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Effects of forest roads on *Ips sexdentatus* infestation in black pine forest

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ABSTRACT

Forest roads are important transportation equipment through forested areas in the rugged, mountainous terrain of northern Turkey. Forest roads harm forest ecosystems due to both the manner in which they are established and how they are used afterwards. Damage to trees that occur during road construction through forests stresses trees, which facilitates outbreaks of bark beetle populations. Bark beetles are significant risk to the health and productivity of Turkish pine forests and to pine forests worldwide. In particular, *Ips sexdentatus* (Boerner) (Coleoptera, Curculionidae, Scolytinae) is a particularly destructive species of bark beetle in Turkish forests. Their damage to coniferous trees threatens the sustainability of the forest ecosystems. This study primarily aims to assess the intensity of damage that *I. sexdentatus* inflicts on *Pinus nigra* J.F.Arnold stands relative to several parameters: the distance to the nearest forest road, aspect (shady - sunny), slope (0–15% or >15%), and other stand characteristics. In this study, we show how damage by an *I. sexdentatus* infestation in pure black pine stands varies with distance to forest roads and in situ edaphic factors. We sampled 45 plots (400 m^2 each), slope, aspect and distances to the nearest forest road was determined using ArcGIS software and the region's road network overlays. Results showed that trees located within 100 m from the nearest forest road were the most severely damaged ones. The intensity of *I. sexdentatus* damage was about 16% in a hectare. Trees that were in 16–20 cm diameter class were damaged more often. *I. sexdentatus* damage did not show any significant correlation with the slope, aspect or degree of canopy closure.

Türk Tarım – Gıda Bilim ve Teknoloji Dergisi, 6(7): 828-833, 2018

Orman yollarının Karaçam ormanlarındaki *Ips sexdentatus* zararı üzerine etkileri

MAKALE BİLGİSİ

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ÖZ

Türkiye'de genellikle dağlık ve engebeli arazilerde bulunan orman alanlarının işletmeye açılmasında en önemli transport tesisi orman yollarıdır. Orman yolları hem inşaası hem de kullanımı sırasında içinde bulundukları orman ekosistemine önemli zarar vermektedir. Orman ekosisteminde oluşabilecek deformasyonlar Dünya ormanlarında olduğu gibi ülkemiz ormanlarında da önemli risk faktörü olan kabuk böceklerinin zarar durumunu artıracak yönde etkilemektedir. Kabuk böcekleri türlerinden *Ips sexdentatus* (Boerner) (Coleoptera, Curculionidae, Scolytinae) konifer ormanlarında tehlike oluşturabilen ve ormanların sürekliliğini tehdit eden önemli türlerden biridir. Türkiye, Kastamonu İli Gölköy İşletme Şefliğinde yürütülen bu çalışmada Karaçam (*Pinus nigra* Arnold) meşcerelerinde etkin zarar yapan *I. sexdentatus*'un arız olduğu alanın en yakın orman yoluna olan mesafesine, bakı durumuna (gölgeli-güneşli) ve bazı meşcere özelliklerine (çağ-kapalılık) göre zarar etki durumunun değişip değişmediği değerlendirilmiştir. Bu amaçla, 400 m^2 büyüklüğündeki 45 örnek alanın ArcGIS yazılımı yardımı ile bakı durumları belirlenmiş, alana ait yol şebeke planı kullanılarak herbir örnek alanın merkezinin orman yollarına olan mesafeleri tespit edilmiştir. Buna göre, çalışma alanında orman yoluna 0-100 m mesafede bulunan ağaçların daha yüksek oranda böcek zararına uğradığı belirlenmiştir. *I. sexdentatus*'un hektardaki zararı oranı %16'dır. 16-20 cm çap kademesinde bulunan ağaçların daha fazla zarar gördüğü tespit edilmiştir. İki ayrı bakı (güneşli ve gölgeli), üç ayrı tepe kapalılığı (1-2-3) ve iki ayrı eğim grubu (%0-15, %15<)'na göre değerlendirme yapıldığında bu faktörlerin böcek zararı üzerine etkilerinin istatistiksel olarak anlamlı olmadığı görülmüştür.

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Introduction

Many biotic and abiotic factors affect the development of bark beetle (Coleoptera: Curculionidae, Scolytinae) populations and their distribution, which in turn affects host tree mortality (Faccoli, 2002; Akkuzu et al., 2009a). Stresses may trigger bark beetle infestations (Kanat, 2000: Forster et al., 2003), including stress caused climatic extremes, litter decomposition dynamics (Sarıyıldız et al. 2008), location (Akkuzu et al., 2009), avalanche, landslide, frost, lightning strikes and human alterations. Although bark beetle epidemics are one of many factor affecting mortality of trees (Fettig et al., 2007), variations in beetle populations play a vital role regulating ecological dynamics in forest ecosystems (Forster et al., 2003).

Extensive economic and ecological losses resulting from bark beetle damage are common in coniferous forests (Franceschi, 2005). Bark beetle infestations occur worldwide, but especially in northern hemisphere conifer forests, for example those in the USA (Bakke, 1989; Reeve, 1997; Lee et al., 2007; Christopher et al., 2012) and in Turkey (Ozcan et al., 2011a; Akkuzu and Guzel, 2015). The six-toothed pine bark beetle is one of the most destructive insect pest in European pine forests (Jactel and Gaillard, 1991) and causes significant economic losses (Sarıkaya et al., 2012).

Bark beetles reduce the growth rate of infested trees (Christopher et al., 2012) and widespread outbreaks lead to a general drying of infected forests due to the expansion of canopy openings (Pickett and White, 1985, Kanat, 2000). Therefore, beetle infestations are a significant risk factor in forests. The potential for outbreaks of bark beetle species in their native habitat should be taken into account when developing sustainable forest management plans (Black et al., 2010).

Forest roads constitute the most substantial anthropogenic impact to forests (Acar and Gumus, 2005). They provide access for timber removal and reforestation projects, silvicultural intervention, fire-fighting, pest and disease control, assessment of forest health (Gorcelioglu, 2004), and provide transportation and access to multiuse forest resource activities, such as recreation (Ryan et al., 2004, Cetin and Sevik, 2016a, b) on site and in time (Gorcelioglu, 2004).

Most forest roads in Turkey are single-lane roads that provide access to the forest interior, and most forest road networks are planned according to how forest resources will be used (Gumus, 2009; Ozturk 2009). However, hastily-executed logging operations often damage forests (Altunel et al., 2016), creating favorable conditions for insect infestations (Salek and Kerim, 2014). The impacts of roads on forest environments are both localized in spatial extent (with variety of biotic and abiotic factors at play) and spatially widespread (at the road network scale) (Daigle, 2010). Road construction in forests tends to be particularly damaging to forest ecosystems in steep terrain (Gorcelioglu, 2004). According to Spellerberg (1998), direct losses occur to habitat during road construction as well as impacts to microclimate conditions in near-road areas. Tree injuries caused by abiotic factors mentioned in forests are also in question (Hudler, 1984). Injuries to trees occur when material rolling during road construction, debris ejected from explosions to create road cuts, and drilling operations (Gumus et al., 2009). Injured trees are stressed, which reduces their nutrition, water and mineral uptake (Hartman, 2007), making them more sensitive to attacks by bark beetles than healthy trees (Ozcan et al., 2006, DeGomez and Celaya, 2013). Long-term stress of trees may provide ideal conditions for a rapid increase in beetle populations, which spread quickly to nearby, otherwise healthy trees (Power et al., 1999).

Methods for assessing the risk of beetle damage in forests would be useful for both helping reduce the risk of damage (by quantifying pre-epidemic conditions) and for measuring the efficacy of various pest control measures undertaken to prevent or reduce damage. Such protocols should take into account the degree of infestation on trees relative to specific stand features and distance to forest roads. The protocol should also be sensitive to societal values inherent to the forest roads, such as their use in forest management and their vital role in providing transportation among nearby villages. In this study, we show how damage by an *Ips sexdentatus* infestation in pure black pine stands varies with distance to forest roads and in situ edaphic factors

Materyal and Method

This study was carried out in black pine stands in the Golkoy Planning Unit (41˚ 42’58”–41˚ 52’40” N and 33°42’22’–33°36’03’’E), Kastamonu Province, in the northwest region of Turkey (Figure 1).

I. sexdentatus damage to black pine stands was noted in spring 2016 (March, April, and May). Forty-five sample plots (400 m^2 each) were randomly selected at various slope, aspects and elevations (Figure 2). Within these plots, 635 black pine trees were evaluated to determine extent of *I. sexdentatus* damage. Diameters of all surveyed trees were measured at the breast height (130 cm).

In each sample plot, ages of two trees were determined (total 90 trees all plots). The central coordinate of each sample plot was recorded using Global Position System (GPS) and the study area was mapped using the ArcGIS software. In addition, slope, aspect, elevation of the sample plots was mapped. Distances from the centers of the sample plots to the closest forest road were calculated from the maps.

Relationships between distance to the nearest forest road and the other factors (slope, aspect, stand characteristic) were interpreted using non-parametric, Chi-square tests with data grouped by damaged vs. healthy trees and by aspect and diameter class. The importance of differences between the beetle damage intensity to distance to road from plots center was tested using one-way variance analysis (One-way ANOVA), which was one of the parametric tests we used. ANOVA was allowed because our data was organized by minimum interval scale data and showed a normal distribution (Ozdamar 2004). Normality tested with Kolmogorov-Smirnov (K-S) showed that the data was distributed normally ($P>0.05$). Furthermore, correlation analysis was carried out to test the relationship between the number of trees in a sample plot vs. the number of trees with beetle damage. All statistical analyses were performed using SPSS® 20.0 for Windows® software.

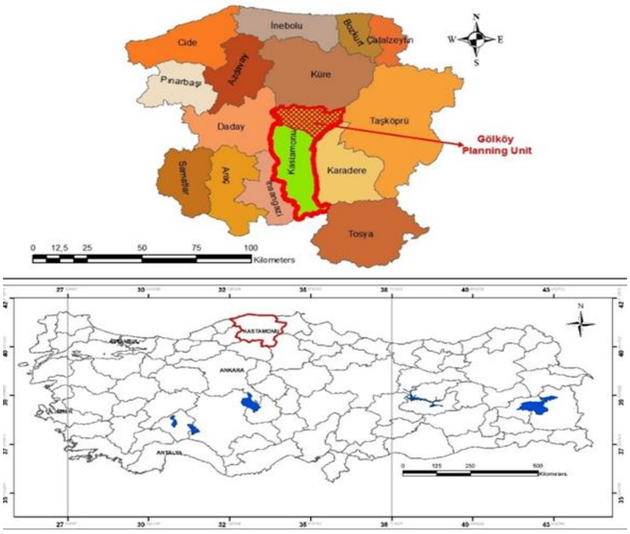

Figure 1 Location of study area

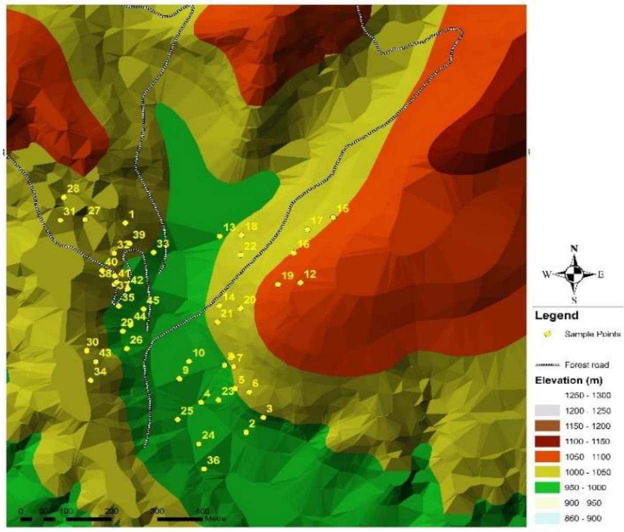

Figure 2 Sample points on digital terrain model in study area

Results and Discussion

Mean elevation of the study sites was 1000 m and mean tree age assessed in sample plots was 19 years old. We determined that *I. sexdentatus* damaged 16.1% (n =102) of 635 trees sampled in all plots (15.9% ha−1). The highest percent damage (54.8%) to trees was to the 16–20 cm diameter class. The distribution of trees damaged, by diameter class and aspect, is provided in Table 1. Trees in the 24–28 cm diameter class had the highest rate of damage (52.4%) (Figure 3).

The distribution of the number of damaged vs. healthy trees were significantly different in diameter classes ($P<0.05$), but not in aspect ($P>0.05$) (Table 1). That is, trees located on sunny aspects were damaged 2% more than the trees growing on shady aspects (Figure 4).

Crown closure was categorized into four categories (less than 10% (0), 11% to 40% (1), 41% to 70% (2), 71% to 100% (3)) and by two slope (0–15% and <15%). The map of sample plots by slope and degree of crown closure are shown in Figure 5. Pest-damaged trees and healthy trees did not differ significantly relative to slope or amount of crown closure ($X^2 >0.05$) (Table 2).

A positive and significant linear relationship was found (99% confidence level) between the total number of trees in each sample plot and the number of trees damaged by *I. sexdentatus* ($r =0.738$, $P=0.00$; $n =45$). An increase in the number of damaged trees with the density of trees caused the death of tree and the stands depending on the density of available *I. sexdentatus* in the stands. A similar correlation was shown by Ozcan et al. (2011b) for spruce forests damaged by *Ips typographus* (Coleoptera, Curculionidae). That study concluded that bark beetle damage negatively affected the sustainability of the forest.

The distance between the center points of a sample plot to the nearest forest road was assessed for the three categories of distance: 0–50 m, 50–100 m, >100 m. Distances between the center points of sample plots and the closest forest road varied between 1.2 and 248.6 meters, with 35.6% (n =16) of 45 sample plots within 50 m of a road, 31.1% (n =14) within 50–100 m, and 33.3% (n =15) located more than 100 m from the nearest road (Table 3).

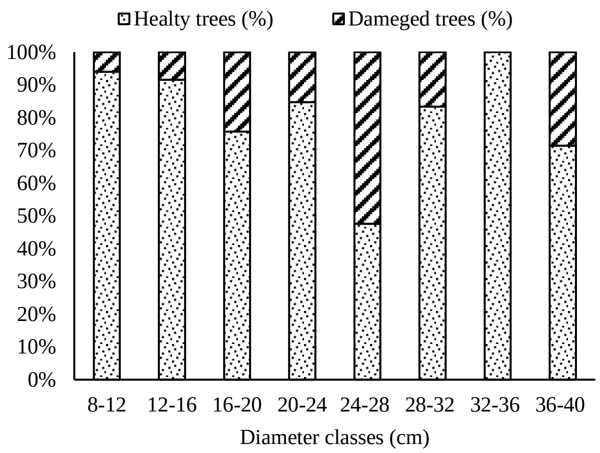

Figure 3 Distribution of healthy and damaged trees, by diameter class

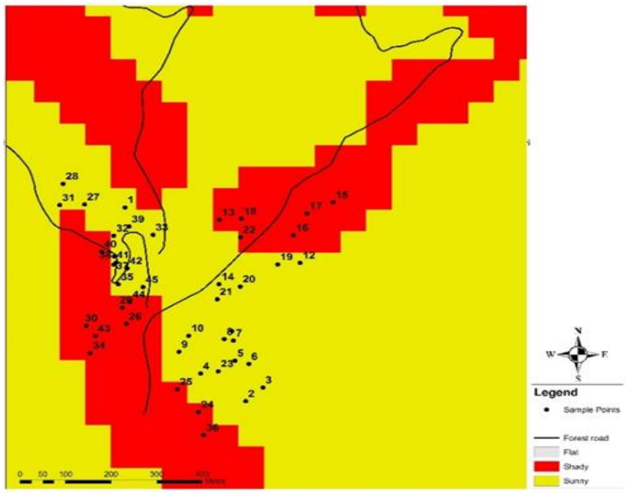

Figure 4 Distribution of sample areas according to aspect in the field of study

Table. 1 Diameter class of damaged trees, by aspect. Chi-square (X^2) values pertain to aspect.

Aspect			Diameter classes (cm)								X^2	*P
			8-12	12-16	16-20	20-24	24-28	28-32	32-36	36-40		
Shady	Healty trees	n	35	78	68	8	1	-	-	-	14.825	0.005
		%	18.4	41.1	35.8	4.2	0.5	-	-	-		
	Damaged trees	n	3	7	24	3	1	-	-	-		
		%	7.9	18.4	63.2	7.9	2.6	-	-	-		
Sunny	Healty trees	n	43	129	107	31	9	10	9	5	38.015	0.000
		%	12.5	37.6	31.2	9.1	2.6	2.9	2.6	1.5		
	Damaged trees	n	2	12	32	4	10	2	-	2		
		%	3.1	18.8	50	6.3	15.6	3.1	-	3.1		
Total	Healty trees	n	78	207	175	39	10	10	9	5	50.597	0.000
		%	14.6	38.8	32.8	7.3	1.9	1.9	1.8	0.9		
	Damaged trees	n	5	19	56	7	11	2	-	2		
		%	4.9	18.6	54.8	6.9	10.8	2	-	2		

Table 2 Chi-square(X^2) test results of damaged trees according to crown closure and slope

		Crown closure			*P	Slope		*P
		11-40%	41-70%	70-100%		0-15%	15-35%	
Healty trees	n	110	54	369	0.543	294	239	0.680
	%	20.6	10.1	69.2		55.2	44.8	
Damaged trees	n	20	7	75		54	48	
	%	15.4	11.5	16.9		52.8	45.2	

Table 3 Resulting Significant Difference Turkey (HSD) Test for the distance of sample plots to forest road

Distance of sample plots (m)	N	Mean±SE	F	P*
0 - 50	16	2.69±0.27[a]	5.32	0.09
50 - 100	14	2.50±0.33[a]		
100 over	15	1.60±0.13[b]		

* The difference between means is significant at the 0.05 level, [a,b] Letters refer to statistically-significant differences among groups (i.e., a and b are significantly different).

Distance categories to roads were 0-50 m, 50-100 m and more than 100 m (Figure 6). Differences between distance categories (to roads) were determined using one-way ANOVA Difference in mean number of trees damaged by bark beetles were not statistically significant between the 0–50 and 50–100 m distance categories (P>0.05), but for plots located more than 100 m away, the mean was significantly different from the stands closer to roads (P<0.05) (Table 3). This means that trees located within 100 m from forest roads suffered from beetle infestation to a greater degree than plots located further away.

Forest roads should be constructed in a way that is compatible with maintaining forest health (Ryan et al., 2004), while the negative impacts to health should be minimized (Brian, 2001). Keeping these aims in mind should help to minimize the damage done to forests during road construction and usage of roads afterwards. To effectively prevent bark beetle epidemics, it is important to take precautions that reduce injuries to trees during forestry activities (Gumus et al., 2009; Ozcan et al., 2015). The sensibility of host trees does not affect the attack density and frequency of bark beetle infestation in a stand (Power et al., 1999). In addition, the density of attack in free invasions in the stands of *I. sexdentatus* is directly proportional to the increase in the number of beetles (Jactel and Lieutier, 1987). Therefore, it is necessary to determine the factors that cause beetle populations to explode and how pest control can be best applied to sustain forest productivity and health.

Effective pest control requires observations / data on population densities of a pest species throughout its range, careful assessments of stand condition (Ozcan et al., 2011a; 2014), and application of methods to control factors that influence pest damage. Widespread infestations of bark beetles depend on a variety of factors (Ozcan et al., 2014) that should be used as part of an integrated pest management program, including biologic, cultural, mechanical and chemical techniques to the control pests. In this framework, a number of ecological factors should be assessed to understand the various aspects needed to plan beetle control studies (Schowalter, 2012).

This study revealed that the intensity of beetle damage in a forest stand is less prominent in stands located further away from forest roads and that damage is more intense following road construction (Gumus et al. 2009) (Table 3)

Conclusions

There are many factors that affect outbreak and damage condition of bark beetle. In the study, trees where bark beetle occur in areas having similar plantation conditions yet that doesn't have forest way are present with separately and with sparse space. It is observed that trees with the species occur in areas with forest way that are selected as the area of study can be found densely. Thus, it is thought that trees with scolytidae occur in the area of study happened because of deformation due to forest way construction. Moreover, the lack of tree deaths due to beetle damage in the area shows that the type has a population at endemic levels. At the same time, areas that are sensitive to beetle damage happen because of the side effect of forest ways in forest areas.

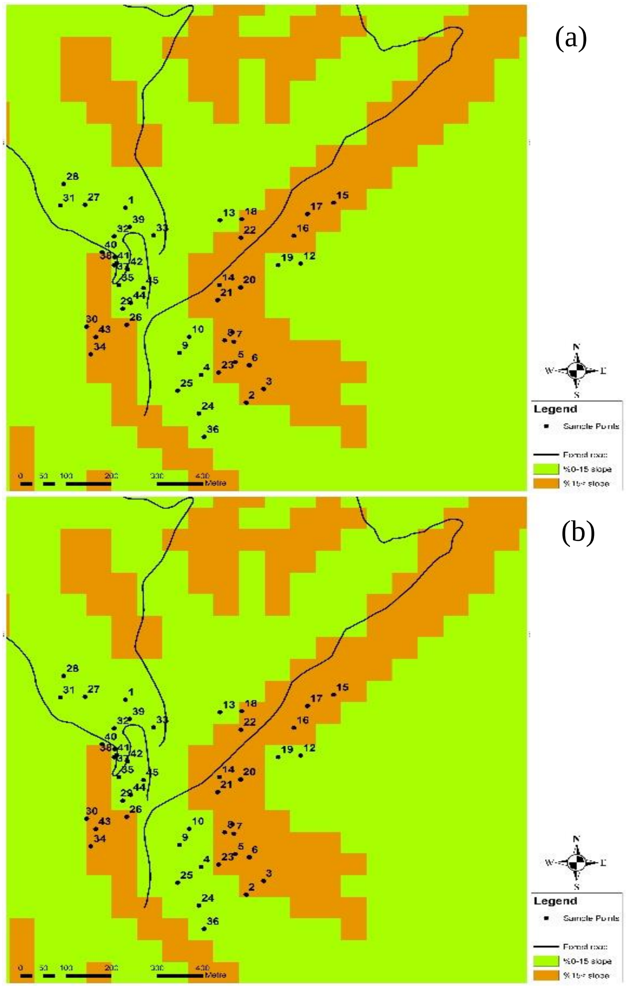

Figure 5 a-b. Slope (a) and crown closure (b) distribution of sample areas in the study area

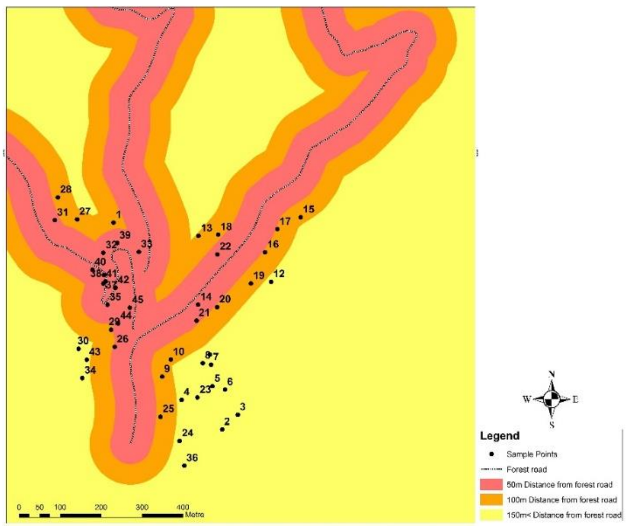

Figure 6 Location map of sample plots relative to the nearest forest road

In addition, we show that tree damage by bark beetles can be predicted from particular geomorphic factors in the landscape (aspect, slope, etc.). Therefore, ecological, economic and social factors should be jointly considered when planning forest roads networks in a way that will maintain the health and sustainability of natural forests.

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