

## Forest Stand Structure Along an Altitudinal Gradient in the ICCAP Area

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### 1. Introduction

Studies on the vegetation of Anatolia have revealed important information on the progressive and regressive development of vegetation during the last 20 thousand years. It will be useful to evaluate briefly climate change in retrospective manner: About 3 million years ago our globe was under the influence of cold climate therefore glaciers occupied large areas on high mountains in Anatolia.

During late *Pleistocene*, Anatolian mountains were covered with glaciers at altitudes above 2000 m in the western and above 3000 m in the eastern regions (Atalay, 1983). Across this cold period, plants of humid and cold environments of the northern sector, *Euro-Siberian* elements, moved towards Anatolia, resulting formation of Alpine grasslands and occurrence of birch (*Betula* spp.) and Scotch pine (*Pinus sylvestris*) below the peri-glacial zone.

In the southern regions, colder and drier climate prevailed. Glaciers in Taurus Mountains obviously prove that climate was harsher. Hence, forests remained isolated along relatively humid Mediterranean coasts. Würm glacial phase may be considered as the phase that *Euro-Siberian* elements (eg. *Fagus orientalis*), which sometimes penetrated into the southern regions, were the commonest elements in Anatolia.

Nearly 3.2 million years back from now (end of *Pleistocene*), decline of *hygrophilous* plants accelerated and the forests formed by these plants were replaced by Mediterranean-type *xerophytic* species. In fact, the *xerophytic* elements did not have an extensive distribution, although they existed before *Tertiary* period at certain locations with a predominantly humid and warm climate.

As mentioned above, the end of *Pleistocene* epoch is the period that Mediterranean-type vegetation became more prominent. Climatic patterns that most resemble the contemporary

climatic conditions date back to 2.8 million years ago. However, it can be said that the Mediterranean vegetation was affected by quaternary glaciations started nearly 2 million years ago.

Representing the contemporary vegetation, *xerophytic* species such as *Quercus coccifera*, *Q. infectoria*, *Olea europaea*, *Pinus halepensis*, and *Pistacia* spp. are known to have widely existed in the Mediterranean basin 80 thousand years ago. Melting of glaciers continued until 10 thousand years ago, preceding the period that today's climatic conditions started to become persistent around the earth.

Significant characteristic of the post-glacial phase was warming. 6000-10000 years back from now, different environmental conditions existed, showing high variation from one geographic region to another. Southwest Anatolian vegetation was previously occupied by steppe and steppe forest formations. However, these were replaced by forests afterwards due to humid and wet climate. Across the period from 7000 to 6000 years ago that was termed as "*climatic optimum*", temperatures and humidity increased in some regions of the earth, including Anatolia. During this period, steppe forest in Anatolia expanded and several *xerophytic* weeds were drifted from African-Arabian region. During the *eremial era*, when a widespread desertification occurred on the earth, hot summers were typical and all seasons were marked by a typical drought. Forest coverage was either very limited or absent. In a broader sense, *eremial* region include Sinai desert, Arabian Peninsula, Mesopotamia, and southern India as well as today's Syria and Iran. Some members of the eremic flora such as *Salsola kali*, *S. ruthenica*, *Iflago spicata*, *Hippocrepis unisiliquosa*, *Poa bulbosa*, *Prosopis farcta*, *Alhagi pseudoalhagi*, *Teucrium polium*, *Salvia palaestina*, and *Fagonia olivierii* penetrated into southern Anatolia (Aslan, 2002; Kutiel et al., 2000; Raina and Sen, 1991;

Shankar and Kumar, 1988; Zohary, 1973). Most of them are widely spread around the Mediterranean and can still be observed in the contemporary vegetation.

## 2. Altitudinal Zonation of the Vegetation in The Study Area

The vascular flora of the eastern Mediterranean region of Turkey consists of 4632 taxa. Accounting for 26 % of this total, 1130 of these plant taxa endemic (Düzenli, 2002). Mountain ranges, rivers and coastal plains in the region form various biotopes that include grasslands above the forest zone, evergreen and deciduous forests, shrublands, riverbeds, lagoons, coastal salt marshes, coastal woodlands and sand dunes.

A total of 1732 plant taxa occur within the province of Adana, which includes Çukurova Deltas with extensive sand dunes and wetlands being the coastal edge of the province. The number of endemic taxa is 364, meaning an endemism rate of 21 % for this region. Moreover, 7 % of these plant taxa are local endemics, which have very limited distribution. Altitudinal zonation of these endemics is shown in Figure 1.

As shown in the Figure 1, the number of endemics increases with altitude until high montane zone that lies above timberline. Between the coastal and alpine zones, 110 endemic plant taxa occur with a wide altitudinal distribution.

Within the ICCAP area, there is a considerable floristic diversity, particularly in the mountainous region. Occurring above timberline (about 2000 m), sub-alpine grasslands are characterized by thorn-cushion formations with typical species of *Astragalus* and *Acantholimon*. This biotope is heavily influenced by grazing. Between 1200 and 1900 m, *Cedrus libani* and *Abies cilicica* subsp. *cilicica* form a montane-forest. *Juniperus excelsa*, *J. oxycedrus*, and *J. drupacea* are accompanying species in this formation. *Pinus nigra* subsp. *pallasiana* occurs mainly at altitudes between 1200-1900 m, above *Pinus brutia* forest zone. Various species of deciduous oak such as *Quercus cerris*, and other broadleaved species like *Fraxinus ornus*, *Carpinus orientalis*, *Ostrya carpinifolia*, and *Sorbus* spp. are accompanying species in these forest communities.

In the region, sub-Mediterranean coniferous forest with *Pinus brutia* being the dominant species is found up to 1200 m. This forest type has a rich understory and is degraded in the areas below 700 m. Up to this altitude a dense *xerophyll* shrubland is the dominant formation. This formation, called machia, consists of several species of evergreen shrubs. *Quercus coccifera* is the most common species in the machia formation. Other important members of this formation are *Ceratonia siliqua* and *Pistacia lentiscus*. Communities of these two species cover large areas especially in the coastal zone. Across degradation of Mediterranean vegetation, macchia is replaced by garrigue formation that consists of several dwarf-cushion species such as *Cistus salviifolius*, *Sarcopoterium spinosum* and *Lavandula stoechas*.

Located between the foothills of Taurus Mountains and the Mediterranean coast, Çukurova is a wide alluvial coastal plain (7000 km<sup>2</sup>) formed by three rivers; Seyhan, Ceyhan and Berdan. These rivers originate in the Taurus Mountains and flow into the Mediterranean Sea (Yılmaz 1998). On the plain, where cultivation is intensive, it is not easy to find any patches of natural vegetation. Only few old, solitary trees of *Quercus ithaburensis* ssp. *macrolepis* from the former oak forest remain. Some remnant 400-1000 year-old individuals of forest trees can be found in the region. In the upper catchment of Seyhan and Ceyhan basins, about 30 monumental individuals of cedar (*Cedrus libani*), fir (*Abies cilicica* ssp. *cilicica*), plane tree (*Platanus orientalis*), kermes oak (*Quercus coccifera*), black pine (*Pinus nigra* ssp. *pallasiana*), juniper (*Juniperus oxycedrus*) and English ivy (*Hedera helix*) were considered as representatives of the natural vegetation (Yılmaz *et al.*, 2004).

A patch of coastal woodland remaining from a former evergreen forest is located at Yumurtalık Bay. Surrounded by salt marshes, this woodland community is dominated by Aleppo Pine (*Pinus halepensis*). In its natural state, the undergrowth consists of macchia species. However, this has partly been degraded to garrigue-type vegetation due to intensive grazing (Alphan, 1998; Yılmaz and Alphan, 1998). Distribution of the bioclimatic belts, including representative vegetation formations, along an altitudinal gradient in Taurus Mountains is

shown in Table 1.

### 3. Results and Conclusion

We employed this study using the data collected at 62 different sub-plots along a transect between the sea level (Yumurtalik) and the altitude of 1530 meters (Aladag). In this context, we sampled 7 stands and identified 3 different forest communities on the basis of forest stand structures and floristic compositions of understory (Table 2). These forest communities are: (1) *Abies cilicica* subsp. *pallasiana* (Mediterranean- Montane), (2) *Pinus brutia* (Mediterranean- Sub Mediterranean) and (3) *Pinus halepensis* forests (Thermo- Mediterranean). (Figure 2).

Results showed that tree species richness is high (three species) for *Pinus brutia* and *Abies cilicica* subsp. *cilicica*, while it is low (one species) for the *Pinus halepensis* forest. Hence, *Pinus halepensis* always occurs as pure stands. Although *Quercus* species are known to have widely existed as the representative of evergreen xerophytic forest in the region, it appears mixed with coniferous forest. Therefore, we were unable to sample a pure *Quercus* community. Instead, only a single sample of *Quercus coccifera* coppice was investigated. The constancy of this species was found 25 % along the transect. The constant forest tree species is *Pinus brutia*, with a constancy level of 40 %. The constancy of *Pinus halepensis* and *Abies cilicica* were calculated, on the other hand, as 24 and 16 %, respectively.

Understory species richness has a strong correlation with altitude in the summer aspect of the flora. Therefore, it was found to be higher at thermo- and sub-Mediterranean zones than that was in the montane belt.

The community of *Abies cilicica* subsp. *cilicica* is obviously distinct from other two communities with its floristic composition. This can be seen in Figure 2. The *Pinus brutia* community is characterized with *Quercus coccifera*, while *Erica manipuliiflora*, *Pistacia lentiscus*, and *Smilax aspera* are found to be characteristic species of the third community.

Life forms are variable along the altitudinal gradient in the region. Table 3 shows variation of life forms and phyto-geographic origin in respect to sample locations included in the ICCAP project area (Table 3). According to data given in the Table,

hemipterophytes increase with the altitude, while therophytes decrease. Mediterranean elements are always dominant along the gradient. However, Irano-Turanian elements show a significant increase at relatively higher altitudes. Throughout Eastern Mediterranean region, the rate of both life forms and phyto-geographical origins of the flora are determined by montane and alpine belt formations as their flora are distinctive with their Irano-Turanian elements. Taking life forms into consideration may help to create future scenarios for climate changes as they result from environmental conditions mainly determined by climate.

Following tools can be helpful to predict likely impacts of climate change on the plant life: Distribution of;

Life forms spectrum,

Phyto-geographic origins of the floristic elements, Endemics, which have limited distribution in specific climatic conditions along the altitudinal zonation of the forest communities.

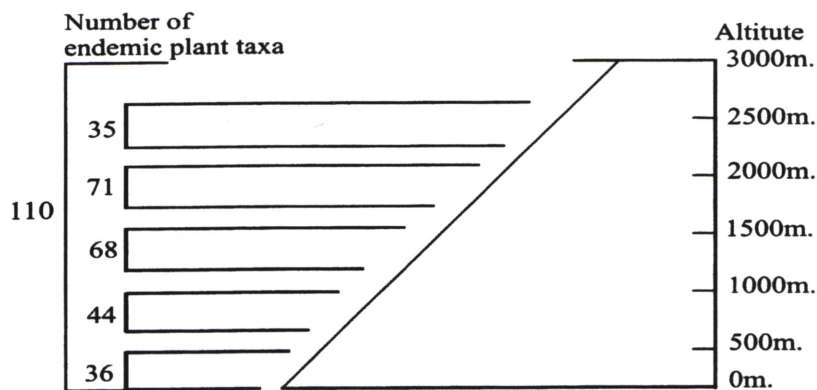
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**Figure 1.** Altitudinal zonation of the endemic plant taxa in the eastern Mediterranean region of Turkey (Yılmaz *et al.*, 2004).

**Table 1.** Distribution of the bioclimatic belts along an altitudinal gradient in Taurus Mountains (Yılmaz, 1996; Kürschner, 1984)

Annual average temperature (°C)	Altitudinal Zonation		Evaluation of bioclimatic belts by different authors			Basic Belts
	Vegetation	Ecological order	Walter, 1968	Zohary, 1973	Barbero & Quezel, 1976	
Permanent Snow cover	-	Nival				
Frozen soil	Criptogams, grassland geophytes	with Sub-nival	Alpin	Alpin	Alpin	Alpin Belt Complex
1 °C Cold	Grassland	Alpin				
4 °C Cold-Temperate	Grassland thorn-cushion formations	Sub-alpin			Sub-alpin	Sub-alpin belt Complex
8 °C Temperate	<i>Abies-Cedrus-Juniperus</i> Forests	Oreal	Sub-alpin	Sub-alpin	Mediterranean-Montane	Mountain belt Complex
	<i>Pinus nigra ssp. pallasiana</i> Forests	Montane	Montane	Oro-Mediterranean	Supra-Mediterranean	
10 °C temperate	<i>Pinus brutia</i> Forests	Sub-montane	Sub-mediterranean		Eu-mediterranean	
13 °C Warm-Temperate	Evergreen xerophytic shrub communities (machia)	Kollin	Mediterranean	Eu-Mediterranean	Thermo-Mediterranean	Planar-Kollin Belt Complex
		Planar				
15 °C Subtropik	Cultivated lands	Mediterranean				

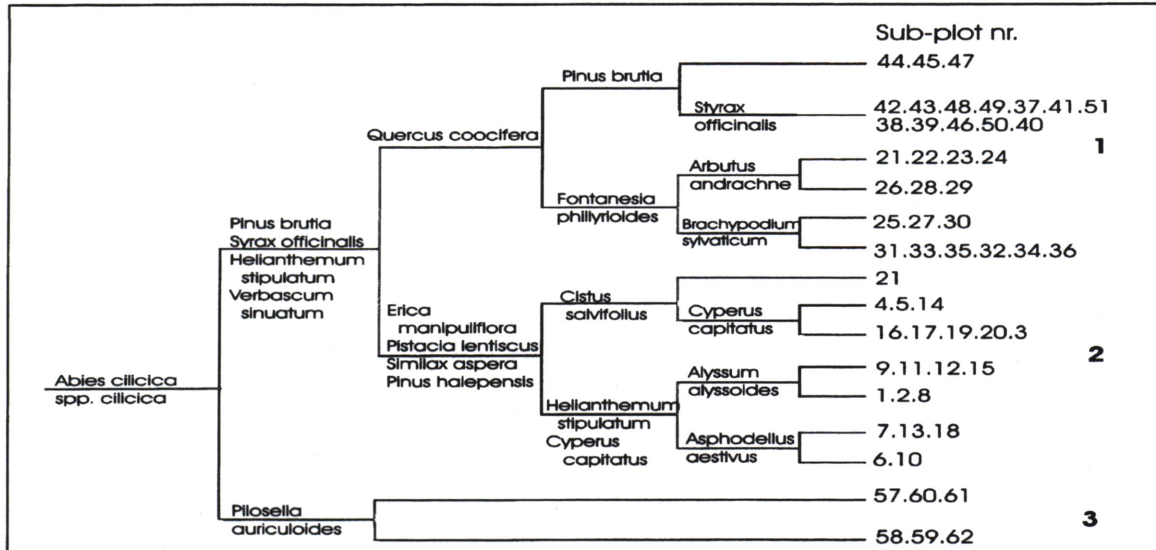


Figure 2. Simplified dendrogram for three distinct forest communities

Table 2. Evaluation of forest stand structures along the altitudinal gradient

Altitude	Locality	Dominant species	Plot size	Subplot size	Sub-plot number	Species richness (number)	Number of total individuals	Relative coverage (%)	Frequency (%)	Constancy (%)
0.00	Yumurtalık	<i>Pinus halepensis</i>	50x40	10x10	1-21	1	2	28	72	24
151m.	Catalan	<i>Pinus brutia</i>	20x20	10x10	22-25	2	4	61	100	40
200m.	Karatepe	<i>Pinus brutia</i>	30x20	10x10	26-31	3	12	96	100	
540m.	Karatepe	<i>Quercus coccifera</i>	6x15	3x5	32-37	3	5	63	100	25
785m.	Aladag-(Center)	<i>Pinus brutia</i>	30x50	10x10	38-52	1	2	36	100	40
1200m.	Aladag	<i>Abies cilicica</i>	40x40	20x20	53-56	3	17	90	100	
1530m.	Aladag-Katran Cukuru	<i>Abies cilicica</i>	20x30	10x10	57-62	3	15	92	100	16

Table 3. Variation of life forms and phyto-geographic origins in the eastern Mediterranean Region (Karaömerlioglu, 1999; Aslan, 2002).

Location	Life Forms (%)					Phyto-geographic Origins (%)		
	Ph	H	Ch	G	Th	Mediterranean	Euro-Siberian	Irano-Turanian
Aladag	21	45.5	4.8	8.5	20.5	-	-	-
Upper Ceyhan Valley	-	-	-	-	-	23.5	3.4	17.2
Adana-Balcalı	13	24	5	4	51	36.8	1.7	3.1
Eastern Mediterranean Region	4.6	49.6	6.6	8	27.2	31.6	4.9	24.9

Ph: phanerophytes; H: hemicriptophytes; Ch: chamaephytes; G: geophytes; Th: threophytes