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Ecology and classification of forests in Turkey

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Abstract

Turkey possesses all types of parent materials or bedrocks like metamorphic, sedimentary and volcanic belonging to different geological era and periods. Some parent materials contain evaporitic sediments with salt, gypsum and high contents of alkaline materials which mostly prevent the growth of climax vegetation. The country has a rugged and high topography, related to tectonic movements, and volcanic activities which mainly occurred in Tertiary and Quaternary eras. The mountains are divided into three groups in terms of formation and ecological importance namely; orogenic mountains, volcanic mountains and uplifted blocks or horst mountains. The ecological importance of the topography is fully stressed by altitude, aspect and climate. The forests in Turkey can be classified on the basis of ecological features as: humid-mild deciduous, humid-cold coniferous on the north facing slopes of coastal belt of Northern Anatolian Mountains; subhumid-cold continental coniferous in the north facing slopes of backward part of Northern Anatolian Mountains; subhumid-semiarid semi continental coniferous on the plateau and mountains of southern basins of northern Anatolian Mountains; semiarid continental Inner Anatolia *Quercus* spp. - *Juniper* spp. - *Pinus nigra*, semiarid-subhumid *Quercus* spp., Mediterranean *Pinus brutia* and oro-Mediterranean coniferous. The excessive cutting, wrong silvicultural practices, opening of agricultural fields inside the forests, and clear-cutting system are changing the vegetation structure of forests. Some of the forests in the country are accepted as relict forests.

Keywords: Forest classification; ecology; biodiversity; Turkey

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1. Introduction

More than 50 percent of the land cover in Turkey is ecologically suitable for the growth of forests. However, there is severe destruction leading to degeneration of major part of this forest cover in the country especially in the semiarid areas. The country possesses a forest cover of 22 million ha, equaling to 27 percent of the total land mass of Turkey (Mayer and Aksoy, 1986; Ozturk *et al.,* 1991; Ozturk *et al*., 2008a). Nearly 42 percent of these forests are dominated by coniferous species (30 % *Pinus* spp., 4.6 % *Juniperus* spp., 0.9 % *Abies* spp., 0. 7 % *Picea orientalis*, 0.5 % *Cedrus libani*, and 5 % mixed coniferous forests). The broad-leaved species cover 53.3 percent (22.7 % *Quercus* spp., 3.3 % *Fagus orientalis*, 0.2 % *Alnus* spp., 0.1 % *Castanea sativa*, 0.1 % other broad-leaved species, 18.5 % mixed broad-leaved forests and 8.4 % maquis), and mixed coniferous and broad leaved forests 4.5 percent (Çolak *et al*., 2006). The type of forest and its vegetational composition enlighten the ecological features of a country, region or a given area. The forests are of immense importance as biodiversity spots with a rich diversity and the vegetation is home to diverse fauna as well as shrubs and herbaceous plants as an undercover (Atalay, 2006; Efe, 2010; Ozturk *et al*., 2010a). Climatic features, topographic characteristics like altitude, aspect, mountain ranges, depression, deep and narrow valley form different habitats even in the same region, which lead to an increase in the biological richness including forest diversity as well as stand types (Atalay, 1995; Ozkan *et al.,* 2010). The aim of this study is to present the forest classification in Turkey together with its vegetational composition in relation to the existing ecological conditions.

2. Material and Method

This research was largely based on field studies conducted between 1975 and 2013. This study only includes the native distributional areas of the forest types in Turkey and their vegetation composition. The studies on the ecology of *Picea orientalis, Cedrus libani, Fagus orientalis*, *Pinus brutia, P. nigra, P. sylvestris* and their seed transfer studies by Atalay (1984; 1987a; 1992a; 2001; 2002; Atalay *et al.,* 1998), Atalay and Efe (2010a; 2010b; 2012) and Gucel *et al*. (2008) have contributed very valuable information on the forest vegetation of Turkey as well as their classification. During the field study the relationships between forest areas and their natural environment such as topographic features (altitude, aspect, the direction of the mountain ranges), parent material, soil and biotic factors were evaluated. The climatic data obtained from the meteorological stations covering 30 years included mean annual temperature, precipitation, relative humidity and cloudiness. The solar radiation intensity especially during the vegetation period was also taken into account in order to show the relationship between the climatic conditions and the native distribution areas of forests and their classification. Moreover, many topographic profiles and geological cross-sections were generated in order to show the relationships between distribution of forest vegetation and parent material, topographic characteristics, competition and other features.

3. Results and Discussion

3.1. Ecological Aspects of Mountains

These include geological, topographical and climatic features of the country as these enlighten the ecological importance of forest cover in Turkey.

3.1.1. Geology

The land cover in Turkey contains all types of parent materials or bedrocks like metamorphic, sedimentary and volcanic belonging to different geological era and periods (Atalay, 2011). Some parent materials containing evaporitic sediments with salt, gypsum and highly alkaline materials mostly prevent the growth of climatic vegetation. A sparse halophytic vegetation occurs on the evaporitic sediments of Oltu-Narman Basin, in the eastern part of Aras Basin, especially between Kağızman and Iğdır cities, in NE Anatolia, and salty and gypsum deposits extending between Çankırı and Sivas in NE part of Central Anatolia (Atalay, 1987b).

Ultrabasic rocks containing peridotite-serpentine materials are exposed along the orogenic mountain ranges of Anatolia and determine the productivity of forest stands. Well and deep weathered serpentines with rich plant

nutrients create suitable habitat for the growth of trees. The good site class black pine stands occur on the deeply weathered serpentine in the Karsanti (Pos) locality, N of Adana; Yılanlı and Eskele localities of Mugla province; and Yazıcık and Camiyani localities in the western part of Black Sea. But low and unweathered serpentine mass forms a poor habitat for the forests due to low cation exchange capacity which prevents the root development. Therefore the stands of low productive *Pinus brutia* and *Pinus nigra* occur on the less weathered serpentine mass as seen in the Taurus Mountains (Efe, 1998; Atalay and Efe, 2010a; 2012).

Although the nutrient capacity of volcanic tuff and sand deposits, and the sandy soil which develops on the granite and gneiss is very low, they produce a suitable habitat for the growth of *Pinus sylvestris* in NE Anatolia, especially around Sarıkamış town, whereas productive *Pinus pinea* stands are abundant on the granite in Kozak plateau and Koçarlı (Aydin) in the Ege region. The reason for this is that water and air circulation of these rocks creates suitable conditions for the root development, especially taproots (Atalay and Efe, 2010a; 2012).

Topography

Turkey as a whole has a rugged and high topography. This is related to the tectonic movements, and volcanic activities which has mainly occurred in Tertiary and Quaternary eras. Turkey's mountains are divided into three groups in terms of formation and ecological importance (Atalay and Efe, 2010b).

***Altitude*:** Along the high mountains rising over 2000 m elevations there are, at least, three altitudinal vegetation levels or forest belts. In the North Anatolian Mountains, three main forest belts can be observed namely; broad-leaved deciduous, coniferous and alpine grass between 0-1200 m, 1200-2000 m, and above 2000 m respectively. In the Taurus Mountains altitudinal distribution of the forest zones is as follow: 0 -1000/1200 m *Pinus brutia* zone, 800-2000 m encompasses Oromediterranean coniferous forests and subalpine zone starts above the natural timberline. In Inner Anatolia, we mainly come across steppes below 1000-1200 m, the altitudes between 1200-2000 m hold dry forest zone, followed by a commencement of subalpine vegetation. In NE Anatolia, forest zone occurs between 1800-2700 m due to the severe continentality. The mountains exceeding 2000 m elevation are responsible for the vertical zonation of vegetation and forest belts (Fig. 1, 2, 4).

Aspect: Aspect is one of the major factors responsible for the biological richness and typification of forest in the mountainous areas. There is a considerable difference in the distribution of different forest types between the north-facing and south-facing slopes (Fig. 1, 4, 7). This is related both to solar radiation intensity and the amount of precipitation. As a general rule, the north-facing slopes of the mountains locating in the northern part of the Anatolia are covered with the humid forest and/or hydrophytic species because they receive much rainfall and less radiation than southern slopes. As such the broad deciduous humid forests composed of *Fagus orientalis, Tilia rubra, Tilia tomentosa, Quercus* sp., *Alnus barbata*, *Alnus glutinosa* and hydrophytic herbaceous plants cover grow along the lower belt of the North Anatolian mountains. The upper parts of the north-facing slopes of the coastal belt of the North Anatolian Mountains are the main occurrence areas of humid-cold forests composed of *Picea orientalis, Abies nordmanniana, and A.bornmulleriana* and *Pinus sylvestris* (Fig. 1, 2, 4).

In North Anatolian Mountains, solar radiation intensity is higher on the slopes facing south than other slopes. Therefore, dry forests and shrubs are common on the lower south-facing slopes. For example, in the upper part of the North Anatolian Mountains *Pinus sylvestris* stands are common due to high solar radiation and cold-subhumid conditions. The lower slopes are generally covered by *Pinus nigra* and *Quercus* species which are resistant to drought. Red pine (*Pinus brutia*) and maquis communities are common on the bottom and lower part of the Kelkit valley, Erbaa-Niksar and Taşköprü depressions (Fig. 7). In general the a rich biodiversity and different types of forest stands on the north-facing slopes of North Anatolian mountains are more than those of southern slopes.

The southern slopes of Taurus Mountains receive more precipitation than the north-facing slopes due to the fact that the fronts coming from the southern sectors are mostly prevented by the mountain ranges. The southern slopes of Taurus Mountains extend only along the costal belt of the Mediterranean Sea and are the main areas of productive *Pinus brutia* and humid maquis communities due to abundant precipitation and intense solar radiation. Towards the upper parts of the Taurus Mountains *Cedrus libani*, *Abies cilicica* and *Pinus nigra* appear. But some *Pinus brutia* and *Quercus* sp. clusters occur on the southern part of the SE Taurus Mountains due to continental influences, in the South-East Anatolian Region (Atalay 1987a; Boydak *et al*., 2008).

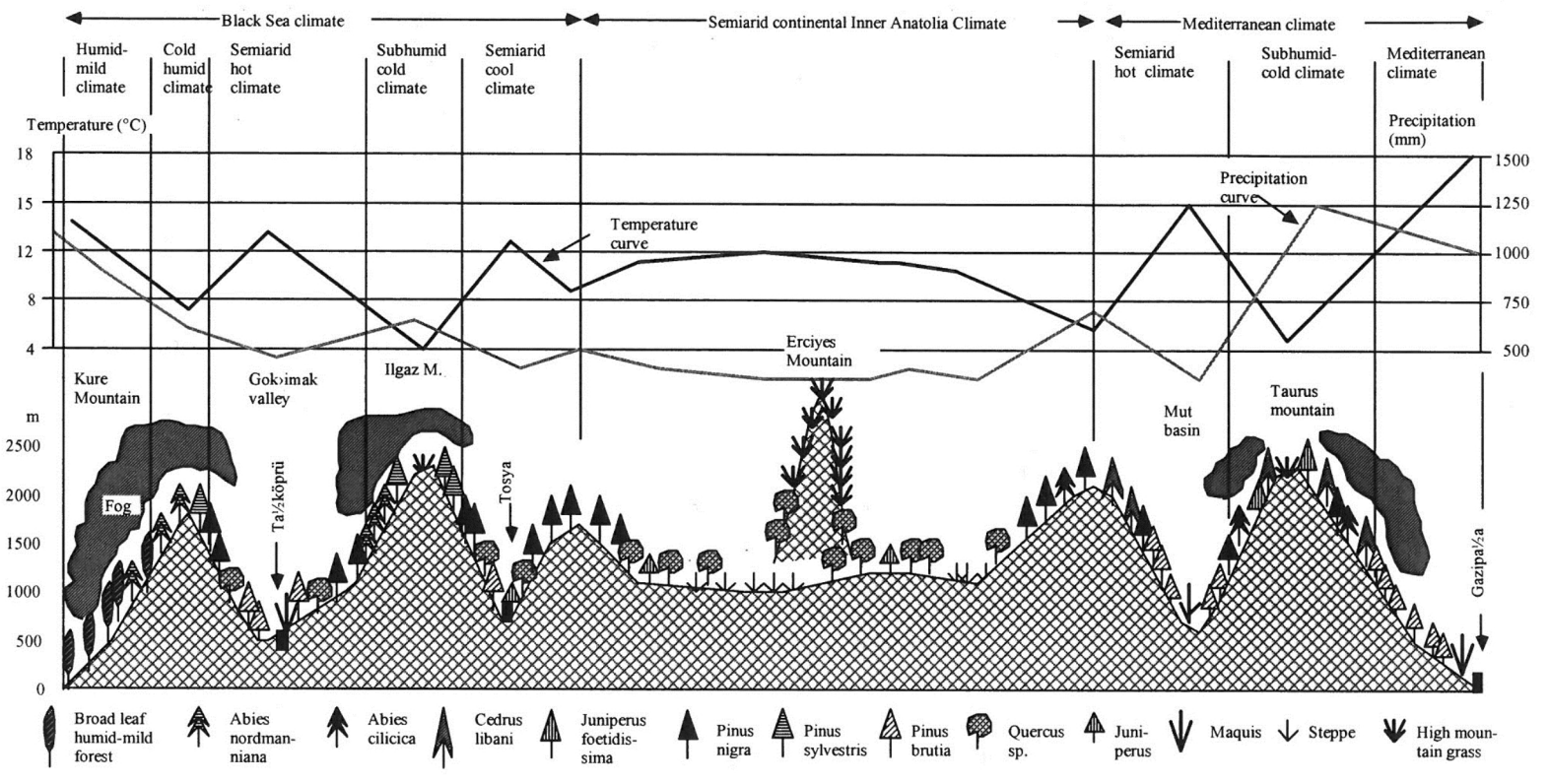

Fig. 1. Climatic and vegetation profiles in N-S direction from Black Sea to Mediterranean Sea).

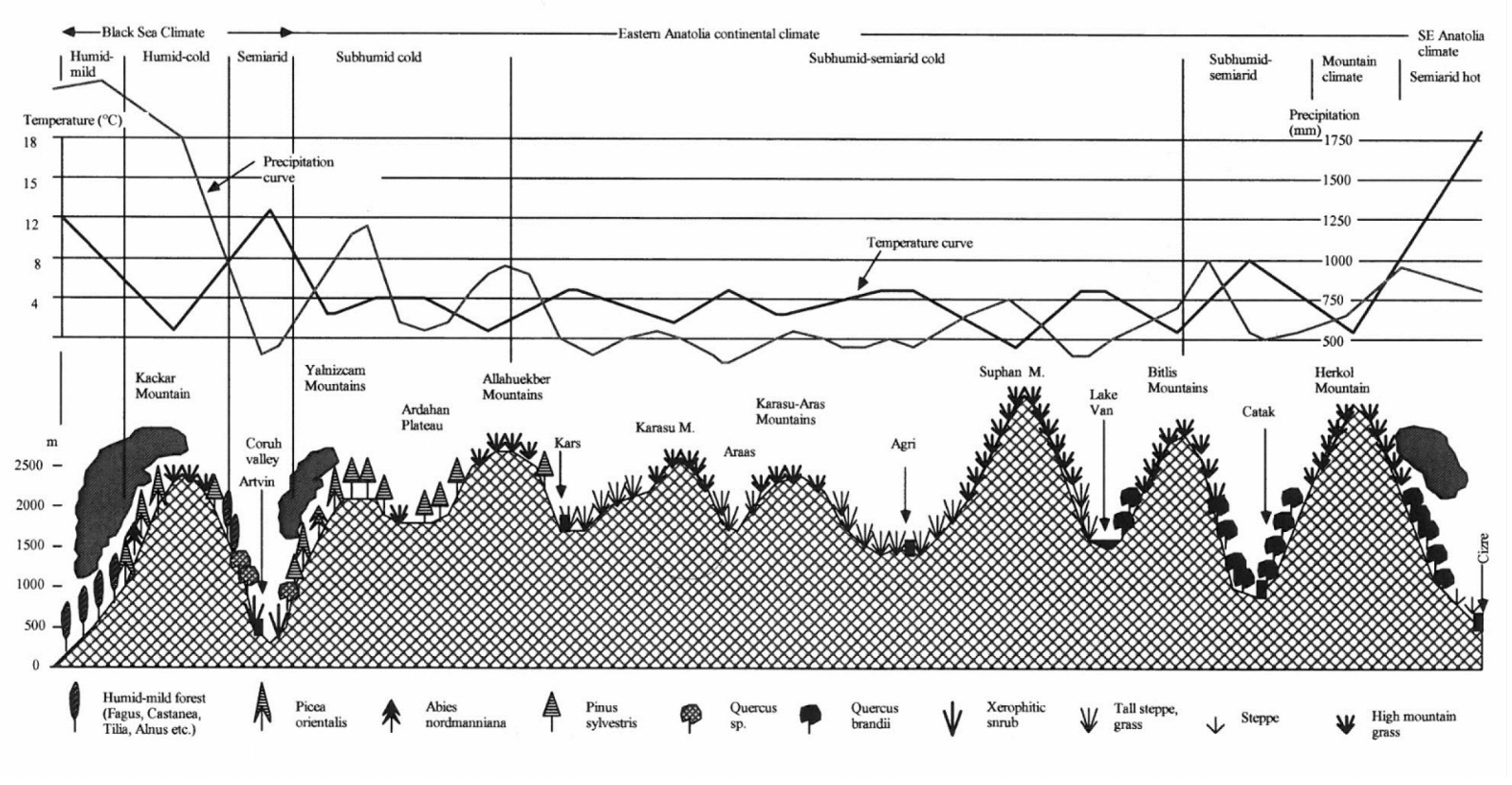

Fig. 2. Vegetation profiles in N-S direction from the Northeast to Southeast Anatolia (Atalay and Efe, 2010).

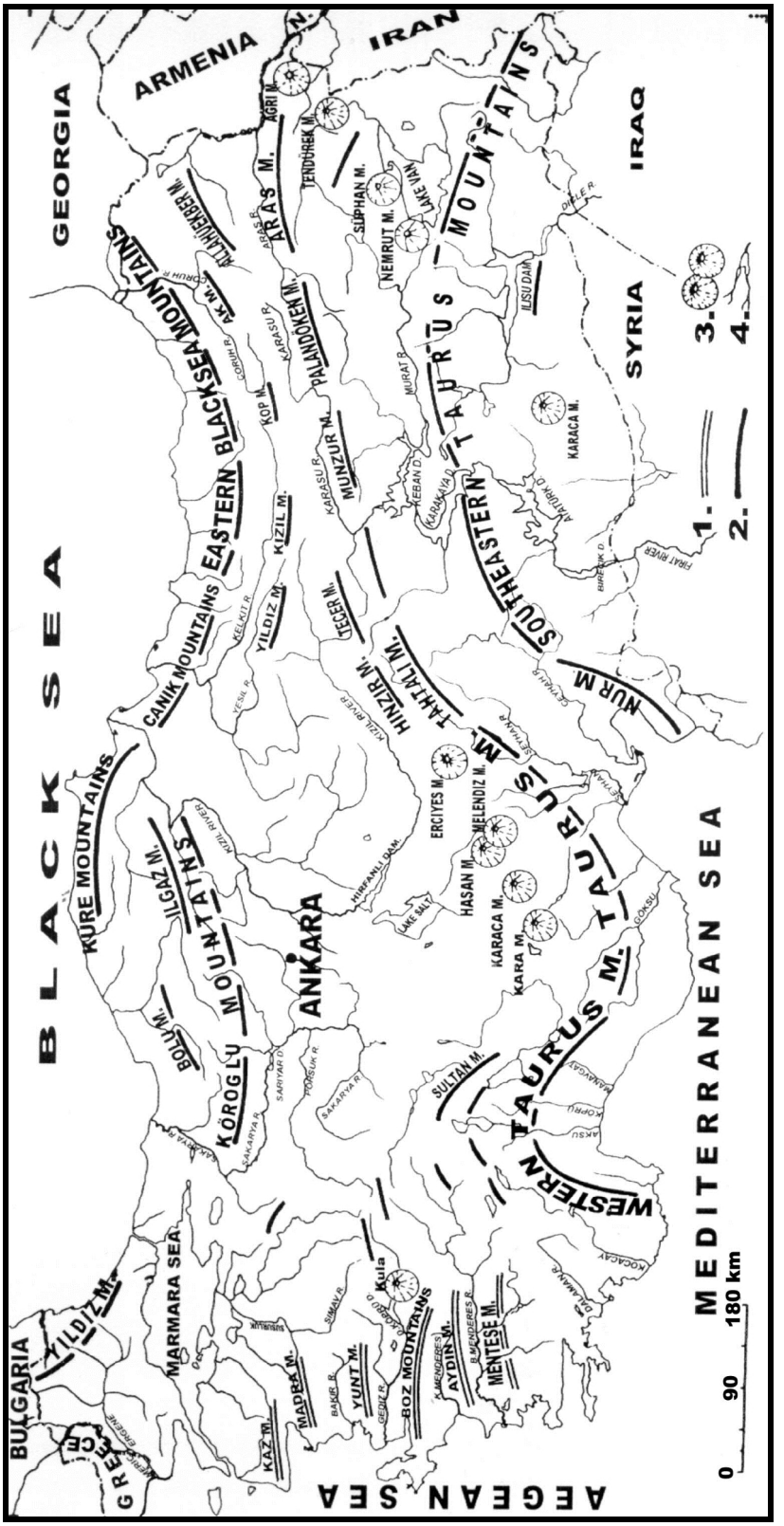

Fig. 3. Mountains of Turkey

In the Marmara Region, deciduous forests composed of mainly *Fagus orientalis*, occur on north facing slopes of Ulu-Domaniç mountain range. This area is one of the main occurrence areas of *Abies bornmulleriana*. However, the Mediterranean vegetation and *Pinus brutia* forest is common on the lower south facing slopes of the mountains in Marmara Region. This aspect is common on valley slopes. In fact, *Pinus nigra* stand occurs on the south slope and *Fagus orientalis* stand appears on the north facing slopes of the wide valley connecting Inegol depression.

In the Ege Region, maquis vegetation and *Pinus brutia* forests are widespread on the slopes facing-south of the mountains (Fig.6). While small *Castanea sativa* communities grow on the northern slopes of Aydın and Boz mountains.

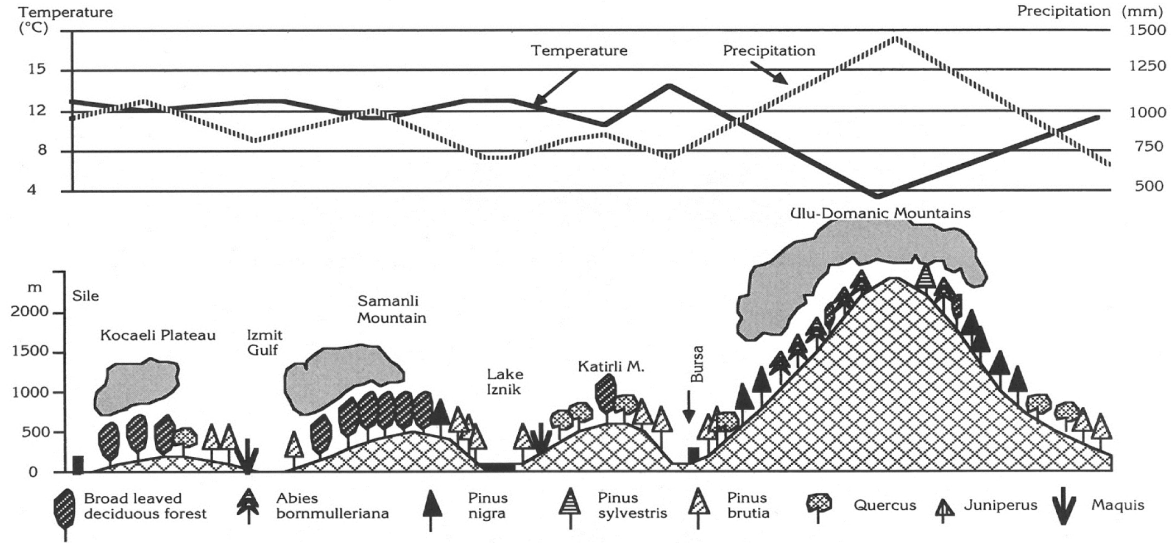

Fig. 4. Climatic and vegetation profiles in N-S direction from Marmara Region, NW of Anatolia (Atalay, 1994).

On the other hand a temperature inversion occurring in the depressions determines the vegetation distribution. *Pinus nigra* stands occur in the Inegol depression, at an altitude of 200 m, because temperature falls as low as -20 °C during winters. The Ovacık depression in the Ege Region is another location where *P.nigra* occurs at elevation of 800 m on Boz Mountain. Here *Pinus nigra* forest occurs on the bottom of Ovacık depression, while *Pinus brutia* is common above 1000 m. In the deep karstic depressions in the Taurus Mountains *Abies cilicica* grows on the bottom, while *Pinus brutia* occurs at an elevation of 1000 m.

3.2. Climate

Turkey has several climate types due to its geographical location, topographical features and degree of continentality. Major types are disused below:

Black Sea climate: It can be divided into three subclimates (Atalay, 2010) (Fig. 5). The “Black Sea humid-mild climate” generally prevails on the northern slopes of the North Anatolian Mountains. The temperature in January is around 5-6°C on the coast but falls to 0°C at an elevation of 1000 m. In July, temperatures lie between 22°C and 24°C on the coast, decreasing to 20°C at 1000 m elevation. The mean annual precipitation is over 1000 mm (Rize 2300 mm, Zonguldak 1200 mm), all seasons are rainy, and relative humidity is high. No water deficiency occurs.

Humid cold climate is dominant over 1000 m on the northern slopes of coastal Black Sea Mountains. Total annual precipitation is over 1000 mm and summer period is rainy in the coastal area due to orographic precipitation; fog is a common feature being dominant on the high slopes facing north. The mean annual temperature changes between 6-12°C between 1000-2000 m elevations. The temperatures in winter are generally under the freezing point.

Subhumid-Semiarid climate prevails along the depressions and Kastamonu Plateau in the backward region of Black Sea. The amount of annual precipitation is around 800 mm in the highlands of this area but below 500 mm in the depressions. Summer temperatures and direct solar radiation are higher on the bottom of depressions than the coastal areas of Black Sea. Mean annual temperatures lie between 6-10°C in the plateau surfaces but are above 12°C in the bottom of depressions.

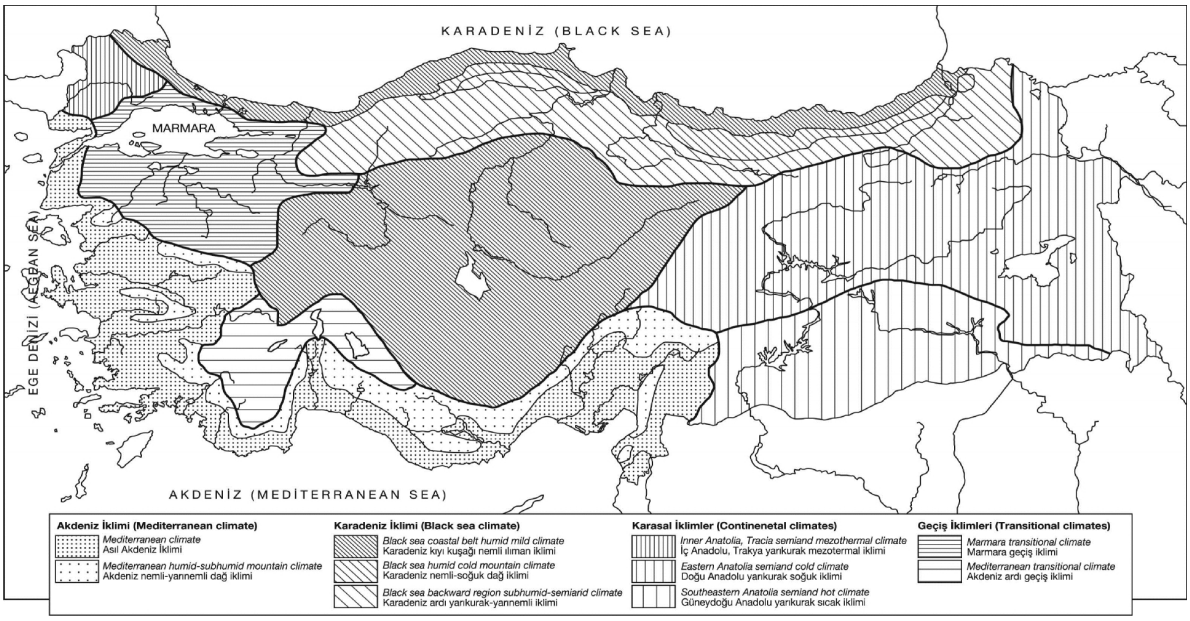

Fig. 5. The main climate types of Turkey (Atalay, 2010)

Mediterranean climate: It prevails on the Ege and Mediterranean coasts and continues as far as the western part of SE Anatolia and is classified into two subtypes due to topographic condition, especially altitude (Fig. 4). Thermo Mediterranean climate is dominant between 600-800 m in the Aegean region, and 1000-1200 m in the Mediterranean region especially on the south facing slopes of Taurus Mountains.

The mean annual temperature is around 15°C in the north of Aegean region and ranges between 19-20°C in the southern part of Mediterranean Region. The winter temperature is around 5°C in the north of Aegean Sea coast but rises up to 8-10°C along the Mediterranean coast. The summer temperatures change between 25°C and 30°C in the of N-S direction.

Subhumid-humid Mediterranean mountain sub-climate prevails in the highlands of the Mediterranean region. There is an increase in the precipitation over 1000 m elevation, in general; because of the fronts originating from the middle and SW part of Mediterranean Sea, which are considerably hindered by Taurus Mountains. The orographic rainfall seldom occurs on the upper parts of Taurus Mountains during summer. The humid part of the region is the slope facing west of Nur Mountains. The mean annual temperature in the oro-Mediterranean belt ranges from 10/12°C to 5/7°C, the temperature rises up to 20°C in summer, but is below freezing point during winters between 1000 m and 2000 m.

Continental climate: This dominated the continental part of Anatolia and is divided into three subclimates based on degree of continentality, precipitation and temperature conditions. Semiarid climate characterized by dry and hot summers, somewhat cold and snowy winters prevails in the inner part of Thrace and Inner Anatolia. Annual total precipitation is less than 400 mm, mostly 300-350 mm, but there is an increase towards the upland areas. Mean annual temperature is 10-12°C, the temperature is below the freezing point in winters but rises up to 25°C during summers in the lowlands.

Semiarid cold climate of East Anatolia is characterized by very cold and snowy winters, hot and dry summers. The annual precipitation is up to 1,000 mm in the upland areas, but decreases to 300 mm in the depressions; this figure is less than 300 mm in the Iğdır depression which is the driest part of Turkey. The mean annual temperature is about 3-6°C in the high plateau of Eastern Anatolia.

Semiarid hot climate of SE Anatolia is characterized by somewhat mild and rainy winters, very hot and arid summers in the western part of SE Anatolia. The temperatures have been recorded as 5-6°C in winter which rises up to 30-35°C during summers. Annual total precipitation lies around 400-500 mm on the lowlands, but exceeds 1000 mm in the highlands facing south of SE Taurus Mountains. Relative humidity decreases as low as 2 % even on the same day in summer. The potential evaporation is much more than 3000 mm.

4. Forest classification

The forest ecosystems in Turkey hold a unique position from the point of its natural reserves (Atalay *et al*., 1985; Atalay, 2002; 2008; Efe and Sonmez, 2006). The main forest types, according to mainly climatic regions of Turkey are as follow:

Turkey has numerous forest stand types due to the fact that habitat changes frequently occur in the very rugged mountainous areas. For example, the stands of *Pinus sylvestris-Fagus orientalis, Abies bornmulleriana-Fagus orientalis-Pinus sylvestris, Abies bornmulleriana-Fagus orientalis, Pinus nigra-Fagus orientalis-Pinus sylvestris, Pinus nigra-Abies bornmulleriana, Pinus nigra-Fagus orientalis-Abies bornmulleriana, Pinus nigra-Quercus cerris, Pinus nigra-Pinus sylvestris* and *Pinus sylvestris-Abies bornmulleriana* are established at an elevation of 1000-1200 m between Daday-Arac towns in subhumid condition of Kastamonu plateau (Atalay and Efe, 2010a; 2010b).

Humid-mild deciduous forests of Black Sea coast: The coastal belt of the Black Sea Region is the main distributional area of the broad-leaved deciduous forests. Acid soils with rich organic content and mull humus dominate the area due to humid and temperate climatic conditions. The biological richness is high compared with other regions of Turkey. Turkey has approximately 10000 plant species and nearly half of these occur in the Black Sea Region. Indeed, Black Sea region presents a wide variety of local climates, soils and habitats which support a rich and diverse tree and herbaceous vegetation. For example, *Alnus barbata* and *A. glutinosa, Fraxinus* spp. grow along the stream valley and in the places where ground water table is high. Some Mediterranean plants such as *Pinus brutia, Olea europea, Arbutus andrachne, and Myrtus communis* are common in somewhat sunny areas of middle and western coastal belts of Black Sea Region (Ozturk and Vardar, 1973). Hydrophytic vegetation is widespread along the valleys. The understory of forests is the mainly occupied by hydrophytic and hydrophillous shrubs and herbaceous vegetation. In this region, broad leaved deciduous forests range between 0-1200/1500 m and are composed of *Fagus orientalis, Tilia rubra, T. tomentosa, Castanea sativa, Carpinus orientalis, Fraxinus ornus, F. oxycarpa, Alnus glutinosa, A. barbata, Acer campestre, A. platanoides* and *Quercus species* mostly *Q. robur, Q, hartvissiana* (Dönmez, 1968; Yalçın, 1980; Atalay, 1982; 1984; 1992b; 1994; Atalay *et al*., 1985; Engin, 1992; Ozturk *et al*., 1997, 1998). The shrub layers of these forests mostly contain *Prunus laurocerasus, Ilex colchica, Cornus mass, Corylus avellana, C. colurna, Daphane ponticum,* together with *Rhododendron ponticum, Buxus sempervirens, Sambucus nigra, Sorbus aucuparia, Viburnum lantana* and few other species.

Pure and mostly mixed *Fagus orientalis* forests are dominant along the coastal belts and they rise as high as 1700 m in the locality of Kumbet temporary settlement in Dereli town, Giresun. Mixed *Fagus orientalis* forests are associated with *Picea orientalis; Picea orientalis* and *Alnus barbata; Castanea sativa; Castanea sativa* and *Tilia rubra; Abies nordmanniana, A. bornmulleriana* and *Picea orientalis*. Pure *Alnus barbata* forests are common along the valleys of Eastern Black Sea subregion. *Fraxinus* and *Alnus* forests are common on the wetlands around Igneada in Thrace and Lake Acarlar in Kocaeli Peninsula, W of Istanbul (Donmez, 1968; 1979). In general, broad leaved forests contain many tree and shrub species. For example, a forest area along the valley extending between 900-1500 m in the south part of Trabzon city is associated with *Fagus orientalis, Carpinus betulus, Ulmus glabra, Acer cappadocicum, Acer platanoides, A. trauwetteri, Quercus hartwissiana, Taxus baccata, Rhododendron ponticum, Sambucus nigra, Vaccinium arctostaphylus, Salix caprea, Castanea sativa, Tilia rubra, Alnus glutinosa, Juglas regia, Corylus avellana, Platanus orientalis, Rubus discolor, Ilex colchica, Sorbus torminalis* and *Frangula alnus* (Engin, 1992).

Castanea sativa forests are also common along the coastal belt of Black Sea. *Quercus* species are also widespread within the mixed deciduous forests; the leading species are *Q. robur, Q. hartwissiana Q. pontica* (only east of Black Sea region), *Q. macranthera* ssp. *syspirensis*, *Q. petraea, Q. infectoria,* and *Q. cerris*.

Humid-cold coniferous forests: These forests are mainly grows between 1000/1200-2000 m on the north slopes of the North Anatolian Mountains and are divided into two types;

a. *Picea orientalis* and *Abies nordmanniana* forests in the eastern Black Sea region: The existence of the *Picea orientalis* is related to the heavy fog conditions. During summers and/or vegetation period, cool and humid air mass coming from Black Sea rises along the north facing slopes of the Eastern Black Sea Mountains leading to the formation of fog and orographic rainfall. *Picea orientalis* beginning from the Black Sea coast occurs as a mixed forest with broad leaf species mostly *Fagus orientalis* between 1000-1500 m, and appears as a pure forest between 1500-2000 m on the north facing slopes of Giresun and Eastern Black Sea mountains. *Picea orientalis* forests are also widespread at an elevation of 800-2400 m in the Şavsat-Ardanuc, Posof and Barhal basins in the eastern backward side of Black Sea region. In some upper parts of these areas *Picea orientalis* forests are associated with *Pinus sylvestris* and *Abies nordmanniana*. The most productive *Picea orientalis* forest occurs in the Peynirli locality in Ardanuc basin.

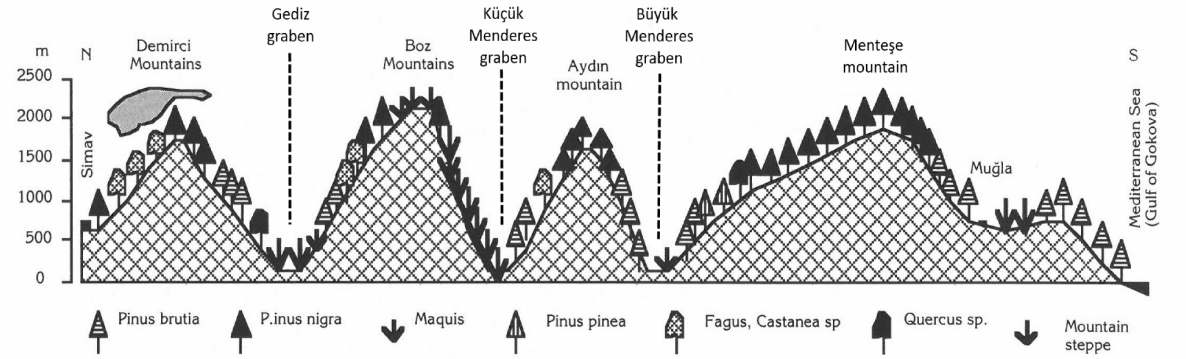

Fig. 6. Vegetation profiles in N-S direction from the western part of Aegean Region (Atalay and Efe, 2010).

The height of some *Picea orientalis* attain to 40 m. A *Picea orientalis* tree 67 m tall had been cut down in the past. Although the highest one in the Caucasus Mountains is 65 m tall (Alemdağı, 1967; Atalay, 1984; 1992; Atalay *et al.,* 1985; Atalay and Efe, 2012**)**.

b. *Abies bornmulleriana* forests occur in the middle and western part of Black Sea region: These forests are widespread on the north facing slopes of Kure Mountains. Here pure fir forests are mostly common on the north facing slopes and upper parts of the south facing slopes receiving fog. *Pinus sylvestris, Fagus orientalis* and *Rhododendron ponticum, Taxus baccata, Buxus sempervirens* and other shrubs are present as ground vegetation and are observed within *Abies bornmulleriana* forest. On the other hand, the north facing slopes of the mountains getting fog in the western backward part of the Black Sea region is natural occurring areas of *A. bornmulleriana* forest. The north facing slopes of Ilgaz Mountains and Ulu-Domanic mountain ranges are the main distributional areas of pure *Abies bornmulleriana, Abies bornmulleriana-Fagus orientalis* forests. The best example is seen in the eastern extension of Ulu-Domanic mountain range (Fig. 4). *Abies equi-trojani* forest, the endemic species for Anatolia, is common on the upper north facing slopes of Kaz Mountains in the SW part of Marmara region (Efe *et al*., 2010). *Pinus nigra* and *Fagus orientalis* are also common in some part of *Abies equi-trojani* forest (Çepel *et al*., 1977; Atalay, 1992b; Efe *et al*., 2013a; Efe *et al*., 2013b). The North Anatolian Mountains abound in many alpine grasses above 2000 m.

Subhumid-cold continental coniferous forests: These forests are mainly composed of *Pinus sylvestris* which is generally widespread on the south facing slopes of the backward region of Black Sea and the high plateaus of NE Anatolia. Pure and productive *Pinus sylvestris* forests are common on the Erzurum-Kars and Ardahan Plateaus (Alemdağ, 1967; Çepel *et al*., 1977; Tetik, 1980; 1986; Atalay and Efe, 2012). The mean annual temperature is under 6°C; the temperatures on some days during winter fall below -40°C, and rise during summers exceeds 30°C,

the mean temperature of summer months is about 15-16°C. Mean annual precipitation is over 600 mm, most of which is in the form of snowfall. During the late spring and early summer period convectional rainfall occurs due to continentality. Other main distributional areas of *Pinus sylvestris* forests occur on the Köroğlu Mountains, in the southern part of Middle and western part of Black Sea region, in the upper part of the Kelkit basin in the eastern part of Black Sea region, on the upper northern slopes of Sundiken mountains, N of Eskisehir, on the upper part of Turkmen mountains in the east of Aegean region (Fig. 7). Mixed *Pinus sylvestris* forests are associated with *Abies bornmulleriana, Fagus orientalis* and *Picea orientalis*. These are common in the eastern part of Black Sea region. Other *Pinus sylvestris* forests associated with *Abies bornmulleriana, Fagus orientalis, Buxus sempervirens, Taxus baccata, Corylus avellana, Cornus mass* are common in Egriova locality in the S of Karabük city, on the northern slopes of Ilgaz and Ulu Mountains; Uluova locality, W of Küre Mountains; and the mountainous areas in the west of Kastamonu plateau in the western part of Black Sea (Fig. 1) (Aydınözü, 1987).

Generally in the humid areas the shaded lower story of *Pinus sylvestris* forests supports a regeneration of *Abies* and *Fagus* seedlings. The trees formed from these regenerations change *Pinus sylvestris* forests into *Abies bornmulleriana* and *Fagus orientalis* mixed forests. In somewhat low humidity areas, *Pinus sylvestris* and *Pinus nigra* forests are common. These forests occur in the lower part of Kastamonu plateau, on the upper part of the backward depressions of Black Sea region; in the south of Kutahya and on Turkmen and Murat Mountains in the east of Aegean region.

Pure *Pinus sylvestris* forests are also common on the northern high slopes of Ak Mountain in the NE part of Inner Anatolia, but their productivity is low due to semiarid-subhumid conditions and low nutrient availability on siliceous parent material mainly composed of gneiss and micaschist.

Subhumid-semiarid semi continental coniferous forests: These forests mainly belong to *Pinus nigra* forests. Indeed, subhumid-semiarid and sunny conditions mostly prevailing between the upper part of the semiarid tectonic depressions and lower boundary humid areas in north Anatolia form the main distributional areas of *Pinus nigra* forests. These areas mostly cover the plateaus of middle and western part of Black Sea Region and the mountainous areas of Marmara and Aegean regions. Productive pure black pine forests occur between 1000-1500 m in Kastamonu and Kibriscik plateaus and the northern section of Kaz Mt. and Alacam mountains in Dursunbey, S of Marmara Region. In the Aegean Region the mountains of Turkmen, Murat, Sandıklı and Egrigöz are the main areas inhabited by *Pinus nigra* forests. *Pinus nigra, Quercus* and *Carpinus* mixed forests are common in the areas where drought evidently prevails, especially in the lower boundary of these mountains. *Pinus nigra, Pinus sylvestris, Abies bornmulleriana, Fagus orientalis* mixed forest is common on the upper north facing slopes of Kure Mountains. *Cistus laurifolius* communities are dominant on the lower story of *Pinus nigra* forests where parent materials are composed of granite, gneiss, micaschist and quartzite schist especially in the mountains in the W Anatolia (Atalay and Efe, 2010a; 2010b; 2012).

Semiarid dry forests of depressions of Black Sea, Marmara and Lakes Region: The tectonic depressions in the backward region of Black Sea and Marmara Region, inner part of Thrace and deep valley bottom in Mediterranean region face semiarid, somewhat hot climatic conditions. Winter temperatures rarely drop below freezing point and summers are hot and rainless. These areas are encircled by mountain ranges mostly occur in the rainshadow areas. They lie in the backward regions of Black Sea extending along the tectonic depressions called Northern Anatolian pull-apart basins and fault lines. The leading depressions are Erbaa-Niksar, Kelkit valley between Niksar and Resadiye, along the bottoms of Kızılırmak river valley, Durağan-Taşköprü and Karabük (Aksoy, 1978; Atalay and Efe, 2010, 2012). In these areas dry forests are composed of *Pinus brutia, Juniperus* mostly *J. oxycedrus, J. excelsa, Paliurus spina christi, Quercus* species mainly *Quercus coccifera, Q. infectoria, Q.petraea* are widespread. *Pinus brutia* forests occur along the Erbaa-Niksar and Durağan-Taşköprü depressions especially on the slopes facing north.

The lowlands of Marmara Region such as Sakarya river valley between Geyve town and Sarıyar Dam, Lake Paradise-Uluabat-Bursa depression are the main distributional areas of *Pinus brutia* and maquis vegetation. The lowlands or tectonic depressions of Lakes Region; which is the zonoecotone between Inner Anatolia continental climate and Mediterranean climate; are the main native areas of occurrence of *Pinus brutia* and *Quercus* forests. Mut Basin located in the Middle part of Taurus Mountain belt is the driest part of the Mediterranean region. The

lowland area of this depression is the major distributional area of maquis and garrique vegetation (Atalay, 1987b; Kantarci, 1982).

Semiarid continental Inner Anatolia oak-juniper-black pine forests: Inner Anatolia; as a whole; is one of the main rainshadow areas of Turkey in the places where semiarid climatic conditions prevail. Brown and Chestnut coloured soils with alkaline reaction and calcium carbonate accumulation in subsoil are widespread (Atalay and Efe 2010). Steppe vegetation is common on the lowlands such as Konya and Salt Lake basin, and the upper Sakarya watershed area of Inner Anatolia, after that and dry forests begin at an elevation of 1000/1200 m and continue as high as 2000 m. In Central Anatolia, *Quercus pubescens* and *Juniperus* sp. are mainly distributed between 1200-1500 m. *Pinus nigra* forest begins after 1500 m and continues up to subalpine grassland. Most of the native vegetation of Inner Anatolia has been seriously destroyed and degenerated. These areas are covered with the steppe vegetation called anthropogenic steppe (Uslu, 1959 Çetik 1986). Remnant black pine forests are only common in the southern part of Ankara namely Beynam forest, the southern part of Kadınhanı town and in the Yozgat Çamlığı. Small clusters of *Pinus nigra* occur in the SE part of Inner Anatolia. The productivity of the *Pinus nigra* forests here is low due to arid conditions. The shrub layer of *Pinus nigra* forest is mainly composed of *Quercus pubescens, Juniperus* and *Cistus laurifolius,* mostly common on the siliceous and volcanic tuff and sand, notably in the Köroğlu Pass in N of Afyonkarahisar city (Atalay and Efe, 2010a; 2010b).

Oak clusters composed of *Juniperus oxycedrus*, *J. excelsa* and *J. communis* are common on very limited areas, such as northern edges of mountains, southern edges of Sundiken Mountains and between Çayıralan-Akdağmadeni towns in western edges of Ak mountains. Oak forests mainly composed of *Quercus pubescens*, a climax oak species for Inner Anatolia, is common around Ak mountain and Akdağmadeni town (Çetik, 1986).

Semiarid-subhumid cold oak forests: In the western and southern part of East Anatolia productive oak forests are well represented, because the mountainous areas of northern part of the SE Anatolia and the western part of East Anatolia get abundant precipitation reaching up to more than 600 mm, this figure is over at least 800 mm in the high south facing slopes of SE Taurus and Mercan mountains (Fig. 2). These areas are covered with oaks forests, composed of *Quercus brantii, Q. libani, Q. ithaburensis* ssp. *macrolepis* and *Q. infectoria*. Majority of oak forests in the E and SE Anatolia have been partly and completely destroyed (Atalay 1994; Ozturk *et al*., 2006). Presently most of the productive forests occur in the vicinity of Bingöl and Mardin provinces and some parts of Mercan (Munzur) mountains. Irano-Turanian steppe vegetation occurs as a ground flora in most of oak forests.

Mediterranean Red Pine forests: The coastal belt of the southern part of Gallipoli peninsula and the Aegan and Mediterranean coasts are under the influence of Mediterranean climate. The main natural distribution areas of *Pinus brutia* forests are common as climax vegetation on the lower or thermo belt of the Aegean, Marmara and Mediterranean regions and they are very resistant to drought. Germination and regeneration are much more dominating than other forest trees; red pine seed is very resistant to the forest fires (Atalay *et al.,* 2008; Ozturk *et al.,* 2010b; Uysal *et al*., 2008; 2011). Protected fire areas are occupied by red pine seedlings in a very short time. It begins at the sea level and rises up to 300-400 m in Marmara, 700-800 m in the Aegan region and 1500 m in the Mediterranean region. These forests also occur on the depressions called Taşova-Erbaa-Niksar, Osmancık-Kargı and Durağan-Taşköprü in the backward part of Black Sea Region, between Sinop and Bafra cities in the coastal area of Black Sea and lowlands of Marmara region (Fig. 1, 4) (Atalay, 1988; 1994; Atalay *et al*., 1998; 2008; Efe, 1996; 1998).

Biomass productivity and the physical appearance of the *Pinus brutia* are determined by the physical and chemical properties of parent materials and the amount of precipitation and ground water table. The biomass productivity is very low on the quartzite and peridotite-serpantine bedrock. For example, red pine stands occurring on low weathered serpantine-peridotite bedrock in Datça Peninsula and in the vicinity of Köyceğiz are in shrubby appearance. In addition to this, poor stands exist on quartzite and siliceous parent materials in Foça district, Izmir (Ozturk *et al*., 1983). The productive and class one *Pinus brutia* forests occur between 400-800 m in the south facing slopes of the Taurus Mountains, because respiration during the night is lower than the coastal areas of Mediterranean region. The upper parts of *Pinus brutia* forests are associated with *Pinus nigra* and *Cedrus libani*.

Maquis vegetation

This vegetation is composed of *Quercus coccifera, Arbutus andrachne, A. unedo, Phillyrea latifolia, Calicotome villosa, Spartium junceum, Myrtus communis, Laurus nobilis, Juniperus oxycedrus, Ceratonia siliqua, Pistacia*

lentiscus, P. terebinthus, Olea europaea, Styrax officinalis grow on lowerstory of Pinus brutia forests in the Aegean and Mediterranean regions (Ozturk, 1995; Ozturk *et al*., 2002). When Pinus brutia forests are partly and completely destroyed the maquis vegetation spreads in the climax Pinus brutia forest areas. For this reason, maquis vegetation in the Mediterranean region is secondary vegetation (Ozturk *et al.,* 2006; 2008a; 2011). In protected areas maquis elements grow as trees (Ozturk *et al.,* 2012). If *Pinus brutia* trees are common among sparse maquis stands, the seeds germinate on open sunny sites among these and over time *Pinus brutia* again occupies the sparse maquis sites. So maquis vegetation remains in the lower story of Pinus brutia. On the other hand, in dense maquis areas germination of the red pine seeds is prevented, because Pinus brutia seeds germinate on bare soil rich in minerals and under direct sun light.

Maquis elements have a deep root system so that they occur even on thin soil cover, stony-rocky areas (Uslu, 1985; Atalay, 1994). Most of them are evergreen and fast-growing in character. If they are clear-cut frequently their biomass productivity increases. Maquis areas serve as the main grazing areas for animals, especially goats. *Quercus coccifera, Q, ilex, Pistacia lentiscus, Cistus* spp., and *Calicotome villosa* are resistant to forest fires, and they regenerate from root stocks after forest fire. Therefore, maquis vegetation in the karstic land tends to be stabile due to the fact that the roots of maquis elements develop deeply along the cracks and between the limestone strata.

Garrigue (phrygana) vegetation

This shruby vegetation is slightly shorter than maquis and also called low matorral. It occupies all parts of the coastal areas of Turkey. The vegetation is composed of low, thorny formations, mainly of hemispherical shrubs which are generally deciduous during the dry season; develop at places where both maquis and red pine forests are completely cleared. There are no selective affinities related to parent materials. In fact the garrigue vegetation occurs both in *Pinus brutia* forests as well as in the maquis. Maquis and garrigue formations occur widely in the Aegean region in the west Anatolia (Efe *et al.,* 2011). But, garrique vegetation is dominant in the areas where natural equilibrium has got deteriorated and on completely burnt areas. On the other hand, stony and arid parts of the thermo Mediterranean belt are covered with garrigues (Efe, 1996). The best example is the Mut Basin which is driest part in the region due to rain shadow (Efe, 1998a).

Oromediterranean coniferous forests

Oro-Mediterranean coniferous forests are common on the upper parts of mountains under the Mediterranean climatic influence prevailing on mountains both in Aegean and Mediterranean regions. In the humid parts of the oro-belt of Taurus Mountains, *Cedrus libani, Pinus nigra* and *Abies cilicica* forests are dominant. *Pinus nigra* forests occur between 1200 and 2000 m in the Taurus Mountains. They grow very well on the soft bedrock such as flysch and colluvial deposits and are often associated with *Cedrus libani* and *Abies cilicica*. Pure and productive *Pinus nigra* stands occur around Lake Beyşehir, Lake Eğirdir, Söğüt plateau between Antalya-Gazipasa and in the eastern part of Taurus mountains (Karsantı province) (Kantarci, 1982; Bozkus, 1987; Atalay, 1987a; Atalay, 1988; 1992; Efe, 2005; Atalay *et al.,* 2008; 2010).

Abies cilicica forests occur between 1150-2000 m on the slopes facing north and 1450-1550 m on the slopes facing-south in Taurus Mountains. The optimum growth areas are generally occur between 1200-1800 m. *Abies cilicica* appears rarely in pure stands but is mostly mixed with *Pinus nigra* and *Cedrus libani*. Pure *Abies* stands are common on the foggy areas of Taurus Mountains. Best example of pure *Abies* stands are common in the vicinity of Çamlıyayla town, in middle Taurus Mountains. *Abies cilicica* forests are also common between 1300-1500 m in the Nur (Amanos) mountains, East of Iskenderun Gulf (Atalay and Efe, 2010a; 2010b; Bozkus, 1987).

Cedrus libani is one of the climax trees of oro-Mediterranean belt beginning at an elevation of 800 m and reaches up to 2000 m on the southern slopes of the Taurus Mountains. It also continues up to 2200 m in the inner section of the mountains. The main distributional areas of cedar forests extend between Boz Mountain (Acıpayam) in the west, Aegean Region and Ahır and Nur mountains in the east. It continues towards the southern boundary of Inner Anatolia. Cedar forests occur both in mixed and pure stands, occupying the altitudes between 800-2000 m in the vertical direction in the southern parts of the Taurus, 1400-2100 m in the backward areas of the Taurus Mountains and 500-550 m and 1800-2000 m in the Nur Mountains, east of Taurus.

Fig. 7. Main forest groups according to the ecological regions of Turkey (Atalay, 2002).

It can be clearly said that cedar avoids the extreme maritime as well as continental climates in Anatolia. It prefers humid cool wind during the vegetative period. This wind blows from the northern sectors in the Lakes Region and southern sectors in the upper part of Taurus Mountains. Therefore optimum growing areas of cedar occur in the transitional region, called Lakes Region zonoecotone, between Mediterranean and Inner Anatolia and on the upper south slopes of Taurus Mountains (Atalay, 1987a). Although it has been reported that cedar only grows on the karstic lands in Taurus Mountains (Sevim, 1955), these trees grow on all parent materials containing marl deposit, schist, quartzite, and limestone belonging to Tertiary, Mesozoic and Paleozoic eras.

Juniper (*Juniperus excelsa, Juniperus foetidissima*) forests are common on the upper parts Taurus Mountains in places where coniferous forests, composed of cedar and black pine, have been completely removed. As such, the juniper dominated areas can be regarded as a regressive step and/or a cover forming secondary succession (Akman, 1974). Indeed the juniper seeds originating from the manure of the birds easily germinate on the bare ground in the destroyed coniferous forest areas. We come across *Juniperus communis* ssp. *nana* in the highest part of the forest belt (Atalay, 1987b; Eler, 1988).

Oak (*Quercus libani, Q. infectoria, Q. cerris*) forests are mainly occur between thermo and oro-mediterranean belt and extend up to an elevation of 800-1200 m, and are common in the western and eastern parts of Taurus. The common species of the oak forests are: *Quercus libani, Q. frainetto, Q. cerris* and *Q. infectoria*. They usually dominate the places where continental climatic effects prevail in the inner section (Yaltırık, 1984).

Broad-leaved deciduous forests associated with *Fagus orientalis, Castanea sativa, Tilia tomentosa*, etc. also grow on the west-facing slope of the Nur Mountains because of the fact that Mediterranean humid air rising from the Gulf of Iskenderun leads to orographic rain and fog formation in this area during the summers.

Quercus vulcanica; which is the endemic and relict species distributed on Taurus Mountains only; flourishes on karstic depressions with thick and damp soil cover in the Dedegöl and Davraz mountains. In this habitat a group of humid trees and shrubs belonging to Euro-Siberian elements such as *Sorbus torminalis, Tilia rubra, Fraxinus excelsior, Ulmus glabra* and *Ostrya carpinifolia* occur with *Quercus vulcanica* cluster (Gökşin, 1985; Atalay, 1987a).

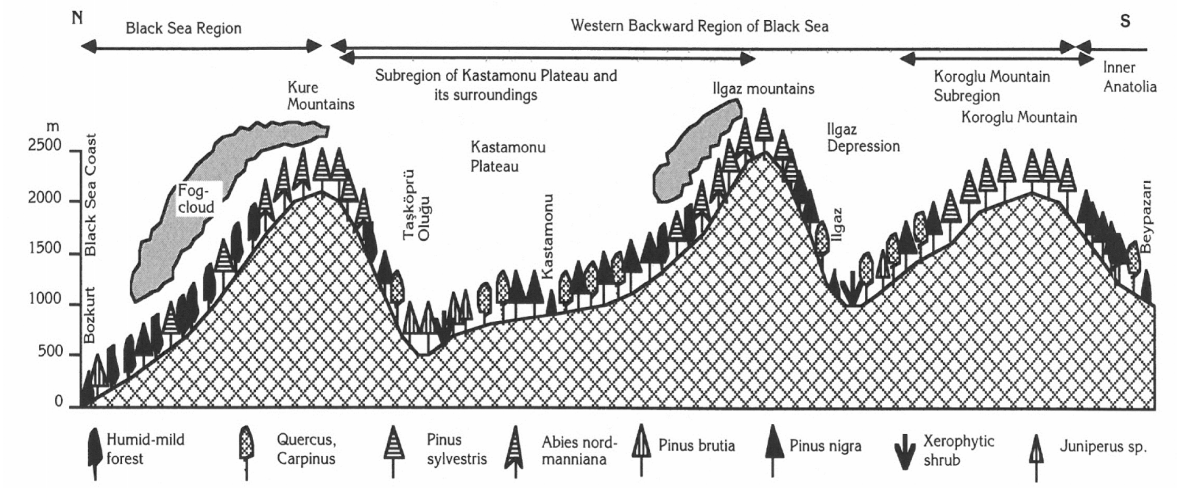

Fig. 8. Vegetation profiles in N-S direction from west of Black Sea Region (Atalay and Efe, 2013).

Relict forests and clusters

The relict vegetation occurs in the higher parts of mountains. During the last glacial period, maximum phase occurred during 18.000-20.000 years BP, the upper parts more than 2000 m high encircling the coastal areas of Anatolia and the mountains more than 2500-2600 m altitude in the inner part of Anatolia were occupied by the glaciers. Under the cold-somewhat dry climatic condition the Euro-Siberian plants like *Pinus sylvestris*, *Betula* sp. were widely distributed below the glaciated areas and migrated as far as western Anatolia and high southern parts of

Taurus Mountains. During the present climatic condition these trees migrated towards the upper part of the mountains, especially north-facing slopes. Indeed the birch communities are common on the Erciyes volcanic mountain in Inner Anatolia, Ağrı mountain, Nemrut volcanic caldera and the Mercan Mountains in the east Anatolia and on the eastern parts of Black Sea Mountains (Boydak, 1985; Zeist *et al*., 1991; Atalay, 1992a; 1998). *Pinus sylvestris* clusters also appear in the upper section of Ceyhan river basin in the Taurus Mountains, and coastal belt of Black Sea coast especially around Trabzon and Kurucasile and Çoruh valley between Artvin and Borçka towns. Some poor P.sylvestris clusters occur in the Hekimhan district in the Eastern Anatolian Region (Atalay and Efe 2012). The growth of plants belonging to the last glacial period is related to the existence of high mountainous areas. In addition to this, the tertiary relict and endemic forests of *Liquidambar orientalis* are common in the surroundings of Lake Köycegiz in SW Anatolia on areas with high ground water table, hot and wet climatic conditions (Ozturk *et al*., 2004; 2008b). It can be stated that the existence of these plants belonging to past climatic conditions also increased the forest types and composition in Anatolia.

5. Effects of humans and competition on the vegetation composition of forests

Improper silvicultural applications and the destruction of the natural vegetation have led to change in the composition of native forest vegetation. The existence of the *Picea orientalis, Abies nordmanniana* and *Pinus sylvestris* mixed forest in the sunny habitats in the eastern backward region of Black Sea is related to the regenerative growth of *Abies* and *Picea* under the canopy of *Pinus sylvestris* forests. This regenerative growth inside the pure *Pinus sylvestris* forests changes into a mixed forest composed of *P. sylvestris, Abies nordmanniana* and *Picea orientalis*. An overcutting of *Pinus sylvestris* trees in the mixed forests changes it into *Abies nordmanniana* and *Picea orientalis* forests. These forests are common in the upper Şavşat and Ardanuç basins, in the eastern backward region of Black Sea.

On the other hand, the abandoned agricultural fields and areas clear cut in the northern part of the Northern Anatolia are first occupied by *Pinus sylvestris* and *Pinus nigra* regenerations because of the fact that seeds of these pines germinate only on the exposed mineral rich soils (Atalay and Efe, 2010a; 2010b; 2012).

The composition of forest vegetation in Turkey changes considerably in the horizontal and vertical direction even in the same climatic region due to the topographical traits of many habitats. The mountainous areas of Anatolia contain abundant plant species and forest types according to different climate types and rugged topography results in the formation of local climates. Namely the altitude in the mountainous areas leads to vertical zonation of forests. We can observe at least three altitudinal forest belts in the high mountain ranges (Atalay, 2006; Efe, 1998b).

Aspect factor also adds to the growth of different forest types between north and south slopes of the mountains on same elevations. For example, *Picea orientalis* forests occur on the north facing slopes of north while *Pinus sylvestris* forests grow on the southern slopes of the North Anatolian Mountains. Mixed forests are associated with not only broad leaved deciduous forest but also coniferous forests occur on the humid habitats. For instance, the humid-mild conditions support the growth of numerous trees and shrubs in the coastal part of Black Sea.

Pure forests grow on the extreme continental and semiarid climatic conditions in the NE and Inner Anatolia and upper parts of the mountains. Indeed, the existence of pure *Pinus sylvestris* forests in the high plateau of NE Anatolia is due to the prevalence of very cold and subhumid severe continental climatic conditions, whereas semiarid conditions form a habitat for the growth of a few trees and shrubs as is Inner Anatolia.

6. Conclusions

In Turkey there are many types of forest classifications according to site class index, yields and natural distribution, vegetation composition and so on. In these publications exact classification depending on climatic regions and the altitudinal belts is mostly missing. There is a need for investigations to be undertaken on the classification of vegetation in the local and regional context. Some publications focus on the classification of flora and herbaceous vegetation, others show complicated results on the forest classification depending on the literature collected (Çolak and Rotherhan, 2006).

In this article discussion has revolved around the forest vegetation of Turkey but, the area of Thrace has not been included. We have tried to review main forest types of Turkey together with the profiles mostly in the N-S directions

in order to put forward the distribution of forests in the country. A major contribution has been the consideration given to the relationships between climatic changes which occurred during the Quaternary and present day distribution of vegetation formation.

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