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Original Article

Variation of tree diameters along road edges: the case of Karacabey linden forest in Bursa, Turkey

Yol kenarları boyunca ağaç çaplarının değişimi: Bursa Karacabey ıhlamur ormanı örneği

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ABSTRACT

Roads have important effects on forest ecosystems including degradation and fragmentation of habitats. However, light availability along the road edge increases which reflects the diversity and amount of plant species. This study is aimed to investigate the road edge effect on tree growing by measuring the differentiation of tree diameters along a sample road located within Linden stands. The study was conducted in Karacabey province of Bursa where Linden has the largest distribution in Turkey. Field data were collected from sample trees selected from 5-meter-wide stripes at road edge and from control zone away from road edge. The tree diameters at breast height (DBH) and trunk core samples were collected from sample trees located in the specified zones. Statistical analysis was conducted to indicate whether there is a differences in DBH and DBH growth values between trees at road edge and ones at control zone. The results indicated that increasing distance from road edge resulted in reduction in the average tree diameters as well as DBH growth values. There was a statistically significant difference between DBH values for trees at road edge and ones at control zone. On the other hand, there was no significant difference between DBH growth values.

Keywords: Diameter growth, linden, road edge effect, road network

ÖZ

Yol ağları, orman ekosistemleri üzerinde habitatların bozulması ve parçalanması gibi önemli etkilere sahiptir. Öte yandan, yol kenarı boyunca ışık mevcudiyetinde görülen artış, bitki türlerinin çeşitliliğine ve miktarını da yansımaktadır. Bu çalışmada, yol kenar etkisinin ağaçların büyümesi üzerindeki etkisini araştırmak amacıyla Ihlamur meşceresinde bulunan örnek bir yol ağı boyunca ağaç çaplarındaki değişim ölçülmüştür. Çalışma, Ihlamurun Türkiye'de en geniş yayılış gösterdiği Bursa'nın Karacabey ilçesinde gerçekleştirilmiştir. Arazi verileri yol kenarındaki 5 metre genişliğindeki şeritlerden seçilen ve yol kenarından uzakta kontrol bölgesinden seçilen örnek ağaçlardan toplanmıştır. Verilerin toplanması sırasında belirlenen bölgelerdeki tüm örnek ağaçların göğüs yüksekliği çapı ölçülmüş ve artım burgusu ile artım kalemleri alınmıştır. Daha sonra, yol kenarındaki ağaçlar ile kontrol bölgesinde yer alan ağaçlar arasında çap ve çap artımı değerlerinde bir farklılık olup olmadığını belirlemek için istatistiksel analiz yapılmıştır. Sonuçlara göre, yol kenarından olan mesafenin arttırılmasıyla, ortalama ağaç çaplarında ve çap artımı değerlerinde azalma görülmüştür. Yol kenarındaki ağaçlar ve kontrol bölgesinde yer alan ağaçlar arasında çap değerleri açısından istatistiksel olarak anlamlı bir fark bulunmuştur. Öte yandan, çap artım değerleri arasında anlamlı bir fark tespit edilmemiştir.

Anahtar Kelimeler: Çap artımı, ıhlamur, yol ağı, yol kenarı etkisi

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INTRODUCTION

Road networks located within the forested areas have important functions in terms of sustainable management of forest resources (Gümüş, 2015). If they are not planned considering ecological constraints roads potentially cause adverse effects on integrity and stability of natural habitats in forest ecosystems by forming edge effects (Eker and Çoban, 2010; Yilmaz et al., 2010; Gülci et al., 2017). There are differences in growth, survival, and reproduction in edge habitats and compared with interior habitat for both flora and fauna (Naghdi et al., 2017). Due to variation in temperature, mois-

ture, and light availability along the edge habitats, populations of species especially the ones requiring higher light conditions tends to increase in fragmented habitats (Picchio et al., 2018).

The effects of road edges on growth of trees vary depending on the various factors such as tree age, tree diameter, distance to road, and road width. Growth rate of large size adult trees are usually higher in forest edges than on forest interior comparing with growth rate of seedlings (Bembenek et al., 2013). Based on the previous studies, there is a positive relationship between annual growth rate and the average tree diameter (Naghdi et al., 2017). The distance from the road plays important role on the growth rate of trees. As the distance from road edges increases, the annual growth rate of trees reduces. Road width also effects the growth rate since the width of the road affect the amount of light availability along the road edge.

Even though there are international studies on the subject of road edge effects on tree growth, this subject has not been studied in Turkey. The main objective of this study was to find an answer to the question on the effect of road network on the variation of tree diameters along a sample road within the Linden stands. The study area was Karacabey province of Bursa where Linden has the largest distribution in Turkey. Linden flowers are one of the most valuable non-wood products that are mainly used in medical and cosmetic industries due to the active substances such as tannins, mucilage, sugar, oils, gum. Besides, boiled Linden flowers are commonly consumed as herbal tea in Turkey to prevent flu and cold, relief chest and bronchi, and relax nervous system (Tuttu et al., 2017). In the field applications, sample road sections were selected within Linden stands, and tree ring widths and DBHs of sample trees were measured from both the road edge and control zone away from road in the forest.

MATERIAL AND METHODS

Study Area

The study area was selected from Yeniköy Forest Enterprise Chief of M.Kemalpaşa Forest Enterprise Directorate (FED) located in the border of Bursa Forestry Regional Directorate (Figure 1). This area hosts one of the largest Linden forests in the world. Within the border of the city of Bursa, there are 700 hectares of Caucasian Linden (*Tilia rubra*) forests and 400 hectares of Silvery Linden (*Tilia tomentosa*) forests. Field data were collected along the sample road section located in the middle of Linden stands. The road was 3-km long with gravel surface and its average with was 4 meters.

Method

Field data were collected from two sample Linden trees selected from 5-meter-wide stripes at the road edge and from control zone which is about 50 meters away from the road edge. In both locations, data was collected from two diameter classes (small; 25-35 cm and large; 35-45 cm). Measurements were repeated for 6 sample road sections with 500 meters length along 3 km-long road section located in the middle of Linden stands (Figure 2). During the data collection, the diameter measurement at DBH and trunk core sample at DBH was collected from all the sample trees located in the specified zones (Figure 3). Tree cores were sanded with

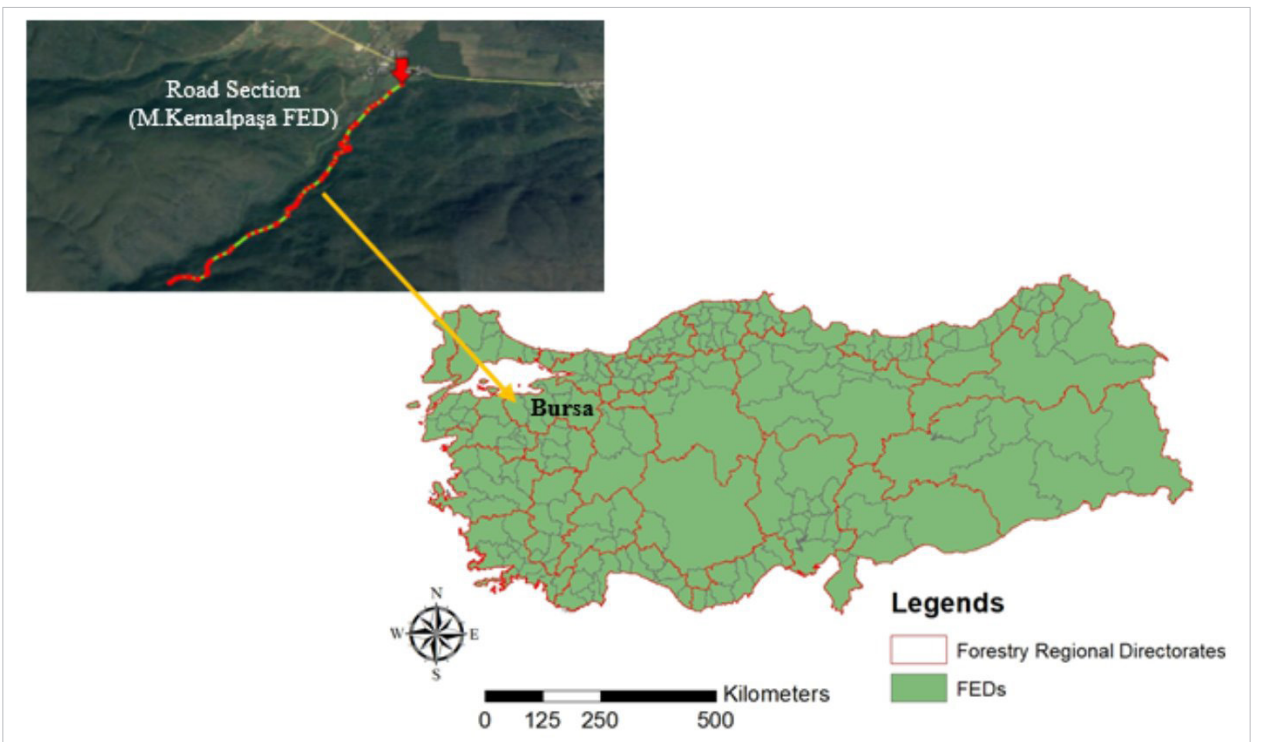

Figure 1. Study area

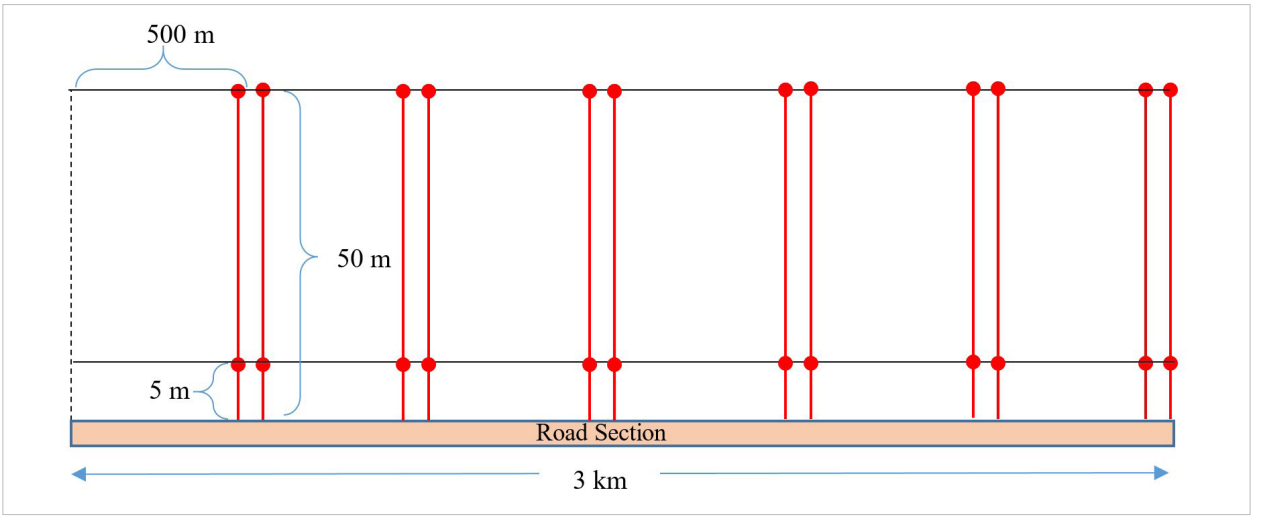

Figure 2. Field data collection pattern along the road section

Figure 3. Diameter measurement (left) and trunk core sample collection (right) in the field

fine sand paper in the open air till they were visible by a magnifying glass. Then, tree ring widths were measured and DBH growth values of sample trees were calculated for last 10 years.

One-way ANOVA analysis was used to assess the significance of observed differences in average DBH and DBH growth under different distances from the roads and two tree diameter classes. Turkey's test was used to compare the DBH and DBH growth value between two distance classes for two diameter classes. The significance level of $\alpha = 0.05$ was applied for statistical analysis using SPSS 16.0. (SPSS Inc., Quarry Bay, Hong Kong).

RESULTS AND DISCUSSION

The road edge effect on tree growing was investigated by measuring the differentiation of tree diameters along road network located within the Linden stands. The results showed that the average DBH of sample trees for the both dimeter classes were higher at the road edge area (Table 1). Thus, increasing the distance from the road, the average diameters tend to reduce (Stempski and Jablonski, 2014). The analysis of variance indicated that there was a statistically significant difference between DBH values in different tree diameter classes for both distance classes ($p<0.001$) (Table 2).

The road edge effect on DBH growth value was investigated by measuring the diameter growth of sample Linden trees at last 10 years for two diameter classes. It was that the average DBH growth of sample trees for the both dimeter classes were higher at the road edge area (Table 3). Therefore, increasing the distance from the road, the average DBH growth value was reduced (Naghdi et al., 2017). Figure 4 and 5 indicates the DBG growth values in two diam-

Table 1. Tree DBH values (cm) between two distance classes for two diameter classes

						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Min	Max
Road Edge (5 m)	Small DBH	12	31.67	2.43	0.70	30.13	33.21	26.00	34.00
	Large DBH	12	39.75	2.34	0.68	38.26	41.24	36.00	44.00
	Total	24	35.71	4.74	0.97	33.70	37.71	26.00	44.00
Control (50 m)	Small DBH	12	29.17	2.55	0.74	27.55	30.79	25.00	33.00
	Large DBH	12	38.83	2.21	0.64	37.43	40.24	36.00	43.00
	Total	24	34.00	5.46	1.15	31.70	36.31	25.00	43.00

DBH: diameters at breast height; Std: standard; Min: minimum; Max: maximum

Table 2. ANOVA analysis of DBH values in different distance classes

		Sum of Squares	df	Mean Square	F	Sig.
Road Edge (5 m)	Between Groups	392.04	1	392.04	69.05	0.00
	Within Groups	124.92	22	5.68		
	Total	516.96	23			
Control (50 m)	Between Groups	560.67	1	560.67	98.42	0.00
	Within Groups	125.33	22	5.70		
	Total	686.00	23			

DBH: diameters at breast height; Sig: significant

Table 3. DBH growth values (mm) between two distance classes for two diameter classes

						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Min	Max
Road Edge (5 m)	Small DBH	12	19.22	4.93	1.42	16.09	22.35	15.54	28.75
	Large DBH	12	18.72	4.16	1.20	16.07	21.36	14.75	29.69
	Total	24	18.97	4.47	0.91	17.08	20.86	14.75	29.69
Control (50 m)	Small DBH	12	17.11	4.73	1.37	14.10	20.11	12.41	26.90
	Large DBH	12	16.17	4.69	1.35	13.19	19.15	11.00	26.00
	Total	24	16.64	4.63	0.95	14.68	18.59	11.00	26.90

DBH: diameters at breast height; Std: standard; Min: minimum; Max: maximum

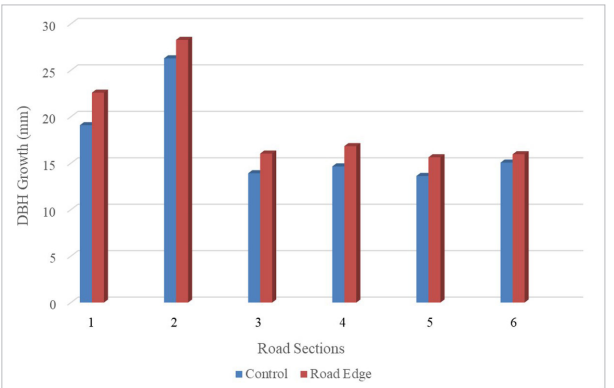

Figure 4. DBH growth values in small diameter class for two road distance classes

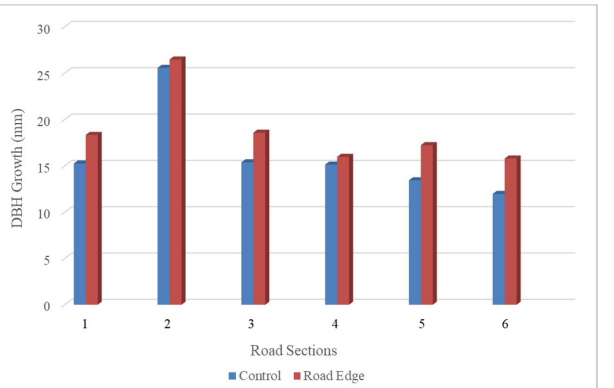

Figure 5. DBH growth values in large diameter class for two road distance classes

Table 4. ANOVA analysis of DBH growth values in different distance classes

		Sum of Squares	df	Mean Square	F	Sig.
Road Edge (5 m)	Between Groups	1.52	1	1.52	0.07	0.79
	Within Groups	457.98	22	20.82		
	Total	459.49	23			
Control (50 m)	Between Groups	5.29	1	5.29	0.24	0.63
	Within Groups	487.57	22	22.16		
	Total	492.87	23			

DBH: diameters at breast height; Sig: significant

Table 5. ANOVA analysis of DBH values in different diameter classes

		Sum of Squares	df	Mean Square	F	Sig.
Small DBH	Between Groups	37.50	1	37.50	6.05	0.02
	Within Groups	136.33	22	6.20		
	Total	173.83	23			
Large DBH	Between Groups	5.04	1	5.04	0.97	0.33
	Within Groups	113.92	22	5.18		
	Total	118.96	23			

DBH: diameters at breast height; Sig: significant

Table 6. ANOVA analysis of DBH values in different diameter classes

		Sum of Squares	df	Mean Square	F	Sig.
Small DBH	Between Groups	26.86	1	26.86	1.15	0.30
	Within Groups	513.22	22	23.33		
	Total	540.08	23			
Large DBH	Between Groups	40.72	1	40.72	2.05	0.17
	Within Groups	436.67	22	19.85		
	Total	477.39	23			

DBH: diameters at breast height; Sig: significant

eter classes for different road distance classes. The results indicated that DBH growth value was higher in small diameter class (25-35 cm). However, one-way ANOVA analysis showed that there was no statistically significant difference between DBH growth values in different tree diameter classes for both distance classes (Table 4).

One-way ANOVA analysis was also used to assess the significance of observed differences in average DBH and DBH growth under two tree diameter classes for different distances from the roads. It was found that there was a statistically significant difference between DBH values in different distance classes for small diameter class ($p<0.05$) while there was no significant difference between DBH values for large diameter class (Table 5). The results also indicated that there was no statistically significant difference between DBH growth values in different distance classes for both tree diameter classes (Table 6).

CONCLUSION

The road edge effect on tree growing was investigated by measuring the differentiation of tree diameters along road network located within the Linden stands. The results indicated that increasing the distance from the road edge causes reduction in the average tree diameters as well as DBH growth values. Thus, the distance from the road plays important role on the growth rate of trees due to mainly amount of light availability along the edge habitats. This finding revealed that tree volume loss due to removal of trees during road construction can be potentially restored through the volume increment of the trees along road network at long run. In this study, the effects of road edge on tree growth was investigated on Linden trees whose flowers are one of the most valuable nonwood products in Turkey. The findings of this study also revealed that the road edges can provide suitable habitats for nonwood spe-

cies. In order to estimate potential impacts of road edges on non-wood products further studies should be conducted on growth, survival, and density of different species along road edges.

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