JOURNAL OF FOREST SCIENCE, *57*, 2011 (10): 459–465

Effects of selection and shelterwood method on quality and quantity of trees along skid trails in beech (*Fagus orientalis*, Lipsky) forests

R. Naghdi[1], A.M. Jalali[2], K. Mohamadi[3], M. Akbarimehr[1]

[1]*Department of Forestry, Faculty of Natural Resources, University of Guilan, Somehsara, Iran*

[2]*Department of Forestry, Faculty of Natural Resources, University of Mazandaran, Babolsar, Iran*

[3]*Department of Forestry, Faculty of Natural Resources, University of Kurdistan, Sanandaj, Iran*

ABSTRACT: The effects of two silvicultural methods on quality and quantity of forest trees (along skid trails) were studied. The aim of this study was to compare the effects of shelterwood and selection methods on forest stand, and to compare the results with intact stand. Asalem forests were selected for this research. The belt transects of 10 × 100 m were used to collect the data. The plots were classified as those with low traffic, medium traffic, high traffic and control. The analysis of data showed that the degree of damage to forest stand, quality and quantity of trees on control plots was lower than along skid trails. In addition, there was a significant difference between high-quality trees in the two methods (P = 0.007). Furthermore, silvicultural methods showed significant differences in skewness and plummeting of low-quality trees (P = 0.014). In general, it can be concluded that trees in selection method were in better shape than those in shelterwood method related to quantity parameters. The results suggest that the damage caused by a silvicultural method can be reduced by using better methods and pre-harvest planning.

Keywords: skid trail; shelterwood method; selection system; beech forests; tree quality; tree quantity

The Caspian forest is located in the north of Iran; it covers northern slopes of the Alborz Mountains and is classified as a mountainous forest. The majority of these forests are managed as uneven aged and about 60% of them are used for timber production. Logging operations always lead to severe disturbing effects on forest ecosystems. Disturbance of soil surface, changes in chemical and physical properties of soil and damage to natural regeneration and tree stand are the main effects of logging operations and wood extraction on soil and forest stand (Naghdi et al. 2009). Heavy machinery traffic on skid trails affects soil, regeneration, and residual trees which can also affect the growth of forest stand. Since the skid trail covers about 30% of felling gaps, machinery traffic causes disturbance of soil and stand (Murphy 2004). Compaction, rutting, soil displacement, clogging of drainage system and removal of forest floor mass on skid trails are major disturbing effects of logging machinery (Rab 2004; Ampoorter et al. 2007; Makineci et al. 2007; Naghdi et al. 2009). Soil compaction and removal of forest floor mass can limit the growth of tree roots along skid trails. Neither are there any oxygen, nutrients and water in soil that are necessary for trees; these are other disturbing effects of logging machinery (Hager, Sieghardt 1992; Davies et al. 1992). The results of this change can affect tree height, diameter growth, canopy condition and other quantity and quality aspects of trees and regeneration along the skid trails; so forest fertility decreases in the long run (Rab 1994; Kozlowski 1999; Makineci et al. 2008). Also, tree stem and crown collisions during logging operations can affect height, diameter growth and canopy quality (Lamson et al. 1985; Han, Kellogg 2000). Anderson et al. (1994) showed that the root biomass on landing and skid trail was significantly different

Table 1. General properties of the study area and collected samples

Compartment No.	Number·ha^{-1}	Volume·ha^{-1} (m^3)	Proportion of *F. orientalis* (%)	Area (ha)	Mean height (m)	Mean diameter (cm)	Mean crown coverage (%)
23	197	164	76.58	37	21.76	46.53	85
35	305	181	41.79	39	22.69	48.07	80

from the control area after 25 years. They also reported a decrease in height and diameter growth of Eucalyptus seedlings in comparison with the control area. Studies on structural and compositional aspects of forests and the effects of exploitation, fire, clear cutting and other human activities on the dynamic characteristics were focused rather on tropical forests (Richars 1952; Brunig 1970; Holdridge et al. 1971; Whitmore 1984; Thang 1987; Favrichon 1998; Okuda et al. 2003). To ensure sustainable forest management, more precise studies are needed to clarify the effects of logging on stand structure, floristic composition, and species diversity, including that of non-timber species (Shugart, West 1981; Favrichon 1998). In addition, canopy structure and features of the forest after logging provide a good indicator for predicting the ecological soundness of logging (Clark et al. 1996). However, the stand structure and the species composition of major tree families in logged forests differed distinctly from those observed in the primary forest (Okuda et al. 2003). Such differences have also been reported in the African, South American, and Central American tropical regions (Crow 1980; Chapman, Chapman 1997; Webb 1997; Withman et al. 1997; Panfil, Gullison 1998; Finegan, Camacho 1999).

This study attempts to assess the effects of different operating systems (shelterwood cutting and selection system) on the quality and quantity of single tree growth. The aim of this study was to determine some tree features such as characteristics of tree crown, diameter, height etc. along skid trails in a ground skidding system after 20 years in shelterwood method and after 10 years in selection method.

MATERIAL AND METHODS

The study was carried out in two beech (*F. orientalis*) stands in the north of Iran (Guilan province). The area is located between 48°44'36" and 48°49'58" of longitude, and between 37°37'23" and 37°42'31" of latitude. The elevation ranges between 300 and 2,100 m a.s.l. The study area has a humid climate. It is dominated by beech (*F. orientalis*), hornbeam and alder. The shelterwood method has been used in practice as well in the majority of scientific forestry projects in northern forests of Iran. However, the selection method has been implemented in practice during the last decade. For this study, Compartments No. 35 and 23 were selected that are situated in District 1 and 2 Nav, Asalem forest, which is located in the north of Iran (Fig. 1). Brief general properties of the two studied compartments are shown in Table 1. Methods of harvesting in these compartments (No. 35 and 23) were selection and shelterwood, respectively, and there have not been any operational activities in these two compartments since 10 and 20 years ago. The longest skid trail was selected in each compartment. The length of the skid trail for shelterwood and selection method was 850 and 650 m, respectively. The average longitudinal slope of skid trails was approximately 20%. In logging methods, manual felling (chain saw) and wheeled skidder were used for wood extraction. The other ecological conditions of the studied area were the same. For this investigation, three classes of traffic were identified in each skid trail. The class *High* was the part of the skid trail close to the landing which had the highest traffic, the class *Medium* with an intermediate distance to the landing which had a medium traffic, and fi-

Fig. 1. The map of the study area

nally the class *Low* was the ultimate part of the skid trail which had the lowest traffic. Then tree quality and quantity were considered in skid trails by 10 × 100 m transects (Nagaike et al. 1999) in each traffic class. Furthermore, the same transects were selected 50 m away from the operational area as the control plot to compare results of the quantitative and qualitative parameters. The quantitative parameters were mean diameter, mean height, crown and dominant heights. It was necessary to compare the crown length in diameter classes separately. Since, the studied trees in both shelterwood and selection systems were included in diameter classes of 40 and 60 cm, the samples were grouped into these classes and then the crown length comparisons between two silvicultural systems were performed in these mentioned diameter classes. The surveyed quality parameters were the existence of curvature which is defined as any skewness through the main trunk of the trees, plummeting which represents how much the trees are vertical, and the type and length of existing cracks. Three plots of 0.1 ha were established for each traffic class at three points of the route in order to evaluate damage caused by the two harvesting methods (8 plots in total). Our procedure was randomly designed. Data analysis included *t*-test and non-parametric Friedman test that was done using the SPSS software (SPSS 1999).

To investigate differences between high-quality trees, all plots (skid trail and control) in the two methods were assessed in terms of determining optimal tree quality (vertical status without cracks and tear). To do this, all measured trees along skid trails were divided into two groups of high-quality and low-quality trees. The trees with highly positive qualitative properties such as verticality of trunk with no crack, vitality of crown, and being plummeting were included in the high-quality group. The trees in the low quality grops did not have the above-mentioned properties ang were deficient in one characteristic at least.

Tree quality was anaysed by the non-parametric Friedman test, and they have been compared in two ways. In order to survey the differences between low-quality trees, plots were compared together regarding the low and high curvature, non-verticality and tear. Considering most of the dominant trees in each locatiok would take a long time. The height of dominant trees can be a good index for fertile factor in many countries. For estimating the height of dominant trees, the average height of 100 trees with larger diameter per hectare was measured (Zobeiry 1993). As each method was done in 0.1 ha, both in the selection and shelterwood method the heights of the 10 thickest trees among 39 existing trees along the skid trail were measured. In the investigation of the influenes of selection and shelterwood methods on crown length, most trees were grouped into two diameter classes of 40 and 60 cm. Two diameter classes in selection and shelterwood methods were anaysed by *t*-test.

RESULTS

Quality parameters of trees

Investigation of high-quality trees

The results of samples in each method, each of which were compared with control plots separately, showea significant differencet in a 95% confidence interval of means (0.05 error level) (Table 2). Then, plots in the two methods (shelterwood and selection method) were comparer with each other, which provided significant differences in a 99% confidence interval of means (0.01 levels) (Table 3). The highest quality was found out on control plots, low-traffic skid trail and moderate traffic skid trail

Table 2. Comparison of high-quality trees in each method with control plots by the non-parametric Friedman test

Method	Skid trail traffic	Mean rank	df	Chi-square	*P*
Selection method	low	3	3	9	0.029*
	medium	2			
	high	1			
	control	4			
Shelterwood method	low	2.83	3	8.97	0.032*
	medium	2.17			
	high	1			
	control	4			

*with significant differences at 0.05 error level

Table 3. Comparison of high-quality trees in two methods by the non-parametric Friedman test

Method	Skid trail traffic	Mean rank	df	Chi-square	*P*
Selection method	low	5.67	7	19.3	0.007**
	medium	4.5			
	high	2.67			
	control	7.33			
Shelterwood method	low	4.33			
	medium	2.83			
	high	1			
	control	7.67			

**with significant differences at 0.01 error level

in the selection method. In fact, the tree quality in selection method was higher than shelterwood method.

Investigation of low-quality trees

The results showed that in both comparisons of skewness (existence of curvature) and being plum-meting a significant difference in a 95% confidence interval of means was revealed between the two investigated systems. The least damage can be seen in control samples, low and medium traffic of the skid trail in selection method, respectively. Finally, trees along the high traffic skid trail in selection method were damaged to a lesser extent than trees along the high (heavy) traffic skid trail in shelterwood method (Tables 4 and 5).

Furthermore, damage to beech (*F. orientalis*) in selection method was smaller than in shelterwood method and trees along skid trails were in better shape (Fig. 2).

Table 4. Comparison of low-quality trees in each method with control plots by the non-parametric Friedman test

Method	Skid trail traffic	Mean rank	df	Chi-square	*P*
Selection method	low	2	3	10.34	0.016*
	medium	3.13			
	high	3.75			
	control	1.13			
Shelterwood method	low	1.75	3	6.35	0.039*
	medium	2.38			
	high	4			
	control	1.88			

*with significant differences at 0.05 error level

Table 5. Comparison of low-quality trees in two methods by the non-parametric Friedman test

Method	Skid trail traffic	Mean rank	df	Chi-square	*P*
Selection method	low	2.75	7	17.6	0.014*
	medium	3.75			
	high	6.50			
	control	3.25			
Shelterwood method	low	4.13			
	medium	6.13			
	high	7.25			
	control	2.25			

*with significant differences at 0.05 error level

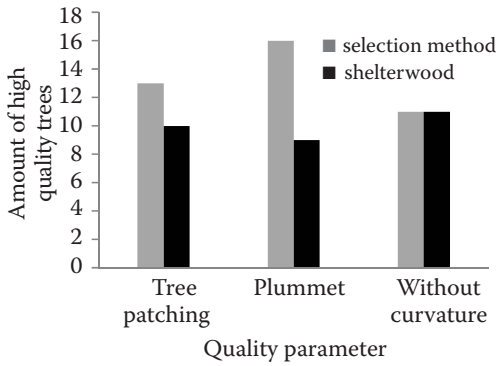

Fig. 2. Comparison of the quality of trees in shelterwood and selection methods

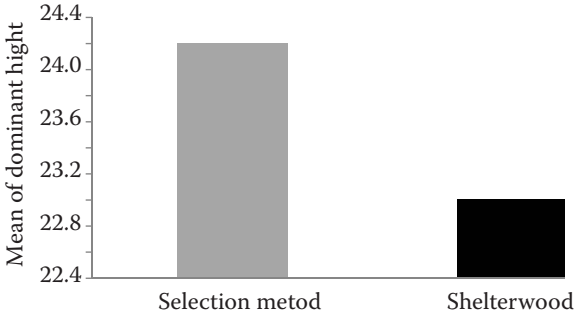

Fig. 3. Comparison of dominant height of trees in two silvicultural methods

Table 6. Analysis of variance of crown length in two diameter classes

Diameter class	*t*	df	*P* (2-tailed)	*P*-value
40 cm	2.3	15	0.036	*
60 cm	1	9	0.343	Ns

*with significant differences at 0.05 error level; Ns – without significant differences

Trees quantity

Dominant height

The result of considering the height of thick trees showed that the average height of dominant trees in selection and shelterwood methods was 24.2 and 23 m, respectively (Fig. 3). Therefore it can be concluded that the fertility index in selection method is better than in shelterwood method.

Crown length

The results of comparison of crown length between two silvicultural systems in two groups or 40 and 60 cm diameter are shown in Table 6. Average crown length of trees in selection and shelterwood methods was 4.6 and 3.9 m, respectively, which was a significant difference in favour of the 40 cm diameter class. But, no significant differences were found in the 60 cm diameter class.

DISCUSSION

Timber harvesting with insufficient planning, improper operation techniques and lack of the control of operations result in severe damage to forest soil, residual trees, seedlings, and wood production. This damage can lead to environmental degradation such as damaged trees, compacted and infertile soil, erosion and turbid water (Eroglu et al. 2009). Previous research revealed that logging intensity significantly influenced forest stand and flora population and it could have some effects on the forest ecosystem (Bisong, Mfon 2008). The results of this study showed that there were significant differences in quantitative and qualitative characteristics of trees between skid trail plots and control plots in selection and shelterwood methods. The comparison of trees existing along 10 and 20 years old skid trails (in selection and shelterwood methods, respectively) showed that there were significant differences in the tree properties such as fertility and vertical curvature so that the qualitative characteristics in selection method were significantly better than those in shelterwood method. The reason could be more frequent traffic and higher harvesting intensity in shelterwood system than in selection system in the same period. The results of qualitative characteristics showed the minimum quality of trees in shelterwood method with high traffic on the skid trail. The results of high traffic areas indicated that they had the highest portion of skidding, so these areas were destroyed more than other areas, and they will need longer time for improving the soil fertility and subsequently this will result in reducing the investigated tree quality parameters. This situation occurred to a lesser extent in selection method because logs are more scattered in the operation area and the density of skid trails and skidding intensity are lower. Log gathering and transportation from the operation area were done with higher intensity in shelterwood method, so that soil and stand damage on harvested areas and skid trails were greater than in selection method. The results of this study showed that the effects of shelterwood method would remain in the forest after 20 years.

The comparison of quantitative features such as height of dominant trees and crown length in both selection and shelterwood methods showed

that the mean crown length and height of dominant trees in selection method were significantly larger than in shelterwood method. In shelterwood method because of a high number of logs in the harvested area, there are higher frequencies of transportation on skid trails than in selection method, so the amount and severity of damage and wounds caused to trunks and roots of remaining tree are greater (Hoseini 2002). However, stressed soil and changes in the soil properties can affect the diameter and height growth of trees (Lamson et al. 1985; Anderson et al. 1994; Han, Kellogg 2000).

Jalali (1996) considered the reasons for wizening of beech (*F. orientalis*) trees; four sites of beech (*F. orientalis*) in the north of Iran (Mazandaran) were selected and studied. The results showed that although some elements were limited in some parts of the forest soil such as phosphorus and organic carbon in soil horizons, these deficiencies were not high enough to cause beech (*F. orientalis*) wizening. In fact, the physical factors such as root-race situation, hydromorph soil, impenetrable clay layers, soil compaction and soil texture are effective in determination of the health of beech (*F. orientalis*) trees. This study showed that the most important destructive factor for forest health in anthropic activity that must be controlled and programmed. Because other factors such as species kind, age, environmental factors etc. can affect qualitative and quantitative parameters of residual stand, they should be studied thoroughly in the future.

After one decade of implementing the selection system in the northern forests of Iran it is necessary to consider the quality and quantity of residual trees in logging areas and to compare them with results of implementing the shelterwood method. Although each harvesting method can cause distinctive damage to remaining tree, site index and soil, the intensity of damage can be reduced by means of better timber harvesting and silvicultural method. This study showed that the proper planning of skid trails in selection system with low traffic on skid trails can reduce the impairment of tree quality and quantity recognizable many years after. Therefore, the construction of skid trails should be planned before logging operations commence and preharvest planning should be carried out after finishing these operations in order to conserve residual stand, regeneration and soil fertility. Choosing the better logging method (such as selection method) with two key recommendations mentioned above, can help us to reach the sustainable forest management and to preserve forest ecosystems.

Acknowledgement

The authors wish to gratefully thank Shafaroud Forest Corporation management ans personnel for their suppots and heps sSpecial thanks go to PhD candidate Mr. Ismael Ghajar from Tarbiat Modares University, who read the paper and offered valuable advies.

References

Ampoorter E., Goris R., Cornelis W.M., Verheyen K. (2007): Impact of mechanized logging on compaction status of sandy forest soils. Forest Ecology and Management, ***241***: 162–174.

Anderson H., Boddington D., Van Rees, H. (1992): The long-term effects of saw log-only harvesting on some soil physical and chemical properties in East Gippsland. [Unpublished.] Department of Conservation and Environment, Victoria, Australia: 29.

Bisong F.E., Mfon P. (2008): Effects of logging on forest regeneration in South-Eastern Nigeria. Environmental Research Journal, ***2***: 115–121.

Brunig E.F. (1970): Stand structure, physiognomy and environmental factors in some lowland forests in Sarawak. Tropical Ecology, ***11***: 26–43.

Chapman C.A., Chapman L.J. (1997): Forest regeneration in logged and unlogged forests of Kibale National Park, Uganda. Biotropica, ***29***: 396–412.

Clark D.B., Clark D.A., Rich P.M., Weiss S., Oberbauer S.F. (1996): Landscape scale evaluation of understory light and canopy structure: methods and application in a neotropical lowland rain forest. Canadian Journal of Forest Research, ***26***: 747–757.

Crow T.R. (1980): A rainforest chronicle: A 30-year record of change is structure and composition at EI Velde, Puerto Rico. Biotropica, ***12***: 42–55.

Davies D.B., Eagle D., Finney B. (1992): Soil Management. 5th Revised Ed. Ipswich, Farming Press Books and Videos: 286.

Eroglu H., Oztruk U.O., Sonmez T., Tilki F., Akkuzu E. (2009): The impacts of timber harvesting techniques on residual trees, seedlings, and timber products in natural oriental spruce forests. African Journal of Agricultural Research, ***4***: 220–224.

Favrichon V. (1998): Modeling the dynamics and species composition of tropical mixed species uneven-aged natural forest: effects of alternative cutting regimes. Forest Science, ***44***: 113–124.

Finegan B., Camacho M. (1999): Stand dynamics in a logged and silviculturally treated Costa Rican rain forest. Forest Ecology Management, ***121***: 177–189.

Hager H., Sieghardt M. (1992): Damage to forest sites through soil compaction. Central für des Gesamt Forest, ***101***: 109–120.

Han H.S., Kellogg L.D. (2000): A comparison of sampling methods and a proposed quick survey for measuring residual stand damage from commercial thinning. Journal of Forest Engineering, ***11***: 1–8.

Holdridge L.R., Grenke W.C., Hatheway W.H., Lian T., Tosi J.A. (1971): Forest Environments in Tropical Life Zones: A Pilot Study. Oxford, Pergamon Press: 747.

Jalali G.A. (1995): Causes of beech (*F. orientalis*) trees in the forest areas Wizening Sari. [PhD Thesis.] Tehran, Tarbiat Modarres University: 157.

Kozlowski T.T. (1999): Soil compaction and growth of woody plants, Scandinavian Journal Forest Research, ***14***: 596–619.

Lamson N.I., Smith H.C., Miller G.W. (1985): Logging damage using an individual-tree selection practice in Appalachian hardwood stands. Northern Journal of Applied Forestry, ***2***: 117–120.

Makineci E., Gungor B.S., Demir M. (2008): Survived herbaceous plant specieson compacted skid road in a fir (*Abies bornmulleriana* Mattf.) forest – A note. Transportation Research Part D: Transport and Environment, ***13***: 187–192.

Makineci E., Demir M., Yilmaz E. (2007): Long-term harvesting effects on skid road in a fir (*Abies bornmulleriana* Mattf.) plantation forest. Journal of Building and Environment, ***42***: 1538–1543.

Murphy G. (2004): Long-term impacts of forest harvesting related soil disturbance on log product yields and economic potential in a New Zealand Forest. Silva Fennica, ***38***: 279–289.

Naghdi R., Bagheri I., Lotfalian M., Setodeh B. (2009): Rutting and soil displacement caused by 450C Timber Jack wheeled skidder (Asalem forest northern Iran). Journal of Forest Science, ***55***: 177–183.

Nagaikea T., Kamitania T., Nakashizuka T. (1999): The effect of shelterwood logging on the diversity of plant species in a Beech (*F. orientalis*) (*Fagus crenata*) forest in Japan. Forest Ecology and Management, ***118***: 161–171.

Okuda T., Suzuki M., Adachi N., Quah E.S., Hussein N.A., Manokaran N. (2003): Effect of selective logging on canopy and stand structure and tree species composition in a lowland dipterocarp forest in peninsular Malaysia. Forest Ecology and Management, ***175***: 297–320.

Panfil S.N., Gullison R.E. (1998): Short term impacts of experimental timber harvest intensity on forest structure and composition in the Chimanes forest in Bolivia. Forest Ecology and Management, ***102***: 235–243.

Rab M.A. (2004): Recovery of soil physical properties from compaction and soil profile disturbance caused by logging of native forest in Victorian Central Highlands, Australia. Forest Ecology and Management, ***191***: 329–340.

Rab M.A. (1994): Changes in physical properties of a soil associated with logging of *Eucalyptus regnan* forest in southeastern Australia. Forest Ecology and Management, ***70***: 215–229.

Richards P.W. (1952): The Tropical Rain Forest: An Ecological Study. London, Cambridge University Press: 450.

Shugart H.H., West D.C. (1981): Long-term dynamics of forest ecosystems, American Scientist, ***69***: 647–652.

SPSS (1999): Statistical analysis software (Standard Version 10.0.1.). SPSS Inc.

Thang H.C. (1987): Forest management systems for tropical high forest, with special reference to Peninsular Malaysia. Forest Ecology and Management, ***21***: 3–20.

Webb E.L. (1997): Canopy removal and residual stand damage during controlled selective logging in lowland swamp forest of northeast Costa Rica. Forest Ecology and Management, ***95***: 117–129.

Whitman A.A., Brokaw N.V.L., Hagan J.M. (1997): Forest damage caused by selection logging of mahogany (*Sweitenia macrophyla*) in northern Belize. Forest Ecology and Management, ***29***: 87–96.

Whitmore T.C. (1984): Tropical Rain Forests of the Far East. 2nd Ed. Oxford, Oxford University Press: 352.

Zobeiry M. (1993): Forest Inventory (Measurement of Tree and Stand). Publication of Tehran University: 401.

Received for publication November 29, 2010
Accepted after corrections May 17, 2011

Corresponding author:
Dr. Ramin Naghdi, University of Guilan, Faculty of Natural Resources, Department of Forestry, Somehsara, P.O. Box 1144, Iran
e-mail: rnaghdi@guilan.ac.ir