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Native occurrence areas of Anatolian Scots pine (*Pinus sylvestris* L. var. *sylvestris*) forests and their vegetation composition in Anatolia, Türkiye

Anadolu sarıçamının (*Pinus sylvestris* L. var. *sylvestris*) doğal yayılış alanı ve vejetasyon bileşimi

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Abstract

Anatolian Scots pine (*P. sylvestris* var. *sylvestris*) forests spreading in the northern part of Anatolia, Türkiye, and covering 2.1 million hectares show great variation in terms of the vegetation composition depending on both ecological conditions and human interference. The spreading and/or growing of Scots pine is mostly related to the sunny cold, subhumid continental climatic conditions as well as the cold and semiarid climate. It begins at the coastal belt of the Black Sea coast and rises up to 2700 m in the NE part of Anatolia, and continues towards the semiarid continental part of Central Anatolia. Scots pine is associated with *Fagus orientalis, Castanea sativa, Tilia rubra, T. tomentosa, Alnus barbata, A. glutinosa, Quercus* sp., etc. in the lower belt of the Black Sea coast, with *Picea orientalis* and *Abies nordmanniana* in the eastern upper belt of the Black Sea Mountains, and with *Abies bornmulleriana* in the middle and western parts of the Black Sea Region. It is composed of *Pinus nigra* and *A. nordmanniana subsp. equi-trojani* in the backward or southern parts of the Black Sea Region. Pure Scots pine stands occur in the subhumid continental part of NE Anatolia and the semiarid-subhumid continental part of Inner Anatolia. This study aims to highlight the natural occurrence of its forests, and to introduce their main vegetation composition reflecting ecological conditions.

Keywords*:* Scots pine, ecology, climate change, biotic factors

Öz

Anadolu'nun kuzeyinde yayılan ve 2,1 milyon hektar saha kaplayan Anadolu sarıçam (*P. sylvestris* var. *sylvestris*) ormanlarının bileşimi, ekolojik koşullara ve insan etkisine bağlı olarak önemli değişme gösterir. Sarıçamın yetişmesinde ve yayılışında güneşli soğuk, yarınemli karasal iklim koşulları etkilidir. Sarıçam; Karadeniz kıyı kuşağında *Fagus orientalis, Castanea sativa, Tilia rubra, T. tomentosa, Alnus barbata, A. glutinosa* ve *Quercus* sp. ile, Doğu Karadeniz kıyı dağlarının yüksek kesimlerinde *Picea orientalis* and *Abies nordmanniana* ile Orta ve Batı Karadeniz bölümlerinde ise *A. nordmanniana subsp. equi-trojani* ile karışık meşcereler halindedir. Ayrıca Karadeniz Bölgesi'nin ardında veya güneyinde *Pinus nigra* ve *A. nordmanniana subsp. equi-trojani* ormanlarında yer alır. Saf sarıçam meşcereleri, Kuzeydoğu Anadolu'nun yarı nemli karasal alanlarında ve Orta Anadolu'nun yarı kurak, yarı nemli alanlarında görülür. Bu çalışmanın amacı, sarıçamın doğal yayılış alanı ve ekolojik koşullara göre vejetasyon bileşimini ortaya koymaktır.

Anahtar kelimeler*:* Sarıçam, ekoloji, iklim değişikliği, biyotik faktörler

1. Introduction

Scots pine (*P. sylvestris*) forests show a wide distribution in the northern part of the Eurasia continent. In these areas, Scots pine is mostly found in pure stands and associated with birch, fir, spruce, and other broadleaved trees, like willow. It grows under the humid cold maritime climate in the Western part of Europe and the British Isles, and the severe continental and very cold climate in Siberia. But in Anatolia, Scots pine grows humid-mild and humid-cold in the northern part of the Northern Anatolian Mountains facing north or the Black Sea, semi-continental subhumid conditions in the backward regions of the Black Sea or the northern parts of Anatolia, severe continental and cold condition in the NE Anatolia and subhumid-semiarid conditions in the Inner Anatolia. In Anatolia, according to the field study, Scots pine (*P. sylvestris* var. *sylvestris*) begins as small clusters at the seashore of Black Sea coast within the deciduous forest and continues the upper part of mountainous areas, especially on the slope facing south.

The northern part of Anatolia is one of the native spreading areas of Scots pine forests. In Anatolia, three varieties of Scots pine are found out (Akkemik 2018):

-*Pinus sylvestris* L. var. *sylvestris*

-*Pinus sylvestris* L. var. *hamata* Steven

-*Pinus sylvestris* L. var. *compacta* (Tosun) Ü. Akkemik

Scots pine (*P. sylvestris* var. *sylvestris*) is the most common native forest tree of Northern Anatolia. So, the dominant species of Scots pine in Anatolia is accepted as *P. sylvestris* var. *sylvestris*.

Up to now, the relationship between physiographic and edaphic traits on the growth of pure Scots pine stands has been investigated. The botanical properties of Anatolian Scots pine were examined (Eliçin 1971; Tosun, 1988; Akkemik, 2018). Silvicultural applications of Scots pine were carried out (Pamay, 1962). Site class index, productivity and the native spreading areas of Scots pine were examined (Alemdag, 1967; Özdemir, 1974; Ercanlı et al., 2006). Ecological properties of Scots pine forests in NE Anatolian were made (Tetik, 1986). The general distribution of the Scots pine in Anatolia was mentioned (Acatay,1957; Akan, 1955; Atalay, 1994; 2014a; Atalay et al., 1985; 1963). Detailed ecological properties of Scots pine forests and their seed transfer regions were carried out (Atalay and Efe, 2012). In this context, this study aims to highlight the natural occurrence of *P. sylvestris* forests and introduce their main vegetation composition, reflecting ecological conditions.

2. Materials and Methods

This study considers only the native distribution of Scots pine and its vegetation composition as a material. For this reason, all native distribution areas of Scots pine forests in Anatolia were visited between 2008 and 2020. During the field study, the relationship between the natural distribution areas and topographic factors, such as altitude, aspect, direction of the mountain ranges, and climatic data covering the period from 1975 to 2006 obtained from meteorological stations, as well as parent material, soil, and biotic factors were taken into consideration.

The climatic maps, such as mean annual temperature, precipitation, relative humidity and cloudiness, and solar radiation intensity especially during the vegetation period were drawn. Subsequently, *P. sylvestris* distribution map overlapped on the climatic map in order to show the relationship between the climatic properties and the native distribution areas of Scots pine. On the other hand, many topographic profiles and geological cross-sections were generated to illustrate the relationships between the distribution of the Scots pine and parent material, topographic properties, competition situation and the other trees.

3. Findings

3.1. Natural distribution of Scots pine

The native occurrence areas of Scots pine are widespread in the mountainous areas of the northern part of Anatolia in general. The northern Anatolian mountain ranges extend in an east-west direction in the northern part of Anatolia and are deeply dissected by rivers flowing into the Black Sea. Faulting movements have led to the formation of depressions such as Kelkit, Erbaa-Niksar, Ilgaz-Osmancık, and Durağan-Taşköprü (Figure 1). Scots pine begins at the coastal belt of the Black Sea, rises up to 2700 meters in NE Anatolia, and continues as far as the northern part of Anatolia and the north of the Hekimhan district of Malatya province in the east. Scots pine appears not only in mixed forests but also in pure forests, in accordance with climatic conditions. In the humid-temperate and humid-cold Black Sea Region, Scots pine is associated with oriental beech (*F. orientalis*), fir (*A. nordmanniana* subsp. *nordmanniana*), and oriental spruce (*P. orientalis*), but in the continental areas of the Backward Regions of the Black Sea and the northern part of Inner Anatolia, it is seen as pure forests (Figures 4 to Figure 8).

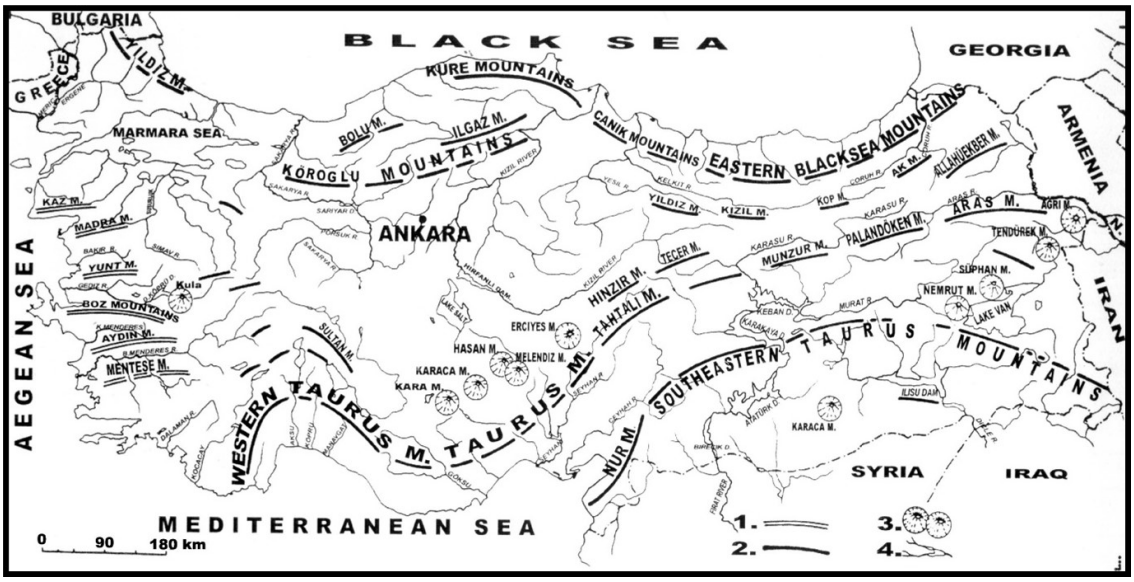

Figure 1. Main mountains and rivers of Türkiye: 1) Horst mountains, 2) Orogenic mountains, 3) Volcanic mountains, 4) Rivers

Şekil 1. Türkiye'nin başlıca dağları ve ırmakları: 1) Horst dağları, 2) Orojenik dağlar, 3) Volkanik dağlar, 4) Nehirler

In order to present detailed information about the spreading areas and floristic composition of Scots pine, it is necessary to examine them according to climatic regions. For example, the Coruh Basin, which is located in the eastern part of the Black Sea Region, covers the Coruh River drainage basin and is ecologically divided into five subregions. In the Ardanuc-Şavşat basin, located in the northern part of the Coruh basin, Scots pine is composed of *A. nordmanniana* subsp. *nordmanniana* and *P. orientalis* on the north-facing slopes due to the fog formation. In the Peynirli locality, S of Ardanuc district, dense/lush forest is composed of *P. sylvestris, A. nordmanniana* subsp. *nordmanniana,* and *P. orientalis*. The height of these trees is more than 30 meters.

Middle Coruh Basin, extending between Ispir and Yusufeli districts, has pure and productive Scots pine forests growing under direct solar radiation on the upper part of two sides of the Coruh River valley. However, toward the Barhal Basin, which is located in the NE part of the Kackar Mountain, *P. orientalis* forests containing very small Scots pine clusters appear on the slopes receiving fog. On the upper part of this basin, pure Scots pine forests are found at elevations above 2000 meters, along with Scots pine forests coexisting with oriental spruce due to the cold and humid conditions.

As to the bottom of the Coruh Valley extending between Artvin and Borcka districts, its vegetation composition considerably changes as compared to other parts of the Coruh Basin because of the mild and somewhat humid conditions. Here, Scots pine stands composed of *Arbutus andrachne, Juniperus oxycedrus,* and *Rhus coriaria* belonging to the Mediterranean vegetation region. *Alnus barbata* and *Carpinus orientalis* are also seen. In this area, Scots pine can be considered as a relict tree (Figure 4).

In the lowland of the Coruh Basin, small pure Scots pine and oak-pine clusters are seen due to the arid and sunny environments. The remaining area of the Coruh Basin containing the western part of the Coruh Basin, Oltu, Olur and Tortum basins, which are the main tributaries of the Coruh River, are the semiarid areas due to the rainshadow effect. Here, aspect position is the decisive factor for the spreading of Scots pine. In fact, the main occurrence areas of Scots pine are seen on the upper north-facing slopes of the mountains, because northern slopes get the humid air coming from the Black Sea; but the southern slopes are the main occurrence areas of dry forests and shrub communities due to arid conditions (Figure 5).

It can be stated that the aspect factor is responsible for the distribution of vegetation communities, including Scots pine. The north-facing slopes, receiving humid air mass coming from the Black Sea and fog, constitute the main occurrence areas of *A. nordmanniana* subsp. *nordmanniana* and *P. orientalis* forests, while the southern slopes are the main spreading habitat of pure Scots pine forests, in general.

In the plateau areas of NE Anatolia, on which severe continental climatic conditions prevail, pure and productive Scots pine stands are common.

Here, only Posof Basin, getting humid air masses from the Black Sea, the mixed forests composed of *Rhododendron* sp. and *P. orientalis* are common (Figures 2, 3, 4 and 5).

Kelkit Basin which is the main tributary of the Yesilırmak River, flowing into the Black Sea and can be termed a tectonic basin bounded by mountains, is one of the main distribution areas of Scots pine. The aspect situation of the Basin determines not only the distribution areas but also the productivity of Scots pine stands. The southern slopes of the Canik-Gumushane-Giresun mountains range in the north of the basin are the main pure occurrence areas of Scots pine. On the southern slope of the mountains, Scots pine begins with oaks at about 1300 meters elevation in the bottom of the Kelkit Basin. After reaching elevations of 1500/1600 meters, pure and productive Scots pine stands continue, as high as 2000 meters, toward the foggy areas of the Coastal mountains of the Black Sea Region (Figures 6 and 7). Here, areas under the jurisdiction of the Forestry Enterprise Directorates of Koyulhisar and Mesudiye are covered with mostly pure and productive Scots pine. However, on the north-facing local slopes, fir (*A. nordmanniana* subsp. *nordmanniana*) stands occur. One of the conspicuous properties of the area is the existence of *A. nordmanniana* subsp. *nordmanniana* and *F. orientalis* plants in the lower story of Scots pine. This situation clearly reflects the existence of a humid Scots pine forest in this area (Figure 6).

In the northern slopes of the Kelkit Basin and the Lower basin of Yeşilırmak, *F. orientalis* and *Carpinus* sp. are widespread, Scots pine grows commonly on the upper and south-facing slopes of the mountains, but its productivity is low due to continental aridity effects. The western part of the backward regions of the Black Sea can be divided into following subregions in terms of the spreading and ecological standpoint of Scots pine.

1. The Köroglu Mountain subregion, extending from the southern end of the region, is the main occurrence of pure Scots pine. The upper part of the Kibriscik plateau and almost all parts of the Köroglu Mountains, including Ala Mountains, are one of the pure and productive Scots pine spreading areas. The existence of direct solar radiation and subhumid conditions supports the growth of the Scots pine forests in the above-mentioned areas. But on the north slopes of these mountains getting fog, *A. nordmanniana* subsp. *equi-trojani* clusters are seen.

2. The Kastamonu plateau and its vicinity between the Kure Mountain in the north and the Ilgaz Mountains in the south is another pure and mixture Scots pine distribution area. Scots pine stands occur on the upper part of the black pine (*P. nigra*) forest in the Kastamonu plateau. On the north-facing slopes of the Ilgaz Mountains the leading forests are *P. nigra, Carpinus orientalis, F. orientalis, A. nordmanniana* subsp. *equi-trojani* and *P. sylvestris*; toward the upper northern part of the Ilgaz Mountains pure *A. nordmanniana* subsp. *equi-trojani* and *A. nordmanniana* subsp. *equi-trojani* - *P. sylvestris* forests are commonly seen. Pure *P. sylvestris* stands are widespread on the south-facing slopes of the Ilgaz Mountains (Figure 8). Generally mixed forest areas composed of *P. sylvestris, A. nordmaniana,* and partly *Fagus orientalis* are found on the north slopes of the Kure Mountains.

3. As to the vicinity of Bolu province, forest composition frequently changes depending on the slope/aspect factors. Namely, foggy slopes are the main spreading areas of *F. orientalis*, especially *A. nordmanniana* subsp. *nordmanniana* forests. Along the Bolu-Abant depression, north-facing slopes are mostly covered with pure *A. nordmanniana* subsp. *equi-trojani* forest, while south-facing slopes are the dominant areas of pure *P. sylvestris* stands. South-facing slopes of Kartalkaya Mountains, S of Bolu, are the pure and productive Scots pine forest area. Here in the lowerstory of Scots pine forest *A. nordmanniana* subsp. *equi-trojani* regeneration is seen. In the upper part of the mountainous areas of Bolu province, one can see the tall Scots pine trees within the broadleaved deciduous and fir forest.

4. The Sundiken mountains which are located S of the Sakarya River valley, NW of Anatolia, are one of the natural occurrence areas of Scots pine. Here pure Scots pine stands are common on the north-facing slopes, while black pine stands are common on the high south-facing slopes of this mountain. This situation implies that *P. nigra* is more resistant to drought compared to *P. sylvestris* (Figures 2 and 3).

As to other parts, in the SE part of the geographical Marmara Region, *P. sylvestris* stands as pure and mixture with *P. nigra, A. nordmanniana* subsp. *nordmanniana* and *F. orientalis* occur on the south-facing slopes of the Ulu and Domanic mountains. Only pure *P. sylvestris* clusters are common on the upper and south-facing slopes of the Domanic Mountains. In the Samanli Mountains, on the peninsula in the eastern part of the Marmara Sea, Scots pine clusters appear at an elevation of 700 m, and they are composed of *Fagus* and *Carpinus* within valleys and pure on the hills. The southeast of Lake İznik has a few Scots pine trees associated with Turkish red pine (*P. brutia*), black pine (*P. nigra*),

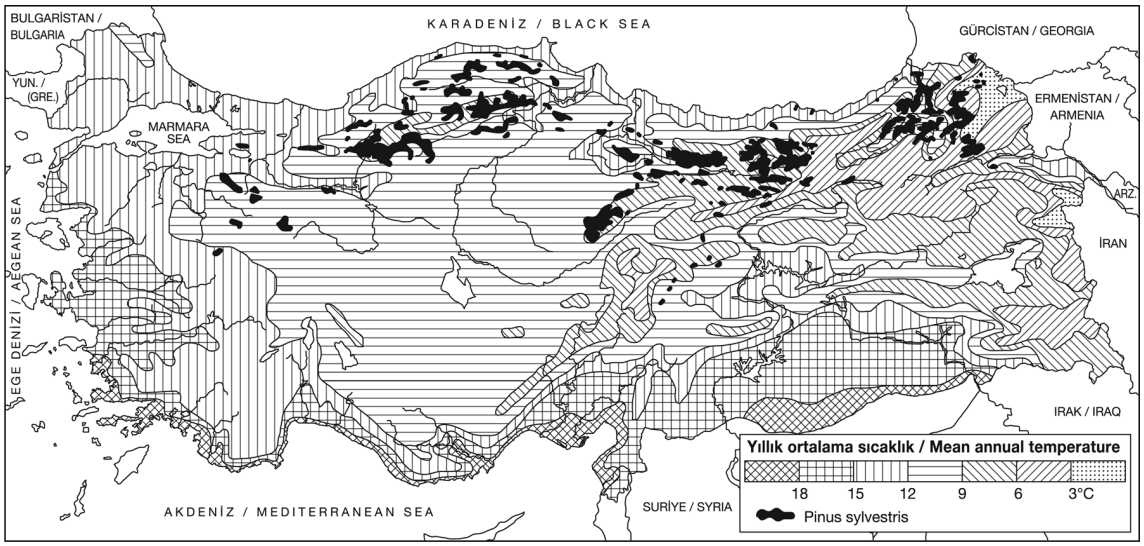

Figure 2. Relationship between native occurrence areas of Scots pine forests, and mean annual temperature of Türkiye

Şekil 2. Türkiye'de sarıçam ormanlarının doğal yayılış alanları ve yıllık ortalama sıcaklık arasındaki ilişkiler

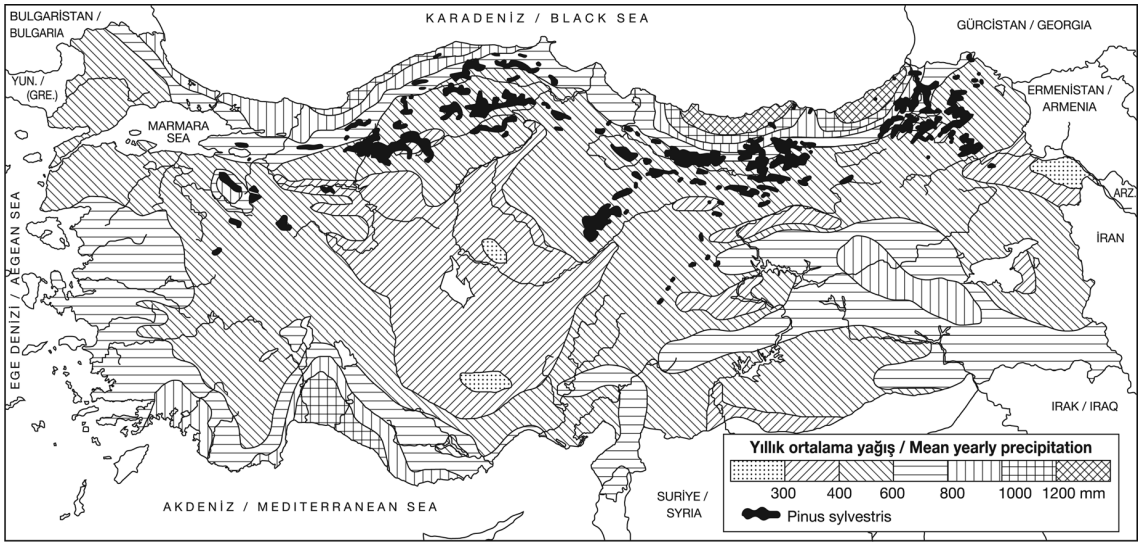

Figure 3. Relationship between native occurrence areas of Scots pine forests, and mean annual precipitation of Türkiye

Şekil 3. Türkiye'de sarıçam ormanlarının doğal yayılış alanları ve yıllık ortalama yağış arasındaki ilişkiler

Arbutus unedo, A. andrachne and *Quercus cerris* on the quartzitic parent materials.

The westernmost location within the Scots pine distribution area is Murat Mountain in the NE part of the Aegean Region. Here pure and mixture stands composed of *P. nigra, Juniperus nana,* and *P. sylvestris* exists on the top and north-facing slopes, and *P. sylvestris*-*F. orientali*s community appears on the north-facing slopes of Murat Mountain due to foggy environment.

The extensive distribution areas of Scots pine forests appear in the southern part of the Akdagmadeni district in the NE part of Inner Anatolia. Here, Scots pine begins at 1300 meters and climbs up to 2000 meters on the north-facing slopes of Ak Mountain. As compared with other Scots pine forests, low-productivity Scots pine forests mainly composed of thin trunks are dominantly seen in the Akdagmadeni region, in general.

Nowadays, the southernmost Scots pine clusters are found in the vicinity of the Hekimhan district of Malatya province. Some of them grow on volcanic sand and tuff, while others on limestone, and some are seen as chaparral appearance on flysch (sandy material). These clusters are taken into considera-

tion as a relict Scots pine.

To sum up, Scots pine grows in small clusters and as individual trees in the humid-temperate and humid-cold climate prevailing on the coastal mountains of the Black Sea region. It is found within deciduous forests and coniferous mixture forests composed of *A. nordmanniana* subsp. *nordmanniana* in the western part of Ordu city, and *A. nordmanniana* subsp. *nordmanniana, A. nordmanniana* subsp. *equi-trojani* and *P. orientalis* in the Eastern Black Sea Region. It can rise as high as 2700 meters in the NE continental Anatolia.

Scots pine forests cover an area of 2.2 million hectares (ha), while Turkish red pine (*P. brutia*) covers 5.4 million ha, and black pine (*P. nigra*) 4.2 million ha.

3.2. Ecological traits of *P. sylvestris*

Climate, topographic features (altitude, exposure/aspects, direction of the mountain range), soil, parent materials, competition and human impact determine the spreading areas and ecological properties of Scots pine. The importance of these factors will be summarized as: Climatologically, Scots pine is adapted to a wide variety of climates. It grows where the mean annual temperature is between 14°C and -2°C; this temperature ranges between 2°C and 6°C in the optimum growing areas. The minimum temperature is below -35°C, and the summer temperature is not over 30°C. The primary distribution of Scots pine indicates that it is a common tree of the continental climate of Anatolia (Figure 2). July with relative humidity representing vegetation period changes between 60% and 80%, and optimally 60%-70% in its optimum growing areas. July evaporation is about 150 mm. Scots pine like *P. brutia, P. nigra* and *P. pinea* is intolerant of shade or diffuse radiation, but it seldom grows as individual trees and small clusters within the broadleaved deciduous and coniferous trees in the foggy areas (Atalay, 2014).

Scots pine grows in all-season rainy regimes like the Black Sea Region, a continental precipitation regime characterized by late spring and early summer rain like NE Anatolia, and transitional regime between the Black Sea and Mediterranean climatic regions. The mean annual precipitation ranges between 500 mm and 2000 mm. There are no Scots pine clusters under 500 mm of precipitation in Anatolia. The increase in precipitation in the continental areas of Anatolia leads to an increase in Scots pine productivity. There is less water deficiency in the optimum growing areas. Compared to other forest tree taxa, Scots pine neither grows in the summer drought like *P. brutia* and *P. nigra,* nor in the perhumid and humid climate like *P. orientalis, A. nordmanniana* subsp. *nordmanniana* and *A. nordmanniana* subsp. *equi-trojani*

Shortly, Scots pine grows under the humid and cold climate of the Black Sea, the Marmara transitional climate between the Black Sea and Mediterranean climates, the subhumid continental climate of NE Anatolia, the subhumid climate of the backward regions of the Black Sea, and the semiarid-subhumid continental climate of Inner Anatolia. The best productive Scots pine forests are found in the subhumid continental climates of NE Anatolia and the backward regions of the Black Sea. The primary distribution of Scots pine indicates that it is a tree of the subhumid continental climate.

3.3. Topography

Topographical properties characterized by altitude, aspect, inclination of slope and the direction of mountain ranges are among the most important factors not only for the distribution but also the productivity of Scots pine. The spreading areas of Scots pine are limited to the south-facing, especially steep slopes of semiarid climatic areas due to intense solar radiation, whereas its productivity increases toward the lower slopes where freely drained bottomland and water available capacity is high in all regions. On the other hand, productive Scots pine forests occur on the north-facing slopes of the subhumid-semiarid areas (Figures 4 to Figure 6). The altitudinal distribution of the Scots pine considerably changes according to climatic regions. For example, its vertical distribution is between 0-2000 m in the Black Sea Region, 1300-2200/2400 m in the backward regions of the Black Sea, 1300-2000 m in the Inner Anatolia, and 1800-2700 m in the NE Anatolia. The lower boundary of Scots pine is higher on the southern slopes than that of the northern slope in the semiarid-subhumid areas in Anatolia (Figures 4 to Figure 8).

3.4. Parent material and soil

Scots pine grows all parent materials belonging to all geological era and period containing metamorphic such as gneiss, micaschist, quartzitic schist and clayey schists, volcanic rocks containing volcanic tuff, sand (pyroclastic material), andesite, dacite, basalt and granite, gabbro, and sedimentary rocks like limestones, flysch alternating clay, sandstone, siltstone, sandy limestone layers, alluvial, colluvial and gravelly terrace deposits (Figures 4 and 7). For example, it is found on the basalts and volcanic sand and tuffs in the vicinity of Sarıkamış in NE Anatolia; andesite and andesitic tuff in Köroğlu mountains, Kartalkaya locality S of

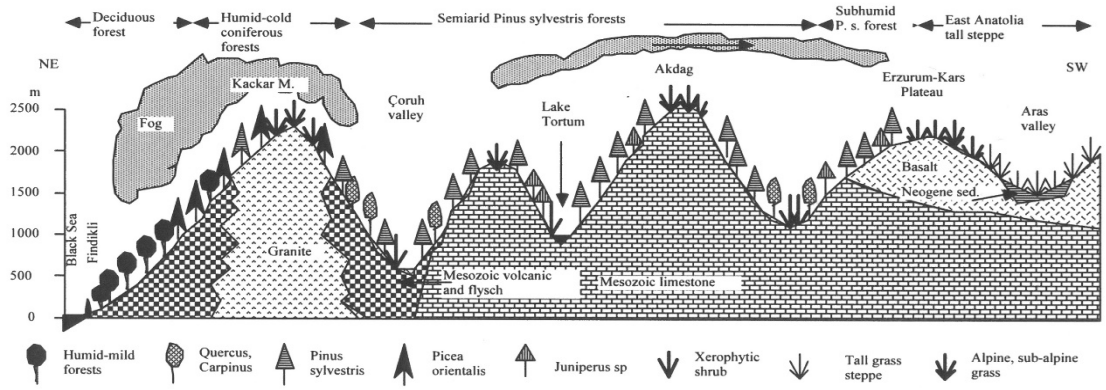

Figure 4. The relationship between the distribution of Scots pine and parent materials in the NE part of Anatolia
Şekil 4. Anadolu'nun KD bölümünde sarıçam ve ana materyal dağılımı arasındaki ilişki

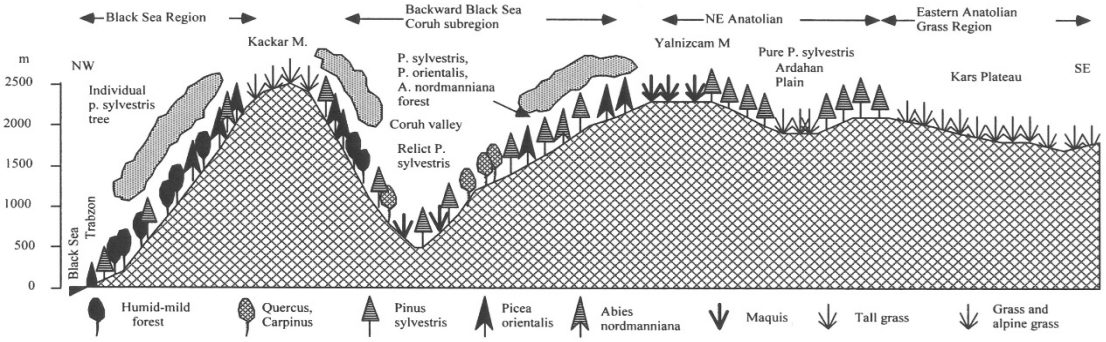

Figure 5. Scots pine distribution from Black Sea coast to the eastern part of Black Sea Region
Şekil 5. Sarıçamın, Karadeniz sahilinden itibaren Doğu Karadeniz'in doğusuna doğru yayılışı

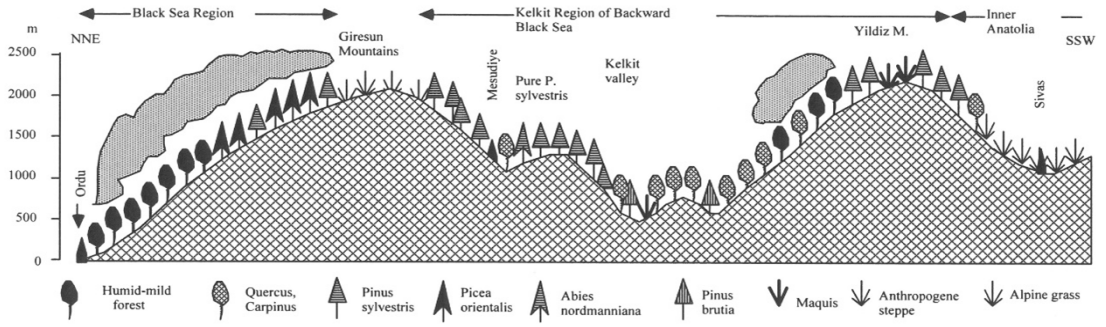

Figure 6. Scots pine forest distribution in the middle and backward region of Black Sea Region
Şekil 6. Sarıçamın, Doğu Karadeniz'in Orta Bölümü ve ardındaki dağılımı

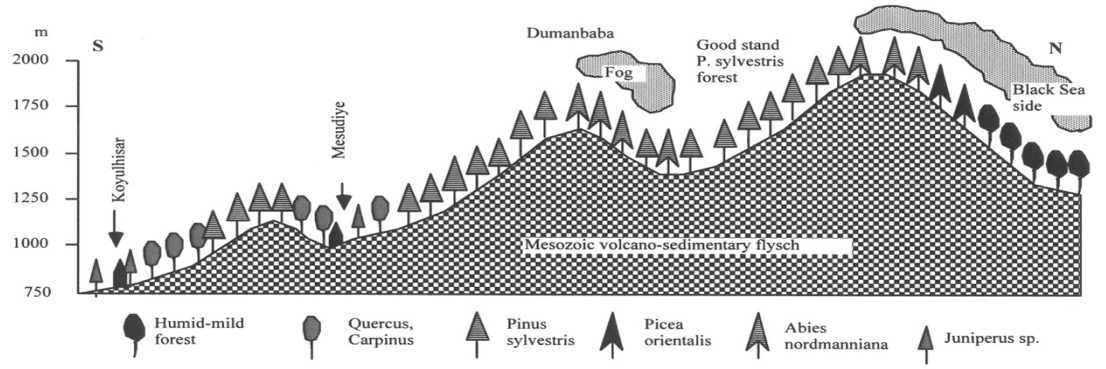

Figure 7. Vegetation profile of northern part of Kelkit depression in the backward region of Black Sea Region
Şekil 7. Karadeniz ardındaki Kelkit depresyonunun kuzey kesimindeki bitki örtüsü profili

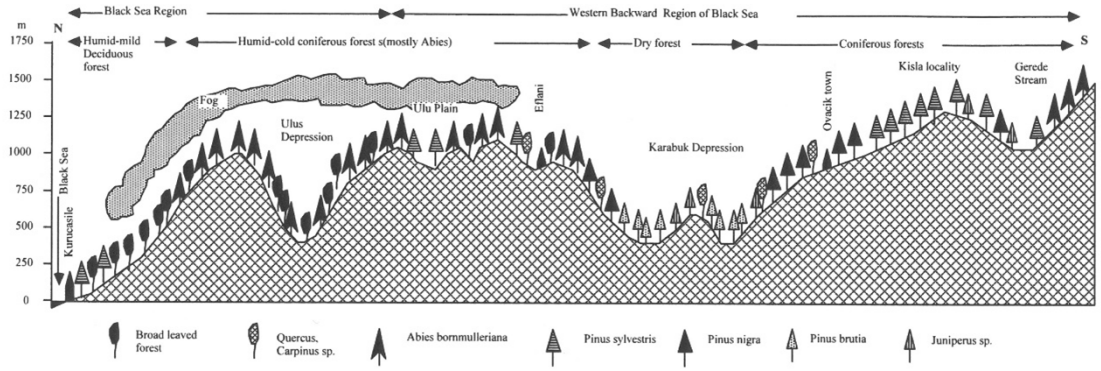

Figure 8. Vegetation profile of the western part of Black Sea Region
Şekil 8. Karadeniz Bölgesinin batı kesimindeki bitki örtüsü profili

Bolu; gneiss and micaschist in Sundiken Mountain and Akdağmadeni region; flysch, clayey limestone and limestone in the backward regions of Black Sea; granite in the Ulu and Domanic mountains, in the vicinity of Dirgine, SW of Black Sea Region; serpentine-peridotite in the southern part of Kelkit region i.e. Yildiz, Cimen and Kizil mountains, and Gaziler Basin in NE Anatolia; chlorite-sericite schist in the Arapdede Mountain, S of Kütahya and Kos mountain, E of Köroğlu Mountains.

Well weathered parent materials and sandy deposits create a suitable habitat for the growth of Scots pine due to the fact that it develops a taproot system. As a general rule, good site index of Scots pine is found soft materials like volcanic sand and tuffs and deeply weathered all parent materials due to the fact that taproot systems dominate. Indeed, the height of the Scots pine is higher on the volcanic tuff and sand than on the basaltic rocks in the Sarıkamış Region (Atalay et. al., 2020). Poor site index is common on the less weathered and hard parent materials. The important aspect of the productivity of Scots pine is the weathering situation of the parent materials.

As to soil properties, Scots pine forests are seen on the intrazonal soils reflecting parent material properties, colluvial soil, rendzina, reddish Mediterranean soil, chernozem, brown forest soil, regosol; the orders of mollisol, alfisol, spodosol, entisol and inceptisol. Its main distribution areas coincide with acid soils.

3.5. Vegetation composition

Scots pine has not only pure forest but also mixed forest with coniferous trees and deciduous broadleaved trees. Pure Scots pine forests are only common in subhumid continental climatic regions like NE Anatolia, and semiarid-subhumid region of Inner Anatolia. In the humid and mild areas, it is associated with beech (*Fagus*), alder (*Alnus*), hornbeam (*Carpinus*), lime (*Tilia*) and chestnut (*Castanea*); in the cold and humid environment it is composed of oriental spruce and fir species, in general. On the other hand, under the dense canopy of Scots pine stands support the regeneration of beech, oriental spruce and fir species. Scots pine, beech and fir mixed forests are common on the slopes facing-north getting fog in the backward regions of the Black Sea (Figures 4 to Figure 8). Best examples are given from the north-facing foggy slopes of Ilgaz and Bolu Mountains.

3.6. Biotic factors

It is very hard to estimate the native spreading areas of Scots pine forests. Indeed, some parts of Scots pine forests have been destroyed in the backward parts of the Black Sea, Inner and NE Anatolian regions. Destroyed areas are replaced by grass vegetation in NE Anatolia, oaks (*Quercus*) and juniper (*Juniperus*) clusters, and agricultural fields in Inner Anatolia.

Deciduous forest with *P. sylvestris* occurs in the abandoned agricultural lands or meadows in the deciduous forest areas, especially coastal mountains of the Black Sea Region. Because abandoned land is firstly occupied by *P. sylvestris* as pioneer succession and seldom *Pinus nigra* regeneration due to the fact that seeds of *P. sylvestris* easily germinate under direct solar radiation. The existence of small clusters and individual Scots pine trees in the deciduous forests in the Black Sea Region is related to the abandoned agricultural land and clear cutting. But with the growth of Scots pine trees, a shade environment forms under the forest. In this case, deciduous plants begin to grow, and over time, the mixed forest containing Scots pine comes into the scene. However, in this forest, Scots pine trees gradually decrease because of the fact that Scots pine regeneration does not occur under the forest floor (Figure 9).

Competition and incorrect silvicultural practices, on the other hand, lead to the change of the natural composition of Scots pine forests (Atalay 2014b). Namely, the young regeneration associated with *F. orientalis* and *Abies* sp. on the lowerstory of pure *P. sylvestris* forest in the humid areas is the responsible for the mixed forest composed of *P. sylvestris*, *F. orientalis* and *Abies* sp. or *P. orientalis*. Here, if *P. sylvestris* trees are excessively cut down, the forest mainly composed of *F. orientalis*, mostly *Abies* or *P. orientalis* forest forms (Figure 10). This forest can be seen in the sunny areas of plateau surface of the Şavşat and Ardanuc basins (Atalay 2014b).

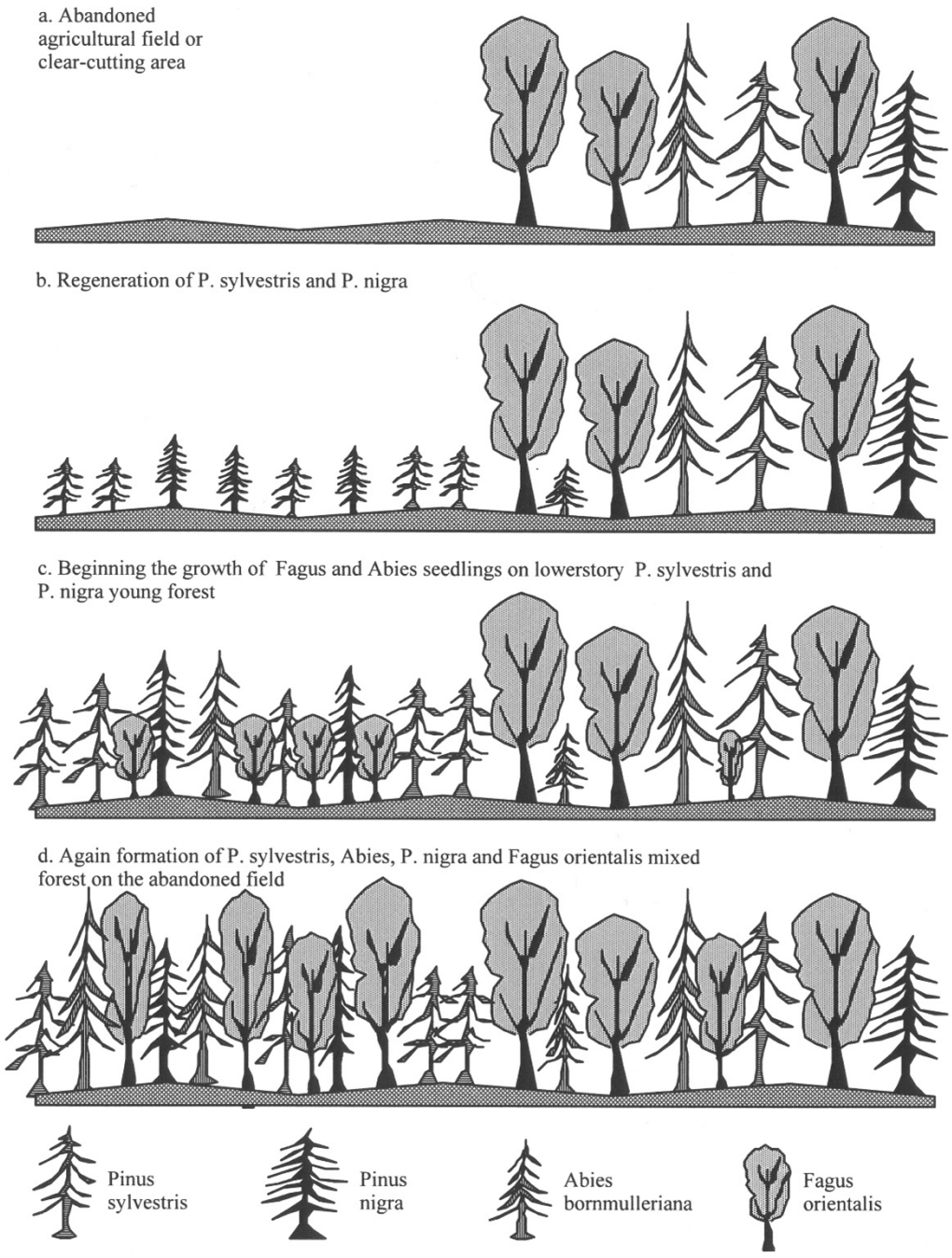

Figure 9. *P. sylvestris* and *P. nigra* trees within deciduous forest formation successions in the humid-mild coastal belt of the Black Sea Region, and on the foggy upper part of the backward region of the Black Sea
Şekil 9. Karadeniz Bölgesi›nin nemli-ılıman kıyı şeridinde ve Karadeniz ardında sisli üst kesimlerdeki yaprağını döken ormanlardaki *P. sylvestris* ve *P. nigra* orman formasyonunun süksesyonları

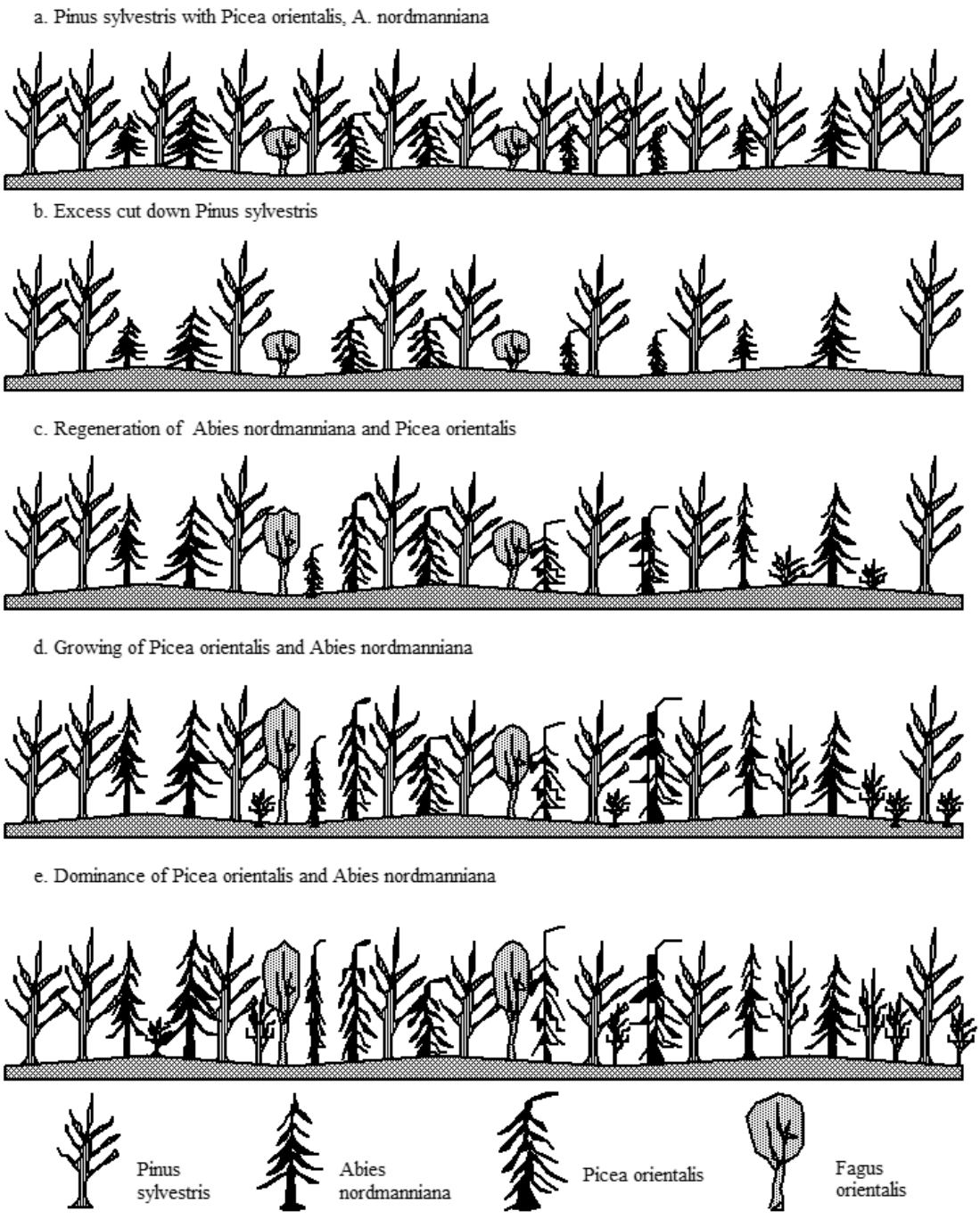

Figure 10. Changes of forest formation in the mixed forests composed of *P. sylvestris, A. nordmanniana* subsp. *nordmanniana, A. nordmanniana* subsp. *equi-trojani* and *F. orientalis* as the result of excess cutting of *P. sylvestris* trees
Şekil 10. *P. sylvestris, A. nordmanniana* sbsp. *nordmanniana, A. nordmanniana* subsp. *equi-trojani* and *F. orientalis P. sylvestris* karışık ormanlarında *P. sylvestris* ağaçlarının aşırı kesilmesi sonucu olan değişmeler

4. Vegetation composition of Scots pine

4.1. Scots pine clusters in deciduous broadleaved forests

Along the coastal belt of the Black Sea, Scots pine clusters and individual trees which are associated with *F. orientalis, T. rubra, T. tomentosa, C. orientalis, C. betulus, C. sativa, Alnus barbata, A. glutinosa, Acer campestre, A. platanoides* and so on are seen, here Scots pine regenerates in these forests on the abandoned fields and open areas with exposed mineral soil. But when Scots pine cluster reaches the maturity age, the fast-growing broadleaved

trees on lowerstory of Scots pine cluster prevent the regeneration of Scots pine due to the shadow effects, so Scots pine cluster disappears. In other words, Scots pine cluster is replaced by the climax deciduous forest. It can be said that the existence of the Scots pine is temporary in the broadleaved forest areas (Figures 4, 5 and 9). Other main occurrence areas of Scots pine are found in Çamburnu and Akçabat localities of Trabzon, and Kurucaşile of Bartın, respectively on the west coast of the Black Sea. These Scots pine clusters can be considered as relict communities. The productivity of Scots pine trees is high due to no water deficiency. The age rings of Scots pine are about 5 mm thick in some places, such as in the Kurucaşile locality (Figure 8).

4.2. Scots pine with coniferous and deciduous forests

This is only seen on the uplands of north-facing slopes of the Northern Anatolian Mountains on which cold-humid climatic conditions prevail, and during the vegetation period foggy condition and orographic rainfall are dominant. There is no water deficiency due to the amount of precipitation, which is more than 1000 mm, and evaporation is low. Here, Scots pine is found in small clusters in the mixed forests of *F. orientalis, Salix caprea, T. tomentosa, T. rubra, Rhododendron ponticum, Sorbus torminalis, Corylus avellana, C. colurna, Cornus mass*, and *A. nordmanniana* subsp. *equi-trojani, Taxus baccata, Buxus sempervirens*, and so on. Scots pine only grows in open areas of the forest and abandoned fields. Leading occurrence areas are seen on the north slopes of the Northern Anatolian Mountains, notably Kure Mountains, the northern part of Giresun Mountains, and the northern part of Bolu Mountain in the Black Sea Region. Some Scots pine is found as individual trees and small clusters. In the clear-cutting areas and abandoned artificial meadows Scots pine grows as secondary succession (Figure 9). Individual Scots pine height reaches some more than 30 m due to reach direct solar radiation, and its productivity is high in the deciduous forest area.

4.3. Scots pine-oriental spruce and fir forests

It is found on the north-facing slopes of all parts of the Black Sea Region and foggy slopes of the Eastern backward part of the Black Sea Region. Here, the annual mean temperature is less than 8°C with very cold winters, and the mean annual precipitation total is over 600 mm, most of which is snowfall. The best example can be given from the north slopes of Yalnızçam Mountains, in the Coruh Basin. Here, oriental spruce (*P. orientalis*) and Scots pine mixed forests are common. Some Scots pine areas have been replaced by fir and spruce due to the excessive harvesting of Scots pine. In the Karagöl locality of the Şavşat-Ardanuç subregion, for instance, oriental spruce (*P. orientalis*) and fir (*A. nordmanniana* subsp. *nordmanniana*) is dominant where Scots pine trees have been excessively cut down. Indeed, open areas of fir and oriental spruce forests are being occupied by young Scots pine regenerations. On the other hand, fir (*A. nordmanniana* subsp. *nordmanniana*) and Scots pine forests occur on the north-facing slopes of the Western and backward parts of the Black Sea Region. One of the leading areas is on the north-facing slopes of the Ilgaz Mountains (Figures 10 and 11).

4.4. Scots pine forest with fir and spruce plants on lowerstory

The canopy or lowerstory of Scots pine forest supports the growth of fir and spruce trees and/or regeneration as in the Taiga forests. In the eastern backward region of the Black Sea Region, understory plants are composed of *A. nordmanniana* subsp. *nordmanniana* and *P. orientalis*, while in the middle and western parts of the region, it is associated with *A. nordmanniana* subsp. *equi-trojani* and *F. orientalis*. These forests are prevalent on the humid areas of the northern part of the backward regions of the Black Sea. The best examples of this can be given from the northern slopes of Kartalkaya locality, Bolu province, and Ballıdag locality, S of Azdavay district, in the Western backward Region of the Black Sea. In the above-mentioned areas, forests covert into mixed forests composed of Scots pine, fir, and spruce when the spruce and fir grow. Since Scots pine trees are excessively cut down in these forests, forests change into pure fir or spruce forests.

4.5. Scots pine with beech, fir and spruce forests

It is commonly widespread on foggy uplands facing north of the backward Black Sea Region. This forest is seen on the lower north-facing slopes of Ilgaz Mountains, the north-facing slopes of Ulu Mountain in Marmara Region, around Mesudiye and Koyulhisar, the southern part of Giresun Mountain, and north of Kelkit locality. The existence of beech and fir is related to suitable humidity condition. Indeed, fir and beech seeds easily germinate in the lowerstory of Scots pine forests (Figures 6 and 11).

4.6. Pure Scots pine forest

It is common in the sunny subhumid part of the backward regions of the Black Sea and subhumid

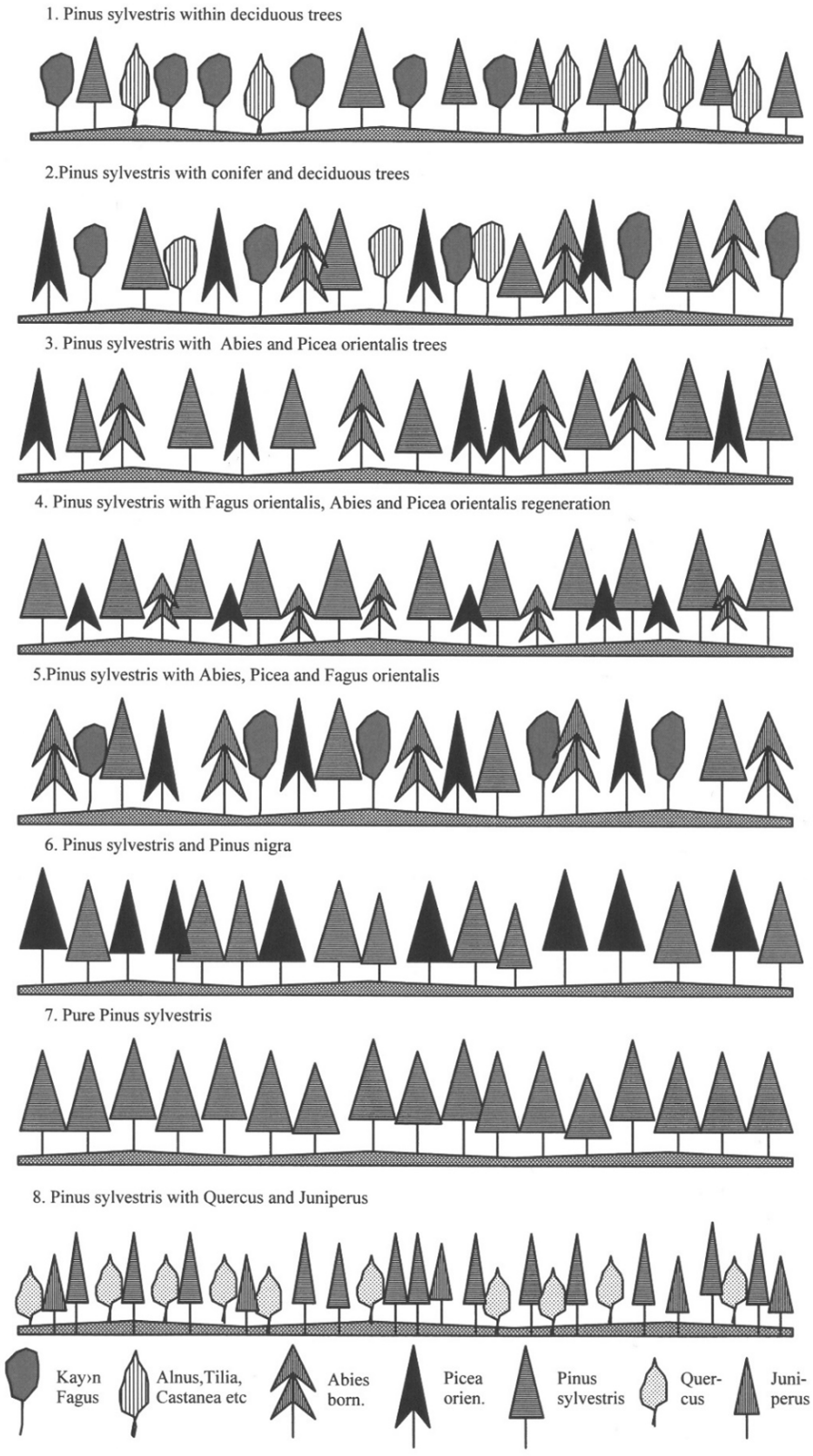

Figure11. Scots pine forest types
Şekil 11. Sarıçam ormanı tipleri

parts of NE Anatolia, the north of Inner Anatolia and the upper areas of Kastamonu plateau. This forest is also climax forest of Anatolia because of the fact that very cold winters with snowy and convectional rainfall occurring last spring and early summer only support the growth very well of Scots pine. Pure and productive Scots pine forests are widespread on the NE Anatolian plateau extending elevations of 1800-2500 m. In the Sarıkamış locality Scots pine rises as high as 2700 m. Here volcanic tuff and sands create a good habitat for the growth of Scots pine because water and air circulation are in good level. On the other hand, Scots pine trees develop a taproot system in the volcanic tuff and sand deposits (Figures 4, 5 and 11).

4.7. Scots pine-black pine forests

This forest forms a transitional zone between black pine and Scots pine forest areas in the upper part of the tectonic depression of the backward regions of the Black Sea, such as Bolu-Gerede and Taskopru depressions, as well as on some parts of the Kastamonu and Kibriscik plateaus on which semiarid-subhumid climatic conditions prevail. The total annual precipitation is 500-600 mm, and the temperature rising 20°C during the summer mounts fall below the freezing point. Water deficiency occurs during the vegetation period. Carbonate accumulation takes place in the subsoil, so soil shows a slightly alkaline reaction. The upper part of Scots pine-black pine changes into form of pure Scots pine forest. In addition to this in a somewhat arid area Scots pine is seen on the north-facing slopes, while black pine occurs on the south-facing slopes. This situation shows that black pine is more resistant to drought than Scots pine.

4.8. Scots pine-oak-juniper forests

It belongs to the semiarid continental part of Inner Anatolia, in general. Here, the annual mean precipitation is less than 600 mm, and the mean annual temperature is over 8°C. The summer period is hot and somewhat dry. This forest is common in the lower part of the Akdağmadeni region, in Inner Anatolia. The productivity of this forest is less than that of other Scots pine forests due to low precipitation and siliceous parent materials composed of gneiss, mica-schist, and quartzitic schist. The Scots pine in the Akdagmadeni region can be added as a relict Scots pine.

5. Discussion and Conclusion

P. sylvestris is one of the leading coniferous species after *P. brutia* and *P. nigra* in Anatolia. For that reason many investigations were carried out on the relationships among the development situation, edaphic and physiographic factors of pure Scots pine forests (Çepel et al., 1977), the ecology and the natural distribution areas of Anatolia were presented (Atalay, 1992a, 1992b 1994; 2008 and 2014a, 2014b; Atalay et al., 1985; Tetik, 1986; Çalışkan et al., 2004), the natural regeneration of Scots pine was studied (Ceylan, 1980; Pamay, 1962; Sevimsoy, 1984), the genetic and morphogenetic properties of Scots pine growing in Türkiye (Eliçin, 1971 and 1970; Tosun, 1988) were also searched. The site class and the yield of Scots pine were carried out (Alemdağ, 1967; Eraslan, 1982; Çepel and Dundar, 1977; Ercanlı et al., 2006). Silviculture of the Scots pine was also studied (Boydak, 1977; Ceylan, 1980).

Çepel et al (1977) pointed out that Scots pine grows both on north- and south-facing slopes, and productive Scots pine forests are found on the north-facing slopes. In terms of slope angle, 75% of total experimental site data of Scots pine forests are found on slopes changing between 1% and 17%. According to the experimental site data, altitudinal belts of 1270-1500 m, 1500-1700 m, 1700-2100 m, and over 2100 m elevation account for 48%; 26.4%; 10.2%, and 15.7%, respectively. These data indicate that a third of the total spreading areas of Scots pine forests are found between 1270 m and 1700 m elevation.

Good and productive Scots pine stands occur on lower slopes and gently undulating surfaces in both the north and south due to the fact that these areas have deep soil and where available water capacity is high. The absence of IV^{th} and V^{th} site index of Scots pine stands on the flat land indicates the importance of the inclination factor for productivity.

Soil depth with 0-30 cm, 30-60 and 60-120 cm accounts for 6%; 23% and 71% respectively in all experimental Scots pine sites. Horizon C is very thick on the deeply weathered andesite, agglomerate, volcanic tuff, colluvial and alluvial material (Çepel et al., 1977).

In this study, the site class index of Scots pine considerably changes according to the climatic traits of the area. Good site index is found in the humid parts of the backward regions of the Black Sea. But in the semiarid-subhumid areas, Scots pine prefers the slopes facing north, especially in Inner Anatolia and the southern part of the Coruh Basin. As a general rule, good site index of Scots pine forests is found at elevations between 1600 m and1800 m in Inner Anatolia, 2000 m and 2400 m in NE Anatolia, 1500 m and 1800 m on the north-facing slope, and 1600 m and1800 m on south-facing slopes of

the backward regions of the Black Sea Region.

Evaporation also determines the productivity of Scots pine. Truly, the amount of the yearly evaporation is more than 600 mm, and July evaporation is less than 150 mm in the optimum growing areas of Scots pine due to the relative humidity being high in the upper slope of the mountains, especially facing north. The mean annual precipitation is less than 600 mm, and July evaporation is more than 200 mm in the semiarid part of Inner Anatolia on which low productive Scots pine stands occur. However, the water holding capacity of the parent materials and the organic content of the soil are important in the growing of Scots pine.

There is no exact knowledge of the importance of the parent material in the growth of Scots pine in the literature. It can be clearly stated that all trees only grow in the early regeneration stage on the soil, but in the late regeneration or maturity stage, the roots of trees and shrubs take their own nutrients mostly from the parent material. For this reason, the chemical and physical composition of parent material and its weathering status are very important factors for the growth of Scots pine. Parent material' cation exchange capacity (CEC) depends on the weathering process and the nutriment capacity of parent materials. For example, CEC is lower than 10 me/100 g on the less weathered serpentine, but this figure is over 40 me/100 g in well and deeply weathered serpentine. For that reason, poor Scots pine stand is found on the low weathered serpentine as seen on the Gaziler Basin within the Coruh Watershed. Soft and clastic sediments and volcanics such as colluvial deposits and volcanic tuffs and sands create a suitable environment for the taproot development of Scots pine. For this reason, Scots pine is found only on the volcanic tuff in the Aras Valley. Shortly, good stands occur on well and deeply weathered parent materials and soil which is rich in organic, thanks to the developed taproot system.

In Turkish literature, there is no detailed information on the formation of deciduous forests with Scots pine. First time, Scots pine forests are classified according to ecological properties and the competition process in this article. As mentioned, the pioneer phase succession on the abandoned and open area is the regeneration habitat for Scots pine and black pine. Because the seeds of these tree taxa easily germinate on the bare land with mineral soil, and after they shelter the ground, seeds of the beech and other broadleaved trees germinate fast. So, the fast-growing deciduous trees once again dominate in the humid and mild areas of the Black Sea Region. On the other hand, some Scots pine clusters founding in the deciduous forests of the Black Sea coast, in the north of Hekimhan district, E Anatolia and in the southeast and NW of Lake İznik, Marmara Region, and in Murat Mountain, Aegean Region can be considered relic enclaves (Atalay, 1992 a, b).

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