GROWTH GRADIENTS OF MULTI-AGED PURE ORIENTAL BEECH STANDS ALONG THE ALTITUDINAL GRADIENTS WITHIN A MESOSCALE WATERSHED LANDSCAPE

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Abstract. Leaf Area Index (LAI) is one of the rare parameters that intend to represent the level of growth and productivity to some extent. Particularly from the ecophysiological and habitat frames, *Fagus orientalis* Lipsky is relatively less discovered species compared to European beech.The most suitable altitudinal ranges within Bartın watershed where multi-aged oriental beech (*Fagus orientalis* Lipsky) stands (*mapobs*) exist, were aimed to be determined based on the LAI measurements. Investigating the trends of the temperature and precipitation were also purposed in order to account the climate dynamics in the region. Bartın watershed is located at the northwestern of Black Sea Region in Turkey. Three sample altitudinal transects covered with *mapobs* were divided into 50 m imaginary gradients from where three hemispherical photographs were taken. LAI was derived from these photographs using the image analysis technique. The increase in the annual average temperature and decrease in the summer precipitation together with the rising winter precipitation indicate summer droughts and silent climate change. More than 60% of all *mapobs* concentrated at the hillsides with moderate slope degrees (15°-30°) on the gradients between 400 and 800 m asl. where annual total precipitation and mean temperature were 1370 mm and 9.6°C respectively. The sample *mapobs* with mean LAI higher than 2.00 occur within a broad range of altitudes between 450 and 1150 m asl. The mean LAI was its minimum levels below 400 m asl. whereas it reached up to 2.71 at the 700-750 m asl. where could be defined as optimum growth gradient for *mapobs* of this watershed landscape. South facing hillsides were relatively less favored aspects for all *mapobs*. The significant vegetation parameter; LAI can readily be used as a precise indicator of forest growth and productivity. Possible consequences of climate change on the forest ecosystems should be evaluated at the landscape scale which allow comprehensive forest landscape planning.
Keywords: *Fagus orientalis Lipsky, Leaf Area Index, landscape ecology, hemispherical photography, climate change*

Introduction

Determining the growth and productivity of the forest trees is significant since these are signs for the ecological health of forest landscape. Although there are numerous factors that influence the growth and productivity of forest trees, the parameters which entirely are able to indicate this growth and productivity, are scarce. In this study, optimum growth gradients of multi-aged pure oriental beech (*Fagus orientalis* Lipsky) stands (*mapobs*) along the altitudinal gradients were analyzed and proposed using the LAI parameter. Initially, all age groups (young, mature and multi-aged) of pure oriental beech stands (*pobs*) were involved within the spatial investigation to conceive general pattern of their distribution in the watershed landscape. Then, the investigation focused merely on multi-aged pure oriental beech stands (*mapobs*) to determine their topographical attributes consisting of altitude, slope and aspect, and to assess LAI differentiation along the altitudinal gradients of transects on sample hillsides. Consequently, the ultimate objective of this research is to provide thoroughly comprehension about climate based landscape ecology of relatively less observed species of *Fagus*; *Fagus orientalis* Lipsky, compared to the European beech (*Fagus sylvatica* L.) which has ultimately reached northern and eastern Poland and the southern regions of Baltic states (Bolte et al., 2007).

Review of Literature

Oriental beech grows up to 50 m in height and has larger leaves with more ribs than European beech (Yaltırık, 1993). It extends from the eastern limits of European beech; Bulgaria throughout northwestern and northeastern Anatolia reaching far to Caucasia and Crimea (Saatçioğlu, 1976; Davis, 1982). It has 7-15 × 5-9 cm dimensioned leaves with 8-12 pairs of lateral veins (Tutin et al., 1993). Since it can tolerate warmer temperatures, it can grow at lower altitudes (down to 150-200 m asl. under mild climate of Marmara) than do European beech which climbs up to 2000 m asl. under relatively warmer climate of Southern Europe (Saatçoğlu, 1976). Oriental beech is sensitive to saline soil and elevated water table, and attains the optimum growth conditions at around 6-8˚C where -20˚C and 40˚C are the extremes (Atalay, 1992, 1998). Minimum and maximum annual precipitations are 600 and 2000 mm respectively at the regions where oriental beech is prevalent (Atalay, 1992, 1998).

Growth and productivity of forest trees are associated with physiological and environmental factors e.g. in majority, soil physical and chemical characteristics, availability of water and nutrients, meteorological conditions, and also involving ecological interactions such as mutual assistance among individual trees (Pretzsch, 2009; Forrester, 2014). Despite amplitude and variability of these influential factors, parameters that are indicators of total growth and productivity of trees are relatively restricted. Leaf area index (LAI) is the cumulative one-sided surface area of leaves over the projected crown area (Bonan, 2008), and is a key parameter indicating the plant productivity and growth (Landsberg and Sands, 2011). The efficiency of LAI as sign for growth and productivity of the canopy has been an interest of many researches (e.g. by Čermák et al., 2008; Bequet et al., 2012) at stand level and of others (e.g. by Asner et al., 2003; Luo et al., 2004) at landscape and global scales. Most of these studies concentrated on the altitudinal gradients in order to account for the spatial variability of this parameter. From the point of tree growth and productivity, and integrated ecosystems concept, not only the spatial variability of this LAI parameter itself but also critical environmental factors particularly the climatic limits should be considered (Waring and Running, 2007). Major climate components e.g. temperature and precipitation differ along the altitudinal gradients of temperate mountainous regions (Barry, 2008), where a further climate change would be responded by a subsequent shifting of temperate forest tree species among the transects of these gradients (Peterson et al., 2005).

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Materials

Watershed characteristics

Bartın Stream draining into Black Sea has a mesoscale watershed which covers 1943 km^2 (*Figure 1*). The watershed is located in between 41°17' and 41°45' northern latitudes, and between 32°13' and 32°60' eastern longitudes at the northwestern of Turkey (*Figure 1*). Altitude of the watershed ranges between 20 and 1735 m asl. where almost 2/3 of the land occupies the first gradients up to 600 m asl. About 71% of the remaining part is within the gradients between 600 and 900 m asl. The main stream is fed by three main tributaries; Gökırmak, Kocanaz and Arıt (Öztürk et al., 2013). Average slope of the watershed is about 15° and about 10% of the watershed is near flat with average slope of 5° mainly concentrated within the lowest altitudinal gradient. The relatively high slopes (30°+) cover only about 4% of the watershed. Aspect is almost evenly distributed to each of the four directions within watershed. On the other hand, hillsides facing the west, cover relatively the highest area with 26%. Except the lowest gradient, western facing hillsides are almost dominant up to 600 m asl. whereas northern facing hillsides dominate the higher gradients up to 1600 m asl. leaving the higher gradients (between 1600-1735 m asl.) again to the western facing hillsides. The watershed is associated with humid mesothermal climate regime (Atalay, 2011). Average annual total precipitation is 1046 mm whereas average annual temperature is 12.6°C (TSMS, 2013). Based on the duration, the dominant wind direction is from west-northwest and north-northeast where Black Sea is situated (*Figure 1*).

The geology of the watershed is largely formed by sandstone-mudstone structures which constitute about 70% of the surface area (TGDMRE, 2007). These structures have been situated almost throughout the watershed. Limestones occur secondarily in the watershed followed by the alluvion which particularly is located at the riparian zones of the stream channels. Gravels, igneous-sedimentary rocks, andesite and rhyodasite are respectively the other geological formations within the watershed. Brown forest soils together with grey-brown podzolic soils have mainly been created on the sandstone-mudstones and they cover almost 80% of the surface area (TMFAL, 2005). Red-yellow podzolic soils, alluvium and colluvium soils exist relatively rare. More than half of the watershed soils are shallow with depths which range between 20 and 50 cm. The alluvium and colluvium soils are generally deep; higher than 90 cm, whereas grey-brown podzolic soils are shallow. On the other hand, more than half of the brown forest soils are very shallow soils with depths which range between 0 and 20 cm.

Agricultural areas, occupying about 37% of the total area, occur particularly at the lower altitudes (TMFAL, 2005; TGDF, 2011). Namely, almost 45% of the agricultural areas are below 300 m asl. whereas about 81% are below 600 m asl. They almost disappear at altitudes higher than 1000 m asl. Rural settlements are scattered around the agricultural areas particularly within the gradients between 200 and 900 m asl. These rural settlements in the form of villages inhabit only about 2% of the watershed. Urban settlements which occupy the other 2%, dominate the lowest altitudes establishing the Bartın province there. Forest which totally covers 58% of the area is the major land use in the watershed (TGDF, 2011). However, 14% of the forests are handicapped. Coniferous stands are only about 11% of the forests. *Pinus nigra* (black pine) and *Abies bornmülleriana* (Bornmüllerian fir) are the major coniferous trees in the watershed. Pure *Pinus nigra* stands appear at relatively broad range of gradients primarily between 100 and 900 m asl. They also exist as mixed stands with deciduous trees i.e. *Carpinus*

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betulus L. (European hornbeam), *Quercus robur* L. (pedunculate oak) and *Quercus petraea* (sessile oak) at altitudes between 200 and 1000 m asl. Pure stands of *Abies bornmüllerina* intensify at relatively the high gradients between 600 and 1200 m asl. where they also establish mixed stands with *Pinus nigra*. They also constitute mixed stands with *Carpinus betulus* L. and, *Quercus robur* L. and *Quercus petraea* at around the same altitudes. Among the minor coniferous trees, *Pinus pinea* L. (stone pine) constitutes rare pure stands particularly at low altitudes (20-200 m asl.), *Pinus brutia* (Turkish Pine) and *Pinus sylvestris* L. (Scots pine) constitute pure stands at mid-altitudes (200-600 m asl.). Almost 2/3 of the forests are composed of deciduous trees. The *Carpinus betulus* L., *Quercus robur* L. and *Quercus petraea* also occur in the form of pure stands that are prevalent at the wide range of gradients from 20 m up to 1100 m asl. in the watershed. *Platanus orientalis* L. (oriental plane) generally dominates the riparian zones of the stream channels.

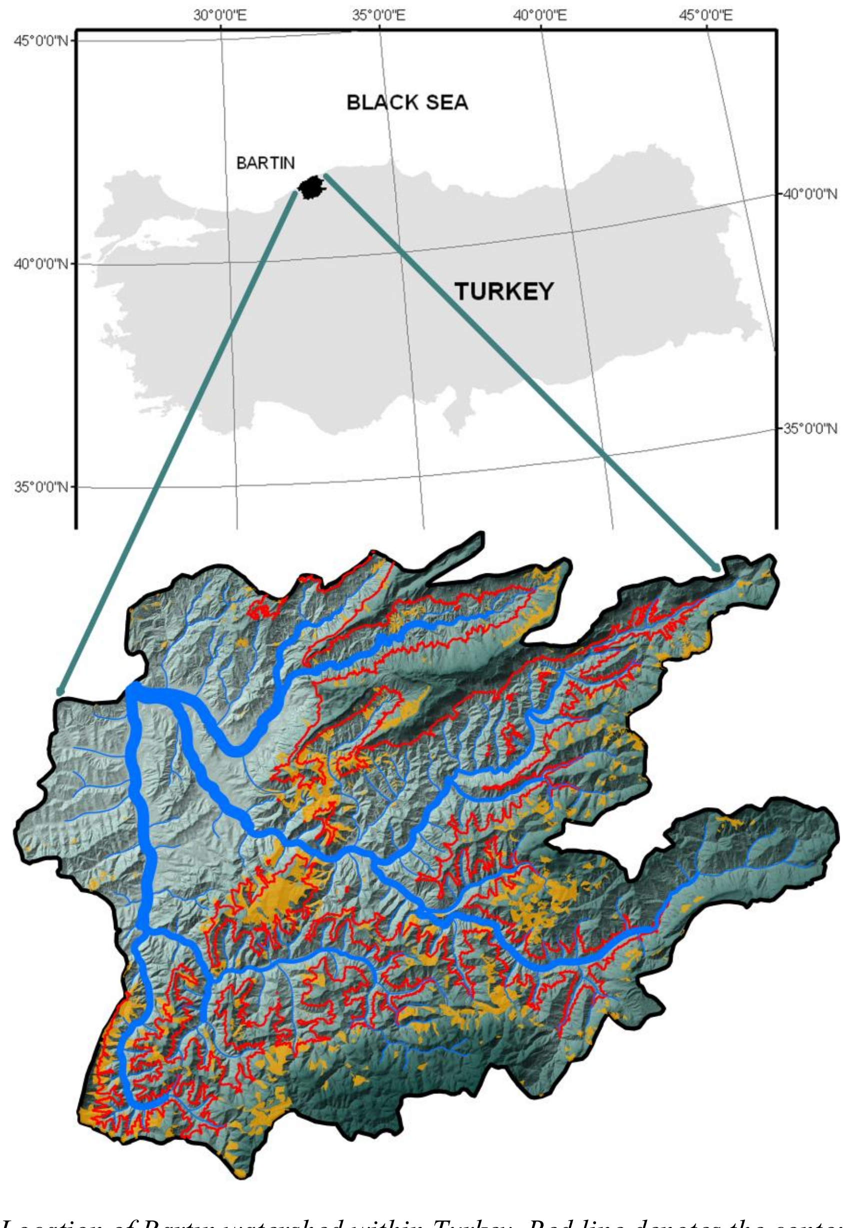

Figure 1. *Location of Bartın watershed within Turkey. Red line denotes the contour of 500 m asl. while orange patches are the pure oriental beech stands (pobs) in the watershed.*

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Characteristics of oriental beech stands and pobs

Fagus orientalis Lipsky is also one of the major deciduous trees which covers the highest portion of forests (~23%) in the watershed among all the other pure stands of tree species (TGDF, 2011). Their pure stands (*pobs*) concentrate between 200 and 1000 m asl., however they constitute mixed stands with *Abies bornmülleriana* particularly at the higher gradients between 700 and 1600 m asl. *Carpinus betulus* L., *Quercus robur* L. and *Quercus petraea* seldom accompany this mixture mainly at the gradients between 600 and 1200 m asl. The mixed stands of *Fagus orientalis* Lipsky, *Abies bornmüllerina* and *Pinus sylvestris* L. are generally met at the gradients between 1000 and 1400 m asl. where is close to the crests of the mountains in the watershed. The deciduous mixtures of *Fagus orientalis* Lipsky occur primarily with *Carpinus betulus* L., with *Quercus robur* L. and *Quercus petraea*, with *Castanea sativa* (sweet chestnut) and with *Tilia tomentosa* (silver linden) between 200 and 700 m asl.

Although *pobs* are widespread along the broad range of altitudinal gradients in the watershed, not all these stands are well-grown with a dense canopy closure. Relatively well-grown *pobs* with canopy closure of over 70% are only about 15% (164 km^2) of the forests and they involve young, mature and multi-aged stands (*Table 1*). More than 3/4 of these stands inhabit the gradients between 300 and 900 m asl. Despite they scarcely exist at the lower altitudes, they tend to perish at the higher altitudes (*Table 1*). The young well-grown *pobs* are in minority and cover 17 km^2 whereas the mature well-grown *pobs* are in majority and cover 77 km^2. On the other hand, multi-aged pure oriental beech stands (*mapobs*) cover 69 km^2 and therefore constitute about 42% of the *pobs* (*Table 2*). The distribution of *mapobs* along the altitudinal gradients is similar with the *pobs*.

Table 1. *Distribution of pure oriental beech stands (pobs-164 km^2) and multi-aged pure oriental beech stands (mapobs-69 km^2) within altitudinal gradients. The canopy closures of all these stands are higher than 70%.*

***pobs* in 163.85 km^2 (%)**	**altitudinal gradients (m asl.)**	***mapobs* in 62 km^2 (%)**
0.07	0-100	0.11
1.61	100-200	1.04
6.03	200-300	4.21
11.60	300-400	10.58
13.36	400-500	14.03
12.87	500-600	16.29
14.22	600-700	17.63
13.29	700-800	13.69
11.70	800-900	8.52
6.61	900-1000	3.85
4.46	1000-1100	4.86
2.90	1100-1200	3.32
1.05	1200-1300	1.62
0.23	1300-1400	0.25

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Table 2. *Based on age category, slope degree and aspect, distribution of multi-aged pure oriental beech stands (mapobs) within altitudinal gradients.*

mapobs	**ratio of slope degree ranges**				**altitudinal**		**ratio of aspects**			
	0-15°	**15-30°**	**30-45°**	**45+°**	**gradients (m asl.)**	**Flat**	**North**	**East**	**South**	**West**
YD	0.09%	0.19%	0.21%	0.00%	**100-200**	0.00%	0.19%	0.15%	0.00%	0.15%
YD	0.49%	2.14%	1.32%	0.02%	**200-300**	0.02%	1.08%	0.53%	0.44%	1.88%
YD	1.12%	7.04%	2.48%	0.10%	**300-400**	0.00%	2.83%	2.31%	1.66%	**3.94%**
YD	1.37%	**11.93%**	3.72%	0.11%	**400-500**	0.01%	**4.19%**	**5.04%**	**3.00%**	**4.90%**
YD	2.25%	**12.38%**	4.15%	0.08%	**500-600**	0.00%	**4.82%**	**7.01%**	**3.59%**	**3.43%**
YD	2.86%	**10.98%**	2.88%	0.04%	**600-700**	0.00%	**4.99%**	**5.19%**	**2.59%**	**3.98%**
YD	1.85%	5.81%	1.28%	0.01%	**700-800**	0.04%	2.60%	2.99%	0.86%	2.47%
YD	0.81%	3.38%	1.27%	0.04%	**800-900**	0.01%	1.47%	1.12%	0.66%	2.23%
YD	0.59%	1.56%	1.03%	0.02%	**900-1000**	0.00%	1.36%	0.24%	0.49%	1.11%
YD	2.31%	4.38%	1.37%	0.01%	**1000-1100**	0.02%	1.59%	1.21%	2.38%	2.86%
YD	1.49%	2.62%	0.35%	0.00%	**1100-1200**	0.02%	1.14%	0.48%	0.83%	2.00%
YD	0.26%	0.85%	0.31%	0.00%	**1200-1300**	0.00%	0.52%	0.43%	0.09%	0.38%
YD	0.14%	0.29%	0.02%	0.00%	**1300-1400**	0.00%	0.02%	0.41%	0.03%	0.00%
in total	**15.65%**	**63.55%**	**20.36%**	**0.44%**		**0.13%**	**26.80%**	**27.12%**	**16.63%**	**29.32%**
ED	0.13%	0.09%	0.03%	0.00%	**0-100**	0.00%	0.06%	0.16%	0.03%	0.01%
ED	0.54%	1.15%	0.37%	0.00%	**100-200**	0.01%	0.97%	0.67%	0.05%	0.36%
ED	1.18%	3.22%	1.45%	0.03%	**200-300**	0.12%	2.07%	1.63%	0.80%	1.27%
ED	1.70%	7.36%	2.88%	0.02%	**300-400**	0.01%	**4.19%**	2.50%	1.69%	**3.57**%
ED	1.48%	6.98%	2.54%	0.02%	**400-500**	0.01%	**3.65%**	2.49%	2.17%	2.68%
ED	1.95%	**8.33%**	2.81%	0.05%	**500-600**	0.00%	**5.52%**	2.58%	2.07%	2.97%
ED	2.97%	**12.24%**	3.09%	0.15%	**600-700**	0.04%	**7.07%**	**4.96**%	2.27%	**4.11**%

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ED	2.35%	**9.73%**	2.52%	0.11%	**700-800**	0.01%	**4.53**%	**4.02**%	**2.57**%	**3.59**%
ED	1.74%	7.09%	1.72%	0.07%	**800-900**	0.04%	2.03%	2.20%	**2.71**%	**3.63**%
ED	0.91%	2.68%	0.59%	0.05%	**900-1000**	0.00%	0.78%	0.43%	1.79%	1.24%
ED	0.76%	1.65%	0.45%	0.06%	**1000-1100**	0.03%	0.70%	0.21%	1.15%	0.83%
ED	0.73%	1.54%	0.42%	0.03%	**1100-1200**	0.04%	1.17%	0.29%	0.65%	0.57%
ED	0.98%	0.80%	0.18%	0.01%	**1200-1300**	0.00%	0.14%	0.10%	0.79%	0.94%
ED	0.06%	0.03%	0.00%	0.00%	**1300-1400**	0.00%	0.00%	0.02%	0.03%	0.04%
in total	**17.46%**	**62.89%**	**19.04%**	**0.61%**		**0.31%**	**32.88%**	**22.25%**	**18.76%**	**25.80%**
MD	0.46%	0.86%	0.28%	0.00%	**200-300**	0.03%	0.08%	0.65%	0.40%	0.45%
MD	1.21%	5.27%	1.40%	0.01%	**300-400**	0.01%	1.04%	**4.41%**	1.53%	0.92%
MD	1.67%	**10.19%**	3.13%	0.02%	**400-500**	0.01%	2.88%	**5.17%**	**4.06%**	2.90%
MD	2.05%	**12.96%**	3.28%	0.01%	**500-600**	0.04%	**3.92%**	**5.20%**	**4.58%**	**4.56%**
MD	3.17%	**11.88%**	2.28%	0.05%	**600-700**	0.00%	**3.66%**	3.83%	2.89%	**7.01%**
MD	5.86%	**11.30%**	1.37%	0.00%	**700-800**	0.23%	**7.16%**	3.41%	1.52%	**6.20%**
MD	2.75%	5.12%	1.19%	0.03%	**800-900**	0.07%	2.66%	2.57%	0.38%	3.40%
MD	0.51%	2.23%	1.29%	0.05%	**900-1000**	0.03%	1.93%	0.06%	0.02%	2.04%
MD	0.19%	2.79%	0.83%	0.01%	**1000-1100**	0.00%	1.27%	0.00%	0.04%	2.51%
MD	0.41%	1.79%	0.58%	0.00%	**1100-1200**	0.00%	0.46%	0.00%	0.03%	2.30%
MD	0.35%	0.75%	0.17%	0.00%	**1200-1300**	0.00%	0.30%	0.00%	0.04%	0.92%
MD	0.10%	0.15%	0.00%	0.00%	**1300-1400**	0.00%	0.11%	0.00%	0.00%	0.14%
in total	**18.73%**	**65.28%**	**15.80%**	**0.19%**		**0.42%**	**25.47%**	**25.29%**	**15.47%**	**33.34%**

YD: Young Trees Dominated; ED: Evenly Trees Distributed; MD: Mature Trees Dominated

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Methodology

Climate and Map Analysis

Vertical distribution of the precipitation and temperature within the watershed was based on the 31 years data (1982-2012) observed by the climate station at 30 m asl. (TSMS, 2013). In order to account for the altitudinal variability of the precipitation, annual total precipitation was assumed to heighten 54 mm for each 100 m gradient asl. (Barry, 2008). Furthermore, dependent upon the weighted averages of monthly precipitation within that annual total precipitation, additional 54 mm was allocated to each month. Lapse rate was assumed to be 0.5°C for each 100 m gradient asl. (Barry, 2008). Besides the annual data, precipitation and temperature in April and June were particularly examined (*Figure 2*) since the budburst occurs in the former whereas LAI achieves the maximum in the latter month (Öztürk, 2015; Öztürk et al., 2015).

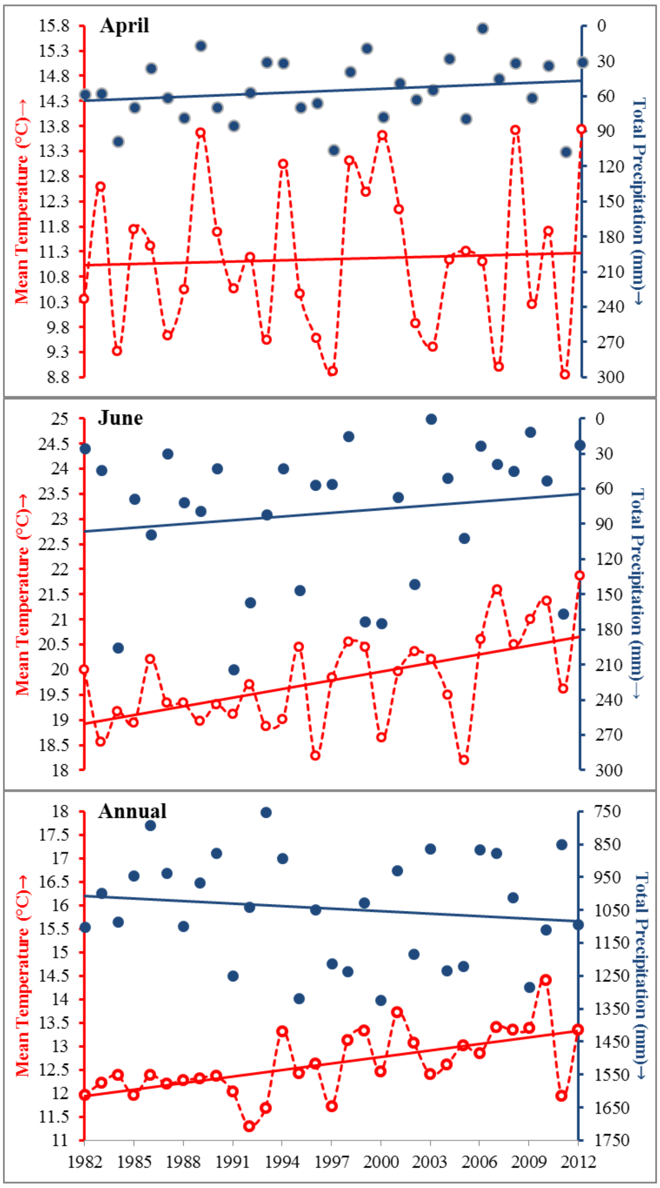

Figure 2. *April, June and annual mean temperature and total precipitation along the period between 1982 and 2012.*

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The model of Urban et al. (2000) suggested that the topographical attributes were effective on the distribution of forests in Sierran landscapes since they influence the water budget along the montane environmental gradients. The topographical analysis; particularly surveying the elevation, slope and aspect of the mountainous landscape were conducted using the Digital Elevation Models (DEM) data added to the Geographical Information Systems (GIS) through ArcGIS Software version 10. The watershed landscape was divided into 100 m altitudinal gradients which are totally 14. The slopes were ranged with 15° intervals; totally four of which the last one covers the hillsides higher than 45°. The aspects consist of the four main ones together with the flat areas. The existence portions of the *pobs* and *mapobs* within these altitudinal gradients, slope ranges and aspects were examined by the conjoint analysis agency of digital stand and topography maps.

Hemispherical Photographing

Hemispherical photographing technique which supplies strong estimates of LAI (Thimonier et al., 2010) was used to determine the LAI of the definite *mapobs*. In order to take the hemispherical photographs within these stands, Sigma 8 mm fisheye lens (Sigma F3.5 EX DG Circular Fisheye-Sigma Corporation, Japan) was mounted on a Canon EOS 5D digital SLR camera (Canon EOS 5D Mark II-Canon Corporation, Japan). Three altitudinal transects along the hillsides covered by *mapobs* of distinct age categories were divided into 50 m imaginary gradients. The photographing procedures were performed on June 12^{th} and 13^{th}, 2012. Mid-June was preferred for the hemispherical photography in order to avoid the impacts of shifting phenology among the altitudinal gradients where almost entirely maximum LAI was reached for the temperate deciduous trees within the same watershed landscape (Öztürk, 2015) and close coastal Black Sea Region (Gaydarova, 2003). Three hemispherical photographs were taken under three discrete canopy projections along the same gradients of three distinct *mapobs*. These projections relatively best symbolize canopy closure structure (>70% canopy closure) of that definite *mapobs*. From the first *mapobs*, 21 hemispherical photographs were taken along 7 altitudinal gradients between 300 m asl. and 650 m asl. Also, 9 photographs from 3 altitudinal gradients between 700 m asl. and 850 m asl. of the second *mapobs*, and 24 photographs from 8 altitudinal gradients between 850 m asl. and 1250 m asl. of the third *mapobs* were taken which ultimately amount 54 hemispherical photographs.

Hemispherical photographs were processed using the Hemisfer software 1.5.3 version (Swiss Federal Institute for Forest, Snow and Landscape Research; Schleppi et al., 2007) to analyze for LAI. During the analysis, automatic thresholding was based on the study of Nobis and Hunziker (2005), and Lang (1987) method was preferred for the determination of the LAI. Non-linearity and slope corrections were done according to Schleppi et al. (2007). For the clumping effect, the methodology of Chen and Cihlar (1995) was incorporated into the calculations to prevent the impact of stems and branches on LAI. Mean LAI of three discrete canopies was obtained to represent that altitudinal gradient concerned.

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Results

Precipitation and temperature (change) analysis

The precipitation and temperature data belong to the meteorological station situated at the lowest altitudinal gradient (30 m asl.) of the watershed. The monthly mean precipitation and temperature data of 2012 were compatible with the long-term (30 years between 1982 and 2011) monthly averages. According to the climatic analysis along the 31 years between 1982 and 2012, the wettest months were October and December each with the average total precipitation of 121 mm while the driest month was May with the average total precipitation of 49 mm. The long term averages of the spring months (March, April, May), summer months (June, July, August), autumn months (September, October, November) and winter months (December, January, February) were 180 mm, 225 mm, 329 mm and 312 mm respectively. The average annual total precipitation of the last eleven years (2002-2012) was only 12 mm (1.2%) higher than that of the first twenty years (1982-2001) manifesting relatively the regular annual precipitation regime. However, additional 41 mm (~14%) precipitation in winter and 43 mm deficient (~19%) precipitation in summer remarked shifting from relatively the year-round to unsteady precipitation conditions and alerted the possible summer droughts. The abundance of water was obvious for the March with approximately the extra 34 mm (65%) precipitation. The summer droughts were particularly pronounced for the June when the precipitation suffered about 33 mm critical decline (37%).

The hottest month was July with the mean temperature of 22.3°C while the coldest month was January with the mean temperature of 4.1°C. The long-term averages of the spring, summer, autumn and winter months were 11.2°C, 21.3°C, 13.4°C and 4.7°C respectively. The average annual temperature of the last eleven years (2002-2012) was approximately 0.7°C higher than that of the first twenty years (1982-2001) indicating the silent climate warming. The warming was more apparent for the summer months (+1.0°C, +1.2°C, +1.3°C for June, July, Aug. respectively) with approximately 1.2°C increase in average temperature. The warming was also valid for the succeeding autumn (+1.0°C, +1.0°C, +0.7°C for Sept., Oct., Nov. resp.) and winter months (+0.4°C, +0.3°C, +0.7°C for Dec., Jan., Feb. resp.) with almost 0.9°C and 0.5°C rising average temperatures. However, the increase was only 0.2°C for the spring months.

Overall mapobs

About 62% of all *mapobs* concentrated at the gradients between the 400 and 800 m asl. (*Table 2*) where annual total precipitation alternated between 1262 and 1478 mm, and annual mean temperature between 10.6 and 8.6°C respectively. The rest of the *mapobs* at the lower and higher gradients, constitute the remaining 16% and 22% respectively. The highest gradient where only about 0.25% of the *mapobs* exists is at 1300-1400 m asl. where annual total precipitation and mean temperature were 1775 mm and 5.9°C respectively. The *mapobs* consist of three age categories: young trees dominated (YD), almost evenly distributed (ED) and the mature trees dominated (MD) ones. They respectively cover about 34%, 42% and 24% of the total *mapobs* area. According to the conjoint analysis of the digital stand and topography maps, the YD of the *mapobs* occurs predominantly at the gradient of 500-600 m asl. with 18.9%, whereas ED and MD prevail at the

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gradients of 600-700 m asl. and 700-800 m asl., each with 18.5% respectively (*Table 2*). On the other hand, more than 60% of all the *mapobs* exist at the hillsides with moderate slope degrees between 15° and 30°. The MD of the *mapobs* are situated relatively rare at the higher slopes compared to the YD and ED ones. West is relatively the prevalent aspect for the hillsides where YD and MD of the *mapobs* are located whereas north is for the hillsides covered with ED ones. For all the *mapobs*, hillsides facing the south are relatively less preferred habitat so that less than 19% of *mapobs* only are at those hillsides.

Sample mapobs

The sample *mapobs* represent each of the three age categories e.g. YD, ED and MD. The mean height and DBH (Diameter at Breast Height- at 1.30 m) of all these *mapobs* were approximately 27 m and 30 cm respectively. The *mapobs* which spread from 300 m asl. up to 650 m asl. are ED ones and are located on the northeastern facing side of Kınataş Hill (*Figure 3*). To the upward of this transect, the mean LAI almost linearly ascended from 1.66 up to 2.47 with only an exception of 1.63 at the altitudinal gradient of 350-400 m a.s.l (*Figure 4*). The mean June precipitation of about 93 mm at the 300-350 m asl. gradient increased up to about 105 mm at the 600-650 m asl. gradient. Conversely, the mean June temperature dropped from 18.3°C down to 16.8°C. Along the altitudinal gradients from 700 m asl. up to 850 m asl., YD of the *mapobs* extends on the northwestern facing side of Oluklar Hill. Among the sample *mapobs*, the mean LAI reached its maximum with 2.71 at the altitudinal gradient of 700-750 m asl. Then, the mean LAI descended to 1.96 at the altitudinal gradient of 800-850 m asl. Inversely, the mean precipitation increased from 110 mm at the altitudinal gradient of 700-750 m asl. up to 114 mm at the altitudinal gradient of 800-850 m asl. However, the mean temperature declined from 16.3°C to 15.8°C. Additionally, MD of the *mapobs* also exists on the northwestern facing side of the Oluklar Hill. The mean LAI initially increased from 1.73 at the altitudinal gradient of 850-900 m asl. up to 2.19 at the altitudinal gradient of 950-1000 m asl. Besides, the mean precipitation of about 116 mm at the altitudinal gradient of 850-900 m asl. climbed to about 120 mm at the altitudinal gradient of 950-1000 m asl. On the contrary, the mean temperature diminished from 15.6°C to 15.1°C. Then, up to the altitudinal gradient of 1100-1150 m asl., the mean LAI fluctuated between 2.16 and 1.94. At the higher altitudes up to the gradient of 1200-1250 m asl. the mean LAI receded back to 1.81 where the mean precipitation and temperature were 130 mm and 13.8°C respectively (*Figure 4*).

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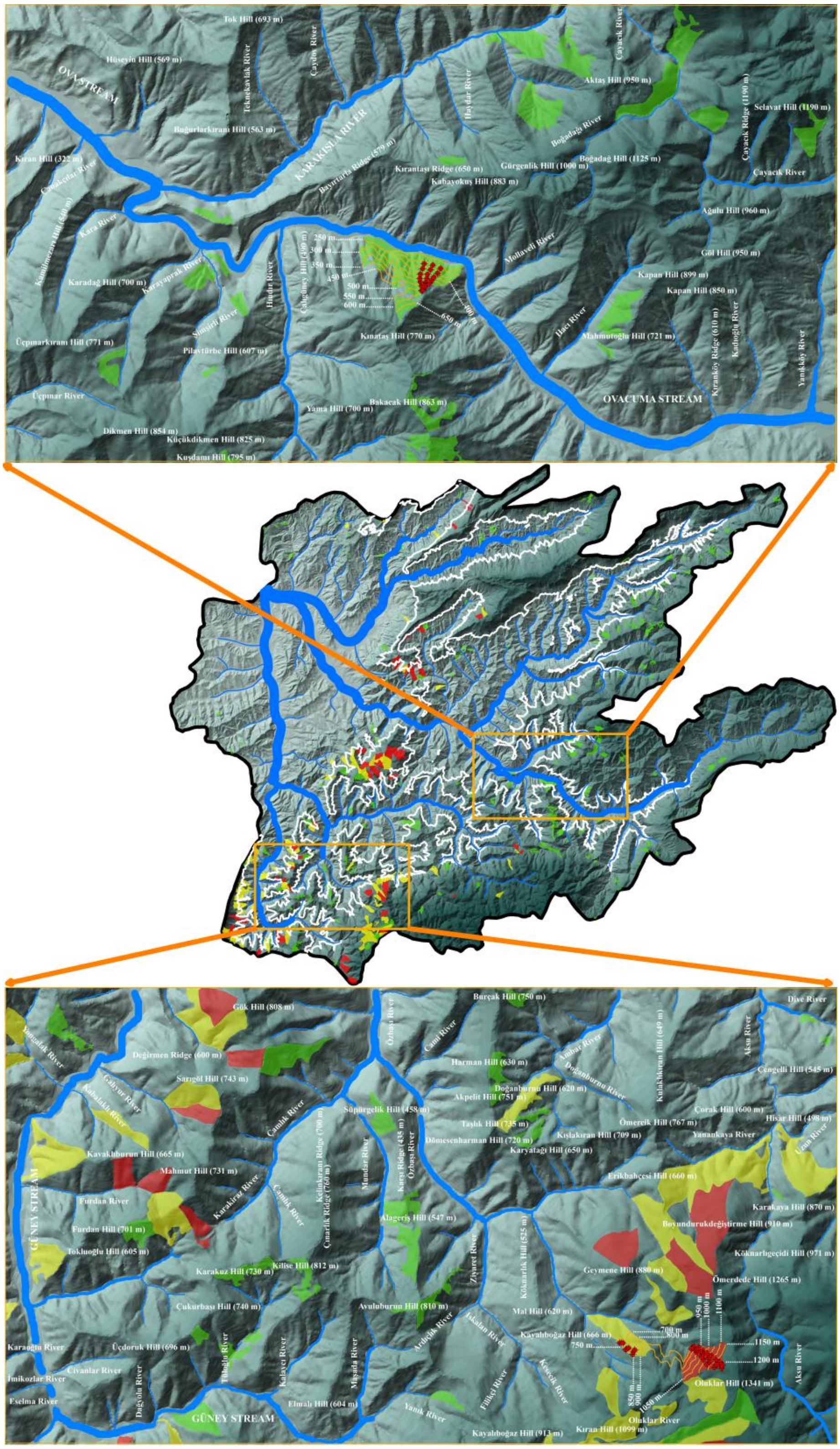

Figure 3. *Hemispherical photographing points of the sample mapobs along the gradients of altitudinal transects in the watershed. Yellow, green and red patches represent young trees dominated (YD), evenly distributed trees (ED) and mature trees dominated (MD) categories of mapobs respectively. White line in the watershed denotes the contour of 500 m asl.*

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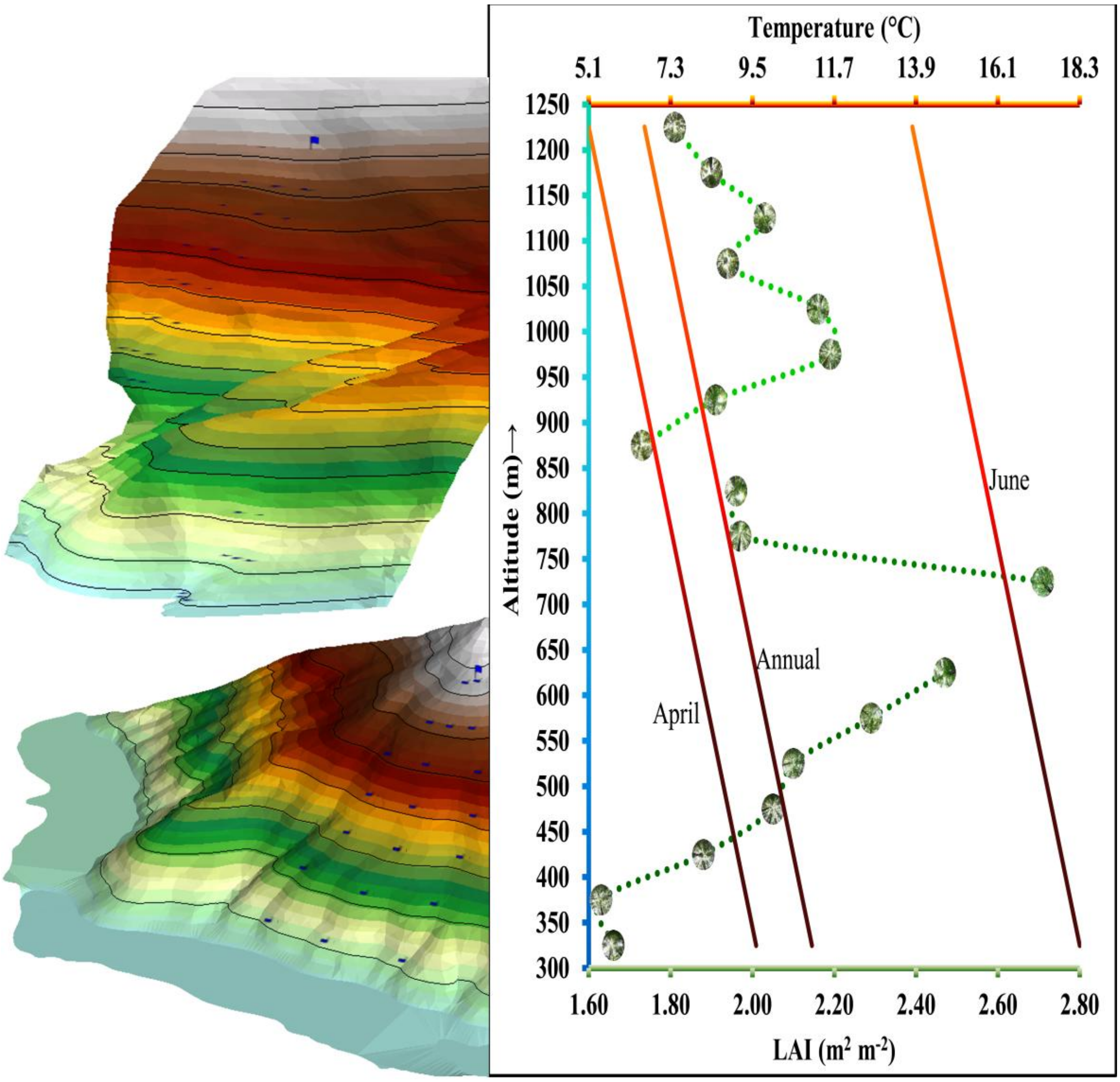

Figure 4. *Three dimensional model of sample altitudinal transects with the hemispherical photographing points along the gradients (left side). Variation of mean LAI values and temperature change along the corresponding altitudinal gradients (right side)*

Discussion

Climatic analysis and mapobs

The *mapobs* have been well suited at the altitudinal gradients between 400 and 800 m asl. in the watershed landscape (*Table 2*). The mean April, June and annual temperatures were 8.1°C, 16.8°C and 9.6°C respectively within these gradients. Fang and Lechowicz (2006) insisted on the growing season warmth had been the prevailing factor for the spatial distribution of beeches and referred to 7.1-10.4°C mean annual temperature particularly for *Fagus orientalis*. Remarkably they mentioned about 20.5°C and 16.1°C mean warmest month temperatures respectively for the lower and upper limits of *Fagus orientalis* which roughly corresponds to 350-400 m asl. and 1200-1250 m asl. gradients respectively in our watershed landscape. Namely, mean temperature of the warmest month; July was 20.5°C and 16.3°C respectively for the aforesaid altitudinal gradients. Utilizing the forest growth models, Mette et al. (2013) tried to project climatic turning point for the mixed stands of European beech and sessile oak for the altitudinal gradient of 300-400 m asl. Ultimately, they estimated 11-12°C for the mean annual temperature and over 18.0°C for the July temperature. Not only the summer temperatures but also the winter temperatures were effective in the growth of old *Fagus sylvatica* L. trees (Di Filippo et al., 2007). The monthly mean temperature dropped down below 0°C for the March at the altitudinal gradients above 1350 m asl. in addition to the winter months; December, January and February when altitudinal gradients above 1150 m, 850 m and 900 m asl. were respectively the critical limits in the watershed landscape. As a matter of fact, the *mapobs* almost already disappeared above 1200 m asl. On the other hand, the mean April, June and annual total precipitation were 73 mm, 105 mm and 1370 mm indicating relatively higher precipitation during the vegetation period. Although Dittmar et al. (2003) reported that in low altitude sites, particularly during the vegetation period, high precipitation had stimulated the growth of European beeches, the annual total precipitation was far beyond the lower and upper criteria; proposed as in order of 745 mm and 912 mm by Fang and Lechowicz (2006). Nevertheless, Mette et al. (2013) estimated critical annual precipitation of 500-530 mm for the mixed European beech and sessile oak forest.

Spatial and topographical distribution of mapobs and LAI

According to the forest landscape model of Elkin et al. (2012), altitude; particularly above 1500 m asl., played a significant reducing role on the growth of *Fagus sylvatica* L. such as on some other coniferous and deciduous species. In other words, altitude is a limiting factor for the plant growth which is associated particularly with the resource availability (Moser et al., 2007). In our study, LAI of *Fagus orientalis* Lipsky obviously changed based on the altitudinal gradients. However, there should be edaphic causes of this change beyond the slope and aspect factors. On the other hand, the literatures have not defined pronounced correlation between LAI and soil organic C and total N (e.g. by Rodeghiero and Cescatti, 2005; Öztürk and Bolat, 2014; Etzold et al., 2014). Öztürk and Bolat (2014) suggested that the decreasing LAI had not led to significant change in the soil organic C and total N. In a study for the Western Black Sea Region of Turkey, it was confirmed that the optimum growth gradient of *Fagus orientalis* Lipsky was around 1000 m asl. from the ecological and regeneration perspectives (Atalay, 1992). Here in this study, it was identified that the lower altitudes down to 700-750 m asl. could be the optimum growth gradient for the *mapobs* of the *Fagus orientalis* Lipsky in the Bartın watershed of Western Black Sea Region. Schleppi et al. (2011) reported that the maximum LAI had decreased by one third from 400 to 2000 m asl. at the Alpine regions of Switzerland. Similar with the LAI, Bresson et al. (2011) determined that the leaf size had diminished with the increasing altitude. Based on the study of Meier and Leuschner (2008), leaf size and LAI were harmonious for the *Fagus sylvatica* L. forest. Within the same watershed landscape, Öztürk et al. (2015) confirmed this relationship also for the *Carpinus betulus* L. trees remarking that the leaf expansion and LAI development were associated with the temperature particularly with the soil temperature. Besides, these two leaf parameters are directly and significantly correlated with each other (Öztürk et al., 2015). Luo et al. (2004) indicated that LAI was positively correlated with precipitation. Relatively cooler northern and western aspects of the hillsides were common for the majority of the *mapobs* (*Table 2*). In their study, Bresson et al. (2011)

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also indicated that the *Fagus sylvatica* L. was associated with north-facing slopes of Western Pyrenees in France.

Overall climate change analysis

Impact of climate warming on the forest ecosystems has scientifically been a growing concern (Theurillat and Guisan, 2001) and first signs of global warming were declared indicating a mean 0.6°C increment in 100 years (IPCC, 2002). Notedly, the annual mean temperature was projected to increase in the Black Sea Region with the increasing annual mean precipitation and decreasing summer precipitation (Lindner et al., 2010). Therefore, several modeling procedures were applied in order to determine the potential and suitable landscapes for the deciduous (Kramer, 2010) and coniferous trees (Horikawa et al., 2009) and shrubs (Dullinger et al., 2004) where those climate warming impacts could adequately be compensated. According to the climatic results of this study, particularly for the summer months, impact of climate warming via increased summer temperatures associated with droughts was apparent for the watershed. Jump et al. (2006) found that particularly at the lower limits of altitudes, the population growth of *Fagus sylvatica* L. toward southern range edge had significantly been obstructed by drought. Also, the excess precipitation prevailed the winter months compared to the past which also was declared by Önol et al. (2014) based on the climate simulations for Black Sea Region. According to Geßler et al. (2007), water-logged soils as well as summer droughts are potential risks for the *Fagus sylvatica* L. forests in the central Europe. One of the scenarios, proposed during an earlier study on climate change indicated an increase of July temperature of 1.5°C which was evaluated under the concept of “moderate climate change” (Kienast et al., 1996). The scenario led up to the 55% change in the potential natural vegetation type by 5-10% increasing the poorly adapted species. Almost the same increment in the July temperature was valid for our watershed which would threaten the species composition of the trees within particularly the natural forest stands.

Conclusions

Based on the LAI analysis, the optimum growth gradient for *mapobs* of *Fagus orientalis* Lipsky were determined as 700-750 m asl. along the altitudinal transects of this mesoscale watershed landscape. However, the *mapobs* with LAI higher than 2.00 that indicates comparatively well-grown trees, have spread relatively broad altitudinal range between 450-1150 m asl. This broad altitudinal range would to some extent allow *Fagus orientalis* Lipsky to compensate the possible ecophysiological and vegetation dynamics impacts of climate warming. Impact of possible climate change not only the force the reorganization of the mountainous forest ecosystems themselves but also threaten the sustainable management objectives in order to protect these ecosystems, as reported by Seidl et al. (2011) and Elkin et al. (2013). On this context, the measures against possible climate change should involve structural alteration of the forest stand composition. Pretzsch et al. (2013) proposed the establishment of mixed stands rather than encouraging pure stands to compensate the potential consequences of climate change on forest productivity.

Since the study area in the Western Black Sea Region has been managed and intervened by the concerned forestry administration, it would not likely lead to the natural reorganization of the *Fagus orientalis* Lipsky stands. Now that the issue does

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involve nature conservation concept and land use perspective (Milad et al., 2011), these possible consequences of climate change on the forest ecosystems should delicately be handled at the landscape scale and the proposals and policies should be introduced in order to achieve comprehensive forest landscape planning objectives. Climate change based future modelling procedures which consider ecological, silvicultural and management principles will assist further forestry practices under ecological planning context. Nevertheless the results of this study reveal significant indicators for the altitudinal growth gradients of *mapobs*, further repetitive measurements involving the same and different forest species within the watershed landscape would support the findings of this study. Furthermore, the results supported the significance of the vegetation parameter; LAI for usage as a precise indicator of forest growth.

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