African Journal of Agricultural Research Vol. 4 (5), pp. 468-473, May 2009
Available online at http://www.academicjournals.org/AJAR
ISSN 1991-637X © 2009 Academic Journals

Full Length Research Paper

Effects of forest roads on foliage discoloration of oriental spruce by *Ips typographus* (L.)

Erol Akkuzu[1]*, Habib Eroglu[2], Turan Sonmez[2], H. Ahmet Yolasigmaz[2] and Temel Sariyildiz[2]

[1]Faculty of Forestry, Kastamonu University, 37200, Kastamonu-Turkey.
[2]Faculty of Forestry, Artvin Çoruh University, 08000, Artvin-Turkey.

Accepted 7 May, 2009

The aim of the study was to investigate the effects of forest roads on foliage discoloration levels of oriental spruce *Picea orientalis* (L.) Link by *Ips typographus* (L.), considering location, ground slope and ground surface type of the spruce stands. The study was carried out over two years (2006-2007) in Artvin-Hatila National Park, Turkey. A total of 480 spruce trees from 12 stands were sampled. The results of the study were as follows: 1) locations of the trees (down-slope, up-slope, and forest interior plots) and ground surface types of the area (rocky and non-rocky grounds) significantly affected the foliage discoloration levels, 2) mean foliage discoloration level of trees were highest in the down-slope plots followed by up-slope and forest interior plots, 3) mean foliage discoloration level of trees grown up on the rocky stands were significantly greater than those on the non-rocky stands, and 4) mean stem volume of the trees with the foliage discoloration level 4 (death) were significantly greater than those with the other foliage discoloration levels (0, 1, 2, 3).

Key words: *Ips typographus*, *Picea orientalis*, forest roads, foliage discoloration, forest fragmentation.

INTRODUCTION

Timber harvesting and road construction on steep terrain have always proved to be a complex problem, involving economic and environmental requirements (Eroglu et al., 2007; Akay, 2006). Transporting logs on steep terrain requires the construction of a relatively dense network of forest roads consisting of skid roads, haul roads and landings (Kolka and Smidt, 2004). Forest roads are vital components for the human use of forested resources (Gucinski et al., 2000). Without roads, it is almost impossible to perform many forestry activities such as harvesting, regeneration, protection, and recreation (Gucinski et al., 2000; Akay et al., 2007).

Roads precipitate fragmentation by dissecting previously large patches into smaller ones, which leads to edge habitat in patches along both sides of the road, potentially at the expense of interior habitat (Reed et al., 1996). The fragmentation due to forest roads can cause microclimatic changes especially along the roadside stands. Trees located near the edge experience different environmental conditions than those located in the stand interior (Oliver and Larson, 1990; Palik and Murphy, 1990; Jose et al., 1996).

Forest roads are also the largest source of sediment in forest ecosystem (Kolka and Smidt, 2004; Akay et al., 2007; Ketcheson et al., 1999; Swift, 1988). Erosion and compaction of organic and nutrient rich surface soil decrease forest productivity (Kolka and Smidt, 2004; Pritchett and Fisher, 1987).

Adverse effects of forest roads on habitat quality for spruce stands influence the susceptibility of trees to biotic agents. The spruce bark beetle, *Ips typographus* L. (Col., Scolytidae), is one of the most destructive biotic agents of spruce (*Picea* spp.), mainly damaging on Norway spruce [*Picea abies* L. (Karst.)] in Europe and oriental spruce [*P. orientalis* (L.) Link] in Turkey. This pest of spruce is distributed throughout Eurasia and caused the loss of 31 millions cubic meters in western and central Europe between 1990 and 2001 (Gregoire and Evans, 2004; Piel et al., 2005). The occurrence of the spruce bark beetle in Turkey was first recorded in Artvin Province in 1984 (Alkan, 1985). Now, it has spread to all over the oriental spruce forests in Eastern Black Sea region of Turkey. The pest has 2-3 generations per year extending from April to September in Artvin. Specific objectives of this study were to determine the effects of forest roads, ground slope, and

*Corresponding author. E-mail: eakkuzu@gmail.com.
Tel.: 00-90-366 215 09 03. Fax: 00-90-366 215 23 16.

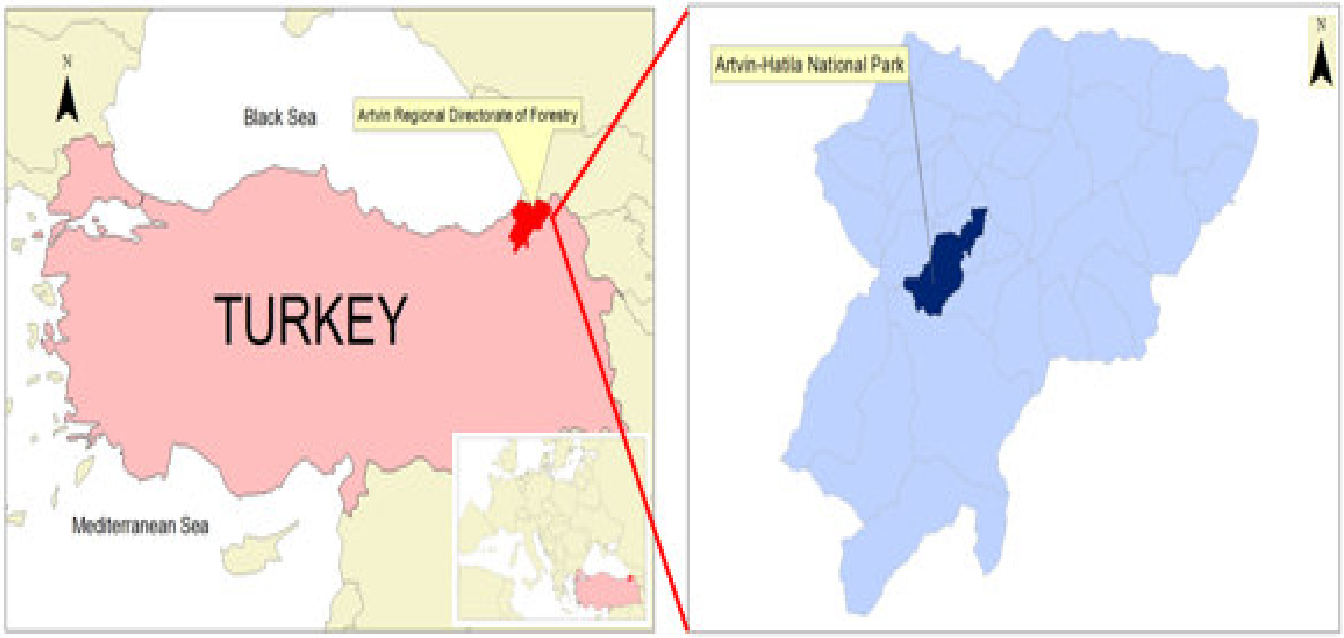

Figure 1. Location of the Artvin-Hatila National Park in Turkey.

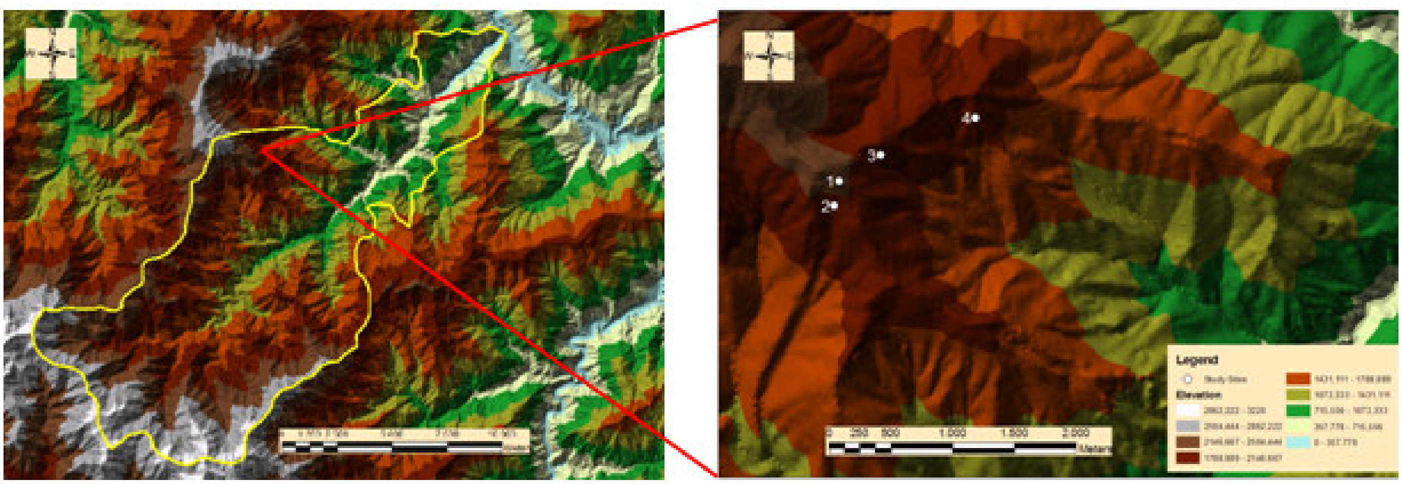

Figure 2. Locations of the measurement sites (1, 2, 3, 4) in Artvin-Hatila National Park.

ground surface type of the stands on foliage discoloration levels of oriental spruce by *I. typographus*, and to determine the effects of stem volumes on host tree preferences by *I. typographus*.

MATERIALS AND METHODS

Study area

The research was conducted between the year of 2006 and 2007 in natural spruce stands of Artvin-Hatila National Park, Turkey (41° 51' N, 41° 06' E) (Figure 1). The dominant tree species of the study area was 101-113 years old oriental spruce, and growing on the southern and southeastern slopes at altitudes ranging from 1900 to 2150 m a.s.l. (Figure 2).

A Garmin GPS receiver was used to record the elevations of the plots and site location coordinates on the study area. Digital maps of the study area were produced by using ArcGIS software (version 9.1) to show the topographic characteristics of the area (e.g. relief, elevation, aspect, slope, etc.) (Figure 2).

Climate is generally characterized by cold winters and semi-arid summers (1948–2000 meteorological data from Artvin Meteorology Station) (Sariyildiz et al., 2005). Average monthly temperature ranged from 32°C in August to -2.5 °C in January in the year 1948-2000. The mean annual precipitation in higher elevations reached over 1100 mm and the lowest temperature was recorded as - 6.1°C in January 2000 (Damar meteorology station at 1550 m) (Sariyildiz et al., 2005).

Sample sites and field methods

Three factors [ground slope (<60 and >60%), ground surface type (non-rocky and rocky ground), and location of the trees (down-slope,

Table 1. Primary features of the observed plots in Artvin-Hatila National Park, Turkey.

Slope (%)	Sites / Slope	Ground type	Location	Mean stand age (year)	Mixture
<60	1/55%	Non-rocky	Up-slope [a]	102	Spruce (95%), Others (fir, beech) (5%)
			Down-slope [b]	107	Spruce (90%), Others (fir, beech) (10%)
			Forest interior [c]	110	Spruce (95%), Others (fir, beech) (5%)
	2/51%	Rocky	Up-slope [a]	112	Spruce (95%), Others (fir, beech) (5%)
			Down-slope [b]	108	Spruce (100%)
			Forest interior [c]	105	Spruce (90%), Others (fir, beech) (10%)
>60	3/63%	Non-rocky	Up-slope [a]	101	Spruce (100%)
			Down-slope [b]	105	Spruce (90%), Others (fir, beech) (10%)
			Forest interior [c]	109	Spruce (100%)
	4/65%	Rocky	Up-slope [a]	104	Spruce (100%)
			Down-slope [b]	113	Spruce (95%), Others (fir, beech) (5%)
			Forest interior [c]	107	Spruce (95%), Others (fir, beech) (5%)

[a] Plots located in up-slope side of the road.
[b] Plots located in down-slope side of the road.
[c] Plots located in forest interior having no edge effect.

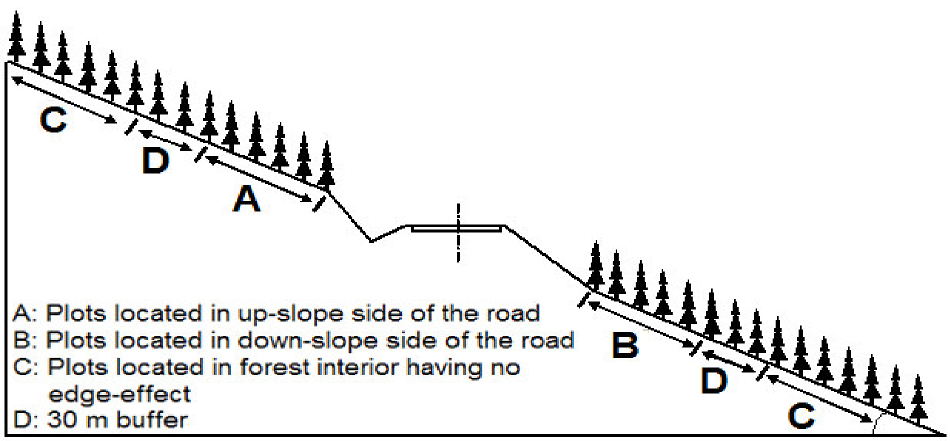

Figure 3. Cross section of a study site shoving up-slope, down-slope and forest interior plots.

up-slope, and forest interior)] were used to test the effects of forest roads on foliage discoloration levels of oriental spruce by *I. typographus.* For this purpose, 12 plots in 4 sites dominated by natural spruce trees were selected in the study area (Table 1 and Figure 3). The slope of the plots ranged from 51 to 65% in the study area (Table 1). The up-slope and down-slope plots extended from the forest road edge to 50 m into the forest. In order to avoid edge-effect, forest interior plot in a site was seperated by 30 m buffers from down-slope or up-slope plots (Figure 3).

A total of 480 trees (40 trees in each plot) were sampled to estimate the foliage discoloration levels in late spring and late autumn. Discolored tree crowns caused by other than *I. typographus* (e.g. fungus, mold, winter injuries, wounds, etc.) were excluded from the sampling process. The foliage discoloration levels of the trees sampled were estimated using the five European foliage discoloration categories [0. 0-10% (no discoloration), 1: >10-25% (slight discoloration), 2: >25-60% (moderate discoloration), 3: >60% (severe discoloration), 4: dead tree] (Anonymous, 2006). Diameters at breast height (1.3 m above ground level) and height of trees were measured in the field. The stem volume of each tree was then calculated using the double entry three volume table of oriantal spruce generated by Akalp (1978).

Statistical analysis

All statistical analyses were performed using SPSS® 15.0 for Windows® software. We analyzed the effects of specified factors (ground slope, ground surface types, locations of trees) on foliage discoloration levels of oriental spruce by *I. typographus* using three-way analysis of variance (ANOVA). Differences in volume between the foliage discoloration levels were tested by one-way analysis of variance (ANOVA). Multiple comparisons were made between factors using the *post-hoc* Least Significant Difference (LSD) Test and Least Significant Difference (LSD) Pairwise Comparison Test. Means were considered to be significantly different when $P \leq 0.05$.

RESULTS AND DISCUSSION

We examined whether locations, ground slope and ground surface types of the spruce stands had any significant effect on the foliage discoloration levels. The results from the three-way ANOVA showed that there was no effect of

Table 2. Three-way ANOVA on the effects of locations within the forest (down-slope, up-slope, forest interior), slope and ground types (rocky ground, non-rocky ground) on foliage discoloration levels of oriental spruce by *I. typographus.*

Source	df	ms	F	P-value
Location	2	74.265	32.778	0.001
Slope	1	0.075	0.033	0.856
Ground type	1	13.333	5.885	0.016
Location x ground type	2	0.452	0.200	0.819
Location x Slope	2	3.056	1.349	0.261
Ground type x slope	1	3.675	1.622	0.203
Location x ground type x slope	2	2.494	1.101	0.334

Table 3. Mean foliage discoloration levels of oriental spruce by *I. typographus* as related to locations of trees.

Location	Number of trees	Mean foliage discoloration level	95% confidence interval
Up-slope	160	1.544b	1.298-1.789
Down-slope	160	2.500a	2.271-2.729
Forest interior	160	1.181c	0.948-1.414

Different letters after the means indicate a significant difference between the means (Least Significant Difference (LSD) Test, $p \leq 0.05$)

Table 4. Mean foliage discoloration levels of spruce trees as related to ground type.

Ground type	Number of trees	Mean foliage discoloration level	95% confidence interval
Rocky	240	1.908a	1.717-2.099
Non-rocky	240	1.575b	1.384-1.766

Different letters after the means indicate a significant difference between the means (Least Significant Difference (LSD) Pairwise Comparison Test, $p \leq 0.05$).

ground slope on the foliage discoloration levels of spruce by *I. typographus* (df=1, f= 0.033, p=0.856) (Table 2). Akbulut (2005) reported that fir species (*Abies bornmülleriana* Mattf.) in the Western Black Sea Region which situated on greater slopes with higher drought risk are under the higher risk of insect damage. The results in the present study do not support these findings since spruce trees of both sites (slope angle of <60 and >60%) in the study area could not be under the water stress because of high annual precipitation (1100 mm).

Three-way ANOVA showed that, locations of the trees (df=2, f=32.778, p=0.001) and ground surface type of the stands (df=1, f=5.885, p=0.016) significantly affected the foliage discoloration levels of oriental spruce. There were no significant interactions between location and ground surface type, (df=2, f= 0.200, p=0.819), location and slope (df=2, f= 1.349, p=0.261), ground surface type and ground slope (df=1, f= 1.622, p=0.203), and location, ground surface type and ground slope (df=2, f= 1.101, p=0.334) (Table 2). The mean foliage discoloration level was highest in the down-slope plots followed by the up-slope and forest interior plots (Table 3). Wind and snow were responsible for broken and fallen spruce trees mostly along the forest roads in the study area. Forest fragmentations due to roads could increase the risk of windthrown events and water stress along the roadside spruce stands. Most often, mass infestations of living trees by the spruce bark beetle occur in stands suffering from the aftermath of heavy winds or from severe drought (Gugerli et al., 2008). Grodzki (2004) also indicated that the occurrence of broken or fallen trees contributed to an increased number of standing trees attacked by bark beetles.

Abiotic components of edge effects for forest habitats often include decreased soil moisture and humidity, increased soil temperatures, and increased penetration of light and wind (Chen et al., 1995; Turton and Freiburger, 1997; Gehlhausen et al., 2000). *I. typographus* usually attacks trees on forest edges and on borders of clearings (Jakuš et al., 2003). In special cases, the interior of the forest stand can be also attacked (Jakuš, 1998). Sunlit trees were preferably attacked, especially after abrupt increases in solar radiation levels (Jakuš, 1998; Lobinger and Skatulla, 1996; Wermelinger, 2004). Bark beetle development is directly affected by phloem temperature, which in turn is dependent on air temperature and direct solar radiation (Wermelinger, 1999).

Table 5. Mean stem volumes of trees as related to foliage discoloration levels.

Foliage discoloration level	Number of trees	Mean volume of trees (m^3)	95% confidence interval
0	154	1.061b	0.922-1.201
1	112	0.951b	0.814-1.088
2	41	0.899b	0.643-1.155
3	50	0.838b	0.597-1.080
4	123	2.115a	1.755-2.475
Total	480	1.267	1.149-1.388

Different letters after the means indicate a significant difference between the means (Least Significant Difference (LSD) Test, $p \leq 0.05$).

Table 4 shows that mean foliage discoloration level of spruce trees on the rocky stands was significantly higher than those on the non-rocky stands (df=1, f= 13.333, p=0.016). Morgan (2004) reported that plants on stony soils may be more susceptible to drought than those plants on stone free soils, regardless of their texture. Severe drought stress weakens the defense of trees against attacks of bark beetles and thereby increases the availability of host substrates (Dunn and Lorio, 1993). Lack of nutrition elements for trees on rocky stands could also increase the susceptibility of trees to bark beetle attacks.

Mean stem volumes of the trees with the foliage discoloration level 4 (death) were significantly greater than those with the other foliage discoloration levels (0, 1, 2, 3) (f= 19.524, p= 0.001, one-way ANOVA) (Table 5). For stem volume of a tree, greater volume means bigger in height and in diameter. In other words, the largest spruce trees in volume, height and diameter were the most susceptible ones in the study area. Zolubas (2003) concluded that attacked trees by *I. typographus* were larger in average height, diameter, and bark thickness than healthy trees.

The results indicated that foliage discoloration levels of oriental spruce by *I. typographus* were strongly correlated with location of trees in a stand (up-slope side, down-slope side or forest interior) and ground surface type of the area (rocky or non-rocky). It was also found that the spruce trees with larger in volume were more susceptible to *I. typographus* attack.

ACKNOWLEDGEMENTS

This study is funded by The Scientific and Technological Research Council of Turkey (TUBITAK) with the project number 106O054. The authors would like to thank Artvin Forestry Commission for permission to carry out the field studies in Artvin-Hatila Valley National Park, Turkey.

REFERENCES

Akalp T (1978). Türkiye'deki Doğu Ladini (*Picea orientalis* Lk.Carr.) Ormanlarında Hasılat Araştırmaları. İ. Ü. Orman Fakültesi Yayını, No. 2483/261, Istanbul.

Akay AE (2006). Minimizing total costs of forest roads with computer-aided design model. Academy Proceedings in Engineering Sciences (SADHANA) 31(5): 621–633.

Akay AE, Erdas O, Reis M, Yuksel A (2007). Estimating sediment yield from a forest road network by using a sediment prediction model and GIS techniques. Build. Environ. 43(5): 687-695.

Akbulut S (2005). Batı Karadeniz Göknar (*Abies bornmülleriana* Mattf.) Ormanlarında Farklı Ekolojik ve Silvikültürel Faktörlerin Böcek Populasyonu Üzerine Etkileri. Abant İzzet Baysal Üniversitesi Bilimsel Araştırma Projeleri Sonuç Raporu, Düzce.

Alkan S (1985). Şavşat İşletmesi Ormanları'nda *Dendroctonus micans* Kug. (dev soymuk böceği). Orman Mühendisliği Dergisi 22(1): 59-62.

Anonymous (2006). Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests, Part II: Visual assessment of crown condition. U.N. Economic Commission For Europe, Convention on Long-Range Transboundary Air Pollution.

Chen JQ, Franklin JF, Spies TA (1995). Growing season microclimatic gradients from clear-cut edges into old-growth douglas-fir forests. Ecol. Appl. 5: 74–86.

Dunn JP, Lorio PL (1993). Modified water regimes affect photosynthesis, xylem water potential, cambial growth, and resistance of juvenile *Pinus taeda* L. to *Dendroctonus frontalis* (Coleoptera: Scolytidae). Environ. Entomol. 22: 948-957.

Eroglu H, Acar HH, Ozkaya MS, Tilki F (2007). Using plastic chutes for extracting small logs and short pieces of wood from forests in Artvin, Turkey. Build. Environ. 42: 3461-3465.

Gehlhausen SM, Schwartz MW, Augspurger CK (2000). Vegetation and microclimatic edge effects in two mixed-mesophytic forest fragments. Plant Ecol. 147: 21-35.

Grégoire JC, Evans HF (2004). Damage and control of BAWBILT organisms - an overview. In: Lieutier F, Day KR, Langstrom B (eds) Bark and wood boring insects in living trees in Europe, a synthesis, Kluwer Academic Publishers, Netherlands pp.19-37.

Grodzki W (2004). Some reactions of *Ips typographus* (L.) (Col.: Scolytidae) to changing breeding conditions in a forest decline area in the Sudeten Mountains, Poland. J. Pest Sci. 77: 43-48.

Gucinski H, Furniss MJ, Ziemer RR, Brookes MH (2000). Forest Roads: A Synthesis of Scientific Information. United States Department of Agriculture Forest Service, USA.

Gugerli F, Gall R, Meier F, Wermelinger B (2008). Pronounced fluctuations of spruce bark beetle (Scolytinae: Ips typographus) populations do not invoke genetic differentiation. For. Ecol. Manag. 256: 405–409.

Jakuš R (1998). Types of bark beetle (Coleoptera: Scolytidae) infestation in spruce forest stands affected by air pollution, bark beetle outbreak and honey fungus (*Armillaria mellea*). Anz. für Schädlingskunde 71: 41-49.

Jakuš R, Schlyter F, Zhang QH, Blaženec M, Vaverčák R, Grodzki W, Brutovsky D, Lajzová E, Turčáni M, Bengtsson M, Blum Z, Gregoiré JC (2003). Overview of development of an anti-attractant based technology for spruce protection against *Ips typographus*: from past failures to future success. J. Pest Sci. 76: 89-99.

Jose S, Gillespie AR, George SJ, Kumar BH (1996). Vegetation responses along edge-interior gradients in high altitude tropical forest in Peninsular India. For. Ecol. Manag. 87: 51-62.
Ketcheson GL, Megahan WF, King JG (1999). ''R1-R4'' and ''BOISED'' sediment prediction model tests using forest roads in Granitics. J. Am. Water Resour. As. 35(1): 83–98.
Kolka RK, Smidt MF (2004). Effects of forest road amelioration techniques on soil bulk density, surface runoff, sediment transport, soil moisture and seedling growth. For. Ecol. Manag. 202: 313-323.
Lobinger G, Skatulla U (1996). Untersuchungen zum einfluss von sonnenlicht auf das schwärmverhalten von borkenkäfern. Anz. für Schädlingskunde 69: 183-185.
Morgan JW (2004). Drought-related dieback in four subalpine shrub species, Bogong High Plains, Victoria. Cunninghamia 8(3): 326-330.
Oliver ChD, Larson BC (1990). Forest Stand Dynamics. McGraw-Hill, New York.
Palik BJ, Murphy PG (1990). Disturbance versus edge effects in sugar-maple/beech forest fragments. For. Ecol. Manag. 32: 187-202.
Piel F, Gilbert M, Franklin A, Grégoire JC (2005). Occurrence of *Ips typographus* (Col., Scolytidae) along an urbanization gradient in Brussels, Belgium. Agric. For. Entomol. 7: 161–167.
Pritchett WL, Fisher RF (1987). Properties and Management of Forest Soils. Wiley, New York.
Reed RA, Johnson-Barnard J, Baker WA (1996). Contribution of roads to forest fragmentation in the rocky mountains. Conserv. Biol. 10: 1098-1106.
Sariyildiz T, Anderson JM, Kucuk M (2005). Effects of tree species and topography on soil chemistry, litter quality and decomposition in Northeast Turkey. Soil Biol. Biochem. 37: 1695–1706.
Swift LW (1988). Forest access roads: Design, maintenance and soil loss. In: Swank WT, Crossley DA (eds) Forest hydrology and ecology at Coweeta, Springer-Verlag pp: 313-324.
Turton SM, Freiburger HJ (1997). Edge and aspect effects on the microclimate of a small tropical forest remnant on the Atherton Tableland, North-Eastern Australia. In: Laurance WF, Bierregaard RO (eds) Tropical forest remnants. University of Chicago Press, Chicago. Pp. 45-54.
Wermelinger B (2004). Ecology and management of the spruce bark beetle *Ips typographus* – a review of recent research. For. Ecol. Manag. 202: 67-82.
Wermelinger B, Seifert M (1999). Temperature-dependent reproduction of the spruce bark beetle *Ips typographus*, and analysis of the potential population growth. Ecol. Entomol. 24: 103–110.
Zolubas P (2003). Spruce bark beetle (*Ips typographus* L.) risk based on individual tree parameters. In: Proceedings of the IUFRO international meeting on forest insect population dynamics and host influences, Kanazawa pp. 96-97.