Estimation of Moss Harvest Amount and Biomass per Hectare for Sustainable Moss Harvesting in Türkiye

Serhat URSAVAŞ (serhatursavas@gmail.com)
Çankırı Karatekin University
Recep SÖYLER
Çankırı Karatekin University

Research Article

Keywords: Bryophyte, Plantations, Potential, Semi-arid, Syntrichia ruralis, Hypnum cupressiforme var. lacunosum

Posted Date: September 29th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3372501/v1

Additional Declarations: No competing interests reported.

Abstract

While moss harvesting is legally permitted in Turkey, the lack of inventory studies in harvested areas puts significant pressure on moss species. Additionally, there are not enough studies on how much moss can be harvested per hectare from well-maintained forest areas. Eldivan Mountain with a size of 4,200 ha was chosen as the study area. In this area, a sampling point was determined every 300 meters. At each point, moss species were detected in an area of 4 m2 on the ground and 50 m2 on the tree. The total identified moss taxa cover an estimated area of approximately 97,216,557 m2, and their air-dry weight is 44,640,972 kilograms. The most widely distributed species on the ground is *Syntrichia ruralis* with 64,772,801 m2 and 623,268 kg. On the tree, it is *Hypnum cupressiforme* var. *lacunosum* with a width of 3,937,266 m2 and 1,448,533 kg. Harvesting of these species is not correct since there is not enough rainfall in Turkey to develop epiphytic moss taxa. For sustainable moss harvest, it is best to harvest 1/3 of its total wealth. For a sustainable moss harvest, it is recommended to harvest 2 tons per hectare in Turkey. In addition, it should be kept in mind that moss harvesting without an inventory study may cause damage to rare, sensitive and endemic moss species.

Introduction

Although there are data on the harvest of mosses in the USA, these data are generally related to epiphytic mosses. There is no complete data on how much moss can be harvested on the ground. When considering commercial harvesting of epiphytic moss, the United States stands out as the foremost country in this industry. The U.S. boasts a diverse range of non-timber forest products (NTFPs) harvested from its forests, including floral greens, mushrooms, and medicinal herbs. The commercial value of these products is estimated to be worth millions of U.S. dollars annually (Jones et al., 2002). Forest bryophytes, encompassing both mosses and liverworts, are among these valuable non-timber forest products. Harvested moss is sold both domestically within the United States and is also exported, primarily for decorative purposes within the florist and horticulture trades (Alexander, 2002; Blatner, 1997; Vance & Thomas, 1997). In the Pacific Northwest, mosses and liverworts are harvested from trees and shrubs at a rate of at least 3.7 million kg/year (fresh weight; Muir et al., 2006, Peck, 2006).

There are not many studies on how much mosses can be harvested per hectare. According to Peck and McCune (1998), Mosses contain 26% moisture even when harvested with air dry weight. An estimated 693 kg/ha for the mosses inventory on the Hebo Ranger District in Oregon. In the study conducted in this region, since the humidity rate does not change much in summer and winter months, 26% moisture content is included as a standard in the air-dry weight (Peck & McCune, 1998). There is no data on how mosses are distributed per hectare and how many of them can be harvested, both in Europe and Turkey.

According to Ursavaş and Söyler (2015), about 184 tons of moss is harvested from Turkey every year, without any inventory study on bryophytes. However, there is no detailed study in Turkey on how much area biomass bryophytes, which have very important functions on the ecosystem, have or how much they spread both outside the forest ecosystem and in the forest ecosystems.

The aims of this study are as follows; (1) To estimate how much of bryophyte biome is coming from a semi-arid area afforested with Anatolian black pine approximately 60-70 years ago. (2) Which species have come to the area? (3) In how many area (m2) do these species spread? (4) What is the approximate air-dry weight of these species? (5) Did species diversity change according to aspect? and (6) How much moss must be harvested per hectare (ha) for sustainable harvest? (7) How many moss biomes are on the forest floor and in the area epiphytically?

Research Area

Çankırı Eldivan Mountain: It is an area of 4,200 hectares, which was gradually afforested after a flood in 1952. The dominant three type of the area is Anatolian black pine (*Pinus nigra* subsp. *pallasiana* (Lamb Holmboe)), but it is also possible to observe Scotch pines (*Pinus sylvestris* L.) in the area. It is also possible to encounter small groups of old Anatolian black pine, Downy oak (*Quercus pubescens* Willd.) and Common oak (*Quercus robur* L.) in the area. Eldivan Mountain is within the borders of Eldivan district of Çankırı province.It is located between 40°31'32”- 40°26'16" North latitudes and 33°32'12”- 33°24'02" East longitudes (cf. Figure 1.) The highest point of Mount Eldivan is 1810 m, and the lowest elevation is 1000 m. (Ursavaş & Tuttu, 2020).

The research area is located in a semi-arid region. According to the data from the General Directorate of Meteorology of Turkish Republic between 1929-2021, the highest temperature recorded in the area was recorded in July with 42.4 ºC, and the lowest temperature was recorded in March with -20.5 ºC. The average highest temperature was recorded as 31.2 in August, the lowest average temperature was recorded as -3.9 in January, and the annual average precipitation is 416.8 mm (OGM, 2021).

As reported by Ursavaş and Öztürk (2016), due to Thornthwaite classification the area has a climate type that exhibits "Arid-less humid, mesothermal, moderate water excess in winter and close to full continental climate conditions".

Materials and Methods

When reviewing bryophyte inventory studies worldwide, there is a scarcity of research specifically focused on conducting bryophyte inventories. This gap is particularly pronounced in countries like Türkiye, characterized by a semi-arid climate, where forest ecosystems serve as habitats for rare, delicate, and highly endangered endemic bryophyte species. Consequently, the creation of a comprehensive inventory documenting bryophyte species in these areas holds immense significance.

In order to make an inventory of the bryophytes in the area and calculate their estimated biomass, we first need to determine the distance between the sampling points. Second we need to decide how many square meters of observation area we need to take in order to estimate the bryophyte species on the ground and on the tree at the sampling point. Then, it is necessary to go to the determined observation points and take bryophyte samples and identify them. In addition, the features such as slope, aspect, elevation of these determined observation points, and the age, height and diameter of the tree species

were recorded in the land book. Then, the air-dry and oven-dry weights of the identified species were weighed in the laboratory environment, and the obtained data were interpreted by making statistical analyzes.

When several bryophyte biomass studies are examined, the distance and size of the sampling areas taken in the field show variations (Peck & McCune, 1998; Borges et al., 2018). According to Peck and McCune (1998), in their study named “Commercial moos harvest in Northwestern Oregon: biomass and accumulation of epiphytes”, it was stated that the inventory study by taking a sampling point at 200 m or 300 m distances according to the field size is a reliable method. Since the research area covers a large area (i.e., 4,200 ha), sampling intervals was taken as 300 m by using ArcMap 10.3 software package. For the field study, a total of 449 sampling stations were determined. Sampling points start from the upper left corner and increase sequentially as one moves east to the right and from top to bottom (cf. Figure 2). Other physiographic factors of the sampling station (aspect, slope, and elevation) were also noted during the land survey in the field guide.

Many researchers have chosen different areal sizes to calculate the biomass of bryophytes on the ground at each sampling location, for example, Fenton and Frego (2005) 0.5 m x 0.5 m (0.25 m^2), Vanderpoorten et al., (2004) 1 m x 1 m (1 m^2). But all of these researchers worked in relatively small areas. Due to the wide scope of our research, Piessens et al., (2008), the sample size was chosen as 2x2m (4 m2) in this study (cf. Figure 3).

Each moss material in the sample areas was first photographed in its natural environment, the width and length of the mosses were measured with the help of a measuring instrument (tree meter, tape meter, etc.), and the area they covered was calculated as cm^2 and noted (cf. Figure 4). Each moss clusters entering the experimental area was measured and noted separately.

If the station point coincides with areas such as a stream, spring water, road, bedrock, which hinder the sampling process, another locality representing the area 50 m ahead of 50 m behind the road, stream, etc. is considered.

To calculate the inventory of mosses on the trees in the sampling area (Caners et al., 2013), moss samples were measured on tree species in an area of 50 m^2 (a circle with a radius of 3.98 m) (cf. Figure 5).The areas covered by the mosses on the species such as trees, bushes and shrubs entering the area were recorded in the field book in cm^2 by measuring the width and length with the help of a measuring instrument (i.e., tape measure). Other calculations were made as samples taken from the ground. In addition, the diameter and age of the trees with moss on them were calculated from the height of 1.30 m (d: 1.30 m) above the soil surface, entering within the 50 m^2 prefix area, and the age of the tree with the help of the increment auger. No measurement was made when there was no moss on the trees entering the sampling area.

Collected samples were brought to the laboratory and left to dry for 1-2 days in an environment out of direct sunlight. Specimens were identified under the microscope with the help of flora books belonging to various countries (Smit, 2004; Lawton, 1971; Nyholm, 1981; Heyn & Herrnstadt, 2004; Greven, 2003; Cortini, 2006). The soil, stone fragments, needle leaves and other foreign mosses on the dried samples were meticulously cleaned (cf. Figure 6). Small samples were cut as 2x2 cm and large samples as 4x4 cm and the excess was removed. In this way, moss species within a 4m2 area were calculated, since each observation point represents an area of 9 ha, the species in a 4m2 area were proportioned to 9 ha, and finally, the estimated distribution of moss species in an area of 4,200 ha was calculated. Then, air dry weight of each sample was measured with the help of a precision balance (0.000) and recorded.

As a result of these measurements, the type and the area coverage (m^2) of moss species in each sampling area together with, the corresponding air-dry weights were determined.

Data Analysis

The data analysis was performed using the Statistical Package for the Social Sciences version 20.0 software package (IBM Corp, Armonk, NY). Skewness and kurtosis were employed to assess the normality of the data distribution. As the data exhibited a normal distribution, parametric tests were utilized.

Moreover, the relationship between the moss species identified at the sampling points and variables such as altitude, aspect, area covered, and air-dry weights was examined using the ANOVA test. This test aimed to determine if there were any significant associations between these factors and the moss species detected.

Results and Discussion

Out of the originally planned 449 points, only 412 points were sampled during the field studies. This reduction of 37 points was necessary because these locations lacked forest cover, including areas used for agriculture, plantations, and lakes. These excluded points were either empty areas, man-made structures such as roads and fields, or areas with degraded forests. Data were collected from the remaining 412 sample points, and all identified moss taxa were categorized based on the areas they covered, as presented in Table 1. Furthermore, Table 2 provides information specifically on epiphytic moss species. The distribution of moss taxa throughout the entire study area was measured in square meters (m2), and their weights were calculated in kilograms (kg).

Fieldwork was conducted at 412 designated points, and out of these points, a total of 77 sample points yielded no bryophyte specimens. The absence of bryophytes at these stations is primarily concentrated in degraded stands and south-facing aspects, as well as areas dominated by Anatolian black pine (*Pinus nigra* subsp. *pallasiana* (Lamb.) Holmboe) and Scots pine (*Pinus sylvestris* L.) saplings. It is inferred that the dense tree communities in these areas restrict sunlight penetration, thereby hindering sufficient photosynthesis by mosses. Through the identification of bryophyte samples at the remaining 412

observation points, a total of 28 genera from 13 families and 50 moss taxa belonging to these genera were identified.

Table 1. Distribution of taxa according to the areas they cover in the whole study area.

Taxon	Covered area (m^2)	Total air-dry weight (kg)
Syntrichia ruralis (Hedw.) F. Weber & D. Mohr	**67,016,378**	**734,119**
Abietinella abietina (Hedw.) M. Fleisch.	**10,245,200**	**19,860,166**
Lewinskya rupestris (Schleich. ex Schwägr.) F. Lara, Garilleti & Goffinet	**2,141,650**	**5,215,816**
Homalothecium sericeum (Hedw.) Schimp.	**1,880,639**	**1,199,937**
Pseudoscleropodium purum (Hedw.) M. Fleisch.	**1,575,000**	**838,133**
Brachythecium erythrorrhizon Schimp.	**1,438,227**	**632,625**
Hypnum cupressiforme var. *lacunosum* Brid.	**1,287,230**	**705,483**
Brachythecium albicans (Hedw.) Schimp.	**1,189,922**	**740,600**
Hypnum cupressiforme var. *cupressiforme* Hedw.	**1,125,948**	**2,230,200**
Homalothecium philippeanum (Spruce) Schimp.	**973,040**	**800,150**
Brachythecium glareosum (Bruch ex Spruce) Schimp.	**945,000**	**478,566**
Homalothecium lutescens (Hedw.) H. Rob.	**819,644**	**466,888**
Syntrichia ruraliformis (Besch.) Mans.	**603,633**	**420,933**
Tortula subulata Hedw.	**582,108**	**1,821,545**
Rhytidiadelphus squarrosus (Hedw.) Warnst.	**525,000**	**761,133**
Hylocomium splendens (Hedw.) Schimp.	**525,000**	**318,422**
Dicranum scoparium Hedw.	**452,791**	**842,481**
Brachytheciastrum velutinum (Hedw.) Ignatov & Huttunen	**411,211**	**458,681**
Dicranum tauricum Sapjegin	**397,133**	**429,022**
Encalypta rhaptocarpa Schwägr.	**378,000**	**830,200**
Syntrichia virescens (De Not.) Ochyra	**364,700**	**923,533**
Orthotrichum anomalum Hedw.	**225,400**	**140,350**
Syntrichia norvegica F. Weber	**225,166**	**342,766**
Amblystegium serpens (Hedw.) Schimp.	**223,844**	**191,800**
Campylophyllopsis calcarea (Crundw. & Nyholm) Ochyra	**210,000**	**129,266**
Lewinskya striata (Hedw.) F. Lara, Garilleti & Goffinet	**204,088**	**213,188**

Tortella densa (Lorentz & Molendo) Crundw. & Nyholm	**178,500**	**127,866**
Bryum sp. Hedw.	**157,266**	**321,766**
Eurhynchium striatum (Schreb. ex Hedw.) Schimp.	**157,266**	**39,666**
Syntrichia caninervis var. *gypsophila* (J.J. Amann ex G. Roth) Ochyra	**131,133**	**126,000**
Tortella tortuosa (Schrad. ex Hedw.) Limpr.	**130,723**	**238,127**
Grimmia funalis (Schwägr.) Bruch & Schimp.	**122,933**	**302,533**
Ceratodon purpureus (Hedw.) Brid.	**112,233**	**443,333**
Lewinskya affinis (Brid.) F. Lara, Garilleti & Goffinet	**109,128**	**110,851**
Schistidium confertum (Funck) Bruch & Schimp.	**105,000**	**67,200**
Ptychostomum imbricatulum (Müll. Hal.) Holyoak & N. Pedersen	**102,822**	**198,644**
Lewinskya speciosa (Nees) F. Lara, Garilleti & Goffinet	**91,373**	**99,400**
Heterocladiella dimorpha (Brid.) Ignatov & Fedosov	**84,000**	**84,000**
Tortula marginata (Bruch & Schimp.) Spruce	**80,733**	**99,866**
Grimmia trichophylla Grev.	**68,515**	**111,448**
Syntrichia laevipila Brid.	**59,266**	**62,533**
Tortula inermis (Brid.) Mont.	**53,822**	**56,933**
Grimmia ovalis (Hedw.) Lindb.	**28,700**	**60,666**
Gymnostomum calcareum Nees & Hornsch.	**26,133**	**102,666**
Pulvigera lyellii (Hook. & Taylor) Plášek, Sawicki & Ochyra	**26,133**	**20,533**
Grimmia pulvinata (Hedw.) Sm.	**16,893**	**28,140**
Anoectangium aestivum (Hedw.) Mitt.	**16,800**	**133,933**
Encalypta streptocarpa Hedw.	**9,333**	**62,533**
Schistidium apocarpum (Hedw.) Bruch & Schimp.	**7,700**	**13,066**
Tortula vahliana (Schultz) Mont.	**4,200**	**3,266**
TOTAL	**97,216,557**	**44,640,972**

Table 2.Taxa detected only on the tree and their amounts in the whole study area.

Taxon	Covered on tree (m^2)	Air-dry weight (kg)
Hypnum cupressiforme var*. lacunosum* Brid.	3,937,266	1,448,533
Homalothecium sericeum (Hedw.) Schimp.	3,324,844	2,015,377
Brachythecium erythrorrhizon Schimp.	3,307,500	1,592,733
Syntrichia ruralis (Hedw.) F. Weber & D. Mohr	2,243,577	1,642,900
Hypnum cupressiforme var. *cupressiforme* Hedw.	2,083,783	1,089,666
Homalothecium philippeanum (Spruce) Schimp.	1,400,000	855,944
Orthotrichum anomalum Hedw.	840,000	505,866
Homalothecium lutescens (Hedw.) H. Rob.	826,700	408,566
Lewinskya striata (Hedw.) F. Lara, Garilleti & Goffinet	274,244	317,488
Brachytheciastrum velutinum (Hedw.) Ignatov & Huttunen	194,211	220,500
Dicranum scoparium Hedw.	120,691	328,883
Lewinskya affinis (Brid.) F. Lara, Garilleti & Goffinet	105,466	3,511,946
Lewinskya speciosa (Nees) F. Lara, Garilleti & Goffinet	73,344	78,477
Syntrichia laevipila Brid.	58,800	62,533
Tortula inermiş (Brid.) Mont.	28,233	14,233
Pulvigera lyellii (Hook. & Taylor) Plášek, Sawicki & Ochyra	26,133	20,533
Syntrichia virescens (De Not.) Ochyra	21,000	20,066
Grimmia pulvinata (Hedw.) Sm.	9,333	12,133
Amblystegium serpens (Hedw.) Schimp.	933	326
TOTAL	**18,876,058**	**14,146,703**

As a result of the calculations, *Syntrichia ruralis* is the most dominant (67,016,378 m^2) species in the study area. Then, respectively; *Abietinella abietina* (10,245,200 m^2), *Lewinskya rupestris* (2,141,650 m^2), *Homalothecium sericeum* (1,880,639 m^2) and *Pseudoscleropodium purum* (1,575,000 m^2) come. The five taxa with the least distribution are respectively: *Tortula vahliana* (4,200 m^2), *Schistidium apocarpum* (7,700 m^2), *Encalypta streptocarpa* (9,333 m^2), *Anoectangium aestivum* (16,800 m^2) and *Grimmia pulvinata* (16,893 m^2). In this study, the air-dry weights of the species were calculated at 24 °C and 50-60% humidity. Accordingly, when comparing the dry weights of the mosses detected in the area, the first

five species are as follows: *Abietinella abietina* (19,860,166 kg), *Lewinskya rupestris* (5,215,816 kg), *Hypnum cupressiforme* var. *cupressiforme* (2,230,200 kg), *Tortula subulata* (1,821,545 kg) and *Homalothecium sericeum* (1,199,937 kg) (cf. Table 1).

A total of 19 taxa were identified on the tree (cf. Table 2). These taxa are as follows; *Amblystegium serpens, Brachythecium erythrorrhizon, Brachytheciastrum velutinum, Dicranum scoparium, Grimmia pulvinata, Homalothecium sericeum, Homalothecium lutescens, Homalatecium philippeanum, Hypnum cupressiforme* var. *cupressiforme, Hypnum cupressiforme* var*. lacunosum, Lewinskya affinis, Orthotrichum anamalum, Pulvigera lyellii, Lewinskya speciosa, Lewinskya striata, Tortula inermis, Syntrichia ruralis, Syntrichia laevipila* and *Syntrichia virescens*. We think that the inability of taxa to spread too much on the tree is due to the lack of sufficient moisture in a semi-arid area.

The first five species with the highest distribution in terms of the area they cover on the tree are as follows: *Hypnum cupressiforme* var*. lacunosum, Homalothecium sericeum, Brachythecium erythrorrhizon, Syntrichia ruralis,* and *Hypnum cupressiforme* var*. cupressiforme.* Since the study area is in a semi-arid area, we can say that these species mentioned in Table 2. are drought-resistant species. According to Proctor et al., (2007) shoots of many mosses can survive for a year or more. Keever (1957) observed new growth in shoots of *Grimmia laevigata* from herbarium specimens stored for as long as 10 years. *Anoectangium compactum* is recorded as surviving 19 years air dry and *Syntrichia ruralis* regenerated from protonemata after 14 years air dry (Bristol, 1916; Maheu, 1922). During dry periods, mosses go into a dormant state, and when there is enough moisture in the air, they can continue their vital activities again (Glime, 2017).

According to the ANOVA test, the effects of elevation, aspect, slope and station factors on the species are statistically different by looking at the sigma (sig. value <0.05) value. However, these factors did not differ in terms of area covered (ha) and species weight (cf. Table 3).

Table 3. Descriptive statistical analysis results of the study area.

	Number of Samples	A.A.	S.D.	The biggest	The smallest	VC
Species	542	21.23	13.19	43	1	62,13
Covered(m^2)	690	141.6	481.8	6750	0	340,25
Weight (kg)	690	127.60	437.30	8510	0	342,71

AA: Arithmetic average, VC: Variation coefficient, SD.: Standard deviation

As seen in Table 4, there is a very high statistical relationship between altitude and aspect and the number of moss taxa according to the value of P<0.05. Again, a very high correlation was found between the area covered by the taxa and the slope. A very high correlation was also observed between the weights of the taxa and the slope.

Table 4. The ANOVA test results of the study area.

Moss Taxa Distribution	Number of Taxa		Area Covered (ha)		Samples Weight	
	F	P	F	P	F	P
Altitude	1.61	0.00*	0.35	1.00	0.31	1.00
Slope	1.17	0.23	2.22	0.00*	1.63	0.01*
Aspect	3.53	0.00*	1.29	0.22	0.85	0.57

F: ANOVA analysis (one-way analysis of ANOVA), P* < .05.

The results of one-way ANOVA following by S-N-K post-hoc test showed (cf. Figure 7), that (A) there were no differences between the total covered areas in terms of aspect (F=1.245 and p= 0.293) and slope (F=1.259, p= 0.288). (B) The results of one-way ANOVA showed that there were no differences between the total air-dry weights in terms of aspect (F=1.061 and p= 0.365) and slope (F=2.315, p= 0.075).

Conclusion

In this study, after the flood disaster in the Eldivan district of Çankırı province in 1952, afforestation work was carried out over an area of 4,200 hectares (42,000,000 m2) on Eldivan Mountain from 1960 to 1970. When it is assumed that there were no bryophyte samples in the area before the afforestation work was carried out. The main aim of this study was to estimate how many bryophytes came to the area after this afforestation study. A large part of the research area is afforested with Anatolian black pine, and high-altitude hills are afforested with Scots pine. It is possible to come across old Anatolian black pine, oak and poplar stands in small groups in the region.

The mosses that come to these areas with the afforestation works to be carried out in arid and semi-arid areas by especially water-poor countries such as Turkey will help to retain more water in the forest ecosystem. Assuming no moss was found in the area prior to the reforestation work. With this afforestation work carried out in 1960-1970, suitable environmental conditions for bryophyte were provided and 97,216,557 m2 and 44,640,972 kg of moss material was brought to the area. But no liverwort specimens were found in the study area. The fact that the research area is located in one of the semi-arid regions of Turkey is actually an indication that there is not enough moisture in the area for the development of liverworts.

The distribution of moss species in the area by aspect is as follows. The taxon with the highest distribution in the north is *Brachythecium erythrorrizon* with 18%. It is followed by *Dicranum scoparium* 15% and *Hypnum cupressiforme* 14%, respectively. The taxon with the highest distribution in the south is *Syntrichia ruralis* with 42.11%. Then, respectively; *Brachythecium erythrorrizon* 15% and *Hypnum cupressiforme* 10%. The taxon with the highest distribution in the eastern part is *Syntrichia ruralis*, 20%. Then, respectively; *Brachythecium erythrorrizon* 19%, *Dicranum scoparium* 8%, *Brachytheciastrum*

velutinum 8% and *Tortella tortuosa* 8%. The taxon with the highest distribution in the west is *Syntrichia ruralis* with 24%. Then, respectively; *Hypnum cupressiforme* is 10%, *Homalothecium lutescens* 9%, *Brachythecium erytrorrizon* 7% and *Tortella tortuosa* 7%. If we look at the distribution ratios of the moss species, we can say that *Syntrichia ruralis* is the most dominant species in the area, regardless of the aspect. In every aspect, it appears as a species adapted to life.

The study area is located within the borders of Ankara Regional Directorate of Forestry. Until now, in different amounts, at different times and periods, moss material was collected in Adana, Antalya, Balıkesir, Bolu, Bursa, Çanakkale, Denizli, İstanbul, İzmir, Isparta, Kütahya, Kastamonu, Mersin, Muğla, Sinop and Zonguldak Regional Directorates of Forestry (cf. Figure 8). The collected products were evaluated in Turkey and no sales were made abroad for commercial purposes. The collected mosses are generally thought to be used in the floriculture and sapling industry. However, production is allowed in Turkey regardless of the continuity of mosses and their role in the habitat. To prevent the unconscious and uncontrolled moss harvest resulting from this situation, it is necessary to carry out inventory studies as soon as possible, especially in the areas where the recall is made, and even these studies should be considered in the new management plans. As a result of technically insufficient production, some moss species are in danger of extinction. In addition, the continuity of other moss species is endangered due to over-collection. In order to prevent all these conditions, we think that at most one third of the bryophyte amount in the area is extremely important for a sustainable harvest.

The development of epiphytic moss species is quite limited in regions such as Turkey with an average annual precipitation of 573 mm (Sarış, 2021). Therefore, for a sustainable moss harvest, mosses should not be harvested from trees in water-poor countries such as Turkey. The study area has a mean annual precipitation of 427 mm and a temperature of 11.9 °C (Ediş et al., 2022). Accordingly, the air-dry weight of all mosses in the research area is 44.640.972 kg. The weight of only epiphytic species is 14.146.703 kg. 44.640.972 - 14.146.703 = 30.494.269 kg are the air-dry weights of moss on the ground only. According to Peck and Muir (2008), it would be appropriate to remove 1/3 of all moss in the area for a sustainable moss harvest. There are 30.494.269 / 3 = 10,164,756 kg of harvestable air-dry moss. It was calculated as 10,164,756 kg / 4,200 ha = 2,42 kg harvestable moss per hectare in the research area. In a well-maintained optimum larch stand. In terms of sustainability, an average of 2 tons/ha of moss harvest can be considered appropriate.

According to Ursavaş et al., (2013), The forest regional directorates in Turkey that engage in intensive harvesting are located in Balıkesir, Bursa, and İzmir. The respective sizes of these forest areas are as follows: İzmir spans 1,021,027 ha, Bursa covers 771,364 ha, and Balıkesir encompasses 632,038 ha. (Özgür & Çevirme, 2021). Considering the areal sizes of Regional Forestry Directorates and the amount of precipitation per square meter are higher than our research area, there does not appear to be a problem in terms of sustainability. However, a re-harvest planning for the mosses on the ground should not be made before 5 years have passed from the harvest time in the harvested region (Peck, 2006).

This study holds significant importance as it marks the pioneering moss inventory conducted in Turkey. It is crucial to note that the moss species gathered in Turkey are not traded internationally, and the quantity of harvested moss does not pose sustainability concerns. Moreover, given the insufficient rainfall in Turkey, the harvesting of epiphytic species should be avoided, focusing solely on above-ground harvesting. It is of utmost importance to expedite moss inventory studies, particularly in the Balıkesir, Bursa, and İzmir Regional Directorates of Forestry, where extensive moss harvesting occurs, in order to unveil the moss species endemic to those regions.

Declarations

Author contribution

Serhat Ursavaş wrote the article, helped collect data from the field, made the figures and tables. Recep Söyler collected the data from the field and analyzed the data in the laboratory. All authors reviewed the manuscript.

Acknowledgments

We would like to express our appreciation to Dr. Ferhat BOLAT for his expertise in conducting the ANOVA analyses. Additionally, we acknowledge Dr. Semih KUTER for his valuable contribution in reviewing the article's English language.

Competing interests The authors declare no competing interests.

Ethics approval All authors have read, understood, and have complied as applicable with the statement on “Ethical responsibilities of Authors” as found in the Instructions for Authors.

Data availability Data is contained within the article.

Funding

This study was not supported by any institution or organization.

References

1. Alexander, S. (2002, April, 02). The Montreal Process Criteria and Indicators. Criterion 6 Indicator 47. Area and percent of land used for subsistence purposes. U.S. Sustainable Forestry Report. From: http://www.fs.fed.us/research/sustain.
2. Blatner, K.A. (1997). Special forest products markets in the Pacific Northwest with global implications. Ch. 3. In N. C. Vance J. Thomas (eds.), Special Forest products: biodiversity meets the marketplace. USDA Forest Service General Technical Report WO-63: 42-53– 8c S.
3. Borges, P. A., Cardoso, P., Kreft, H., Whittaker, R. J., Fattorini, S., Emerson, B. C., Gil, A., Gillespie, R. G., Matthews, T. J., Santos, A. M. C., et al. (2018). Global Island Monitoring Scheme (GIMS): a proposal

for the long-term coordinated survey and monitoring of native island forest biota. Biodiversity and conservation. 27:2567–2586.

4. Bristol, B. M. (1916). On the remarkable retention of viability in moss protonema. New Phytologist, 15:137–143.
5. Caners, R. T., Macdonald, S. E., & Belland, R. J. (2013). Bryophyte assemblage structure after partial harvesting in boreal mixedwood forest depends on residual canopy abundance and composition. Forest Ecology and Management. 289:489–500.
6. Cortini, P. C. (2006). Flora dei muschi d'Italia (Sphagnopsida, Andreaeopsida, Bryopsida. I parte), 817–1235 p.
7. Ediş, S., Tuttu, G., Aytaş, İ., Tuttu, U., & Özcan, A. U. (2022). Analysis of temporal and spatial change in Acıçay (Çankırı) Riparian Zone. Artvin Coruh University Journal of Forestry Faculty. 23(1):1–10.
8. Fenton, N. J., & Frego, K. A. (2005). Bryophyte (moss and liverwort) conservation under remnant canopy in managed forests. Biological Conservation. 122:417–430.
9. Glime, J. M. (2017, July 17). Water Relations: Physiological Adaptations. Chapt. 7-5. In: Glime, J. M. Bryophyte Ecology. Volume 1. 7-5-1 Physiological Ecology. Ebook sponsored by Michigan Technological University and the International Association of Bryologists. Last updated 17 July 2020 and from http://digitalcommons.mtu.edu/bryophyte-ecology/.
10. Greven, H. C. (2003). *Grimmias* of the World. Leiden: Backhuys Publishers, 250 p. The Netherlands.
11. Heyn, C. C., & Herrnstadt, I. (2004). The Bryophyte Flora of Israel and Adjacent Regions. The Israel Academy of Sciences and Humanities, Jerusalem, 719 p.
12. Jones, E. T., McLain, R. J., & Weigand, J. (2002). Nontimber Forest Products in the United States. University Press of Kansas. Lawrence, KS.
13. Keever, C. (1957). Establishment of *Grimmia laevigata* on bare granite. Ecology. 38:422–429.
14. Lawton, E. (1971). Moss Flora of Pacific Northwest. Journal of Hattori Botanical Garden Laboratory. Michigan. 760 p.
15. Maheu, J. (1922). Régéneration du *Barbula ruralis* aprés quatorze ans de sécheresse par protonémas primaries propaguliféres et protonémas secondaires bulbigénes. Bulletin de la Societe Botanique de France. 69:330–334.
16. Muir, P. S., Norman, K. N., & Sikes, K. G. (2006). Quantity and Value of Commercial Moss Harvest from Forests of the Pacific Northwest and Appalachian Regions of the U.S. The Bryologist. 109(2):197–214.
17. Nyholm, E. (1981). Illustrated Moss Flora of Nordic Mosses. Fasc. 6. Lund: Nordic Bryological Society.
18. OGM. (2021, April 02). T.C. Tarım ve Orman Bakanlığı, Meteoroloji Genel Müdürlüğü. from https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=CANKIRI in Turkish, Accessed: 02April,2021.

19. Özgür, H., Çevirme, M. (2021). 2020. Türkiye Orman Varlığı. T.C. Tarımve Orman Bakanlığı, Orman Genel Müdürlüğü, Orman İdaresi ve Planlama Dairesi Başkanlığı. Ankara. ISBN 978–605–7599–68–1.
20. Peck, J. E., & McCune, B. (1998). Commercial Moss harvest in northwest Oregon: Biomass and accumulation of epiphytes. Biological Conservation. 86:299–305.
21. Peck, J. E., & Muir, P. (2008). Biomass Inventory and Regrowth Rate of Harvestable Tree and Shrub Moss in the Oregon Coast Range. West. J. Appl. For. 23:34–39.
22. Peck, J. E. (2006). Towards sustainable commercial moss harvest in the Pacific Northwest of North America. Biological Conservation. 128:289–297.
23. Peck, J. L., Hoganson, H., Muir, P., Ek, A., & Frelich, L. (2008). Using Inventory Projections to Evaluate Management Options for the Nontimber Forest Product of Epiphytic Moss. Forest Science. 54(2):185–194.
24. Piessens, K., Stieperaere, H., Honnay, O., & Hermy, M. (2008). Efects of management and adjacent forest on the heath land bryophyte layer. Basic and Applied Ecology. 9:253–262.
25. Proctor, M. C. F., Oliver, M. J., Wood, A. J., Alpert, P., Stark, L. R., Cleavitt, N. L., & Mishler, B. D. (2007). Desiccation-tolerance in bryophytes: a review. The Bryologist. 110(4):595–621.
26. Sarış, F. (2021). Evaluation of Domestic Water Supply and Use Statistics of Turkey. Turkish Journal of Geographical Sciences. 19(1):195-216.
27. Smit, A. J. E. (2004). The Moss Flora of Britain and Ireland. Cambridge University Press. 1012 p.
28. Ursavaş, S., Birben, Ü., & Albayrak, R. B. (2013). OdunDışı Orman Ürünü Olarak Karayosunlarının Ülkemizdeki ve Yurtdışındaki Durumu. 2023'e Doğru 2. Doğave Ormancılık Sempozyumu. In Turkish.
29. Ursavaş, S., & Öztürk, E. (2016). Çankırı Karatekin Üniversitesi, Orman Fakültesi, Araştırma ve uygulama ormanında ölü ağaçlar üzerinde tespit edilen karayosunları. Anatolian Bryology. 2(1–2):21–46.
30. Ursavaş, S., & Söyler, R. (2015). Orman Bölge Müdürlüğü Bazında Hasat Edilen Karayosunlarının Miktarları ve Satış Rakamları. Kastamonu Üniversitesi Orman Fakültesi Dergisi. 15(2):241-251.
31. Ursavaş, S., & Tuttu, G. (2020). Çankırı Karatekin Üniversitesi, Orman Fakültesi Araştırma ve Uygulama Ormanının Karayosunu FlorasınaKatkılar. Anatolian Bryology. 6(1):27–40.
32. Vance, N. & Thomas, M. (1997). Bryophytes associated with *Acer circinatum*: recovery and growth following harvest. Pp. 267–271. In Kaye T, Liston A, Love R, Luoma D, MeinkeR, Wilson M. (eds.), Conservation and Management of Native Plants and Fungi. Native Plant Society of Oregon, Corvallis, OR. & J. Thomas, (eds.). 1997. Special Forest products: biodiversity meets the marketplace. USDA Forest Service General Technical Report. WO-63:1–163.
33. Vanderpoorten, A., Delescaille, L., M., & Jacquemart, A. L. (2004). The bryophyte layer in calcareous grassland after a decade of contrasting mowing regimes. Biological Conservation. 117:11–18.

Figures

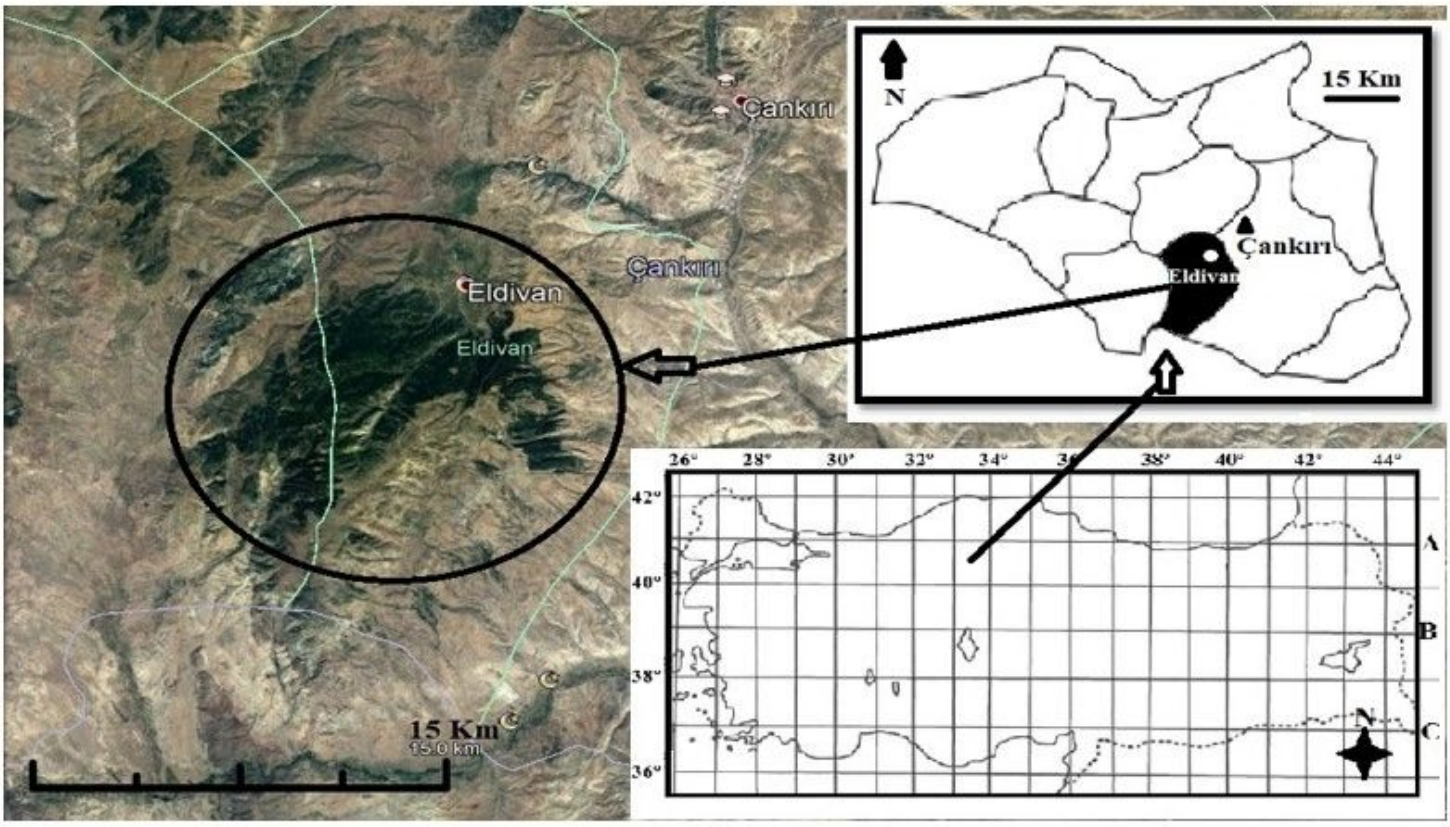

Figure 1

The location of the Eldivan mountain, (developed from Google Earth, 2022).

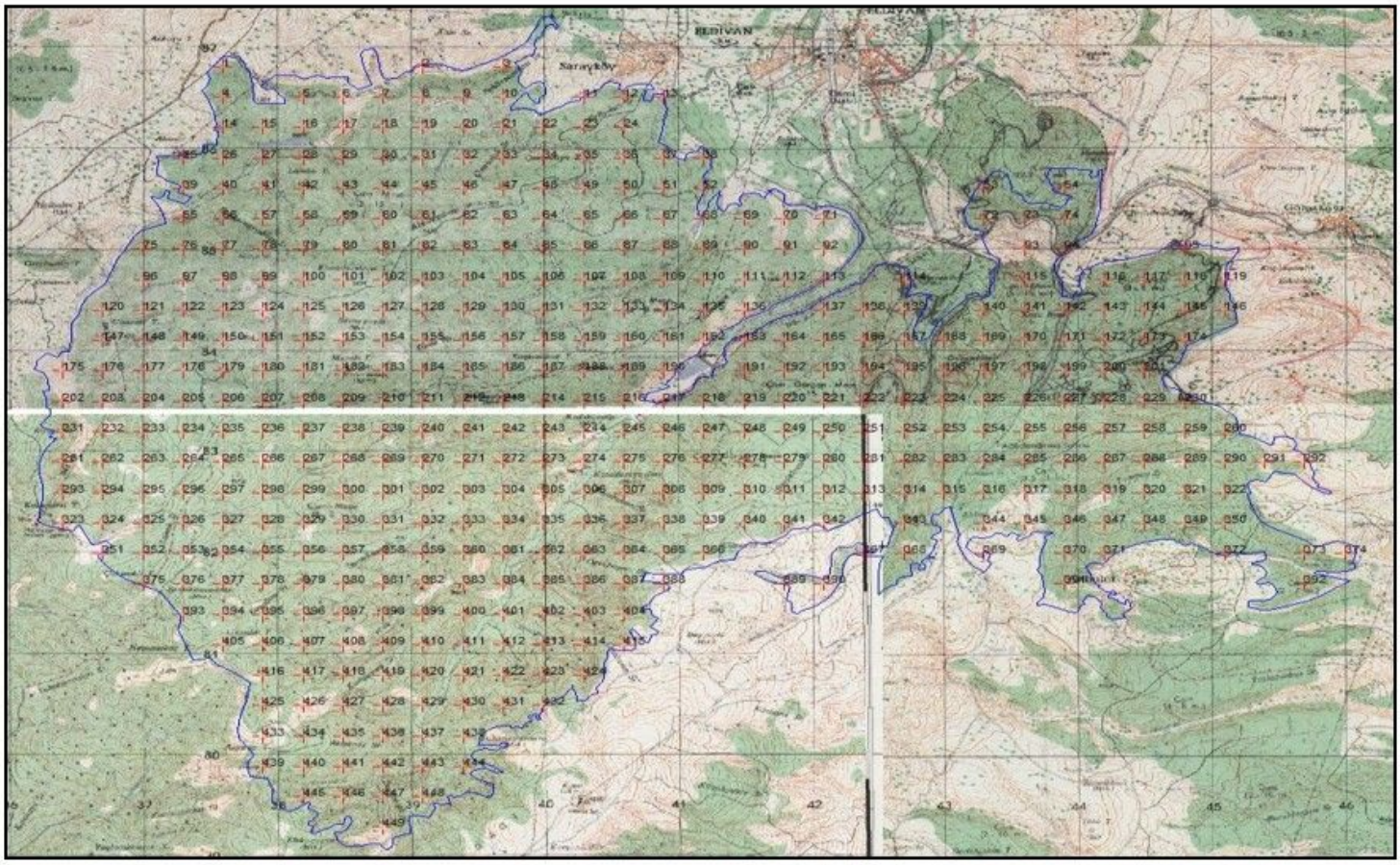

Figure 2

Sampling points taken at 300 m interval in the study area.

Figure 3

Four square meter sampling area (2 x 2 = 4m^2).

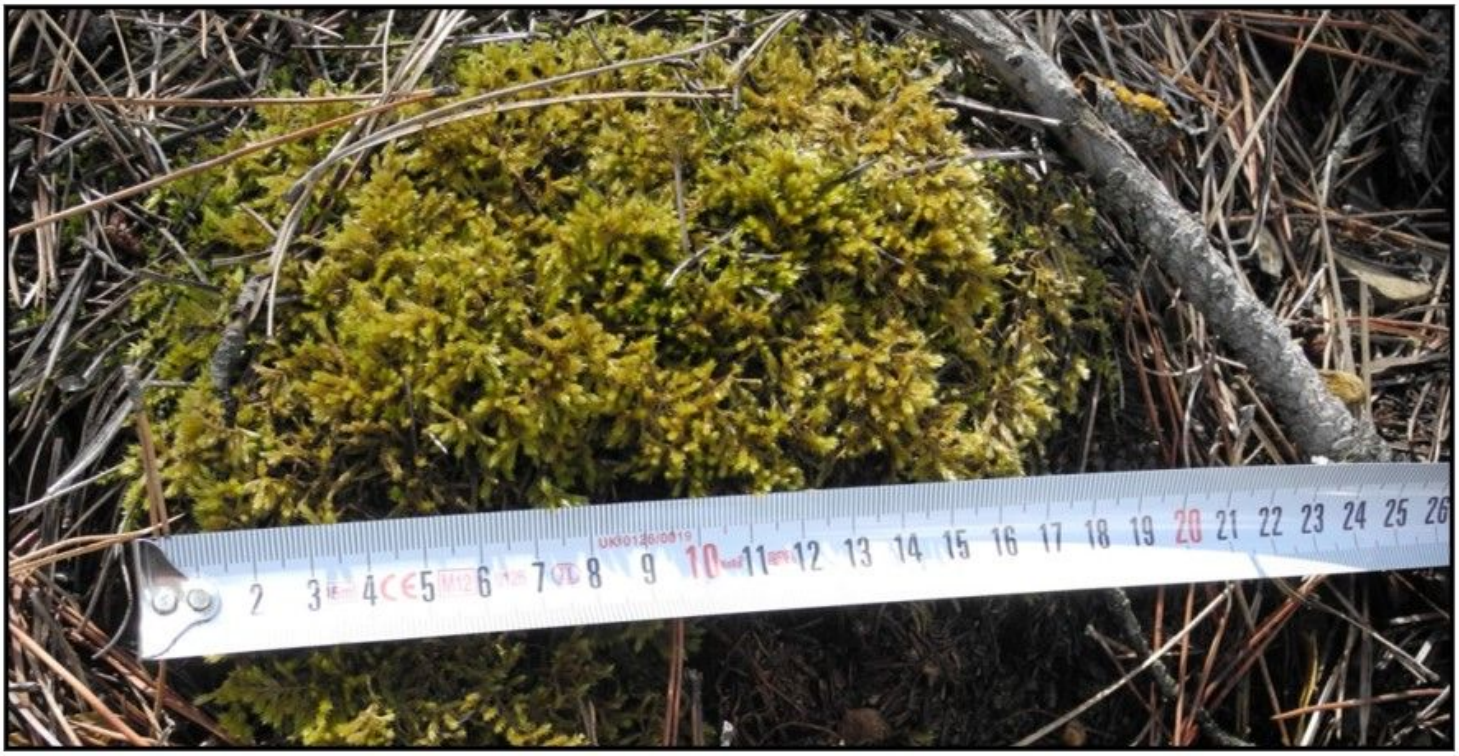

Figure 4

Measurement of the width and length of the moss samples.

Figure 5

Sample area of 50 m^2 for epiphytic bryophytes on the tree.

Figure 6

Cleaning and sizing of moss samples from foreign matter.

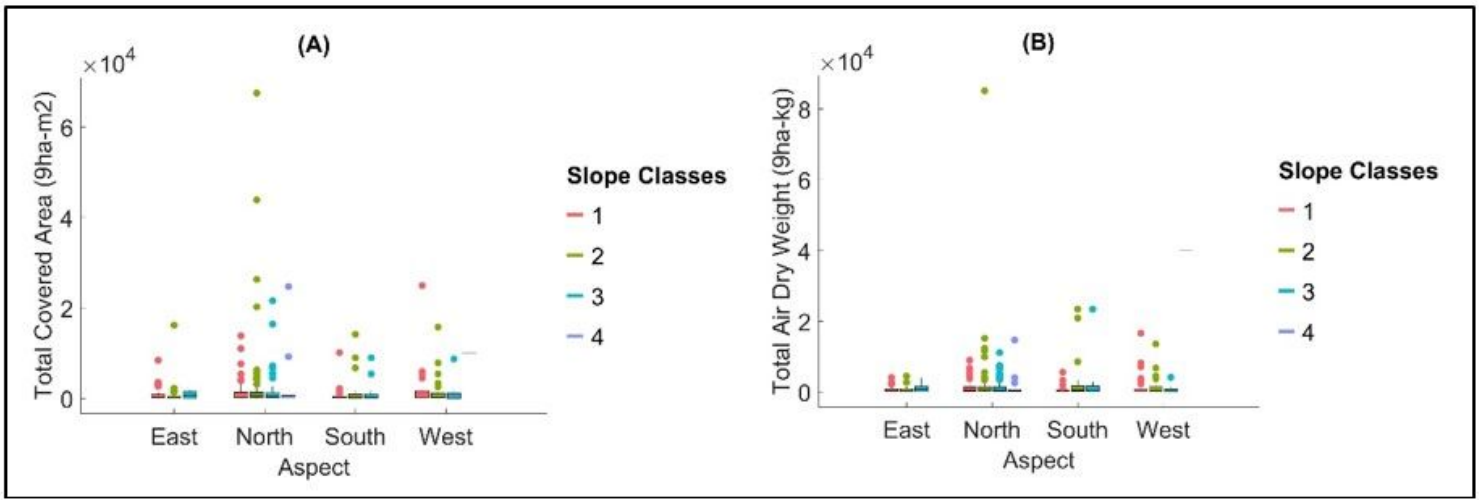

Figure 7

The total covered area and the total air-dry weight of Moses in terms of aspect and slope classes (Slope class 1: ≤10%, 2: 11-20%, 3: 21-33%, and 4: 33%>).

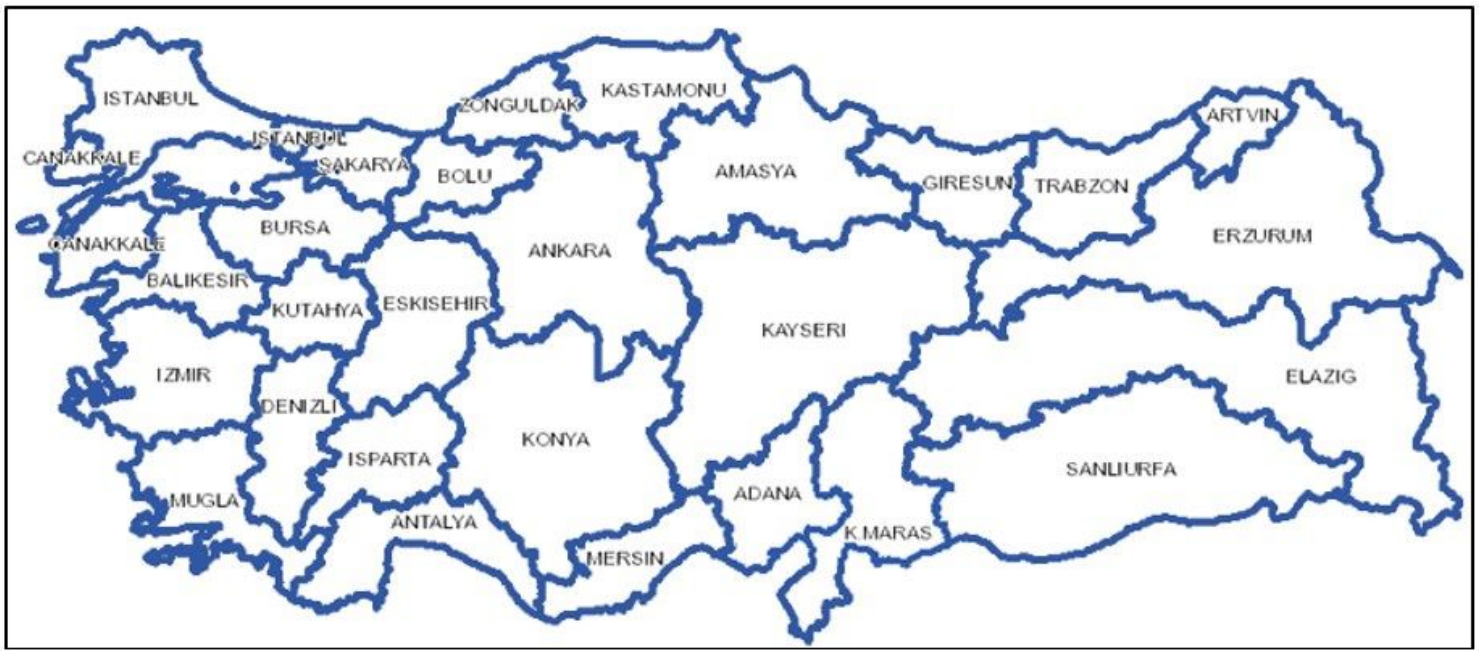

Figure 8

Map showing Regional Directorates of Forestry in Turkey.