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Ecophysiological variation of European Hornbeams along the foliation period in semi-rural recreational forest landscape

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Abstract: Determination of the ecophysiological characteristics of deciduous trees in the recreational areas allows construction of planning objectives particularly for the urban forests. Analysis of a multipurpose vegetation parameter; LAI (Leaf Area Index) together with definite meteorological variables supplies to an extent the comprehension of those ecophysiological characteristics. Around this scope, the LAI dynamics of *Carpinus betulus* L. trees in a recreational area were monitored and analyzed along the foliation period of approximately three months. The mean LAI which was only 0.80 during the budburst stage gradually escalated reaching 1.49 after the flushing stage. The increment of the leaves in size and numbers led to the mean LAI achieve its climax with 3.41 in early May. Then, the mean LAI experienced a stable period until the end of May. The change in the mean LAI were subjected to correlation test especially with the air and soil temperatures. The correlations between the mean LAI and, in particular the soil temperature ($r \geq 0.95$) and air temperature were high and significant ($P<0.01$). There were no definite correlation between the mean LAI and mean sunlight duration, air humidity and total precipitation. Impact of air temperature on the LAI of *Carpinus betulus* L. trees indicates the vulnerability of the recreational area to possible urban heat oriented climate warming. On the other hand, the influence of soil temperature on the mean LAI warns the susceptibility of the recreational area to possible anthropogenic pressure resulting in soil compaction and regeneration difficulties. Consequently, sustainable management of this recreational area necessitates the anticipation and mitigation of these possible destructions.

Keywords: *Carpinus betulus* L., recreational area, canopy architecture, Leaf Area Index (LAI), hemispherical photographs.

Yarı-kırsal rekreasyonel orman peyzajında yapraklanma dönemi boyunca Avrupa Gürgeninin ekofizyolojik değişimi

Özet: Rekreasyon alanlarında bulunan yaprak döken ağaçlarının ekofizyolojik özelliklerinin tespit edilmesi, bilhassa kent ormanları için planlama hedeflerinin tesis edilmesine imkân sunar. Çok amaçlı bir bitki örtüsü göstergesi olan YAİ'nin (Yaprak Alan İndisi) bazı meteorolojik değişkenlerle birlikte analiz edilmesi bu ekofizyolojik özelliklerin bir nebze anlaşılmasına yardım eder. Bu çerçevede, bir rekreasyon alanında bulunan *Carpinus betulus* L. ağaçlarının YAİ dinamikleri, yaklaşık üç ay süren yapraklanma dönemi boyunca izlenmiş ve analiz edilmiştir. Tomurcuklanma döneminde sadece 0.80 olan ortalama YAİ, kademeli olarak artarak yaprak verme döneminden sonra 1.49'a ulaşmıştır. Yaprakların boyut ve sayılarındaki artış, ortalama YAİ'nin 3.41 ile Mayıs başında zirvesine ulaşmasına neden olmuştur. Daha sonra ortalama YAİ, Mayıs sonuna kadar sabit bir dönem geçirmiştir. YAİ'deki değişim, özellikle hava ve toprak sıcaklıkları ile korelasyon testine tabi tutulmuştur. Ortalama YAİ ile hususen toprak sıcaklığı olmak üzere ($r \geq 0.95$) ve hava sıcaklığı ($r \geq 0.84$) arasında yüksek ve önemli ($P<0.01$) korelasyonlar mevcuttur. YAİ ile ortalama güneşlenme süresi, hava nemi ve toplam yağış arasında belirgin bir korelasyon söz konusu değildir. Hava sıcaklığının *Carpinus betulus* L. ağaçlarının YAİ'si üzerindeki etkisi, rekreasyon alanının, şehrin ısısına bağlı muhtemel bir sıcaklık artışından zarar görme ihtimalini ortaya koymaktadır. Öte yandan, toprak sıcaklığının ortalama YAİ üzerindeki etkisi, rekreasyon alanının, toprak sıkışması ve gençleşme güçlüğüne yol açan muhtemel insan baskısına hassasiyetini vurgulamaktadır. Dolayısıyla, bu rekreasyon alanının sürdürülebilir yönetimi, olası tahribatların öngörülmesini ve hafifletilmesini gerektirir.

Anahtar Kelimeler: *Carpinus betulus* L., rekreasyon alanı, tepe çatısı mimarisi, Yaprak Alan İndisi (YAİ), yarıküre fotoğraflar

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1. INTRODUCTION

Deciduous trees exhibit distinct ecophysiological traits based particularly on the meteorological variables (Bonan, 2008). Among those multiple variables, temperature is the main driving force for the sequence of phenological stages (Waring and Running, 2007). Beginning with the budburst, foliation stage occurs with the emergence of the first leaves. These leaves develop in size until they reach maximum in dimension and quantity (Öztürk, 2015). The development of the leaves end with relatively a stable stage which then defoliation stage associated with leaf discoloration takes place. All these stages lead to the physiological changes within the leaf and, consequently canopy architecture of the deciduous trees.

Beyond their role on light transmission (Link et al., 2004) and shade supply against rising sunshine (Oke, 1989), deciduous trees which cover recreational sites offer visual dynamics particularly during their foliation stages (Marsh, 2010). Recreationists enjoy these visual dynamics throughout several perspectives involving especially the frontal and underside aspects. Temporal succession of these landscape displays can be monitored by continuous analysis of Leaf Area Index (LAI) (Öztürk, 2015). The vegetation parameter; LAI indicates the one-sided area of the leaves over the projected crown area of a broadleaf vegetation (Bonan, 2008; Kara et al., 2011). Drawing the seasonal course of LAI for a recreational area provides the determination of recreation potential within that area. Furthermore, LAI pattern together with the climate pattern along the foliation period supports to discover the ecophysiological characteristics of that associated landscape. In this study, the LAI of the European hornbeams (*Carpinus betulus* L.) in the semi-rural forest landscape was observed regularly along the foliation period. This landscape carries the recreation potential such as other urban forests within the region (Öztürk and Bolat, 2012; 2014). The correlations between the air-soil temperature and LAI were also investigated in terms of evaluating ecophysiological characteristics of European hornbeams which then will assist the determination of recreation potential of that forest landscape.

The deciduous tree species; *Carpinus betulus* L. flushes ovate and acute leaves with 5-10 × 3-5 cm dimensions. The bark of the *Carpinus betulus* L. is smooth and grey whereas the trunk is grooved (Davis, 1982). The approximately 25 m tall tree; *Carpinus betulus* L. is prevalent in Europe and spreads from northwestern-northern Turkey to Caucasia and Iran (Yaltırık, 1993). Although the ecophysiological (Bréda et al., 2006) and phenological (Asshoff et al., 2006; Vitasse et al., 2009) studies on *Carpinus betulus* L. are widespread for Europe, the ones for Turkey are relatively restricted to few studies (e.g. Öztürk et al., 2015).

2. MATERIALS AND METHODS

The study area constituting the recreational *Carpinus betulus* L. stand covers approximately 3.6 ha where the periphery is 922 m. The area is a preserved forest which has been determined to carry recreation potential and be able to serve the vicinity with its social, cultural and aesthetic characteristics (TGDF, 2011). The area is located within the 32° 20′ eastern longitudes and 41° 36′ northern latitudes (Figure 1). The average altitude of the recreational area is 30 m asl. (above sea level). Brown forest soil (TMFAL, 2005) has formed on sandstones and mudstones (TGDMRE, 2007). The soil is moderate deep with average depth of 70 cm (TMFAL, 2005). Although the surface of the recreational area is almost plane, the aspect can be defined as western with a slight inclination towards west. Agricultural areas and rural settlements are the major land uses nearby the study area. The road leading to the Bartın University and the villages is passing nearby the study area (Figure 1). (TGDF, 2011). Few old pedunculated oaks (*Quercus robur* L.) remain only at the northern edge of the stand; beside the road.

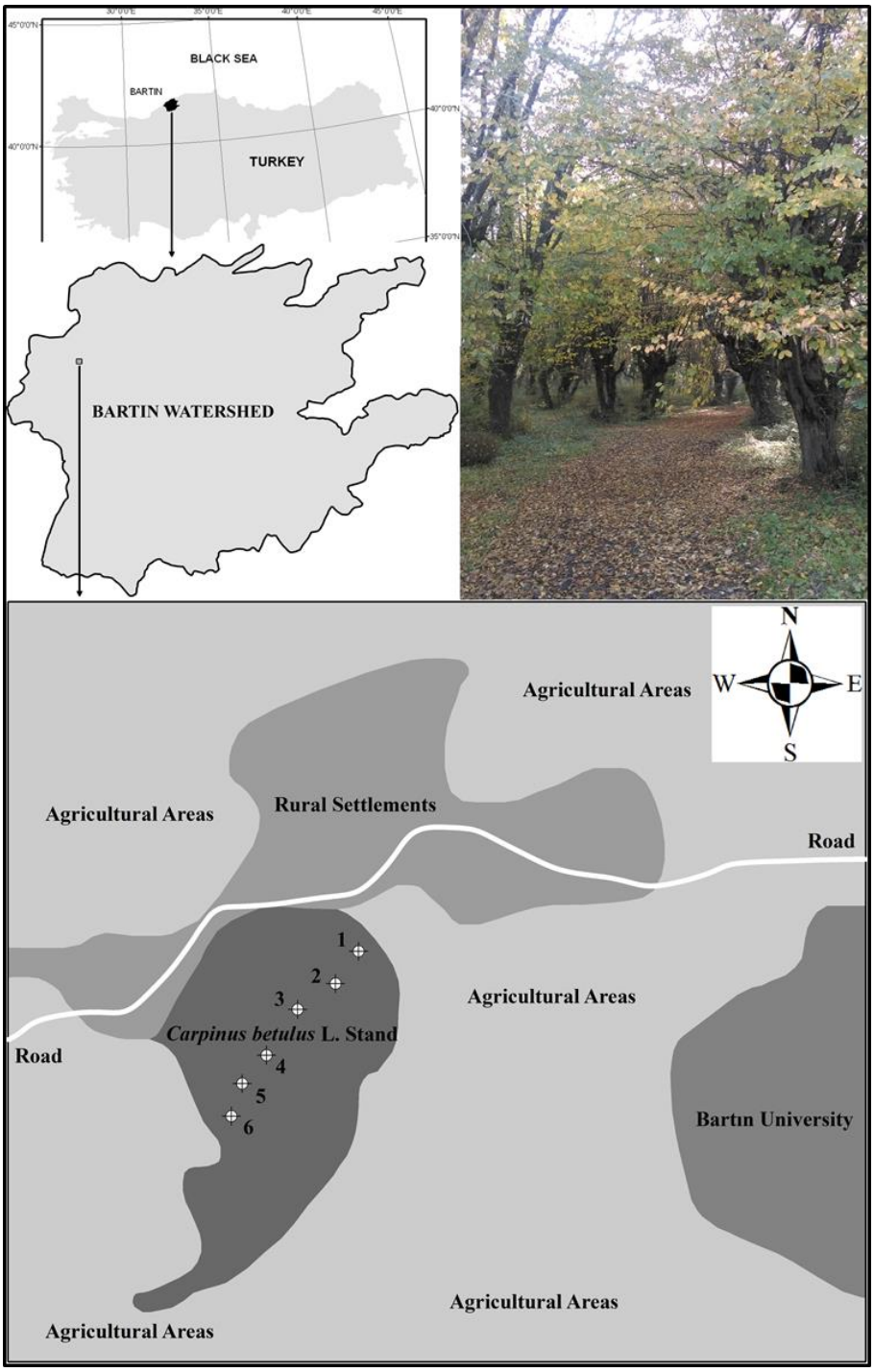

Figure 1. Location of the study area within the Bartın watershed and Turkey (left). Instant digital photography of the recreational *Carpinus betulus* L. stand (right). *Carpinus betulus* L. stand together with the nearby road and other land uses including the agricultural areas, rural settlements and Bartın University (bottom). The six hemispherical photographing points within the stand (bottom).

Şekil 1. Çalışma alanının Bartın havzası ve Türkiye içerisindeki konumu (sol). Rekreasyonel *Carpinus betulus* L. meşceresinin anlık dijital fotoğrafı (sağ). *Carpinus betulus* L. meşceresi ile civarındaki yol ve tarım alanlarını, kırsal yerleşimleri ve Bartın Üniversitesi'ni kapsayan diğer alan kullanımları (alt). Meşcerenin içerisindeki yarı-küre fotoğrafların çekildiği altı adet nokta (alt).

The average height of the European hornbeam trees ranges between 15 and 25 m whereas the average DBH (diameter at breast height) ranges between 20 and 40 cm (TGDF, 2011). The mean canopy closure of the recreational stand is 55% (TGDF, 2011). There is almost no lower vegetation under the major canopy within the recreational area. According to the 30 years (between 1982 and 2011) of meteorological data belonging to the meteorological station at the city center of Bartın, average annual temperature is 12.6°C within the region and the average annual total precipitation is 1044 mm (TSMS, 2014). The hottest month is July with mean temperature of 22.2°C and the coldest month is January with mean temperature of 4.1°C (Figure 2). The wettest month is October with total precipitation of 123 mm whereas the driest month is May with total precipitation of 49 mm (Figure 2). Therefore, the region drops into the mesothermal climate regime (Atalay, 2011). The dominant wind direction is from west-northwest and north-northeast where Black Sea exists (TSMS, 2014).

Six sample points were assigned for the hemispherical photographing and analysis of the LAI (Figure 1). Average distance between the points is 30 m. The exact locations of the sample points were chosen based on the projections which best represent the upper canopy variation within the recreational area. Hemispherical photographing started on the February 28th of 2014 (59th day of year) and finished on the May 29th of 2014 (149th day of year). In between this three months period, 14 visits to the field were carried out resulting with 84 hemispherical photographs in total. The intervals between each visit lasted about 4 to 10 days dependent particularly upon the weather conditions. Namely, the rainy and sunny days are not convenient for the hemispherical photographs (Öztürk, 2015) which are taken looking upwards beneath the canopy (Jonckheere et al., 2004). The hemispherical photographs were subjected to image analysis technique using the version 2.13 of Hemisfer software in order to acquire LAI (Schleppi et al., 2007). Automatic thresholding based on the study of Nobis and Hunziker (2005) was used whereas Lang (1987) methodology was preferred during the analysis of LAI. The corrections were based on the combined methodology of Chen and Cihlar (1995) to avoid clumping effect and Schleppi et al. (2007) in order to account non-linearity and slope.

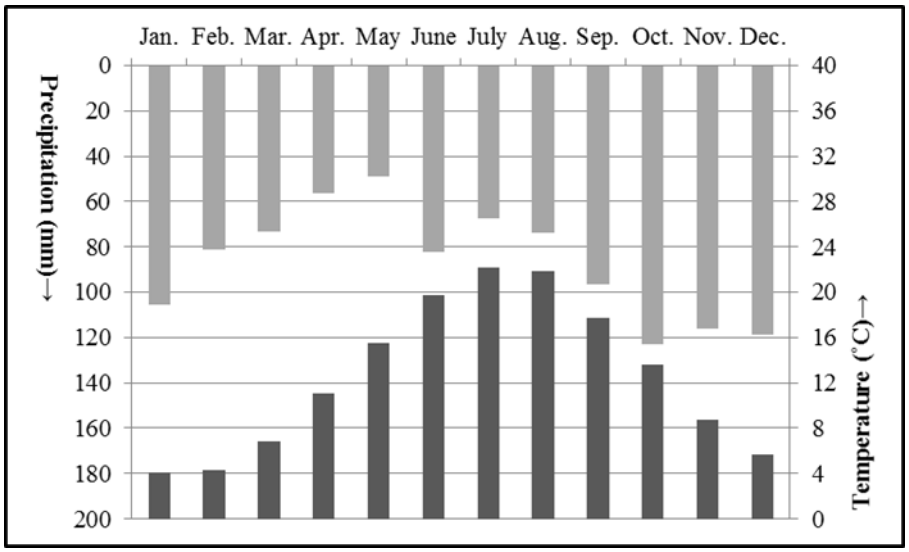

Figure 2. Mean monthly total precipitation data (left-grey bars-downwards). Mean monthly temperature data (right-dark bars-upwards).
Şekil 2. Aylık ortalama toplam yağış verileri (sol-gri çizgiler-aşağı doğru). Aylık ortalama sıcaklık verileri (sağ-koyu çizgiler-yukarı doğru).

For the three months research period, the mean, maximum and minimum air and soil temperatures together with the air humidity, sunlight duration and precipitation data acquired from the local meteorological station were evaluated with the measured LAI values. The average of these meteorological data including the temperatures, air humidity and sunlight duration and the total precipitation along the intervals between the

photographing dates were subjected to statistical tests. For solely the first photographing date of February 28th, the average meteorological data and the total precipitation values of the previous week were incorporated. The Pearson correlations between the LAI, and the meteorological data were analyzed (Devore and Farnum, 1999) using SPSS 23.0 software (SPSS Inc., Chicago, IL). As a result of statistical analyses, assessment of significance of the differences among LAI and meteorological data was also achieved.

3. RESULTS AND DISCUSSION

Initially, at the budburst stage in the first half of March, the mean LAI was around 0.8 (Figure 3). However, Öztürk et al. (2015) determined the late March for the budburst of *Carpinus betulus* L. in another recreational site within the same region. The mean air temperature was about 7.7°C in that budburst stage when the minimum and maximum air temperatures were -2.6°C and 23.2°C respectively in our study area. Bonan (2008) mentioned about above 5°C in order to begin the budburst stage for the temperate deciduous trees. Meinen et al. (2009) declared the top 40 cm of the soil where *Carpinus betulus* L. trees particularly intensify. The mean temperature of soil at 50 cm depth was 10.2°C (Figure 3). As a matter of fact, the correlation between the mean LAI and the mean temperature of the soil at 50 cm was quite high (r=0.97) indicating also the high significance (P<0.01). Although the mean air temperature was similar with the recreational site of Öztürk et al. (2015) within those distinct budburst stages, the mean soil temperature of our site was higher particularly for the deeper soil. Meanwhile, the mean sunlight duration was only 3 hours whereas the total precipitation was abundant with almost 85 mm along for that budburst stage. Therefore, the mean air humidity was around 83%.

After flushing of the first leaves, the mean LAI climbed from 0.92 (day 78) up to 1.49 (day 95). The maximum LAI was at the first photographing point with 1.80 in the early April (Figure 3). On the contrary, there are approximately two more weeks for the leaf unfolding of *Carpinus betulus* L. trees in the central and western Europe as indicated by Asshoff (2006) and Vitasse et al. (2009) respectively. The minimum, mean and maximum air temperatures were -2.7°C, 9.4°C and 23.7°C respectively. The mean soil temperature at 50 cm depth was 11.8°C which declined about 1°C from the surface down to the -1 m deep (Figure 3). The mean sunlight duration in this flushing stage increased up to 6 hours. On the other hand, both the mean air humidity and total precipitation were lower compared to the previous budburst stage.

Sequentially, the leaves increased in size and numbers throughout the following month until reaching the stable period at the beginning of the May (day 125). The mean LAI ascended from 1.49 (day 95) up to 3.39 (day 125) when the maximum LAI was for the third photographing point with 3.61 (Figure 3). Although the closure of the *Carpinus betulus* L. trees in the study area of Öztürk et al. (2015) was higher than our recreational area, the ultimate mean LAI in our area was 0.8 more than their study area. The reason for such a situation could be the older age of trees and yet the absence of anthropogenic pressure within our recreational area. The mean air temperature increased up to 14.3°C whereas the minimum and maximum air temperatures were 1.7°C and 31.6°C respectively along that completion of the foliation (Figure 3). According to the studies of Le Dantec et al. (2000) and Campioli et al. (2011), the time for the maximum LAI of French forests including *Carpinus betulus* L. trees was at least two months later than our study area. For another species; *Fagus sylvatica* L. Bequet et al. (2011) identified the maximum LAI in the late June. Besides, the meteorological variables, altitude is also effective in such a delay for the foliation. The mean soil temperature at 50 cm depth was 15.9°C which reduced almost 4°C from the surface to the bottom during this foliation stage (Figure 3). The mean sunlight duration was constant at 6 hours while the mean air humidity slightly rose to 77%. The total precipitation reached its highest level with 101.3°C throughout the whole foliation period. For the higher altitudes (220 m asl.) in the close region, Öztürk (2015) defined the end of June when the maximum LAI occurred for the *Platanus orientalis* L. trees.

The stable period lasted 24 days until the end of the monitoring when the mean LAI was 3.41 (day 149). The minimum, mean and maximum air temperatures were 6.2°C, 16.2°C and 29.1°C respectively for the stable period (Figure 3). On the other hand, the mean soil temperature at 50 cm depth was 17.8°C which reduced almost 4°C from the surface down to the -1 m during this stable period (Figure 3). The mean

sunlight duration and the mean air humidity slightly increased to 7.3 hours and to 80% respectively. The total precipitation was relatively scarce with 26.5 mm compared to the previous foliation period. According to the results, the site allows recreation to the potential visitors particularly in the foliation and stable periods from the point of LAI. Canopy closure and gap size is effective in the LAI since it is about 55% in the recreational area. Otherwise the LAI would probably have exceeded 4.0. The six sampling points differentiated among themselves from the point of LAI based on their location oriented light regimes. In their recent study, Öztürk and Gökyer (2015) spoke about the significance of light transmission and canopy gaps in order to improve the recreational quality of roadsides.

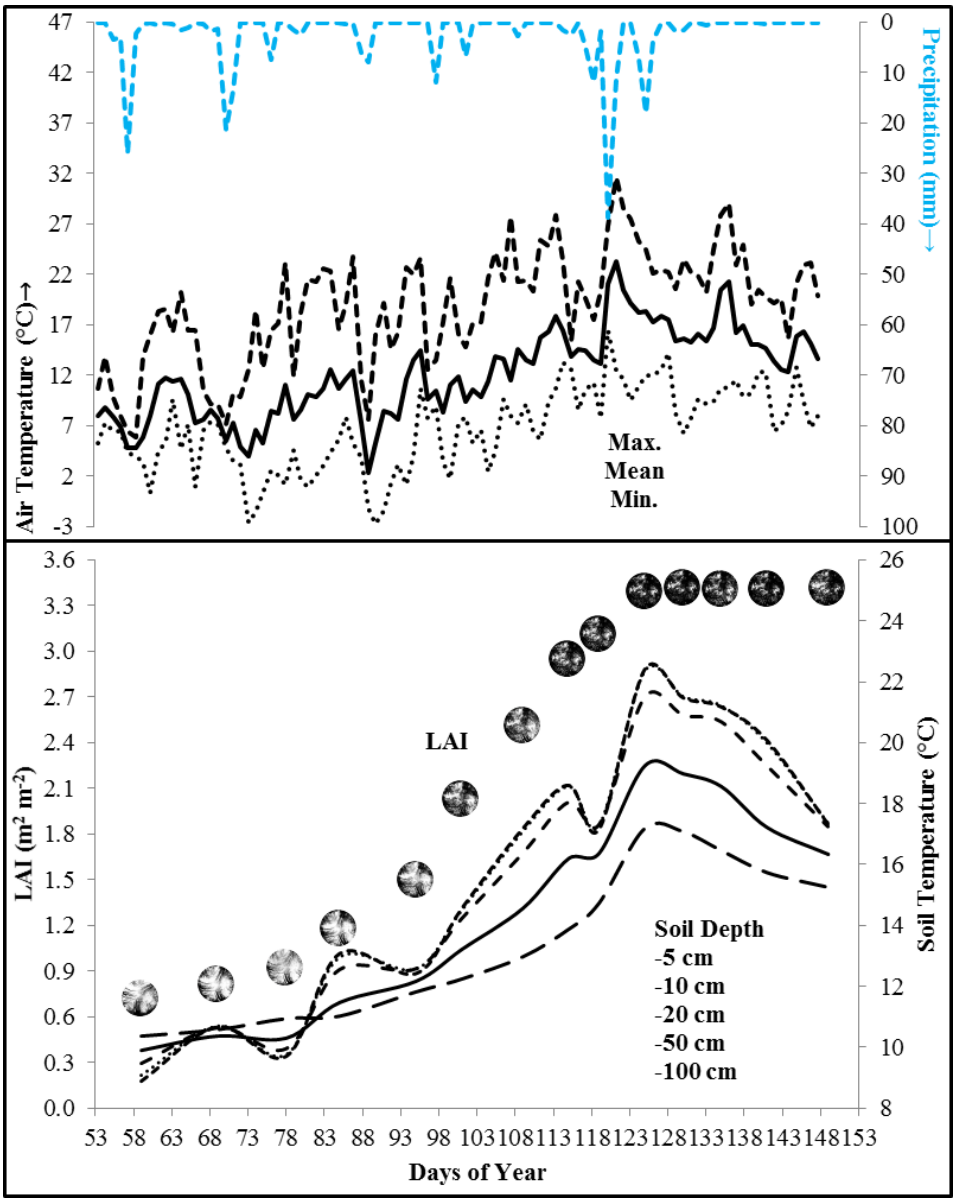

Figure 3. Daily maximum, mean and minimum air temperatures and precipitation (above), LAI and mean soil temperatures of different depths (below) along the monitoring period.
Şekil 3. Gözlem süresi boyunca, günlük maksimum, ortalama ve minimum hava sıcaklıkları (yukarıda) ile YAİ ve değişik derinliklere ait ortalama toprak sıcaklıkları (aşağıda).

4. CONCLUSION

The analytical parameters which can be used for determining the recreational quality and potential of a site are relatively restricted. The LAI is a sort of these parameters that implicitly indicate the recreational quality of a site. Higher the LAI, the more shade is supplied to the recreationists particularly during the foliated period of deciduous trees. Not only it serves as a sign of light interference of trees but also to some extent represents aesthetics and health of the recreational area. Canopy architecture of the deciduous trees is also relatively well symbolized with LAI. Particularly during the budburst and first flushing, tiny and fresh leaves reflect the blooms of the spring. In our study field, the maximum LAI value was quite high for a recreational site which may allow sufficient shade for the recreationists.

Environmental sustainability of the recreational areas covered with deciduous trees is significant, particularly for the ones within the vicinity of the urban periphery. Since there were a strong and significant correlations between the air-soil temperatures and the LAI, urban heat oriented possible climate warming may influence the health of these recreational areas. Furthermore, possible anthropogenic compaction of soil would be destructive for such a site covered with senescent trees. In other words, the regeneration would negatively be affected by growing human pressure. Consequently adverse environmental impacts of the recreationists should formerly be considered in order to achieve the sustainable recreational forest management objectives. Influence of urban sprawl towards the edges of the urban periphery must be delicately handled around the concept of urban forestry.

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