranean regions of Turkey because of human-induced activities or natural conditions (Hernandez et al. 2015; Kavzoglu et al. 2016). According to the 2019 report of the Turkish General of Directorate of Forestry, the total forest area of Izmir metropolitan area was 475,779 ha in 2018. However, in the same year we have lost a total forest area of 298,94 ha with 167 forest fires (RTGDF 2019) and most of these were due to human-induced activities. During the summer of the year 2019, numerous and dramatic forest fires have been erupted and destroyed forest areas in the Aegean region of Turkey. On the 18rd August 2019, Izmir metropolitan area has experienced a forest fire in its Gaziemir, Buca and Karabağlar districts where an approximate forest area of 5000 ha was affected.

At the landscape scale, forest fires partially or completely affect the structure and patterns of existing vegetation (Veraverbeke et al. 2010; Fairman et al. 2016). However, the evaluation of the adverse effects of fires requires an accurate identification and also mapping of the areas affected / damaged by them. The identification and mapping of burned areas in forests are also essential for fire management and post-fire damage estimations. Existing research recognises the critical role played by satellite images and remote sensing techniques in supporting the knowledge about burned and damaged areas by fires in an accurately and prompt way as an alternative for extensive field sampling (Mitri and Gitas, 2004; Chuvieco et al. 2006; Tran et al. 2018). Additionally, there is a growing body of literature that recognises the importance of spectral indices as a rapid and cost effective way for the identification and mapping of burned areas in forests (Chuvieco et al. 2002; Miller and Thode 2007; Mouillot et al. 2014). The identification and mapping of burned forest areas is generally based on the evaluation of the changes in spectral properties of vegetated areas before and after fire incidents (Veraverbeke et al. 2010; Fornacca et al. 2018). Normalised difference vegetation index (NDVI), atmospherically resistant vegetation index (ARVI), normalised burn ratio (NBR) and burnt area index (BAI) are the most popular spectral indices used to estimate and assess the damage caused by forest fires (Chen et al. 2011; Chuvieco et al. 2002; Boschetti et al. 2010; Kavzoglu et al. 2016).

In this study, we focused on the Gaziemir, Buca and Karabağlar districts of Izmir metropolitan city where forest fires occur frequently during the dry and windy seasons, between May and September. The main aim of this study was to compare the performance of five widely used spectral indices in the case of the forest fire occurred in 18th August 2019 in this area. The following objectives was identified to achieve the main aim of this research: to assess the boundaries of burned and unburned areas with spectral indices and evaluate their correspondence with burned / unburned area borders defined according to object-based image classification of high resolution Sentinel 2A satellite image dated 26th August 2019. Such information is crucial to short-term effects of fires in the immediate post-fire environment, including the time to allocate and prioritise resources in burned forest areas (e.g. as earliest as possible in the most affected forest areas) as well as to minimise the erosion of the ground and helping the recovering of the damaged vegetation.

Material and Methods

Study Area

The study area is located in Gaziemir, Buca and Karabağlar districts of Izmir metropolitan city with elevations ranging between 154 and 957 m above the sea level (Figure 1). Whilst Izmir metropolitan city is characterised with typical Mediterranean climate, warm and rainy winters, and hot dry summers; its maximum and minimum average monthly temperatures are 28.0 ºC in July and 8.7 ºC in January (TSMS, 2019). The study area is predominantly covered with Mediterranean vegetation elements of Turkish Red Pine (*Pinus brutia*) and maquis (Nurlu et al. 2013).

Figure 1. Study area

Material

In this study, the forest fire on 18th August 2019 in Gaziemir, Buca and Karabağlar district of İzmir was detected on the basis of satellite images. According to the results of damage estimations made by General Directorate of Forestry, after the fire incident, almost 5000 ha forest area has been burned and destroyed. Whilst a Sentinel 2A satellite image (26th August 2019) was used to map burned / unburned areas as the reference dataset, two Landsat 8 satellite images (7th and 28th August 2019) were used for the calculation of spectral indices. Landsat 8 images used for the calculation of spectral indices to find out the pre-fire and post-fire temporal differences are shown below in Figure 2.

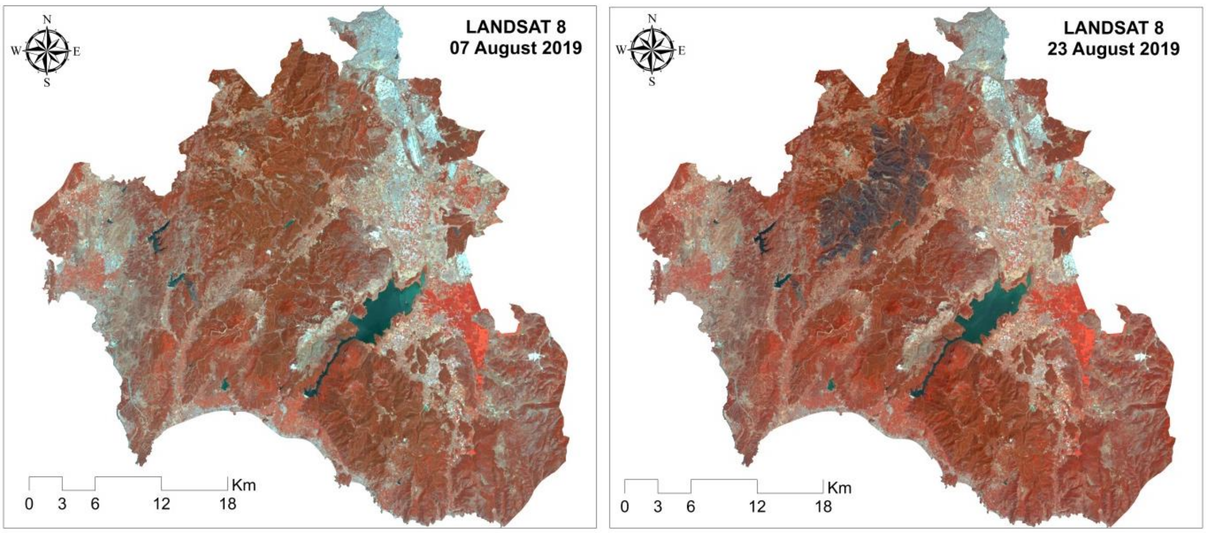

Figure 2. Pre-fire and post-fire Landsat satellite images

Landsat Satellite images were obtained from the United States Geological Survey (USGS) website. There are two different sensors on the Landsat 8 satellite system: Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). 11 different wavelength images are obtained with these sensors. In this study, five spectral bands obtained from OLI sensors were used to detect burned and unburned areas (Table 1).

Table 1. Landsat 8 operational land imagers (OLI) band properties

Band	Wavelength range (μm)	Spatial Resolution (m)	Spectral Width (nm)
Band 2 - Blue	0.435-0.451	30	6.0
Band 4 - Red	0.636-0.673	30	0.03
Band 5 - Near Infrared (NIR)	0.851-0.879	30	3.0
Band 6 - SWIR 1	1.566-1.651	30	8.0
Band 7 - SWIR 2	2.107-2.294	30	18

Methods

The method of the study was composed of 4 stages including the pre-processing of Landsat 8 satellite images, the calculation of spectral indices on Landsat 8 satellite images, the object-based classification of Sentinel 2A image as the reference data, and the comparison of performance of spectral indices based on separability index.

Pre-processing of Landsat Satellite Images

The Landsat satellite images were corrected atmospherically and radiometrically to enhance image quality. The original digital numbers of Landsat 8 bands were converted to radiance values using the procedure and coefficient values proposed by Chander et al. (2003).

Object-based Classification of Sentinel 2A Image

Object based classification of high resolution satellite images is a promising approach for forest fire mapping process, if the most appropriate segmentation parameters are applied. The baseline data source for reference burned / unburned area mapping processes was Sentinel 2A satellite image dated 26th August 2019. Object-based classification of Sentinel 2A satellite image was carried out in eCognition Developer 64 software applying a multi-resolution segmentation and the nearest neighbour supervised classification method. During the multi-resolution segmentation process, pixels of the satellite image are segmented into objects by region-merging technique to form meaningful objects (Pillai et al. 2005; Mathieu et al. 2007). For the multi-resolution segmentation, whilst the scale parameter was set to 15, shape and compactness were set to 0.2 and 0.7, respectively. After segmentation stage, training samples were selected from burned and unburned areas and the nearest neighbour supervised classification method.

Calculation of Spectral Indices

Five widespread spectral indices (NDVI, NBR, NBR2, BAI and ARVI) were calculated from Landsat 8 satellite images to determine the amount of burned and unburned areas (Table 2).

The basic principles of these indices are based on the spectral behaviour of surface characteristics on different spectral wavelengths. For example, the near infrared (NIR) and red (R) wavelengths of the electromagnetic spectrum has a potential for estimating vegetation functioning. In the NIR region of the spectrum, leaf scattering is high due to higher radiation from the canopy in the healthy vegetation structure.

Table 2. Spectral indices calculated in this study

Variable	Abbreviation	Formula	Reference
Normalized difference vegetation index	**NDVI**	(NIR - RED) / (NIR + RED)	Tucker, 1979
An atmospherically resistant vegetation index	**ARVI**	NIR−RED− γ (RED−BLUE)/ NIR+Red− γ(Red−Blue)	Kaufman and Tanre, 1992
The Normalized Burn Ratio	**NBR**	(NIR – SWIR2) / (NIR + SWIR2)	Key & Benson, 2005
The Normalized Burn Ratio 2	**NBR2**	(SWIR1 – SWIR2) / (SWIR1 + SWIR2)	USGS, 2019
The Burned Area Index	**BAI**	1 / (0.1- Red)^2 + / (0.06- NIR)^2	Martin et al., (1998), Chuvieco et al., (2002)

For Landsat 8: RED (Band 4); BLUE (Band2); NIR: Near infrared (Band 5); SWIR1: Short wave infrared (Band 6); SWIR2: Short wave infrared (Band 7)
γ- an atmospheric self-correcting factor was set to 1 (the aerosol model is not available)

However, in the R component of the spectrum, high pigment absorption results in lower reflection of radiation. On the other hand, if the vegetation structure gets poorer depending on fire incidents, NIR reflectance gets lower, and its red and mid-infrared reflectance gets higher (Chuvieco and Congalton 1988). The normalized difference vegetation index (NDVI) combines the reflectance in the R and NIR spectral region and as a measure of the amount of vegetation where the lower the ratio values, the more intense damage to vegetation, in other words the more severe impact of the fire. On the other hand, the normalized burn ratio (NBR) represents the healthy chlorophyll content in vegetation, vegetation moisture and water content of soil by combining the NIR with SWIR reflectances. When a fire incident happens, this causes an increase in the radiation reflection in the R and NIR spectral regions, and a decrease in the reflection in the NIR region (Pereira et al. 1999). As a result, the higher ratio values of the NBR express more severe impacts of fire. Additionally, to emphasise the sensitivity of water in vegetation, NBR2 is calculated by modifying SWIR1 band to NIR band which is used in the original NBR index (USGS 2019). The burned area index (BAI) is computed on the basis of the R and NIR spectrums of the multi-temporal images by highlighting the convergence point of the charcoal signal in recently burned regions. The spectral values of this convergence point (NIR reflectance 0.06 and R reflectance 0.1) were based on literature (see Martin et al. 2002; Chuvieco et al. 2002). The other index used in this study is the atmospherically resistant vegetation index (ARVI), proposed by Kaufman and Tanre (1992), with the aim of reducing the atmospheric influence on the vegetation signal by considering radiance in the blue band, which is generally the most effected band from the atmospheric scattering.

In order to determine the magnitude of changes caused by a fire, the post-fire images of spectral indices are subtracted from the pre-fire images. The advantage of pre / post-fire differenced indices is in their capability to discriminate clearly unburned sparsely vegetated areas and burned areas (Key and Benson 2005; Hammill and Bradstock 2006).

Calculation of Burned and Unburned Areas and Accuracy Assessment

After setting the mean values of each pre / post-fire differenced spectral indices as the threshold for classification, binary maps of burned and unburned areas were created. Then the total accuracy of the derived maps and the accuracy of burned areas were calculated in ArcGIS 10.5 using the reference burned / unburned map. We also calculated the total area of burned and unburned areas to evaluate the performance of spectral indices in determining the magnitude of changes caused by the fire.

Discrimination of Spectral Sensitivity of Burned Areas

The separability index (SI) is widely used to evaluate the performance of spectral indices in terms of their capability for the discrimination of burned and unburned areas. It is computed as follows:

$$M = \frac{|\mu b - \mu ub|}{(\delta b + \delta ub)}$$

μb: mean values of the considered spectral band of the burned; μub: the mean values of the considered spectral band of unburned area; δb: the standard deviations of spectral values of the burned area; δub: the standard deviations of spectral values of the unburned area.

Higher separability index values indicate that the given spectral index has a strong separability attribute whereas lower values reflect that the discrimination of burned and unburned pixels are not as good as the higher SI values. For the calculation of separability index, we used Zonal statistics tool in ArcGIS 10.5. With this tool, the mean and standard deviation values of burned and unburned areas in spectral indices were obtained using the reference burned / unburned map.

Results

Based on the object-based classification of Sentinel 2A image, we obtained the map of fire representing burned and unburned areas (Figure 3). The overall accuracy of the burned / unburned map was 87,12 with a kappa value of 81,10. Tran et al (2018) claim that kappa values greater than 0,77 represent substantial agreement for the accuracy of burned areas. So, our result showed that the accuracy of our burned / unburned map is quite good. The fire affected an approximate area 7625 ha including damaged / burned and unburned areas. Our results showed that %78,7 of the total area was burned (around 6000 ha).

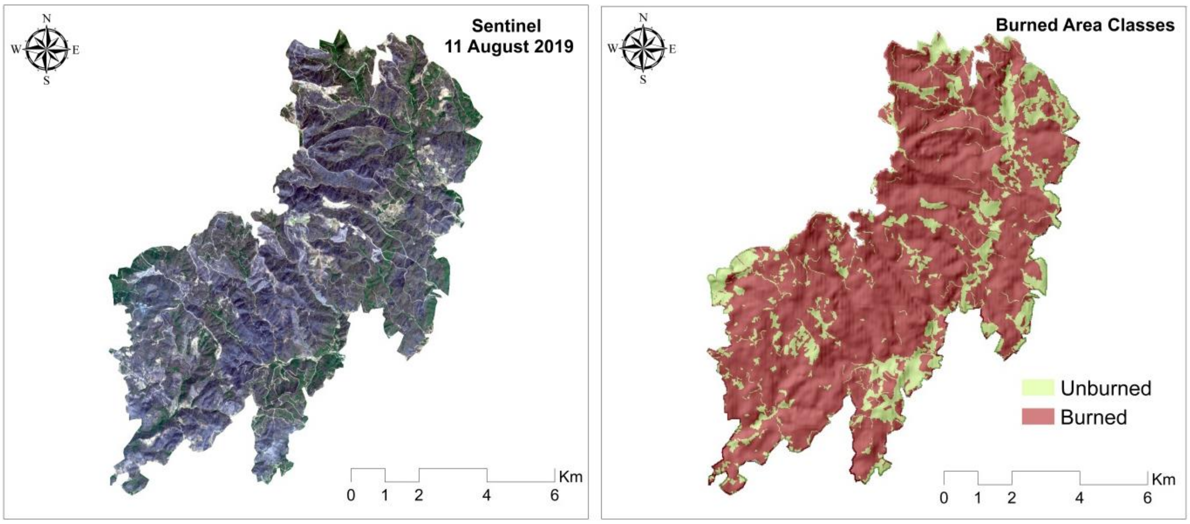

Figure 3. Object-based classification of Sentinel 2A satellite image

The images of spectral indices are shown in Figure 4.

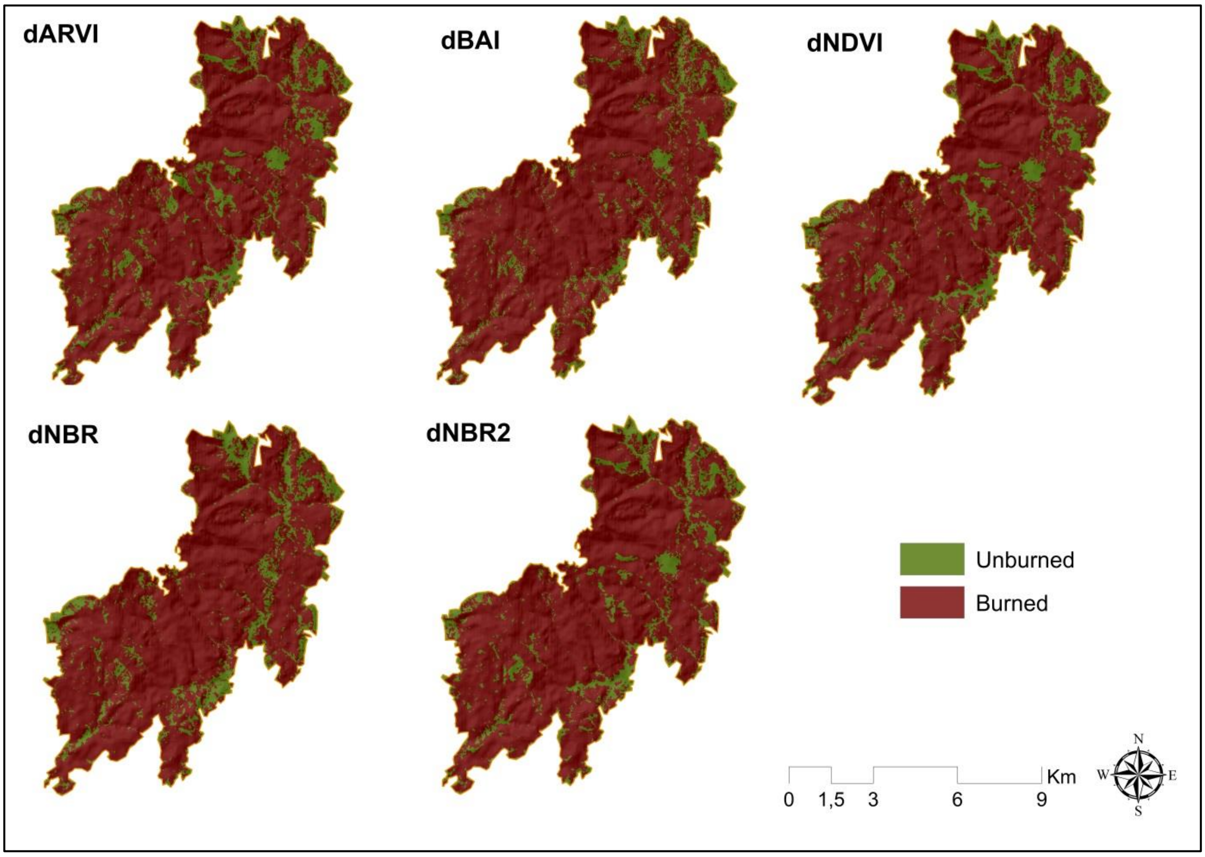

Figure 4. Classification of spectral indices

Threshold values for each spectral index for the classification of burned and unburned areas after the fire were based on the mean and standard deviation values of each index (Table 3).

Table 3. The total area of burned and unburned area obtained from spectral indices

	Area (Ha)					
Classes	**dNDVI**	**dARVI**	**dBAI**	**dNBR**	**dNBR2**	**References data**
Unburned	1422,99	1203,84	1220,4	1199,7	1330,74	1622,52
Burned	6203,88	6423,03	6406,47	6427,17	6296,13	6002,37

The accuracy of each classification is shown in Table 4.

Table 4. Accuracy assessment of each classification for spectral indices

	dNDVI		**dNBR2**		**dNBR**		**dARVI**		**dBAI**	
	PA	**UA**	**PA**	**UA**	**PA**	**UA**	**PA**	**UA**	**PA**	**UA**
Unburned	0,57	0,55	0,62	0,62	0,43	0,53	0,62	0,62	0,33	0,47
Burned	0,87	0,88	0,90	0,90	0,90	0,86	0,90	0,90	0,90	0,84
Overall Accuracy	**0,81**		**0,84**		**0,8**		**0,84**		**0,78**	

PA: Producer accuracy, UA: User accuracy

According to the results of accuracy assessments, dNBR2 and dARVI reported the highest overall accuracy (0,84) with quite high producer and user accuracy levels for burned areas. This was followed by dNDVI, dNBR and dBAI. The producer and user accuracy levels of unburned areas for each spectral index were lower than burned areas. This result was partly attributed to the lower number of accuracy assessment points assigned to the unburned areas because of its total area within the boundaries of the fire incident. At the same time, the borders of burned and unburned areas were mixed. Based on the burned and unburned areas of reference fire dataset, dNDVI resulted in the closest value for burned areas (6203.88 ha) whereas dARVI had the highest burned area coverage (6423.03 ha).

Tran et al (2018) indicate that best-performing spectral indices of fire severity vary according to the type and group of forests. In our case, we have examined the capability of spectral indices in terms of their potential for discriminating burned and unburned areas. Table 5 shows the results of separability index for spectral indices in terms of their capability for the discrimination of burned and unburned areas.

Table 5. Separability index for spectral indices

	dNDVI	dARVI	dBAI	dNBR	dNBR2
MeanB	0,295	-0,227	0,012	0,156	-0,229
Mean UB	0,124	-0,1	0,007	-0,0006	-0,059
Std B	0,121	0,089	0,005	0,121	0,109
StdUB	0,081	0,07	0,004	0,087	0,064
difmean/difstd (m seperation index)	0,847	0,799	0,556	0,753	0,983

Our results showed that the best-performing spectral indices in discriminating burned and unburned areas ranged from 0,847 to 0,983. Based on the values of separability indices for each spectral index, dNBR2 had a strong capability in discriminating burned and unburned areas. This was followed by dNDVI and dARVI indices. Similar to the accuracy assessment of burned and unburned classifications, separability index of dNBR and dBAI were the lowest values as an indication of weaker performance to discriminate burned and unburned areas compared to the above-mentioned indices.

Discussion

Spectral indices offer a rapid and cost effective way for the identification and mapping of burned areas (Miller and Thode 2007; Mouillot et al. 2014). Previous studies have used and compared a variety of spectral indices to map and determine the fire damaged areas in an accurate and prompt way (Boschetti et al. 2010; Kavzoglu et al. 2016). In this regard, this study evaluated the performance of 5 commonly used spectral indices for recently burned areas in terms of their capability for the discrimination of burned and unburned areas in the case of Izmir metropolitan city. For this, total areas of burned and unburned areas in binary maps and their classification accuracies were evaluated together with the differences in the separability index values for the selected spectral indices.

Our results showed that all spectral indices for recently burned areas are valid and valuable tools for separating burned areas from unburned areas at the immediate post-fire assessments in a mountainous region characterised by Mediterranean climate and vegetation. However, whilst dNBR2 spectral index had the highest burned area discrimination ability, dBAI spectral index had the weakest ability for separating burned and unburned areas. In literature, the strong capability of BAI was emphasised in discriminating recently burned areas in particular where the vegetation is mostly covered by woody plants and charcoal rate is high (Chuvieco et al. 2002; Martín et al. 2005; Schepers et al. 2014; Liu et al. 2016). However in our case BAI index had a reverse behaviour because our study area is composed of woody and herbaceous vegetation together (Schepers et al. 2014). Surprisingly, our results have also revealed that dNDVI had a quite strong discrimination ability of burned and unburned areas. This was again due to the presence of woody and herbaceous vegetation together in our study area.

Even though the value of separability indices were different from each other, where dNBR and dBAI had the lowest values, that doesn't necessarily mean that these indices cannot discriminate burned areas. But, these results can simply be attributed to their capability for distinguishing burned and unburned patches with higher rates of errors compared to the other spectral indices that were used in this study (Fornacca et al. 2018). This study supports evidence from previous research which have demonstrated that the performance and behaviour of spectral indices for the separation of burned and unburned areas highly depend on spatio-temporal circumstances like vegetation types and time lags between image acquisition dates (Fornacca et al. 2018). Despite these promising results, some questions remain about the severity of fire incidents. The results of this study do not explain the occurrence of adverse effects of fire on different vegetation types. So, a further study with more focus on severity of fire on different vegetation types is therefore suggested. There is also abundant room for further progress in monitoring the post-fire forest recovery. To develop a full picture of the identification and mapping of burned areas and their adverse effects on vegetation, additional studies can also be conducted based on these indices, as well as with a combination of data from other high resolution sensors.

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Review

Silviculture and tree breeding for planted forests

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Abstract

One of the main issues facing the forestry sector is balancing the demand for forest products and the sustainable management of forest ecosystems. Efficient plantation management and intensive silviculture practices are needed to grow timber in forest tree plantations. Due to the tangible impact on wood production, the plantations area in the world has constantly increased during the last several decades. The annual increase of plantation was 3.3 million ha in the period of 1990-2015. Over the past decades, tree improvement programs have progressed to the second, third, and fourth cycles to provide genetically improved planting stock to plantations. Substantial genetic gain has been realized from major tree improvement programs around the world. The effect of tree breeding on wood and fiber production per unit area has further increased by the modern plantation silvicultural applications, such as soil preparation, fertilization and thinning. Combination of tree breeding and silvicultural applications shortened the rotation ages of plantations, increasing the wood and fiber output per unit time. In this study, the importance of silvicultural treatments and plantation management has been reviewed and how such practices could enhance sustainable management of natural forests.

Key words: Forest management, wood production, wood demand, breeding program

Introduction

Forestry has been an integral part of human beings and included in components meeting human needs. One of the components of forestry is silviculture. Curtis et al. (2007) concisely explained forestry and the role of silviculture in forestry as

> "*Forestry is the science, art, and practice of creating, managing, using, and conserving forests and associated resources for human benefit to meet desired goals, needs, and values. Silviculture is that portion of the field of forestry that deals with the knowledge and techniques used to establish and manipulate vegetation and to direct stand and tree development to create or maintain desired conditions. It is the application of knowledge of forest biology and ecology to practical forestry problems.*"

These explanations underlined that silviculture needs knowledge and technique for vegetation, stand and tree development for desired conditions. On the other hand, the history of silviculture has a fragmentary record from the 13th century. Forestry administrative organizations developed forest management and silvicultural plans in France and Germany in the 17th and 18th centuries with focus on sustainable timber production (Curtis et al. 2007).

Tree breeding alters the genetic composition of the tree population to better meet human needs, to produce the best material for the plantations (Ruotsalainen 2014). Tree breeding focuses on developing genetically improved varieties in an economically efficient manner by maximizing producing per unit time at the lowest possible cost (White et al. 2007). Historically, although some provenance experiments started in the eighteenth century, large-scale tree improvement programs began in the 1950s in 14 countries around the world (Zobel and Talbert 1984, White et al. 2007). Today tree improvement is widespread in the world including many countries in Africa, Asia, Australia, Europe, North America and South America (White et al. 2007). Tree breeding is historically a younger practice than silvicultural practices and it uses genetic principles to select superior individuals for seed orchards or production population.

The man-made forests or planted forests[1] were developed in forestry for different objectives; ranging from the need to obtain sustainable wood and other tangible products, to soil conservation (Shepherd 1986, Evans 2009). In the 1980s, Daniels (1984) characterized that planted forest was a comparatively modern development unlike in classical forestry fixed and positioned in the concept of 'sustained yield'. Besides the concept of sustained yield, using management, he added to securing annual production in a given forest estate and keeping it's in continuity. Increasing trend of plantations in the 1980s and maturing of old plantation, the effect of plantations in forestry was increased (Shepherd 1986, Evans 2009).

Tree breeding was broadened as tree improvement with the application of forest genetics principles and good silviculture to develop high yielding, healthy and sustainable plantation forests (Zobel and Talbert 1984, White et al. 2007). Today, an expansion of tree breeding programs on a global scale has increased yields and value of plantations to meet the rising demand for forest products, while lessening the need to meet this demand for natural forests Therefore, forest tree breeding is an essential part of modern silviculture to increase the economic profit over enlarged wood production (White et al. 2007).

Silviculture and tree breeding are the two most important disciplines that complement each other. The combined effect of silviculture and tree breeding is maximized in plantation forestry. In the literature, there are not many papers covering their joint importance on forest productivity. I hope this article fills a gap. The objectives of this study were 1) elucidate the relationship between silviculture and tree breeding and 2) come up with some recommendations for plantation management for better return from tree improvement programs.

[1] Definition based on Evans (2009a), 'Planted forest' includes all of what is generally understood as 'plantations' or 'forest plantation', but also incorporates other forest types originating largely or wholly from tree planting.

Tree Breeding for Planted Forests

Tree breeding aims to increase the quality and quantity of wood products per unit area from the intensively managed plantations using forest genetics principals (Zobel and Talbert 1984). Many methods in forest tree breeding are characterized like selection (level of species, provenance, population-stand, individual tree), breeding to combine desired traits, polyploidy, breeding with mutations, molecular markers, and genetic engineering (Zobel and Talbert 1984, Eriksson et al. 2013). Tree breeding is a cyclic process, that includes selecting the best trees, intermatting between them, testing their progeny for estimation of genetic merit (White et al. 2007, Eriksson et al. 2013). The progeny tests are an integral part of a breeding cycle. They serve to rank genotypes based on progeny performance, created by intermating and to constitute the next generation breeding population in a recurrent selection method (Namkoong et al. 1988, White et al. 2007, Eriksson et al. 2013). Tree improvement starts with choosing the species(s) for the targeted plantation area. The choice of a species for a breeding program and thus for plantation is a crucial decision. They must be adaptive to the climatic and edaphic factors and resistant to pests and pathogens. After identifying one or more species, the tree improvement program utilizes the natural genetic variation included within species to repackage it into desirable individuals with fast growth, pest/pathogen resistance created by intermating to use in plantations (White et al. 2007). Simply stated, the practical intend of tree breeding is to allow us to alter certain traits of trees or their products to improve their utility, quantity, or value (Daniels 1984). As can be seen, the use of production population, like seed orchards, generated by tree breeding is essential for plantation forestry to increase quality and quantity of wood and fiber in a unit area. The gain from a tree breeding program can be realized by transferring genetically improved material to seed orchards and mass production for the plantations.

Historically, Evans (2009b) indicated that the first woody species which was selected and planted was olive trees about 4000 BC and divided planted forest history into four main periods for: before 1900, 1900-1945, 1945-1980 and 1980-present. Between 1900-1945, most tropical plantations for wood production consisted primarily of pines, eucalyptus, and teak. However, major plantings of trees were non-wood forest products. After 1945, with evidence of the increasing awareness of the silvicultural potential, the plantations were subjected matter of international conferences and meetings like Fourth World Forestry Congress (1954) in India, the Seventh British Commonwealth Forestry Conference (1957), the FAO Seminar on Tropical Pines in Mexico (1960). Then, these initiatives and the gathering momentum of interest prompted the crucial ‘FAO World Symposium on Man-Made Forests and their Industrial Importance’ in 1967. The symposium, with participants from 41 countries produced over 2000 pages of manuscripts confirmed the essence of plantation and widening position all over the world. With the effect of understanding genetic principles on increasing productivity of plantation in the 1950s and maturing of an old plantation, plantation forestry accelerated in 1980's. Indeed, Daniels (1984) characterized the plantation forestry as a relatively modern development meaning a significant departure from classical forestry practice based on the concept ‘sustained yield’.

The importance of plantations and silviculture of plantations were covered extensively (Shepherd 1986). This work described detailed explanations and directions of silvicultural practices for sustainable management of intensive plantations. As an indicator of plantations' importance, it was understood that many countries continued plantation programs whereas some countries massively expanded plantations in the 1980s. Genetically improved material use was also expanded in that period (Evans 2009b). Then, FAO started a ‘Global Planted Forest Thematic Study’ including comprehensive examination of whole planted subsets, determining quantity and quality planted forest resources and analyzing regional and global status of planted forest development (Carle et al. 2009). In the period of 1990-2015, they have annually increased 3.3 million hectares and have reached 291 million hectares in 2015, constituting 7% of the totally 4 billion hectares forest areas in the world (FAO 2016). When plantations constituted 5% of the total forest area, they produced 35% of total wood production in the world (FAO 2001, Carle et al. 2002). An essential tendency continued to increase the sharing of plantations in total wood production. Indeed, Payn et al. (2015) indicated that roundwood production from plantation in the world was 46.3% and could be reached to 89.8% in South America in 2012. On the other hand Carle and Holmgren (2009) estimated that plantation areas would change from 261 to 303 million hectare by 2030. Considering that the plantation area in 2015 was 291 million hectares, the estimation of Carle and Holmgren (2009) seems reasonable. Consequently, plantations have been an integral part of compensating wood demand in the world.

Expansion of plantations in the world has been related to tree breeding programs. The breeding material as the output of tree breeding programs has been widely used in the plantations and wood production from plantations was tangibly increased (Li et al. 1999, White and Byram 2004, Burdon et al. 2008, Haapanen et al. 2015, McKeand 2019). The advanced tree programs reached the 4th cycle and beyond to increase genetic gain from plantations (Isik and McKeand 2019). Using genetic material supplied by tree breeding in plantations can increase the yield, quality, resistance to insects or disease substantially. For example, in *Pinus taeda* the estimated genetic gain in volume for the third-cycle loblolly pine was 63% compared with the unimproved checklot in one of the most advanced tree breeding programs in the world (McKeand 2019).

The Combination of Silviculture and Tree Breeding for Planted Forests

The importance of planted forests to meet global needs for wood and provide various environmental services has been well documented. In this context, tree breeding and silvicultural applications were categorized as the major disciplines to increase the productivity of plantations (Burdon and Moore 2018). They underlined that tree breeding covered selective breeding, delivery systems for genetic gain, arrangement for the deployment of improved breeds or clones to site and silvicultural regimes, whereas silviculture involved to raise or keep site productivity using fertilizer and controlling vegetation competition, pests and disease, to safe stocking control for using of site potential and growing in target trees, and to enhance wood quality by handling of stocking.

Tree breeders commonly use the following formula to explain the derivation of the character of the individual we observe: $G + E = P$. In this equation, P is phenotype, G is genotype and E is environment. Using this equation, Hubert and Lee (2005) characterized the relation between silviculture and breeding. According to this, G is the genotype or genetic make-up of the individual. The E is the environment of genotype. Tree breeding focuses on G to improve the desired traits for silviculture to practice on. Silviculture focuses on E to alter the environment to increase the yield. Some of the silvicultural tools commonly used in plantations are planting spacing of trees, vegetation control, nutrition, thinning etc. The sum of all individual tree characteristics that makes a plantation are contributed by G and E. On the other hand, P is most commonly assessed in terms of external appearance. While G means tree breeding, partly E and partly G means silviculture. Climate variables are part of the E but they cannot be altered by the silvicultural practices. Stanturf et al. (2003) estimated the contribution of tree breeding and silviculture components in southern pine plantation. Silvicultural practices include the stocking control, nutrition, vegetation management, seedling quality, pest management, soil site classification, and site preparation. The contribution of site preparation (silviculture) and tree breeding were the top two factors, and explained 21% and 20%, respectively (Fig. 1). The rest of the contribution was made by the factors related to silviculture.

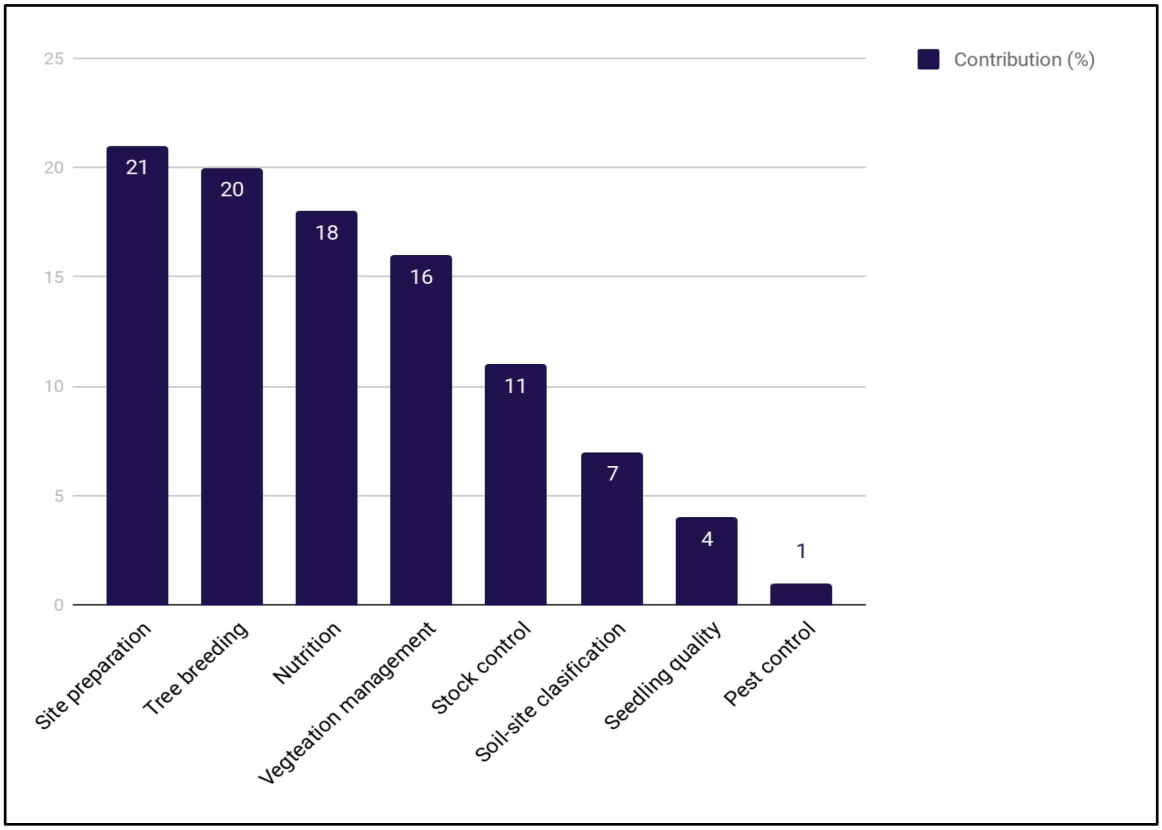

Figure 1. Contributions of the silvicultural practices and tree breeding to wood and fiber productivity in pine plantations in the southern United States (after Stanturf et al. 2003).

Southern United States pine plantations were the major success story in the world for forestry mainly contributed by the tree breeding and silviculture applications (McKeand et al. 2003, Schmidtling et al. 2004, Fox et al. 2007). While the plantation area was less than 2 million acres (~810 000 hectares) in the 1950s in the US South, they reached 32 million-acre (~13 million hectares) by the end of the 20th century. Similarly, production in plantation in the 1960s was ~1 m^3 ha yr^{-1} and it increased to ~4.5 m^3 ha yr^{-1} in the 2000s. The success was a combination of genetic improvement and intensive silviculture in these plantations. Therefore, this region has been characterized as the world's wood basket.

Fox et al. (2004 and 2007) also estimated contribution of production in plantation and compared with natural stand production. The contributions to the production of plantations were site preparation, fertilization, weed control and tree breeding. The contribution of tree breeding in these studies was limited in 1960 and increased in 2010 to about 5 times that of 1960. That is, the rate of contribution of tree breeding to production has steadily increased. Related to the same plantations, McKeand et al. (2003) indicated that 1st, 2nd and 3rd generation seedlings contributed to plantations as 46%, %54 and %0, respectively. In 2018, these contributions of loblolly pine (*Pinus taeda*) for 1st, 2nd and 3rd generation's seeds were 0%, 25% and 75%, respectively (TIP 2019). The 3rd generation seeds also include 4th generation seeds. These trends also reflected seedling prices. The price of open pollinated, the best full sib and clonal varieties were $50, $230 and $350 per thousand seedlings, respectively in the southern United States. Therefore, the estimated gain in volume for the third-cycle was 63% compared with the nonimproved checklot (McKeand 2019).

Applications of combination tree breeding and silviculture can reduce rotation ages due to increasing production of wood per unit time and unit area. Indeed, Fox et al. (2004) showed that rotations age decreased from 50 to under 20 years from 1940 to 2010 due to tree breeding and intensive silviculture. They also underlined that tree breeding, site preparation, weed control, fertilization and density management could considerably increase the financial return from forest management. The driving factor of the realizations of return was mostly the implementation of intensive silviculture in the 1980s and 1990s. However, foresters have used genetic information and deployed better genotype to higher-quality sites that will be managed more intensively in recent decades. Therefore, contribution of tree breeding to wood production in plantations might be more in the future.

Hubert and Lee (2005) reviewed the effect of silviculture and tree breeding on Sitka spruce and concluded that silviculture and tree breeding were powerful tools in increasing the quality and quantity of tree crops. They also indicated the contribution of silviculture and tree breeding to production and suggested a specification related to tree breeding or silviculture or both of Sitka spruce (Table 1). As can be seen in Table 1, tree breeding was specified for short rotation, plantation, and highly heritable traits. However, silviculture was specified for almost all specifications. Since breeders were aware of the importance of silviculture, many literatures related to breeding indicated that genetic material should be used with intensive silviculture for the maximum potential of production in plantations (Zobel and Talbert, 1984, Li et al. 1999, Haapanen et al. 2015, Burdon et al. 2017, McKeand, 2019).

Plantations have reached an important stage in wood production, environmental and soil protection and non-wood production shoving multiple functions of plantations (Evans 2009d). Considering the trend from past to present, it is conceivable that plantations will substitute natural forests. This hypothesis would be difficult to prove. Indeed, Shepherd (1986) and Evans (2009e) stated that natural forests would continue to be important based on forested areas and wood production. Besides, they underlined that plantations would not be an alternative to natural forests, but they can reduce the pressure on natural forests, and complement natural forests (Li et al. 1999). Due to the significant contribution of the plantations to wood production in the world, natural forests can be managed for biological diversity, watershed management, soil protection, gene conservation, and national parks. In this context, forest management and specifically silviculture can be introduced new approaches to sustainable management of both natural forests and plantations. Using knowledge of forest biology and ecology silviculture should be the practice of creating, managing, and conserving forest (natural and plantation) to meet desired goals, needs, and values. On the other hand, considering new approaches like genomic selections, biotechnology, tree breeding seems to widely contribute to wood production in plantation in the near and long future.

Table 1. A list of indicators of using silviculture practices versus using genetic improvement or both to increase the productivity and vigour of plantations (Huber and Lee 2005).

Indication	Consider Silviculture	Consider breeding
Trait to be improved is highly valuable	✓	✓
The trait has to high heritability		✓
The trait has a low heritability but a high natural genetic variation		✓
Trait takes a long time to evaluate in the field	✓	
Flowers at a late age (35+)	✓	
Flowers young (<25)		✓
Easy to vegetatively propagate		✓
Suspect wide-scale interaction with the environment within given region of provenance	✓	
Large areas to be planted and management	✓	✓
Small areas to be planted and management	✓	
Want to develop populations for intolerant sites		✓
Want to immediate and long term return	✓	✓
Intend to natural regeneration	✓	

Conclusion

Plantations in the world have reached 291 million hectares compensating for 43% of wood production in the world. Silviculture and tree breeding are the two main components of plantations. Silviculture is an integral part of forest management in solving forestry problems using the facilities of biology and ecology. Using intensive silviculture in the plantation is essential to meet the demand for wood production in the world. The role of tree breeding in the plantation has also been steadily increased since 1950 and is expected to play more role in the future. However, without intensive silviculture, only using tree breeding is insufficient for maximizing gain from plantations. In conclusion, silviculture and tree breeding complement each other in plantation management to produce wood and fiber in a sustainable way while reducing pressure on natural forests in the world.

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Effects of regenerative cutting on the height growth of Turkey oak (*Quercus cerris* L.) saplings

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Abstract

Turkey oak (*Quercus cerris*) is distributed at the northern, western and southern Anatolia in Turkey. Although these forests are managed by shelterwood systems, degraded forests are subjected to artificial regeneration. In this context, the mature Turkey oak stands in Sipahiler Forests sub-district affiliated Sütçüler Forest District Directorate in Isparta, which did not have natural regeneration conditions, were artificially regenerated by acorn point sowing under the stand shelter. Although the regeneration was successful, the seedlings did not realize sufficient growth. In this context, regenerative cuttings (1- cutting all saplings in the plots from just above the ground level, 2- Cutting saplings from 10 cm height above the ground level, 3- Leaving only one individual at the each sowing plot (excluding the lateral stems) and pruning, 4-Leaving only one individual at the each sowing plot (excluding the lateral stems) without pruning and 5- Control without any cutting and pruning) were applied to the saplings and the 4 years' height growths of saplings were measured. The treatments were realized just before the vegetation period of 2014 and first measurements were done after the cuttings. To determine the height increment, second measurements were carried out after the vegetation period of 2017. As a result of these measurements, the height growth increment for each treatment was realized as follow: 75.25 cm for the saplings cut from ground level, 61.98 cm for the saplings cut from 10 cm height from ground level, 33.62 cm for the saplings of thinned and pruning, 32.80 cm for the saplings of thinned without pruning and 32.80 for the saplings of control. In final, the height growth of regenerative cutting saplings reached to those which were not subjected to cuttings. These results showed that regenerative cutting is promising to foster the growth of Turkey oak saplings. But for a better understanding, longer observation is needed to see the growth differences between the saplings subjected to regenerative cuttings and others, since the height of regenerative cutting saplings is not higher than the others yet.

Keywords: artificial regeneration, degradation, sapling, sprouting

Introduction

The oak genus has a wide distribution in the temperate and subtropic regions of the Northern hemisphere (Nixon 1993) and is represented by over 350 species (Yılmaz 2018). Seventeen oak taxa are naturally distributed in Turkey. These taxa are divided into 3 groups according to the anatomical structures of the wood, the ripening period of the fruit and the leaf characteristics (Yaltırık 1984). These are white oaks, red oaks, and evergreen oaks. Turkey oak (*Quercus cerris*) subjected in this work is one of the oak species under the red oak group.

Oak species are widely distributed in Turkey. In addition to their pure forests, they form mixed ones with other deciduous trees and coniferous as well (Mayer and Aksoy 1986). Especially the steppe forests in the inner and eastern Anatolia are characterized by oak species like *Quercus pubescens* and *Q. brantii* (Akman 1995)

Turkey oak is mainly distributed at the northern, western and southern parts of Turkey which are dominated by Black sea and Mediterranean climates respectively (Yaltırık 1984, Yılmaz 2018). In addition to the pure forests at the north it makes mixed stands with other oaks like *Q. frainetto* and *Q. petraea* and *Fagus orientalis* and the site conditions of these forests were well studied Tecimen et al. (2010, 2013). In the Mediterranean areas, Turkey oak generally forms mixed stands with *Pinus nigra* and shows local pure stands like in Alanya (Antalya), Sütçüler –Eğirdir (Isparta) and Dirmil (Burdur) provinces (Kavgacı et al.2018). Turkey oak also has a wide distribution along the Southern Europe and Balkan (de Rigo et al. 2016).

Like the other oak species, Turkey oak has the sprouting ability as well (Simeone et al. 2019, Odabaşı 1976). Due to that, some Turkey oak forests at northern Turkey were managed as coppice (Odabaşı 1976). But today, conversion studies of these forests to high forests have been still continued (Anon. 2006-2015). Differently from its northern distribution, Turkey oak stands in the Mediterranean parts of Turkey were not managed as coppice. The fact that these areas are generally dominated by sclerophyllous scrublands, forests, and coniferous forest as a result of the Mediterranean climate and the distribution of deciduous forests is limited may be the reason why the deciduous forests in the region were not attempted to manage as coppice. However, the Mediterranean landscape has been under the dense human use for centuries and Mediterranean ecosystems are accepted as man-made ecosystems (Perevolotsky 2005). Turkey oak forests were also affected by human use and mostly degraded, most of which have coppice structure supplying them to sustain during the years. These dense human use resulted in the broken stand structures. Due to that stand structure of Turkey oak forests in the Mediterranean areas is completely different from those in northern Turkey and natural regeneration conditions in these forests almost lost. This process makes artificial regeneration only one solution for the regeneration of degraded mature Turkey oak stands in the Mediterranean areas of Turkey.

As a result of this process, the mature Turkey oak stands in the Sipahiler Forests Province of Sutçüler Forest Enterprise in Isparta were artificially regenerated in 2009 by the method of acorn point sowing under the stand shelter. The regeneration success was high in the area. But during the technical visit to the regeneration area in 2013, it was seen that the growth performance of the saplings was not sufficient. As Turkey oak also has sprouting ability during the initial ages, it was decided to realize a study on the effects of regenerative cuttings on the growth of Turkey oak saplings in the area. Therefore, in this study, we hypothesized that regenerative cutting positively affects the growth of Turkey oak saplings.

Material and Method

This study was carried out in a Turkey oak stand in the Sipahiler Forest Sub-district of Sütçüler Forest Directorate affiliated Isparta Forest Regional Directorate (Fig. 1). The southern part of Sütçüler province is under the dense effect of Mediterranean climate while the northern part of the province consists of an intersection from the Mediterranean to continental climate (Sargın 2009). The study area is located on this intersection. The annual precipitation in Sütçüler province is 914.7 mm. The annual mean temperature is

13,03 °C. The coldest mount of the year is February with 3,3 °C, while July is the hottest mount of the year with 3,9°C. The highest part of the precipitation appears in December and November while it is the lowest in August and July (Büyükgebiz et al. 2008).
The altitude of the study area is about 1050 m. The Turkey oak stand belt in the area represents a transition from *Pinus brutia* forests at the lower vegetation zone to *P. nigra*, *Juniperus excalsa*, *J. foetidissima*, and *Cedrus libani* forests, which are the common tree species of the higher vegetation belt in the region. The scrub layer in the study stand is low and the herb layer is mainly dominated by perennial graminoids.
The topography of the stand was almost flat. It was a degraded forest with low canopy closure. Since natural regeneration conditions were lost, it was artificially regenerated. For this goal acorn point sowing under the stand shelter was applied in 2009. One acorn was sowed in the each sowing point with 1 m distances in a line. The regeneration success of the area was successful, but the saplings were not able to perform sufficient growth performance. In this context, it was thought that regenerative cutting can foster the sapling growth and a sampling design based on regenerative cutting was realized just before the vegetation period of 2014.

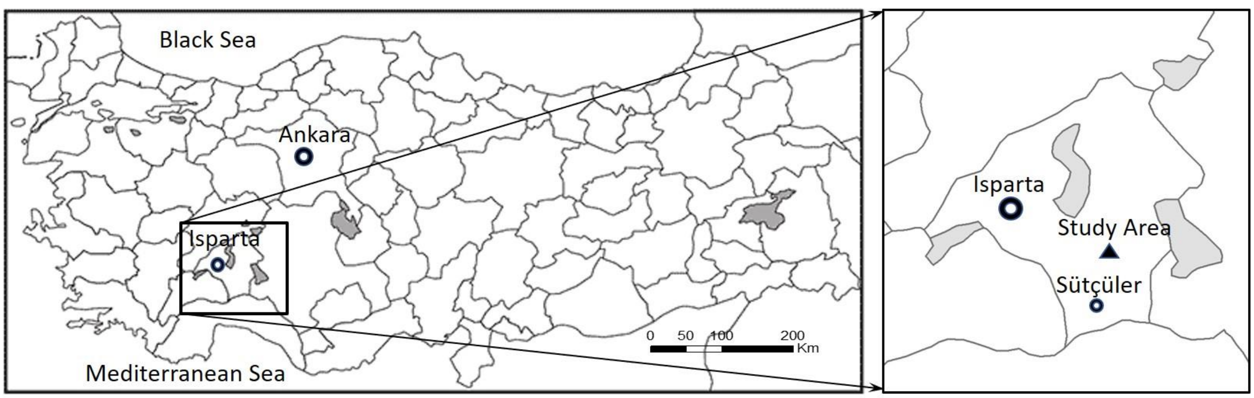

Figure 1. The geographical location of the study area.

The sampling design was set according to the randomized complete block design with 4 replication. Including the control, 5 different treatments were applied (Table 1). After the regenerative cutting in 2014, heights of saplings were measured in cm and recorded. These measurements were repeated after the vegetation period in 2017 to see the growth performances of each treatment.
Table 1. The treatments used for the regenerative cutting.

No	Treatment
1	Cutting all saplings in the plots from just above the ground level
2	Cutting saplings from 10 cm height above the ground level
3	Leaving only one individual at the each plot (excluding the lateral stems) and pruning
4	Leaving only one individual at the each plot (excluding the lateral stems) without pruning
5	Control parcels without any cutting and pruning

After the field measurements, the data were statistically evaluated. Normalization tests were applied to the data. Then, variance analyses were carried out for height increment and heights of 2017. As the difference appeared between groups, the Tukey test was applied to understand the level of difference between treatments.

Results

Regenerative cuttings on saplings were carried out just before the vegetation period of 2014. The heights of these saplings after the regenerative cutting application are shown in Table 2. The second measurement on the sapling was realized after the vegetation period of 2017 to see the effects of treatments. The height of the saplings after the 2017 measurement is submitted in Table 3. So, four years' height growth (cm) of saplings were observed in the study.

Table 2. The heights of the saplings after the regenerative cuttings in 2014. See the Table 1 for the explanation of the treatment legends.

Treatment	N Obs	Minimum (cm)	Maximum (cm)	Mean (cm)	Std Dev	Std Error
1	60	1.00	1.00	1.00	0.00	0.00
2	60	10.00	10.00	10.00	0.00	0.00
3	60	20.00	76.30	40.88	11.05	1.43
4	60	22.00	72.00	42.03	9.01	1.16
5	60	10.00	64.00	41.81	11.39	1.47

Table 3. The heights of the saplings after the second measurement in 2017. See the Table 1 for the explanation of the treatment legends.

Treatment	N Obs	Minimum (cm)	Maximum (cm)	Mean (cm)	Std Dev	Std Error
1	60	35.00	139.00	76.25	22.72	2.93
2	60	37.00	116.00	71.98	15.86	2.05
3	60	30.00	155.00	74.50	27.66	3.57
4	60	42.00	129.00	80.83	22.25	2.87
5	60	21.00	118.00	74.51	20.81	2.68

As a result of these measurements, the height growth increment for each treatment was realized as follow: 75.25 cm for the saplings cut from ground level, 61.98 cm for the saplings cut from 10 cm height from ground level, 33.62 cm for the saplings of thinned and pruning, 32.79 cm for the saplings of thinned without pruning and 32.70 for the saplings of control (Table 4). As the proportion of 2014 measurements to 2017 ones is observed, it is seen that the proportion of control is higher than all of the others (Table 5). But the proportion of the saplings cut from the ground level is lower than the others. It is followed by the saplings cut from 10 cm height. The heights of each treatment for the year 2014 and 2017 is shown in Figure 2.

Table 4. Height growth increment of the saplings. See the Table 1 for the explanation of the treatment legends.

Treatment	N Obs	Minimum (cm)	Maximum (cm)	Mean (cm)	Std Dev	Std Error
1	60	34.00	138.00	75.25	22.72	2.93
2	60	27.00	106.00	61.98	15.86	2.04
3	60	3.500	102.00	33.62	21.52	2.77
4	60	1.00	79.00	38.79	19.47	2.51
5	60	3.00	84.00	32.70	19.20	2.47

Table 5. The proportion of the heights measured in 2014 and 2017 respectively (2014/2017). See the Table 1 for the explanation of the treatment legends.

Treatment	N Obs	Minimum (cm)	Maximum (cm)	Mean (cm)	Std Dev	Std Error
1	60	0.007	0.028	0.014	0.004	0.0006
2	60	0.086	0.270	0.145	0.032	0.0042
3	60	0.311	0.927	0.587	0.152	0.0196
4	60	0.288	0.976	0.548	0.155	0.0200
5	60	0.107	0.938	0.591	0.169	0.0218

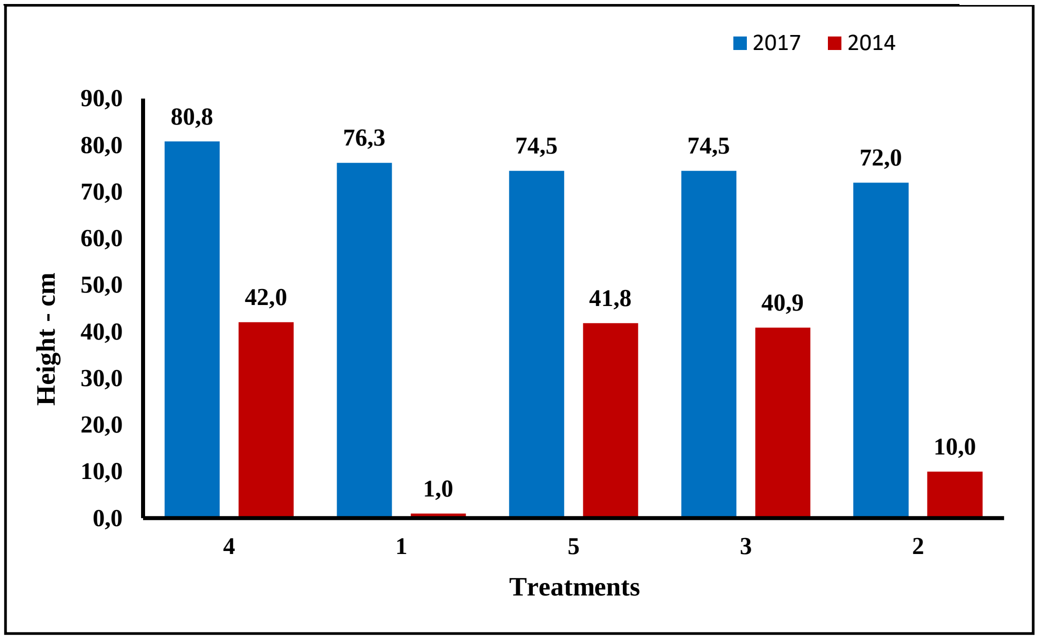

Figure 2. Sapling heights of treatments for 2014 and 2017 measurements. See the Table 1 for the meaning of treatment legends.

To understand whether there are differences between treatments or not, variance analysis was carried out for the measurements of 2017. According to the analyses, it was seen that there were no differences between treatments (Table 6). However, a clear difference occurred between treatments in terms of height increments (Table 7). The saplings cut from the ground level, which showed the highest height increment, was differentiated from other increments (Table 8). It is followed by the saplings of 10 cm height cut treatments as a different group. The other treatments were grouped and showed a similar height growth increment.

Table 6. Variance analysis of height of 2017 measurement.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	806.720	268.906	5.80	0.011
Treatment	4	173.091	43.272	0.93	0.477
Error	12	556.507	46.379		

Table 7. Variance analysis of the sapling height increments between 2017 and 2014 measurements.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	594.412	198.137	7.19	0.0051
Treatment	4	5850.140	1462.535	53.05	<.0001
Error	12	330.819	27.568		

Table 8. Tukey test results for the height growth increment. Means with the same letter are not significantly different. See the Table 1 for the meaning of treatment legends.

Treatment	N	Mean	Tukey Grouping
1	4	75.25	A
2	4	61.98	B
4	4	38.79	C
3	4	33.62	C
5	4	32.70	C

Discussion

The trees are generally known as single plants, erect woody trunks. However, some trees, especially those of Angiospermae, are able of sprouting, which is an induced response of trees to injury or a dramatic change in surrounding environmental conditions (Del Tredici 2001). Sprouting is an important adaptation ability of woody species against the environmental or anthropogenic effects (Retena et al. 2012) especially in Mediterranean type climate areas (Pausas 1999). In the Mediterranean basin, in which Turkey is located on the eastern side, fire, herbivore activity, and clear-cutting are common disturbances and plants have adaptive traits letting them survive after disturbances one of which is sprouting (Vergaquer et al. 2000). Girardclos et al. 2017 stated that sprouting ability is determined by the development, protection, and resourcing of available bud bank, after fire and other dramatic disturbance events such as flooding or wind storms.

Del Tredici (2001) pointed out that sprouting in trees occur in four different ways: collar sprouts from the base of the trunk, sprouts from specialized underground stems, sprouts from roots and opportunistic sprouts from layered branches. Oak species represent the different origins of sprouting. Turkey oak has also sprouts from the base of the trunk. Because of this characteristic, Turkey oak forests like other oak-dominated forests were managed as coppice for years although its wood quality is not high as much as other oak species (de Rigo et al. 2016) distributed in Turkey like *Q. petraea* and *Q. frainetto*.

Differently from the high forests, coppice sustains the same genetic structure for centuries resulting in the narrowing in the genetic diversity (Çalıkoğlu and Kavgacı 2001). Similarly, stand structure is degraded in coppice (Leibundgut 1984). Additionally, soil productive decrease, soil-plant water balance is broken, timber quality and product range are low in coppice (Odabaşı 1976, Kalıpsız 1984). These negative characteristics of coppice caused an action of conversion of coppice to high forests in Turkey (Anon 2006-2015). Similar actions on the conversion of coppice also common for other countries in which coppice is a common management system of deciduous forests (Amorini et al. 1996).

The sprouting ability of Turkey oak supplied it to sustain its distribution in Mediterranean areas in which human use was very intense for centuries and the climate is not suitable for deciduous tree species as much as sclerophyllous species and coniferous. The sprouting character of Turkey oak is common through all its life stages from juvenile age till mature one. Del Tredici (2001) indicated that the time of sprouting in the life cycle of a tree is more important than the morphological origin of the sprout and mentioned that sprouting in the early stages promotes the survival under a variety of stressful conditions.

Although it is different by species, oak-dominated forests are managed by shelterwood and clear-cutting systems (Jo Schweitzer et al. 2016). But clear-cutting needs special conditions like the sufficient amount of juveniles appearance under stand shelter and mesic site conditions. Due to that, the shelterwood system is more suitable and applicable for the natural regeneration of oak-dominated forests. Due to the biological and ecological characteristics of oak forests in Turkey, they were managed by the shelterwood system (Odabaşı et al. 2004). But as the natural regeneration conditions are lost, artificial regeneration is applied to the mature oak forests. One of the methods of artificial regeneration in the oak forests is the acorn point sowing under stand shelter. In this context, the degraded Turkey oak stands in the Sipahiler forest district in Sütçüler forest enterprise in Isparta Turkey were artificially regenerated by this technique. Although the regeneration was successful, the sapling did not perform sufficient growth. In this context, this study based on regenerative cutting to foster the growth of sapling was carried out.

At the end of the four years' growth period after regenerative cutting, the saplings cut from ground level and 10 cm height reached the other treatments and no difference between treatments appeared in terms of height. So, these two saplings showed a clear height growth increment and reached the other treatments. The saplings of ground-level cut showed the highest height increment. The treatments of thinning in the points did not differ from the saplings of control in terms of height increment.

The rapid growth of the saplings subjected to the regenerative cuttings showed the potential use of this applications to the slow-growing regenerations or degraded initial stage stands of Turkey oak. However, despite the rapid growth, these saplings reached the same heights to control at the end of the four years' observations. Therefore, to make a silvicultural suggestion for the managers, a longer period of observation is needed to see whether these saplings will continue their rapid growth against the other saplings or not.

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Evaluation of the natural geophyte taxa of Sarıyer (Istanbul) and their use in urban landscape

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Abstract

Within approximately 5461 km^2 area and 16 million population, Istanbul is considered to be the most important and most crowded city of Turkey. In addition to its unique beauties, it attracts the attention of nature lovers and plant scientists especially with its rich variety of plants which is more than many other countries in the world. 7,2 % of this floristic richness is composed of "geophytes"; which are the plants with bulbous, tuberosus, corm or rhizomous root systems. Sarıyer district, which is located in the north side of Istanbul and being an important part of the city's floristic richness has been chosen as the study area. The floristic diversity of the district is mostly because of the biodiversity of natural forest called Belgrad Forest. In this study, investigating the geophytes of the Sarıyer district, one of the greenest districts of Istanbul, evaluating their aesthetic properties and examining the possibilities of their use in landscape designs is aimed. For this purpose, plant features and design characteristics, habitats and endangerment categories of Sarıyer geophytes have been studied in detail using various sources. As a result of this study; it is found that there has been 44 native genus and 98 exotic geophyte taxa belonging to 12 families. 27,27 % of the genera are belong to Orchidaceae family and it is followed by Amaryllidaceae family with 18,18 %. Also the geophytes in the study are mostly having tuberous root type with 38,78%. When the habitats of these taxa has been evaluated; forest, forest edge areas and shrubs has been found to be the highest rate of 19,85% and 19,73%. When we evaluate the geophyte taxa of Sarıyer in case of their use in landscape designs, their flower colors, flowering periods and textures has become important. In Sarıyer district mostly white and yellow flowering geophyte taxa has been found with 21,43% and 20,41% ratio. It is also seen that most of the geophyte taxa are flowering in March with 23,96% and most of them are 3 months flowering. Also most of them are found to be fine textured with 59,18%.

Keywords: Landscape design, Plant, Geophytes

Introduction

Today, ecological approaches in landscape design have been popular within the concept of sustainability. The necessity of landscape designs compatible with the natural habitats and native plants has arisen (Korkut et al. 2017, Zencirkiran et al. 2018). Plants and planting designs that are the basic elements of landscape design should be responsive with nature. Many features of plants such as line, form, texture and color should be evaluated and the best way of design should be done and the used plants should be appropriate to the ecology of the area (Ayaşlıgil 2005) In this sense, the use of natural plants in the landscape design is of great importance.

Turkey is one of the most important countries of the world in terms of natural plant diversity. Its diversity is because of climate differences, topographic variations, geological and geomorphological variations, diversity of different aquatic environment such as marine, water, river etc., height differences ranging from 0-5000 m and differences in the location of three different phytogeographic areas (Ekim 2005). Within the flora researches in recent years it is revealed that Turkey's flora consists of about 12,500 plant taxa (Özhatay et al. 2003). Geophytes which are the plants that have rhizome, bulbous and tubular root system, is an important part of this rich flora. According to Davis (1965-1985) geophytes are represented by nearly 600 plant taxa in Turkey and about 40% them is endemic. This number is 800 according to Güner (2006) and 900 according to Kandemir and Yakupoğlu (2016).

In general, geophytes spend most of the year under the ground, the above-ground parts turn yellow after the growth is complete, and eventually dry out and die. However, the storage organs under the soil continue to survive (Anonymous 2019). Geophyt types include bulbs, corms, tubers, tuberous stems, tuberous roots, rhizomes and pseudobulbs (Kamenetsky and Hiroshi 2013). Although they are blooming in almost all seasons, they are generally classified as “spring geophytes” which are planted in autumn and bloom in spring and “fall geophytes” which are planted in spring and bloom in summer (Kılıçaslan and Dönmez 2016).

Geophytes has an economic value due to their remarkable flowers and their use in the pharmaceutical industry (Güner et al. 1991). They are the most preferred plants among ornamental plants due to their aesthetic properties, fragrances and usability as cut flowers (Çığ and Başdoğan 2015). The importance of geophytes has been begun to understand in recent years and especially *Tulipa* sp. and also *Muscari* sp., *Narcissus* sp. and *Hyacinthus* sp. have been participated in the landscape designs.

In order to create a composition, it is important to know the structural and visual characteristics of plants. The colors, line and texture properties of the plants should be evaluated and arranged in the best way and should be in accordance with the ecology and structural character of the area to be applied (Ayaşlıgil 2005; Düzenli et al. 2018). Color in design, affects human emotions by facilitating visual perception. Because of its contribution to design, a pleasing coordination of colors will be the goal.

One of the most important elements to be considered in the designs of geophytes is the “color”. While two or more types of flower colors of geophyte taxa are preferred in large areas, it will be more effective to use one flower color in small areas. In large areas short heighted, small flowered and fine textured geophytes such as *Scilla* sp., *Crocus* sp. and *Colcihicum* sp. are preferred to create continuity in design. In general with almost every period of the year geophytes are flowering but mainly they are flowering in spring and autumn. Flowering periods of them are chancing according to the species. With a wisely design the beautiful appearance of their flowering can be spread in a year. (Seyidoglu et al. 2009). As a matter of fact, the importance of colors is undeniable in designs to be made with geophytes as in other landscape plants. As such, the use of bright yellow-flowered *Strenbergia* sp. and light purple-flowered *Colchicum* sp. in groups adds charm and feelings of joy and self-confidence. With the use of *Hyacinthus* sp. with its fragrant purple-colored flowers together with light yellow flowering *Narcissus* sp. evoke joy, purity and innocence, as well as the creation of beautiful looks. In the silent and shady places, the selection of white-flowered species ensures both color harmony and continuity (Seyidoglu et al. 2009; Zencirkıran et al.

2018). Very beautiful looks can be obtained with spherical and spiral shaped flowers with *Allium* sp., *Cammasia* sp. and *Galtonia* sp.

Along with color, many factors such as form, texture, flowering time and flowering periods should not be overlooked in designs. The flowering times of the geophytes vary according to the species and in the design to be made, by applying in a way that the flowering times will span one year, and so beautiful views will be obtained throughout the year.

However, the most effective and natural looks can be created with informal drifts or group plantings in the use of geophytes. While using geophytes as drifts, it is an important approach to design using topography in the form of gently climbing a hillside or surrounding a high point. Another approach is to create a naturalizing effect by sprinkling geophytes on the area. For this purpose, short-sized, small-flowered or fine textured species such as *Scilla* sp., *Crocus* sp., *Colchicum* sp. should be preferred. On the other hand, using geophytes in groups in combination with other plant species, gives the garden continuity and charm. Tall geophytes such as *Lilium* sp., *Fritilllaria* sp., *Tulipa* sp. can be used together; and also the shorter ones such as *Muscari* sp., *Galanthus* and *Crocus* sp. can be used together. It is possible to create a pleasant effect with the use of *Colchicum* sp. in combination with thin-shaped shrubs and using species such as *Anemone blanda* and *Scilla nutans* under trees (Anonymous 2018, Seyidoğlu et al. 2009).

In order to bring different species to the urban landscape, it is important to identify the current status of the geophytes in flora, and to introduce the species to be cultured by evaluating their design features and habitats. From this point, this study deals with the Sarıyer district which is a part of Belgrad Forest and also has different habitats and has appropriate geography for the geophyte taxa. For revealing the current status of natural habitats and plant and design characteristics of geophytes for urban landscape designs has been examined and suggestions have been developed.

Material and Methods

Study area

Sarıyer district has been chosen as the study area because of its geographic location, hosting different habitat types and its high diversity of geophyte taxa. The main material of the study is composed of the natural geophyte taxa of Sarıyer district.

Sarıyer district is located on the European side of Istanbul at the intersection of approximately 41^0 N latitude and 29^0 E longitude. Sarıyer is bordered by Bosphorus in the east, Black Sea in the north, Eyüp in the west, Şişli and Beşiktaş in the south. On the one hand the border with the Bosphorus, on the other hand the fact that the border to the Black Sea increases the level of development. The settlement lies along the coast in Sarıyer. Its surface area is 152,26 km^2 and its altitude is 74m. (Figure 1).

Sarıyer has a temperate and humid climate type. The Walter climate diagram of Sarıyer district according to 1950-2015 climate data has been given on Figure 2 and Table 1. Therefore, Sarıyer is one of the richest districts of Istanbul in terms of plant diversity. The eastern end of the Belgrade Forest is introduced into the district. Furthermore, the area within the Rumelikavağı-Rumelifeneri-Kilyos triangle is largely covered with forests. Sarıyer has the characteristics of Black Sea climate in general. It is mild and humid climate type (Anonymous 2015-2019).

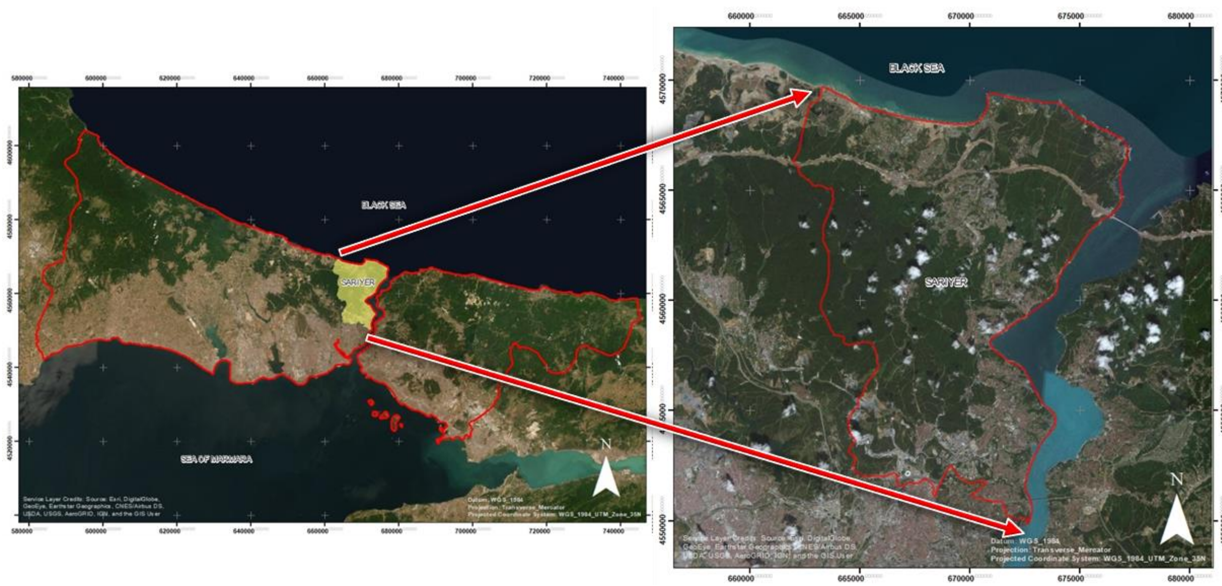

Figure 1. The location of research area in Istanbul

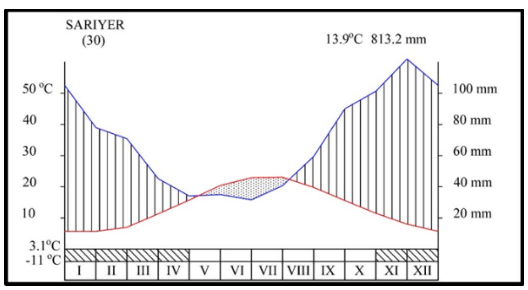

Figure 2 - Climate diagram of Sarıyer (Walter, 1960)

Table 1: The average mean temperature and precipitation data of Sarıyer

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
MAT.	5,7	5,7	7	11,1	15,7	20,4	22,9	23,1	19,8	15,6	11,5	8
MAR.	105	78	70,8	45,2	34,1	35	31,6	40,7	59,5	90	101,3	122

MAT=Mean Annual Temperature, MAR=Mean Annual Rainfall

The district is generally composed of hills and valleys. Due to the terrain, transportation is limited. It is surrounded by seas on both sides and has a coast length of 47 km. On the coast, after a narrow coastline, very steep slopes rise. Among the major elevations seen within the borders of Sarıyer are; Büyüktepe, Tarabya, Maltıztepe, Kocataş Hill, İbrahim Paşa Hill, Şeytandağı, Tabya Hill, Kartaltepe and Ağlamışbaba Hill (Anonymous 2015-2019).

There are many small and large rivers within the borders of the district. Sarıyer has shores to the Black Sea and the Bosphorus. The beaches facing the Black Sea are steep slopes and forested. Black Sea Coast is quite indented protruding on the east of Kumköy but the west part is flat. (Anonymous 2015-2019)

Methods

Data collection, observation and evaluation methods have been used in this study. In the data collection stage, the natural geophytes of Sarıyer, has been evaluated from different references (Bayraktar 2013, Çolak et al. 2013, Davis 1965-1985, Davis et al. 1988, Güner et al. 2000, RHS 2019, Tubives 2004, Yaltırık 1963, Yönelli 1986).

The situated geophyte taxa were evaluated in 2 categories such as 'plant features' and 'design features'. In the concept of plant features; the underground organ structures has been categorized as bulbous, rhizom, tuber and corm. And also the geophyte taxa were evaluated as genus, species or subspecies according to their families. On the other hand, geophyte taxa have been classified according to the endangerment categories by making benefit of 'The Red Data Book of Turkey's Plants' and 'IUCN Red List Categories' (Ekim et al. 2000, IUCN 2019). According to these criteria the geophyte taxa of Sarıyer categorised as CR (Critically endangered), EN (Endangered), VU (Vulnerable), LR (cd) (Conservation dependent), LR (nt) (Near threatened), LR (lc) (Least concern) and DD (Data deficient).

Within the concept of design features; flower structures and texture structures has been evaluated. According to their flower structures they were evaluated in 3 categories such as flower colors, flowering start time and flowering periods which are the most important elements of planting design. (Davis 1965-1985, Davis et al. 1988, Seyidoglu et al. 2009, Tubives 2014, Kılıçarslan and Dönmez 2016, Zencirkıran et al. 2018). The texture properties of the geophyte taxa were evaluated in 2 categories such as texture features and heights. Texture features of geophyte taxa were categorized as fine, medium and coarse texture. For evaluating the data Frequencies analyze at the SPSS 23 package progmamme has been used.

Results

Plant Features

In Sarıyer district, there has been native 44 genus and 98 geophyte taxa belonging to 12 families. In Table 2; geophyte taxa belonging to these 12 families is given.

Table 2. The geophyte taxa of Sarıyer

Family name	Genus name	Taxa name
Amaryllidaceae	*Allium* L.	*Allium ampeloprasum* L., *Allium cepa* L., *Allium neapolitanum* Cyr., *Allium pallens* subsp. *pallens* L., *Allium paniculatum* subsp. *paniculatum*, *Allium roseum* L., *Allium rubellum* Bieb., *Allium scorodoprasum* subsp. *rotundum* (L.) Stearn, *Allium scorodoprasum* subsp. *scorodoprasum* L., *Allium triquetrum* L.
	Gagea Salisb.	*Gagea chrysantha* (Jan) Schultes et Schultes Fil.
	Galanthus L.	*Galanthus gracilis* Celak, *Galanthus nivalis* L., *Galanthus plicatus* subsp. *byzantinus* (Baker) D. A. Webb, *Galanthus plicatus* subsp.*plicatus* Baker., *Galanthus valentinei* nothosubsp. *subplicatus*
	Leucojum L.	*Leucojum aestivum* L.
	Narcissus L.	*Narcissus assoanus* Dufour, *Narcissus jonquilla* L., *Narcissus poeticus* subsp. *poeticus*, *Narcissus pseudonarcissus* L., *Narcissus tazetta* subsp. *aureus* (Loisel.) Baker

	Nectaroscordum Lindl.	*Nectaroscordum siculum* (Ucria) Lindl.subsp. *bulgaricum*
	Pancratium L.	*Pancratium maritimum* L.
	Sternbergia Waldst.et Kit.	*Sternbergia colchiciflora* Waldst. et Kit.
Asparagaceae	*Asparagus* L.	*Asparagus acutifolius* L., *Asparagus aphyllus* subsp.*orientalis* Baker.
	Bellevalia Lapeyr.	*Bellevalia trifoliata* (Ten.) Kunth
	Muscari Miller	*Muscari comosum* (L.) Miller, *Muscari neglectum* Guss., *Muscari parviflorum* Desf.
	Ornithogalum L.	*Ornithogalum narbonense* L., *Ornithogalum sigmoideum* Freyn et Sint., *Ornithogalum sphaerocarpum* Kerner, *Ornithogalum wiedemannii* var. *wiedemannii* Boiss., *Ornithogalum montanum* Cyr., O*rnithogalum orthophyllum* Ten., *Ornithogalum arabicum* L.
	Ruscus L.	*Ruscus aculeatus* var. *aculeatus* L., *Ruscus hypoglossum* L.
	Scilla L.	*Scilla autumnalis* L., *Scilla bifolia* L.
Araceae	*Arum* L.	*Arum byzantinum* Blume
Colchicaceae	*Colchicum* L.	*Colchicum micranthum* Boiss., *Colchicum turcicum* Janka
Geraniaceae	*Erodium* L'Herit.	*Erodium cicutarium* (L.) L'herit., subsp. *cicutarium*
	Geranium L.	*Geranium asphodeloides* subsp. *asphodeloides* Burm. f., *Geranium dissectum* L., *Geranium lucidum* L., *Geranium purpureum* Vill., *Geranium robertianum* L.
Iridaceae	*Crocus* L.	*Crocus biflorus* Miller, *Crocus flavus* Weston, *Crocus olivieri* subsp. *olivieri* Gay, *Crocus olivieri* subsp. *istanbulensis* Mathew, *Crocus pestalozzae* Boiss., *Crocus pulchellus* Herbert
	Iris L.	*Iris pseudacorus* L., *Iris sintenisii* Janka
	Romulea Maratti	*Romulea columnae* subsp. *columnae* Seb.et Mauri, *Romulea linaresii* subsp. *graeca* Beg.
Liliaceae	*Erythronium* L.	*Erythronium dens-canis* L.
	Fritillaria L.	*Fritillaria pontica* Wahlenb.
	Lilium L.	*Lilium martagon* L.
	Anacamptis L.C.M. Richard	*Anacamptis laxiflora* subsp. *laxiflora* (Lam.)R.M.Bateman, Pridgeon & M.W.Chase
	Cephalanthera L.C.M. Richard	*Cephalanthera longifolia* (L.) Fritsch
	Dactylorhiza Necker ex Nevski	*Dactylorhiza romana* subsp.*romana* (Seb.)Soo.
	Epipactis Zinn	*Epipactis helleborine* (L.) Crantz, *Epipactis palustris* (L.) Crantz
	Himantoglossum W.D.Koch	*Himantoglossum carpinum* (Bieb)Sprengel.
	Neotinea Reichb.Fil.	*Neotinea maculata* (Desf.)Stearn.

Orchidaceae	*Neottia* Guettard	*Neottia nidus-avis* (L.) L.C.M. Richard
	Ophrys L.	*Ophrys apifera* Hudson
	Orchis L.	*Orchis papilionacea* L., *Orchis papilionacea* var.*rubra* Jacq., *Orchis laxiflora* Lam.
	Platanthera L.C.M. Richard	*Platanthera bifolia* (L.) L.C.M. Richard, *Platanthera chlorantha* (Custer) Reichb.
	Serapias L.	*Serapias bergonii* E.G.Camus, *Serapias cordigera* L., *Serapias vomeraca* (Burm) Briq. subsp. *laxiflora* Gölz ex Rein.
	Spiranthes L.C.M.Richard	*Spiranthes spiralis* (L.)Chevall.
Primulaceae	*Cyclamen* L.	*Cyclamen coum* Miller var. *coum*
	Lysimachia L.	*Lysimachia nummularia* L., *Lysimachia verticillaris* Sprengel
	Primula L.	*Primula vulgaris* subsp. *sibthorpii* (Hoff.)W.W.Sm. & Forrest
Ranunculaceae	*Anemone* L.	*Anemone nemorosa* L.
	Helleborus L.	*Helleborus orientalis* Lam.
	Ranunculus L.	*Ranunculus constantinopolitanus* (DC.) D'urv., *Ranunculus ficaria* subsp. *calthifolius* (Reichb.) Arc., *Ranunculus ficaria* subsp. *ficariiformis* Rouy et Fouc., *Ranunculus gracilis* Clarke, *Ranunculus marginatus* var. *marginatus* D'urv., *Ranunculus ophioglossifolius* Vill., *Ranunculus repens* L., *Ranunculus saniculifolius* Viv.
Rosaceae	*Geum* L.	*Geum urbanum* L.
Xanthorrhoeaceae	*Asphodelus* L.	*Asphodelus aestivus* Brot.

Geophyte taxa of Sarıyer has been classified according to the endangerment categories in Table 3 (Ekim et al. 2000, IUCN 2019).

Table 3. Classification of geophyte taxa according to the category of endangerment

Danger catagories	Taxa	F (%)
DD Data defficient	*Galanthus gracilis* Celak., *Narcissus jonquilla* L.	12,50
LR (Lc) Least concern	*Allium ampeloprasum* L., *Allium triquetrum* L., *Galanthus plicatus* subsp. *byzantinus* (Baker) D. A. Webb, *Galanthus plicatus* subsp. *plicatus* Baker., *Leucojum aestivum* L., *Asparagus acutifolius* L., *Asparagus aphyllus* subsp.*orientalis* Baker., *Muscari parviflorum* Desf., *Iris pseudacorus* L., *Epipactis palustris* (L.) Crantz, *Neottia nidus-avis* (L.) L.C.M. Richard, *Lysimachia nummularia* L., *Ranunculus ophioglossifolius* Vill., *Ranunculus saniculifolius* Viv.	87,50

F (%): Frequencies of the taxa.

Design Features

Evaluations of flower colours, which is one of the important criteria for landscape design, is given in Table 4.

Table 4. Flower colours of geophyte taxa

Flower Clour	Plant taxa
White	*Allium cepa* L., *Allium neapolitanum* Cirillo., *Allium triquetrum* L., *Galanthus gracilis* Celak, *Galanthus nivalis* L., *Galanthus plicatus* subsp. *byzantinus* (Baker) D. A. Webb, *Galanthus plicatus* subsp. *plicatus* Baker., *Galanthus valentinei* nothosubsp. *subplicatus*, *Narcissus poeticus* subsp. *poeticus*, *Ornithogalum narbonense* L., *Ornithogalum sigmoideum* Freyn & Sint., *Ornithogalum wiedemannii* var. *wiedemannii* Boiss., *Ornithogalum montanum* Cyr., *Ornithogalum orthophyllum* Ten., *Ornithogalum arabicum* L., *Crocus pestalozzae* Boiss., *Cephalanthera longifolia* (L.) Fritsch, *Epipactis palustris* (L.) Crantz, *Platanthera bifolia* (L.) L.C.M. Richard, *Pancratium maritimum* L., *Leucojum aestivum* L.
Yellow	*Narcissus assoanus* Dufour, *Narcissus jonquilla* L., *Narcissus pseudonarcissus* L., *Narcissus tazetta* subsp. *aureus* (Loisel.) Baker, *Asparagus acutifolius* L., *Iris pseudacorus* L., *Lysimachia nummularia* L., *Lysimachia verticillaris* Sprengel, *Primula vulgaris* subsp. *sibthorpii* (Hoff.)W.W.SM. et For., *Ranunculus constantinopolitanus* (DC.) D'urv., *Ranunculus ficaria* subsp. *calthifolius* (Reichb.) Arc., *Ranunculus ficaria* subsp. *ficariiformis* Rouy et Fouc., *Ranunculus gracilis* Clarke, *Ranunculus marginatus* var. *marginatus* D'urv., *Ranunculus ophioglossifolius* Vill., *Ranunculus repens* L., *Ranunculus saniculifolius* Viv., *Geum urbanum* L., *Gagea chrysantha* (Jan) Schultes et Schultes Fil., *Sternbergia colchiciflora* Waldst. et Kit.
Purple	*Allium ampeloprasum* L., *Allium scorodoprasum* L. subsp. *rotundum* (L.) Stearn, *Allium scorodoprasum* L. subsp. *scorodoprasum* L., *Muscari parviflorum* Desf., *Scilla autumnalis* L., *Geranium dissectum* L., *Geranium purpureum* Vill., *Iris sintenisii* Janka, *Anacamptis laxiflora* subsp. *laxiflora, Cyclamen coum* Miller var. *coum, Orchis laxiflora* Lam., *Himantoglossum carpinum* (Bieb)Sprengel., *Romulea linaresii* Parl. subsp. *graeca* Beg., *Colchicum turcicum* Janka, *Bellevalia trifoliata* (Ten.) Kunth
Pink	*Allium paniculatum* subsp. *paniculatum*, *Allium roseum* L., *Allium rubellum* Bieb., *Erodium cicutarium* subsp. *cicutarium* (L.) L'herit., *Geranium lucidum* L., *Lilium martagon* L., *Helleborus orientalis* Lam., *Orchis papilionacea* L., *Orchis papilionacea* var. *rubra* Jacq., *Neotinea maculata* (Desf.) Stearn., *Erythronium dens-canis* L.
Lilac	*Muscari comosum* (L.) Miller, *Geranium asphodeloides* subsp. *asphodeloides* Burm. fil., *Geranium robertianum* L., *Crocus biflorus* Miller, *Crocus pulchellus* Herbert, *Anemone nemorosa* L., *Colchicum micranthum* Boiss.
Purplish Brown	*Arum byzantinum* Blume, *Serapias bergonii* E.G.Camus, *Serapias cordigera* L., *Serapias vomeraca* subsp. *laxiflora* Gölz ex Rein., *Romulea columnae* subsp. *columnae* Seb.et Mauri
Greenish White	*Ruscus aculeatus* var. *aculeatus* L., *Ruscus hypoglossum* L., *Platanthera chlorantha* (Custer) Reichb., *Spiranthes spiralis* (L.) Chevall.
Cream	*Allium pallens* subsp. *pallens* L., *Ornithogalum sphaerocarpum* Kerner, *Dactylorhiza romana* subsp.*romana* (Seb.)Soo.
Orangish Yellow	*Crocus flavus* Weston, *Crocus olivieri* subsp. *olivieri* Gay, *Crocus olivieri* subsp. *istanbulensis* Mathew
Pinkish White	*Ophrys apifera* Hudson, *Asphodelus aestivus* Brot., *Nectaroscordum siculum* subsp. *bulgaricum* (Ucria) Lindl.
Blue	*Muscari neglectum* Guss. ex Ten., *Scilla bifolia* L.
Green	*Asparagus aphyllus* subsp.*orientalis* Baker., *Fritillaria pontica* Wahlenb.
Yellowish Brown	*Neottia nidus-avis* (L.) Rich.
Multicolored	*Epipactis helleborine* (L.) Crantz

Discussion

It was observed that most of the geophyte genera are belong to Orchidaceae family with 27,27 %. The family Orchidaceae is followed by Amaryllidaceae (18,18 %) and Asparagaceae (13,64 %) families. Araceae, Colchicaceae, Rosaceae and Xanthorrhoeacea families represented with a single genera. When the families were evaluated according to the number of taxa, it was observed that Amaryllidaceae was the biggest family with 25,51 % ratio. The family Amaryllidaceae is followed by Orchidaceae (18,87 %) and Asparagaceae (17,35 %) families. However Rosaceae and Xanthorrhoeacea families represented with a single taxon (Figure 3).

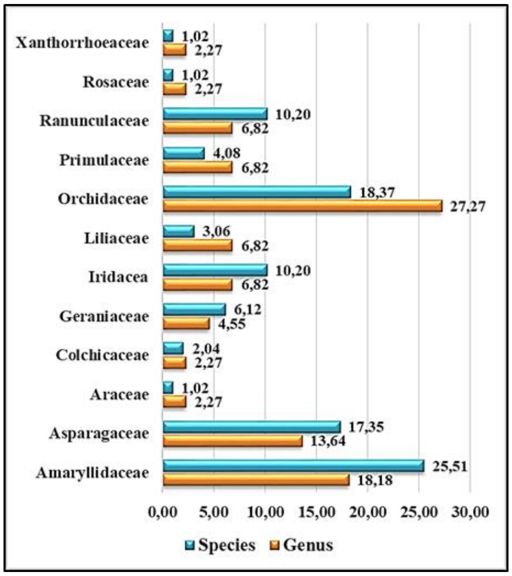

Figure 3. The distribution of genus, species and subspecies of geophytes according to families

When the geophytes of Sarıyer district classified according to their underground types, it is seen that mostly tuberous taxa has been found with the rate of 38,78%, bulbous of 31,63%, rhizome of 19 % and the least corm of 10,20% (Figure 4).

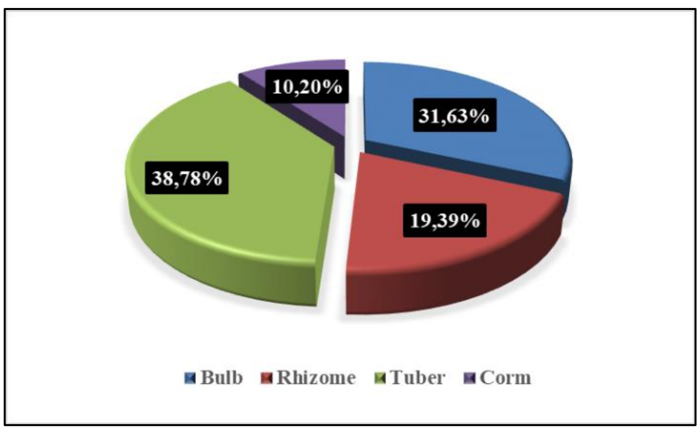

Figure 4. The distribution of geophytes according to underground types

However when the habitats of these taxa has been evaluated, forest, forest edge areas and shrubs has been found to be the highest rate of 19,85% and 19,73%. At the same time the minimum ratio of habitats found to be cultivated areas with 1,12%, road sides 1,87% and degraded habitats with 1,50% (Figure 5).

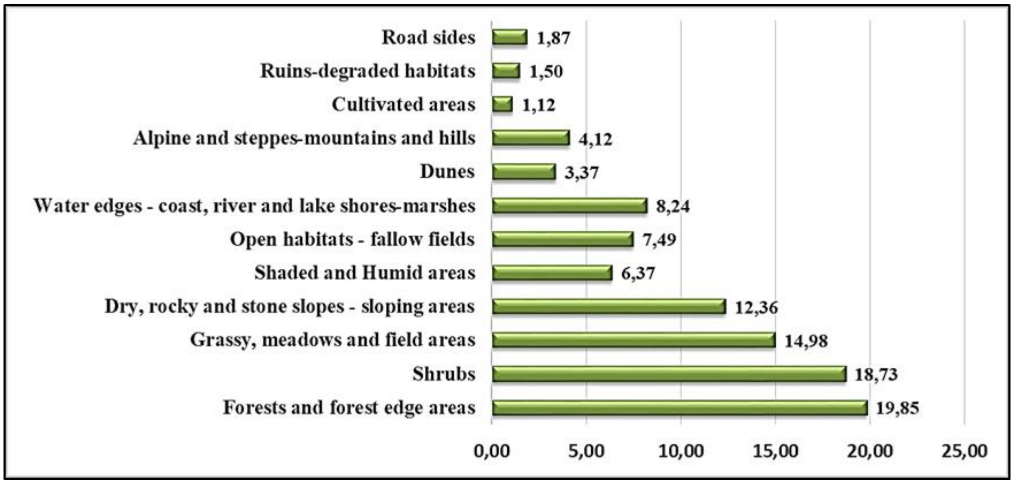

Figure 5. Classification of geophyte taxa according to habitats

On the other hand when they has been evaluated in case of the category of endangerment; it has been found out that most of the taxa are in LR (lc) (Least concern) category with the rate of 87,50 %. The rest of the taxa are in the DD (Data deficient) category with 12,50 %. In the scope of CR (Critically endangered), EN (Endangered), VU (Vulnerable), LR (cd) (Conservation dependent) and LR (nt) (Near threatened) categories no taxa has been found (Table 3).

Within the results of the assessments made by the flower colours of geophytes located in Sarıyer, the highest rate has been white flowered geophyte taxa with 21,43% ratio. 20,41% of them has been found to be yellow flowering species and %15,31 has been purple flowering species. The lowest rate with 1,02% has been yellowish brown and multicolored flowering species (Figure 6).

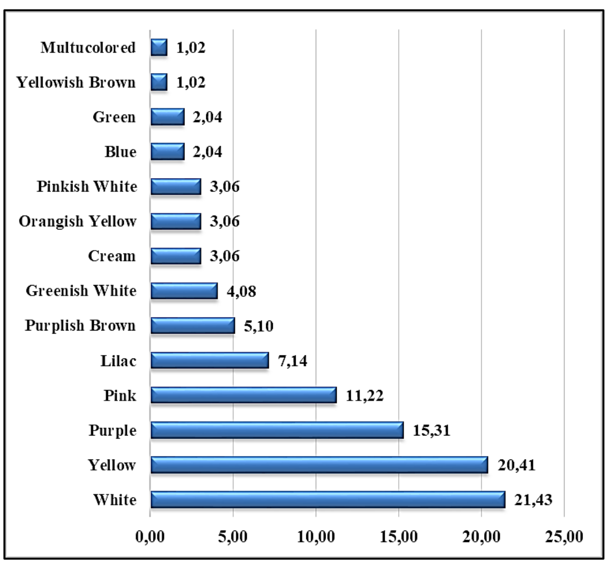

Figure 6. The distribution of geophyte taxa according to flower colours

Flowering start time and flowering periods of the geophytes is a very important issue in planting design as well as their flower colours. Within the results of the assessments made by the flowering times of geophytes located in Sarıyer, it has seen that 35,42% of the Sariyer district geophytes are flowering in March and 23,96% of them are flowering in April. 10,42% of them are flowering in June. Autumn and winter flowering geophytes are the least and also it has seen that in October and December no geophyte taxa is flowering in Sarıyer (Figure 7).

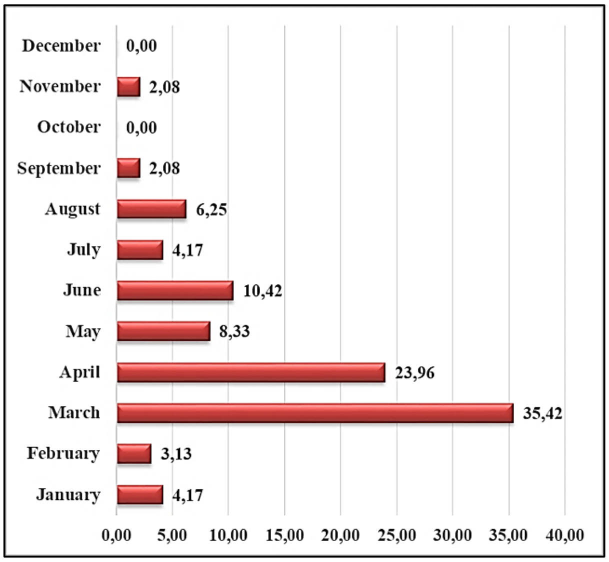

Figure 7. The distribution of geophyte taxa according to flowering start times

However, when the flowering period of the taxa has been examined, it is determined that 41,84% of the detected taxa are 3 months flowering. 26,53% of them are 2 months and 16,63% are 4 months flowering in the flora of Sarıyer. 6 months flowering are with the rate of 3,6% 5 months flowering with the rate of 2,04% and 7 months flowering 1,02%. Also it has been found out that 8 months and more flowering geophytes are absent in the area (Figure 8).

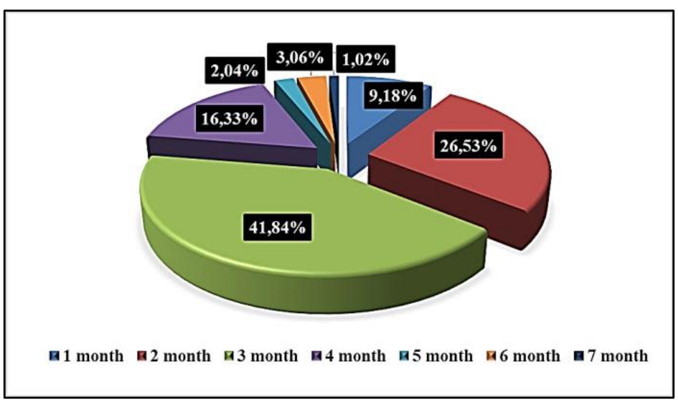

Figure 8. The distribution of geophyte taxa according to flowering periods

When the Sarıyer geophyte taxa has been evaluated in case of their texture structures, it is seen that 59,18 % of them are fine textured and 40,82 % of them are coarse textured. On the other hand it has been examined that 46,41 % of them are short; 22,88 % of them are above 21-40 meters and 3,92 % of them are 100 meters and above (Figure 9).

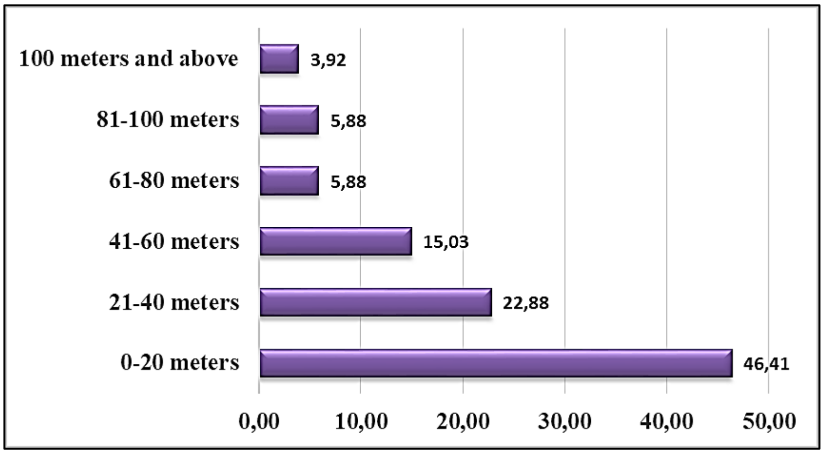

Figure 9. The distribution of geophyte taxa according to plant heights

Istanbul is one of the biggest cities of Turkey; with its floristic diversity. It has approximately 2,500 native plant taxa which is more than many countries around the world. The Sarıyer district which is the study area, constitutes the important source of this diversity by hosting the most important natural forest of the city, called Belgrade Forest which constitutes an important source of wealth (Çoban et al., 2016). The diversity of taxa in the area that grows naturally and requiring minimum maintenance, shows that a sustainable landscape practices available at this area. Therefore Sarıyer district has a different significance for the ecology of Istanbul.

Within this study the native geophyte taxa of Sarıyer and their usage in urban landscape areas has been evaluated and it is found that with 98 natural geophyte taxa, the area shows quite rich diversity in terms of geophytes. The major underground organ structure of them has been found to be bulb (38,78%). According to the number of species in the families, Orchidaceae is the first one, however Rosaceae and Butomace families has been represented by a single species. In terms of endangerment categories the geophyte taxa are usually at LR (lc) (Least concern) category with 87,50% and at DD (Data deficient) category with 12,50%. When they has been categorized according to their habitats; it is seen that they are under the category of mostly forests, forest edge areas and shrubs.

Similarly, Akdeniz and Zencirkıran (2016) found that the geophyte taxa of Bursa province has a rich diversity and their underground structure was mostly bulbous. And also they said that according to the endangerment categories they were mostly at LR (lc) (Least concern) category. However in the study of Avcu et al. (2016) which was about the geophyte taxa of Katran Mountain, the underground organ structures were found to be mostly bulb (40,75%). Sargın et al. (2013) found that at the Alaşehir (Manisa) region, 60 geophyte taxa were native and they were mostly belong to Amaryllidaceae, Araceae, Asparagaceae, Iridaceae, Liliaceae, Orchidaceae, Primulaceae and Ranunculaceae families. On the other hand, Dechir et al. (2019) stated that North-East Algeria is rich in bulbous and corm geophytes with 67 species and 19 endemic species, but also stated that they should be taken under protection.

As a matter of fact, Bradshaw and Handley (1982) stated that natural vegetation requires little intervention and can decrease the cost; Korkut et al. (2017) suggested the use of native plants that do not require much maintenance and suitable for natural structure in the landscape design studies within the framework of ecological approaches. Cabi (2016) stated that the highest genera in Tekirdağ city are *Allium* sp., *Ornithogalum* sp., *Orchis* sp., *Crocus* sp. and *Ophrys* sp. And also the taxons of *Leucojum aestivum*, *Strenbergia lutea, Gladiolus italicus* and *Iris pseudacorus* in the LC endangerment category in Tekirdag bulbous plants.

When we examine the geophytes of Sarıyer according to their design characteristics; it is found out that there are mostly white and yellow flowers in the native flora. And also it has been examined that there is only single taxon in the groups of yellowish green and multicolored flowering ones. *Galanthus* sp. and *Allium* sp. species can be a good example for white flowering species and *Narcissus* sp. and *Ranunculus* sp. species can be given as examples of yellow-flowered species. Geophytes bloom mostly in the spring months and mainly in March and April. It is seen that they stay flowering mostly about 2-3 months. However geophyte taxa are usually short (46,41%) and fine textured (59,18%).

The study of Zencirkıran et al. (2018) which was about the geophyte taxa of Kocaeli province, it was found out that mostly white flowering taxa were in the region. And then yellow, purple and pink flowering taxa were mostly found. On the other hand Seyidoğlu et al. (2009) has said that when we use the geophytes in landscape designs, preferring the short and short flowering species can be preferred in the drifts will be more effective and will achieve a natural appearance.

Conclusion

As a result, Sarıyer district has an importance in terms of geophyte taxa because of its different habitats, climatic properties and its situation in the urban ecology of Istanbul. Geophyte taxa can be used in many areas in the urban landscape such as rock gardens, lawn, bordure etc. Also geophytes constitute an integral part of the flora tourism within their beauty as well as their participation in landscape design with other herbaceous species. For gaining the geophyte taxa to the urban landscape, it is necessary to protect them in their natural areas and its necessary to carry out work related to this issue. Also in the scope of flora tourism, it is important to make flora trips for introducing the geophyte taxa in their own habitats.

According to the results obtained from this study, it is determined that geophytes are located mostly in forest and forest edge areas in Sarıyer region. It was found that they were found in shrubs and thirdly grassy and meadows areas. Based on these habitat areas with geofit species, it is recommended to organize nature walks, which are an important part of flora tourism. Belgrad Forest and edges and open spaces of the forest are very valuable areas in terms of being the habitats where Sarıyer geophytes are mostly located. For this reason, walking routes that will be arranged in a way to follow the flower colors and flowering times of the geofit taxa should be created in the Belgrad Forest and its surrounding. With the announcement of which plants will be observed during the hikes; attention of the nature lovers will be drawn to these environments. Thus, the floristic importance of the Belgrad Forest, which is one of the most important meeting points of nature lovers in Istanbul, will become even more impressive. On the other hand creating public awareness on behalf of the geophyte awareness and promote this wealth will be an appropriate approach. Especially an awareness can be obtained by seing the endangered species in their natural areas.

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Short Communication

A comparative study of Ranked Set Sampling (RSS) and Simple Random Sampling (SRS) in agricultural studies: A case study on the walnut tree

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Abstract
Sampling methods are used extensively in agricultural researches. In the sampling process, taking into consideration the characteristics of the target population and the use of a sampling method which can best represent the population make the estimates more sensitive and lead better estimations for the population. Several sampling methods have been developed for this purpose. In particular, Ranked Set Sampling (RSS) is a method that is used where it is difficult to measure all the units in the population, but it is easy and cheap to sort units in a small-sized population. In this study, we used the data based on the type of walnut tree leafage, Şebin, from a walnut garden established in the province of Giresun. The data was analyzed by using RSS designs and Simple Random Sampling (SRS) method to determine the mean estimators of the population. Finally, estimation performances of the SRS and RSS methods were compared accordingly. The study also emphasizes the advantage the RSS method requires fewer examples than the SRS method.
Keywords: Agriculture, sampling, simple random sampling (SRS), ranked set sampling (RSS), Juglans regia L.

Introduction

As a result of the growing population of the world, the malnutrition and increasing expansion of industrial areas, health problems have increased progressively. Despite great advances in science and technology today, the insensible consumption of natural resources and the economic difficulties have necessitated the multipurpose use of natural resources. On the other side, natural and synthetic antibiotics developed until today to fight against infectious diseases have been underwhelming as a result of resistance of microorganisms. In addition, the presence of various side effects of these antibiotics has led medical science to nature in order to discover new and different antimicrobial substances. For this reason, studies on plants and herbal medicinal raw materials obtained from these plants used in the treatment of various diseases have increased considerably.

Walnut (*Juglans regia* L.), a member of the *Juglandaceae* family, is mostly cultivated in the countries of Northern Hemisphere, such as China, USA, Iran, and Turkey (Zhang et al. 2016). Walnut is species adapted to temperate and continental climates, and it adapts to drought and different soil types. (Salvadó et al. 2005, Figueroa et al. 2017). Walnut is a plant which is used in the production of antimicrobial substances and widely grown throughout the world. Walnut leaves and green bark parts have been used colloquially in our country since ancient times. Green leaves and green bark parts of the plant are collected, dried and stored in mid-June. Then it is boiled and used as a walnut tincture to heal inflamed wounds, as bath admixture against hair loss, fungal infections on hands and feet. Especially, its leaves are brewed to decrease blood sugar level and used because of its regulating effects on digestive disorders, and the leaves boiled to gargle against oral wounds and gingivitis (Yiğit et al. 2009). The green bark and leaf parts of the plant are very important because of their high antioxidant and antimicrobial properties. It is known that bark of the walnut, green rind of fruit and leaves are used in pharmaceutical and cosmetic industries, used as a colourant in the textile industry, and its green bark and leaf parts are used in traditional medicine due to their anti-carcinogenic characteristics (Yiğit et al. 2009). It is known that juglone, which is a substance found in high quantity especially in green leaves, has very strong antioxidant and antimicrobial properties (Yaman 2012). In recent years in Turkey, efforts to establish walnut gardens have been increasing rapidly, and new walnut gardens have been established (Yalçın et al. 2012). Koyuncu and Aşkın (1997) examined the quality change of some walnut types stored in different packaging conditions. Akça (1999) conducted a study on the growth characteristics of Sebin, Bilecik, 32-B-18 and 170B-16 walnut varieties. Kantay et al. (2000) examined the density and resistance properties of walnut wood. Also, Dumanoglu (2000), Şan and Dumanoğlu (2006) and Şan ve Dumanoğlu (2006) studied, the production of walnuts. Sütyemez (2007) investigated the production amounts, flower dust and germination of 32 walnut type under certain conditions. Demir (2018) has developed a new rule (equation) with Prediction and Find Laws algorithms of data mining to calculate colour index (CI) by using an adaptive neuro-fuzzy approach.

Scientific studies on the walnut tree, which has a very significant place for the production of antimicrobial substances, are closely related to the preference of the correct scientific method. Being able to carry out medical research will primarily depend on the yield of the walnut tree. Sampling methods are frequently used in agricultural researches. Studies on obtaining information from samples instead of examining all units about any subject concerned started in the 1940s. The sample is defined as the subgroup containing fewer units than the population, which is created in accordance with various principles from population and represents the population in terms of quality and quantity. Sampling is the process of selection to create the sample representing the population about the research topic (Kılıç 2013). The selection criteria used to create samples are called sampling methods (Çıngı 1994). Thanks to sampling, it is possible to obtain characteristics of the population, such as mean, total, proportion, etc. and interpret this information.

Use of a sampling method that can represent the population best by considering the characteristics of the target population during the sampling process and determining the sample size according to this method can make the estimations for the population parameters more sensitive. Various sampling methods have been developed for this purpose. Sampling methods in the literature are divided into random and non-random sampling methods. Study results obtained by using only random sampling methods can be generalized for the population. Random sampling methods are Simple Random Sampling (SRS), Systematic, Stratified and Set Sampling methods. SRS method is the most basic method in sampling. With this method, n units are randomly selected provided that all units from the population of size N are given equal opportunity to be selected. These selected units form the sample. A list of the units that constitute the whole population is required for SRS method. Even if all the units of the population are reached, it causes time loss in some cases. For this purpose, alternative sampling methods are tried to be found.

The ranked set sampling (RSS) is an innovative sampling design and a cost-efficient alternative to simple random sampling (Balci 2013). Especially the RSS is a method used in cases where measuring all the units in the population is difficult, but sorting the units of a smaller sized sample is easy and cost-effective. From this aspect, the RSS can reduce sampling costs by preventing labour and time loss in researches where expensive laboratory analyses or field measurements are required. This method was first used by McIntyre (1952) in order to estimate the average pasture yield. It has been widely used in agriculture, forestry, sociology, ecological and environmental sciences and medical studies. Martin et al. (1980) estimated the value of a heathland located in a forest in Virginia using the RSS method. With the information obtained as a result of the research, they determined that the variance value found by RSS was smaller than the variance value calculated by the SRS. In this study, the use of the RSS method in estimating the amount of the leaves of the walnut tree, which is also remarkable with its use for medical purposes, was discussed. In the study, data about leaves of the walnut tree of Şebin type from a walnut garden established in the province of Giresun was used. Primarily, different RSS methods were introduced in the study. Then with the help of the data about the type of walnut tree , estimators of population mean were obtained using the RSS designs and the SRS method. In the results and suggestions section of the study, the efficiencies of the SRS and RSS methods in estimating the population mean were compared by the evaluation of the findings obtained.

Data Collection

In this section of the research, Şebin variety of walnut from a walnut garden established in Giresun was examined. 125 branches, which were approximate of the same size, were cut from the trees that are randomly selected from Şebin type. Selected branches were separated by an agricultural engineer to 25 sets of 5 in the laboratory and each unit within the sets was ordered in accordance with the leaf numbers on the branches. Data of 125 branches were evaluated as the population units. Sample data of 25 units, which were taken randomly from Şebin walnut variety by means of SRS and RSS sampling methods, were used to estimate the population mean. The data of 125 branches consisting of 25 5-unit sets cut from Şebin walnut variety are as shown in Table 1. Each cell in Table 1 expresses leaf numbers on a branch.

Materials and Methods

In the RSS method, the sample is selected in two steps. Thus, it shows a good spread over the distribution of the variable concerned (Gökpınar et al. 2005). In the first step, k sets with k size from the finite population are selected by the SRS. Then the units are ranked from small to large in terms of the relevant variables visually or by using a method that does not require precise measurement. In the second step, a ranked set sample is generated by measuring the first unit from the first set, the second unit from the second set, and similarly the k^{th} unit from the k^{th} set with the desired precision in terms of the relevant variable. When this operation is repeated r times, ranked set sample of size $n=rk$ is obtained. The obtained ranked set sample is as shown in Table 2.

While k^2 units are ranked by RSS, the only k of these are actually measured. In this way, the cost of sampling is reduced (Deshpande 2013). However, in the RSS method, errors originating from ranking can occur. For this reason, there are various RSS designs that differ in the steps of selecting sample units, and that function to minimize the ranking errors. Among these, commonly used methods are Extreme Ranked Set Sampling (ERSS), Median Ranked Set Sampling (MRSS), Percentile Ranked Set Sampling (PRSS) and L Ranked Set Sampling (LRSS). The most important factor that enables these methods to be different from each other is the way in which samples are created (Akıncı and Ozdemir 2010a).

The estimator of the population mean by RSS method was first suggested by Takahashi and Wakimoto in 1968. Al- Saleh and Samuh (2009) determined that this suggested estimator is more efficient than the estimator in the SRS method.

Table 1. Data relevant to Şebin walnut tree

Repetition	Set \ Unit	1	2	3	4	5
1	1	71	66	67	58	60
	2	70	68	69	69	67
	3	61	58	67	71	68
	4	65	64	69	72	69
	5	59	66	65	67	65
2	1	65	68	71	58	69
	2	65	69	68	66	66
	3	66	59	65	70	60
	4	65	69	70	65	69
	5	75	62	69	68	69
3	1	69	66	67	69	71
	2	75	66	69	67	69
	3	58	78	70	70	71
	4	79	61	68	70	72
	5	64	69	68	66	71
4	1	70	64	69	69	55
	2	66	64	67	58	59
	3	65	74	70	65	73
	4	67	69	63	66	67
	5	71	62	71	61	69
5	1	68	65	68	82	69
	2	70	63	70	91	69
	3	72	73	64	88	70
	4	63	61	66	57	66
	5	80	71	95	71	68

Table 2. *n=rk* sized ranked set sample

	Repetition			
Set	1	2	…	R
1	$X_{(1)1}$	$X_{(1)2}$	…	$X_{(1)2}$
2	$X_{(2)1}$	$X_{(2)2}$	…	$X_{(2)r}$
…	…	…	…	…
K	$X_{(k)1}$	$X_{(k)2}$	…	$X_{(k)r}$

Balanced Ranked Set Sampling

If the sizes of sets constituted in the RSS method are equal, this method is called Balanced Ranked Set Sampling (BRSS). In $X_{(i:k)j}$ j^{th} repetition, the estimator of the population mean to denote i^{th} ranked sample unit of size k is,

$$\bar{X}_{RSS} = \frac{\sum_{j=1}^{r}\sum_{i=1}^{k} X_{(i:k)j}}{kr} \quad (1)$$

and its variance is

$$Var(\bar{X}_{RSS}) = \frac{1}{kr}\{\sigma^2 - \frac{1}{k}\sum_{i=1}^{k}(\mu_{(i:k)} - \mu)^2\} \quad (2)$$

(Takahasi and Wakimoto 1968, Yıldız 2007). σ^2 given in Equation 2 denotes the population variance. When the population variance is not known, variance estimation by means of RSS method is calculated as;

$$\hat{\sigma}^2 = \frac{1}{(kr-1)}\sum_{j=1}^{r}\sum_{i=1}^{k}[(X_{(i:k)j} - \bar{X}_{RSS})]^2 \quad (3)$$

$$Var(\bar{X}_{RSS}) = \frac{1}{kr} - \left[\hat{\sigma}^2 - \frac{1}{k}\sum_{i=1}^{k}(\hat{\mu}_{(i:k)} - \bar{X}_{RSS})^2\right] \quad (4)$$

When this variance value is compared to the variance value in the SRS method,

$$Var(\bar{X}_{RSS}) = Var(\bar{X}_{SRS}) - \frac{1}{k^2 r}\sum_{i=1}^{k}(\mu_{(i:k)} - \mu)^2 \quad (5)$$

it is seen that the variance of the population mean in the RSS method is smaller (Yıldız 2007).

Extreme Ranked Set Sampling

The ranking should be carried out precisely in order to obtain a better estimator of the population mean of RSS method in comparison with the SRS method. In 1968, Takahashi and Wakimoto proposed ERSS method, which is a practical method for the cases where the sample size is larger than 4, and the ranking cannot be carried out easily. In this method, it is not necessary to rank all units. Only the largest and smallest units are selected (Samawi et al. 1996). In the ERSS method, sampling is done by following the steps below:

- *k* samples of size *k* are selected from the population.
- If the sample size is even, the smallest units from *k/2* sample and the largest units from the other *k/2* sample are selected for the actual measurement. If sample size *k* is odd, the smallest units from *(k-1)/2* samples that are ranked separately, the largest units from *(k-1)/2* sample and median value from *(k+1)/2* sample are selected for the actual measurement. This cycle is repeated *r* times for *kr* units. As a result, *kr* units denote the units of ERSS.

$X_{i(1)}$ and $X_{i(k)}$ are the smallest and largest values of i^th^ sample, respectively (*i*=1,2,3,…,*k*); if this cycle is repeated once, the estimator of the population mean based on ERSS method is calculated as,

$$\bar{X}_{ERSS1} = \frac{1}{k}\left(\sum_{i=1}^{L} X_{i(1)} + \sum_{i=L+1}^{n} X_{i(k)}\right) \quad (6)$$

if the sample size is even. Here, $L = k/2$. If sample size *k* is odd, the estimator of the population mean is calculated as in Equation 7.

$$\bar{X}_{ERSS2} = \frac{1}{k}\left(\sum_{i=1}^{L_1} X_{i(1)} + \sum_{i=L_1+2}^{k} X_{i(k)} + X_{i(\frac{k+1}{2})}\right) \quad (7)$$

Here; $L_1 = (k-1)/2$ and $X_{i(\frac{k+1}{2})}$, denote the median of the sample (k+1)/2. In order to simplify this notation, if *k* is even; the smallest unit of $X_{(i:e)}$: *i*th sample denotes the largest unit (*i=L+1,L+2,…,k*) of (*i*=1,2,…,*L*) and *i*th sample. The smallest of the *i*th sample (*i*=1,2,…,L_1) denoting the largest of the *i*th sample (*i=k+1)/2*), the estimator of the population mean is written as follows: (Muttlak and Abu-Dayyeh 2004).

$\bar{X}_{ERSS} = \frac{1}{k}\sum_{i=1}^{k} X_{(i:e)}$ (8)

Variance is defined as,

$Var(\bar{X}_{ERSS}) = \frac{1}{k^2}\sum_{i=1}^{k} \sigma^2_{(i:e)}$ (9)

Here, it is expressed as,

$\sigma^2_{(i:k)} = E[X_{(i:e)} - E(X_{(i:e)})]^2$ (10)

Median Ranked Set Sampling

In 1997, Muttlak suggested MRSS method in order to find population mean estimator in unimodal symmetric distributions such as normal distribution. This method is based on the median values selected from each set (Akıncı and Ozdemir 2010b). Sample selection steps in MRSS method are as follows:

- k samples of size k are selected from the population.
- Units of each set are ranked.
- If the k sample size is odd, (th smallest ranked units are selected from each sample for measurement. But if the sample size is even, $(k/2)^{th}$ units from the first k/2th sample and $((k+2)/2)^{th}$ units from the remainder $k/2$ the sample is selected. This cycle can be repeated *r* times to obtain *kr* units.

When the abovementioned cycle is repeated once, if the sample size is odd; $X_{i((k+1)/2)}$ denotes the median of i^{th} (i=1,2,3,…,k) sample. If sample size k is even, $X_{i(k/2)}$ is denoted as $(k/2)^{th}$ order statistics of i^{th} (i=1,2,3,…, $L=k/2$) sample, and $X_{i((k+2)/2)}$ is denoted as $((k+2)/2)^{th}$ order statistics of i^{th} ($i=L+1,L+2,…,k$) sample, for cases where k is even and odd, the estimators of MRSS method based population mean are given in Equation 11 and 12, respectively.

$\bar{X}_{MRSS1=} \frac{1}{k}\sum_{i=1}^{k} X_{i((k+1)/2)}$ (11)

and

$\bar{X}_{MRSS2=} \frac{1}{k}\left(\sum_{i=1}^{L} X_{i(k/2)} + \sum_{i=L+1}^{k} X_{i((k+2)/2)}\right)$ (12)

Here; $L = k/2$. In order to simplify the notation above; when $X_{(i:m)}$ the sample size is odd, it is the median of the i^{th} sample when the sample size is even, it denotes $(k/2)^{th}$ order statistics of i^{th} ($i=1,2,…,L=k/2$) sample and $((k+2)/2)^{th}$ order statistics of i^{th} ($i=L+1, L+2,…, k$) sample.

Accordingly, the estimator of MRSS based population mean is determined as,

$\bar{X}_{MRSS} = \frac{1}{k}\sum_{i=1}^{k} X_{(i:m)}$ (13)

Variance relevant to population mean is given in Equation 14.

$Var(\bar{X}_{MRSS}) = \frac{1}{k^2}\sum_{i=1}^{k} \sigma^2_{(i:m)}$ (14)

Here, it is calculated as,

$\sigma^2_{(i:m)} = E\left[X_{(i:m)} - E\left(X_{(i:m)}\right)\right]^2$ (15)

(Muttlak and Dayyeh 2004).

In symmetric distributions, $\bar{X}_{MRSS1}$ and $\bar{X}_{MRSS2}$ estimators are unbiased. But in asymmetric distributions, there are biased estimators. For this reason, MSE value is used instead of variance.

$$MSE(\bar{X}_{MRSS}) = Var(\bar{X}_{MRSS}) + (bias)^2 \quad (16)$$

Percentile Ranked Set Sampling

PRSS was suggested by Muttlak (2003) as an alternative method for RSS. With this method, which is based on the percentage value in the first step of the research, it is aimed to select sample units from different areas of the population (Akıncı and Ozdemir 2010b).

Sampling in the PRSS method is carried out by following the steps below:

- *k* samples of size *k* are selected from the population.
- Units within each set are ranked.
- If sample size *k* is even; $p(k+1)^{th}$ units from the first *k/2* sample and $(q(k+1))^{th}$ units from the second *k/2* sample are selected. Here, $0 \le p \le 1$ and $q = (1-p)$. When selecting sample units, $[(p(k+1))]$ and $[(q(k+1))]$ values are rounded to the closest integer value. If sample size is odd, $(p(k+1))^{th}$ ranked units from the first $((k-1)/2)$ sample and $(q(k+1))$ ranked units from the remainder $((k-1)/2)$ sample and the median of $\left(\frac{k+1}{2}\right)^{th}$ sample is selected for the actual measurement. This cycle can be repeated *r* times to obtain *kr* units.

$X_{i(p(k+1))}$ and $X_{i(q(k+1))}$ denotes $(p(k+1))^{th}$ and $(q(n+1))^{th}$ order statistics of i^{th} ($i=1,2,3,\ldots,k$) sample. In practice, $(p(k+1))$ and $(q(k+1))$ values are rounded to integer value. When *k* is even for the cycle which repeats once using PRSS method, the estimator of population mean is defined as,

$$\bar{X}_{PRSS1} = \frac{1}{k}\left(\sum_{i=1}^{L_1} X_{i(p(k+1))} + \sum_{i=L_1+1}^{k} X_{i(q(k+1))}\right) \quad (17)$$

Here, $L_1 = k/2$. When *k* is odd, the estimator of the population mean is given in Equation 18.

$$\bar{X}_{PRSS2} = \frac{1}{k}\left(\sum_{i=1}^{L_2} X_{i(p(k+1))} + \sum_{i=L_2+2}^{k} X_{i(q(k+1))} + X_{i(k+1)/2}\right) \quad (18)$$

Here, $L_2 = (k-1)/2$ and $X_{i((k+1)/2)}$ are the median of $i=(k+1)/2^{th}$ sample. When the sample size is even and odd, variance values are as specified in Equation 19 and 20, respectively.

$$Var(\bar{X}_{PRSS1}) = \frac{1}{n^2}\left[\sum_{i=1}^{L_2} Var\left(X_{i[p(n+1),n]}\right) + \sum_{i=L_2+2}^{n} Var\left(X_{i[q(n+1),n]}\right) + Var\left(X_{\frac{n+1}{2}\left[\frac{n+1}{2},n\right]}\right)\right] \quad (19)$$

and

$$Var(\bar{X}_{PRSS2}) = \frac{1}{n^2}\left[\sum_{i=1}^{L_1} Var\left(X_{i[p(n+1),n]}\right) + \sum_{i=L_1+1}^{n} Var\left(X_{i[q(n+1),n]}\right)\right] \quad (20)$$

In order to simplify the notation above, if *k* is even, $X_{(i:p)}$, is $(p(k+1))^{th}$ order statistics of i^{th} ($i=1,2,\ldots,L_1$) sample and $(q(k+1))^{th}$ order statistics of i^{th} $(i=L_1+1, L_1+2, \ldots, k)$ sample. Additionally, if *k* is odd, it denotes $(p(k+1))^{th}$ order statistics of i^{th} ($i=1,2,\ldots,L_2$) sample, the median of i^{th} ($i=(k+1)/2$) sample and $(q(n+1))^{th}$ order statistics of i^{th} ($i=L_2+2, L_2+3, \ldots, n$) sample. Accordingly, the estimator of PRSS based population mean is determined as,

$$\bar{X}_{PRSS} = \frac{1}{n}\sum_{i=1}^{n} X_{(i:p)} \tag{21}$$

Variance based on $\bar{X}_{PRSS}$ is given in Equation 20.

$$Var(\bar{X}_{PRSS}) = \frac{1}{n^2}\sum_{i=1}^{n} \sigma_{(i:p)}^2 \tag{22}$$

Here, it is calculated as,

$$\sigma_{(i:p)}^2 = E\left[X_{(i:p)} - E\left(X_{(i:p)}\right)\right]^2 \tag{23}$$

(Muttlak and Abu-Dayyeh, 2004).

In symmetric distributions $\bar{X}_{PRSS1}$ and $\bar{X}_{PRSS2}$ estimators are unbiased. In asymmetric distributions, MSE values of $\bar{X}_{PRSS1}$ and $\bar{X}_{PRSS2}$ estimators are used.

L Ranked Set Sampling

This method, which was suggested by Al-Nasser in 2007 as an alternative to the RSS method, is based on robust L estimators used in the presence of outliers in the population. LRSS method is used to obtain minimum-variance unbiased estimator for population mean that is not affected by outliers in symmetric distributions.

The selection process of the units in the LRSS method is as follows:

- k sets with the size k are selected randomly.
- The units within the sets are ordered based on the relevant variance visually or by a ranking technique practised without measurement.
- On condition that $0 \leq \alpha \leq 0.5$, $l = [k.\alpha]$ LRSS coefficient is determined. Here l coefficient is defined as the largest of integer values which equal to $k.\alpha$ or are smaller than $k.\alpha$.
- From the first ($l+1$) set obtained, $(l+1)^{th}$ ordered units, from the last ($l+1$) set obtained $(k\text{-}l)^{th}$ ordered units and for ($j=l+2, \ldots, k\text{-}l\text{-}1$) set, j^{th} are selected.
- Selected units are measured in terms of relevant variable, and L ranked set sample is with the size k is obtained (Akıncı and Özdemir 2010a).

When $l = 0$ for any sample size, LRSS method transforms into BRSS method. The estimator of the population mean based on LRSS method is defined as,

$$\bar{X}_{LRSS} = \frac{1}{k}\left(\sum_{i=1}^{l} X_{i[l+1:k]} + \sum_{i=l+1}^{k-l} X_{i[i:k]} + \sum_{i=k-l+1}^{k} X_{i[k-l:k]}\right) \tag{24}$$

$\bar{X}_{LRSS}$ the estimator is an unbiased estimator of the population mean for symmetric distributions. The variance of the estimator of $\bar{X}_{LRSS}$ is calculated as

$$Var(\bar{X}_{LRSS}) = \frac{1}{k^2}\left[\sum_{i=1}^{l} Var\left(X_{i[l+1:k]}\right) + \sum_{i=l+1}^{k-l} Var\left(X_{i[i:k]}\right) + \sum_{i=k-l+1}^{k} Var\left(X_{i[k-l:k]}\right)\right] \tag{25}$$

Quartile Ranked Set Sampling

QRSS is a method suggested by Muttlak in 2003. q coefficients are used in creating sample units. In the QRSS method,

- k random samples of size k are selected from the population.
- The units within the sets are ordered based on the relevant variance visually or by a ranking technique practised without measurement.
- If the sample size is even, $(q_l\ (k+1))^{\text{th}}$ smallest ranked unit from the first $\frac{k}{2}$ sample unit and $(q_u\ (k+1))^{\text{th}}$ smallest ranked unit from the second $\frac{k}{2}$ unit is selected for measurement. Here, q_l=0,25 and $q_u = 0{,}75$. Rounded values of $q_1\ (k+1)$ and $q_u\ (k+1)$ are used. If the sample size is odd, $(q_1(k+1))^{\text{th}}$ smallest ranked unit from the first $\frac{(k-1)}{2}$ sample, $\left(q_u(k+1)\right)^{\text{th}}$ smallest unit from the other $\frac{(k-1)}{2}$ sample and the median value of $\left(\frac{n+1}{2}\right)^{\text{th}}$ sample is selected for the actual measurement.
- This cycle is repeated r times to obtain kr units.

When the sample size is even in a single cycle, the estimator of the population mean based on QRSS method is,

$$\bar{X}_{QRSS} = \frac{1}{k}\left(\sum_{i=1}^{L_1} X_{i(q_{1(k+1)})} \sum_{i=L_1+1}^{k} X_{i(q_{u(k+1)})}\right) \quad (26)$$

Here, $L_1 = \frac{k}{2}$. When the sample size is odd, the estimator of the population mean is defined as,

$$\bar{X}_{QRSS} = \frac{1}{k}\left(\sum_{i=1}^{L_2} X_{i(q_{1(k+1)})} \sum_{i=L_2+2}^{k} X_{i(q_{u(k+1)})} + X_{i((k+1)/2)}\right) \quad (27)$$

Here, $L_2 = \frac{(k-1)}{2}$ and $X_{i((k+1)/2)}$ is the median of $(i = (k+1)/2)^{\text{th}}$ sample.

In order to make the formulations more understandable, when sample size k is even; $X_{(i:q)}$ is defined as $(q_1(k+1))^{\text{th}}$ order statistics of i^{th} $(i = 1, 2,\ \dots\ ,\ L_1)$ sample and $(q_u\ (k+1))^{\text{th}}$ order statistics of i^{th} $(i = L_1 + 1,\ L_1,\ \dots\ , k)$ sample. If sample size k is even when it is $\left(q_1(k+1)\right)^{\text{th}}$ order statistics of i^{th} $(i = 1, 2,\ \dots\ , L_2)$ sample, the median of the i^{th} $(i = (k+1)/2)$ sample and $(q_u(k+1))^{\text{th}}$ order statistics of i^{th} +2, $L_2 + 3,\ \dots\ , k)$ sample, the estimator of the population mean based on QRSS is defined as,

$$\bar{X}_{QRSS} = \frac{1}{k}\sum_{i=1}^{k} X_{(i:q)} \quad (28)$$

Variance of $\bar{X}_{QRSS}$ is as given in Equation 29.

$$Var\left(\bar{X}_{QRSS}\right) = \frac{1}{k^2}\sum_{i=1}^{n} \sigma^2_{(i:q)} \quad (29)$$

Here, $\sigma^2_{(i:q)} = E\left[X_{(i:q)} - E\left(X_{(i:q)}\right)\right]^2$.

Moving Extreme Ranked Set Sampling

In cases where the sample size is large, the ranking process becomes difficult. In larger sample sizes, the possibility of ranking errors is higher than in smaller samples. For this purpose, MERSS method was discussed by Al-Odat and Al-Saleh in 2001. The steps of MERSS method are as follows:

- *k* SRS sets of size *1,2,3,…,k* are generated.
- Each set is ordered from smallest to largest visually or by other methods without actual measurement.
- Actual measurements are carried out by selecting the largest units from each set ranked from the first set to k^{th} set.
- 3^{rd} set is repeated, but this time, the smallest units from each set are selected and measured.
- Operations above are repeated *r* times until the desired sample size *n=2rk* is obtained.

In MERSS method, only two extreme values are used. These are the sets of largest and smallest units in various sizes. However, in the BRSS method, all units in all sets are required to be ranked. Because determining the largest and smallest units in each set, MERSS method is a much more useful design than BRSS. With this method, the sample size can be increased without too many ranking errors (Chen et al. 2013).

Results

The descriptive statistics for the data in Table 1 and the results of the analysis of goodness of fit carried out to determine the distribution of the population are given in Table 3. Here, *k=5* and *r*=5.

When Table 3 is examined, it is seen that the distribution of the data of Şebin walnut variety at the significance level of 0.05 conforms to the normal distribution (because it has a p-value greater than 0.05 significance level). Since the distribution of the population is symmetric, the variance values will be considered in the comparison of the estimators from now on. First, a sample of 25 units from the data set was obtained by the SRS method. Table 4 shows the data related to the selected units.

Table 3. Descriptive statistics and results of the analysis of goodness of fit relevant to Şebin data set

Population Characteristics	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**	**Variance**
	55	95	67,792	5,916	35,005
Distribution	**Exponential**	**Gamma**	**Normal**	**Uniform**	**Weibull**
DPLUS	0,2753	0,1608	0,1738	0,4800	0,2314
DMINUS	0,5606	0,1123	0,1105	0,0590	0,1630
DN	0,5606	0,1608	0,1738	0,4800	0,2314
P-Value	0,0000	0,0031	**0,1125**	0,0000	0,0000

Table 4. Units selected by SRS method

Observations				
67	61	64	69	65
65	66	65	70	65
67	71	70	68	69
64	70	73	67	61
70	70	73	66	95

Estimate value of the population mean based on the SRS method using the data in Table 4 is determined as,

$$\bar{X}_{SRS} = \frac{1}{5*5}\sum\sum X^*_{(i)j} = \frac{1}{25}*(67+61+\cdots+66+95) = 68{,}44$$

and variance is determined as

$$Var(\bar{X}_{SRS}) = \frac{\hat{\sigma}^2}{n} = \frac{40{,}923}{25} = 1{,}64$$

In the next step, the estimator of the mean of the population for Şebin walnut variety was tried to be obtained by BRSS method. Locations of the units determined for this are given for the first repetition in Table 5.

Table 5. Units selected for Şebin walnut variety by BRSS method

Repetition	Set \ Unit	1	2	3	4	5
1	**1**	71				
	2		68			
	3			67		
	4				72	
	5					65

Estimate value of the population mean using Equation (1) by means of BRSS is calculated as,

$$\bar{X}_{RSS} = \frac{1}{5*5}\sum\sum X^*_{(i)j} = \frac{1}{25}*(71+68+\cdots+57+68) = 67{,}24$$

and variance is calculated as,

$$Var(\bar{X}_{RSS}) = \frac{1}{kr}\{\sigma^2 - \frac{1}{k}\sum_{i=1}^{k}\left(\mu_{(i:k)} - \mu\right)^2\} = \frac{1}{5*5}\left[35{,}005 - \frac{1}{5}((68{,}6-67{,}24)^2+\cdots+(64-67{,}24)^2)\right] = 1{,}228$$

ERSS, MRSS, and PRSS, QRSS when *p=0,30*, and the ranking positions and values of the units selected in the first repetition, the procedure for selecting the units in the first two repetitions in MERSS method and selected units are given in Table 6. For other repetitions, the same procedures were followed, and samples of 25 units were created.

Estimate value and variance of the population mean for Şebin walnut variety were obtained by using all other RSS methods. The results obtained are given in Table 7.

According to Table 7, it is seen that RSS methods give better results than the SRS method for Şebin walnut variety. It was determined that the distribution of Şebin walnut variety population is normal. It is seen that the RSS method that gives the most efficient estimate value for this data set is MERSS. Methods that give efficient results after MERSS are ERSS, QRSS, BRSS, MRSS and PRSS, respectively.

Table 6. Sample selection steps related to other RSS methods

Method	**Repetition**	**Sets**	**1. Unit**	**2. Unit**	**3. Unit**	**4. Unit**	**5. Unit**
ERSS	**1**	**1**	71	-	-	-	-
		2	70	-	-	-	-
		3	-	-	67	-	-
		4	-	-	-	-	69
		5	-	-	-	-	65
MRSS	**1**	**1**	-	-	67	-	-
		2	-	-	69	-	-
		3	-	-	67	-	-
		4	-	-	69	-	-
		5	-	-	65	-	-
PRSS(0.30)	**1**	**1**	-	66	-	-	-
		2	-	68	-	-	-
		3	-	-	67	-	-
		4	-	-	-	72	-
		5	-	-	-	67	-
QRSS	**1**	**1**	-	66	-	-	-
		2	-	68	-	-	-
		3	-	-	67	-	-
		4	-	-	-	-	69
		5	-	-	-	-	65
MERSS	**1**	**1**	-	-	-	-	60
		2	-	-	-	-	67
		3	-	-	-	-	68
		4	-	-	-	-	69
		5	-	-	-	-	65
	2	**1**	69	-	-	-	-
		2	66	-	-	-	-
		3	60	-	-	-	-
		4	69	-	-	-	-
		5	69	-	-	-	-

Table 7. Relative efficiencies for Şebin walnut variety

	Şebin		
Design	**Mean**	**Var**	**RE**
SRS	68,440	1,640	100,000
BRSS	67,240	1,228	74,878
ERSS	68,400	0,780	47,561
MRSS	69,000	1,480	90,244
PRSS	66,320	1,590	96,951
QRSS	67,200	0,800	48,780
MERSS	67,240	0,760	**46,341**

In addition, RE values obtained for RSS methods according to SRS method for Şebin walnut variety was found to be smaller than 1. Therefore, RSS methods give more efficient results than the SRS method. This indicates the number of units to be considered in order to obtain the related estimate value. When Table 7 is examined, it is seen that MERSS method is more efficient than the classical SRS method in estimation of leaf mean of Şebin walnut variety. The estimate to be obtained with 25 units in the SRS method can be obtained with 12 units in MERSS method.

Discussion

In this study, the parameter estimators of population obtained by RSS method and designs suggested as an alternative to SRS method with reference to leaf data of Şebin walnut variety was compared in terms of efficiency. The application of RSS method, which is a new alternative for sampling methods commonly used in agricultural studies, was presented. Regardless of how large the population is, RSS methods are advantageous because of providing efficient result in small sample sizes. In addition to this advantage, they are widely used especially in ecological studies since they require less cost and labour force. As in the literature, the RSS method allows us to obtain more efficient estimates than the SRS method in our study, as well.

In the application section, data belonging to walnut tree leaf research carried out in Giresun province were used. RE values of RSS designs applied for data set of Şebin walnut variety are calculated in comparison with SRS. The reason for the difference in the RSS method, which gives the most efficient estimate value of population mean of Şebin walnut variety, is a distribution type of population. The efficiency of RSS methods varies depending on ranking errors for symmetric and asymmetric distributions. However, the generalization of this result obtained from a single application is not appropriate. Studies about efficiencies of different RSS designs on estimating the population mean under different distributions are present in the literature. As the RSS methods are more efficient than the SRS method for both distribution types, the preference of the RSS method in studies where the SRS method is applicable will be useful to obtain more efficient results.

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