FORMEC 2010
Forest Engineering: Meeting the Needs of the Society and the Environment
July 11 – 14, 2010, Padova – Italy

HAULING DAMAGES IN A MIXED BEECH OAK STAND

Petros A. Tsioras, Diamantis K. Liamas

Dept. of Harvesting and Technology of Forest Products
Aristotle University of Thessaloniki (POB 227)
Thessaloniki, Greece (541 24)
e-mail: ptsioras@for.auth.gr - dliamas@for.auth.gr

Keywords: forest operations, skidding, tree damage, Greece.

Abstract: *Beech represents a very valuable tree species in Greek Forestry with respect to its potential of wood production. Located at good quality sites, beech forests have a strong potential for further development in terms of wood quality and quantity with proper silvicultural treatments. The objective of this paper is to present the preliminary results from an extended research project conducted in beech stands of Northern Greece. This refers to the damages caused on trees along the skidding trails during the harvesting operations in a mixed beech oak stand. All trees in a width of 2m on both sides of the skidding trails in the study areas have been studied after wood extraction was completed. According to the results, 19.7% of the trees were injured or broken. The majority of the injured trees suffered at least one damage, whose area varied in a broad range. Removal of bark was evident in 38% of the injured trees whereas the combination of removed bark and destroyed wood tissues was found in 53% of the injured trees.*

1. Introduction

Beech represents a very valuable tree species in Greek Forestry with respect to its potential of wood production. Located at good quality sites, beech forests have a strong potential for further development in terms of wood quality and quantity with proper silvicultural treatments. Beech stands cover an area of 336,640 Ha or 5.17% of the total forest area in Greece, and wood standing volume is estimated to 27.6 mil. m^3 (82.3 m^3/ha) which is 20.05% of the total wood volume (Efthymiou, 2009).

In Greece, the State Forest Service develops a 10-year forest management plan for every state owned forest, according to which all the harvesting and silvicultural operations are carried out. In this context, forest worker's cooperatives and contractors are responsible for cutting and skidding the timber to the roadside. Felling of trees is done exclusively with chainsaw and timber is extracted to roadsides or upper-landings by animals (horses and mules) and machines (usually modified agricultural tractors, Unimogs or special forest machines like skidders). According to Efthymiou (2009) the mean wood standing volume of Greek forests is 54m^3/ha for conifers and 27.8m^3/ha for broadleaves, compared to around 250-300 m^3/ha for forests in Central Europe. Low productivity of Greek forests and the fact that around 70% of harvested timber is firewood are some of the most important reasons for the low mechanization level in Greek forest operations.

In modern forestry, ground vehicles are the basis for mechanized felling, processing, and transportation of trees. Mechanization of transportation progressed mainly in the 1960s and 1970s resulting in a large variety of special machines like skidders, forwarders, or clambunk-skidders (Heinimann, 2004). An important consideration in the development of modern forest machinery for skidding and hauling of timber is the minimization of residual tree damages caused by the heavy traffic in the forest stands.

Small-scale farm tractor logging may also be used in certain cases to lessen the environmental impact of a timber harvesting operation. The smaller, lighter farm tractor may be able to operate effectively on partial cuts in dense timber stands where larger skidders or forwarders might possibly cause residual stand damage or soil compaction (Shaffer, 2009).

Animal skidding is a lower productivity system compared to mechanized skidding. Decisive factor for the suitability of animal systems are the needs and characteristics of the forest landowner or working unit, as well as the availability of forest machines. When high production is not needed or desired, the use of animal skidding may have long-term benefits from the avoidance of residual stem damage (Ficklin et al, 1997).

Harvesting systems cause injuries on standing trees that means further, economic losses for the forest management. Those injuries become an input port for fungi decays very often (Vasiliauskas 2001). According to a size of that input port, fungi decays may cause further wood depreciation (devaluation) or even lower increments (Heitzman and Grell, 2002, Limbeck-Lilienau, 2003). Forest management faces then qualitative as well as quantitative losses, which do not reflect in instantaneous values, but in values, which appear in a long term (Dvorak and Cerny, 2003).

The amount and characteristics of skidding damage are affected by the soil, slope, stand and climate conditions. Skidding during the winter is causing less damage to soil and residual trees, as a result of the protection provided by the snow cover (Limbeck-Lilienau 2003). Slope has also been correlated with increased skidding damage (Stampfer et al. 2001). Nevertheless, the amount of damages are also affected by the level of training and consciousness of the people (forest workers, contractors etc) working in forest operations (FAO, 2004)

The rationalization of harvesting systems presupposes the choice of the best suited equipment in multiple levels; economical, ergonomical and ecological. Each choice has distinct advantages and disadvantages, making the choice increasingly difficult and pre-requires in depth analysis and comparison of the different proposed systems.

Objective of this paper is to present the preliminary results from a study conducted in a mixed beech oak forest stand in Chalkidiki (Northern Greece). All damages caused during the skidding operations with a modified agricultural tractor have been recorded and analyzed. The results of this study are compared to other contemporary studies and interesting conclusions can be drawn.

2. Materials and methods

Field work took place in the stand No 116b in the mountainous area of Arnaia (Prefecture of Chalkidiki – Northern Greece) (Figure 1). This is a mixed beech (*Fagus moesiaca*) and oak (*Quercus conferta*) stand with an area of 55 Ha. Data collection started right after the logging operations took place in the summer of 2009. Visits of the area before and during the forest operations enabled the better understanding of the working environment and the wood harvesting conditions.

The study area had an elevation of 590-790 m. and slope ranged between 10-70%. Beech trees were 40-110 years old and oak trees 55-70 years old. The total wood standing volume was 8178 m^3 or 148.7 m^3/Ha. Tree felling and debranching were conducted with chainsaw, while roundwood and fuelwood were extracted with a modified agricultural tractor (FIATAGRI Model 70.90) and mules, respectively. A total of 719.7m^3 was harvested of which 154.2m^3 was roundwood and the remaining 565.5m^3 was fuelwood.

All tree damages caused during skidding were recorded along both sides of the main and secondary skid trails, in a buffer zone of two meters. Also the exact length of skid trails was measured with the help of a hand-held GPS (Garmin Legend HCx) and was found to be 1373m. The width of the skid trails was not fixed, but ranged between 3.4 to 4 meters.

Figure 1. Map of the study area

The tree wounds were investigated according to the method described by Meng (1978). The number of damages, separated into old and new wounds, has been recorded on every residual tree. The location and height on the stem (Figure 2), the wound size and the intensity were also described**.** The division of wounds in damage categories (Table 1) permits an assessment of risk for infections by fungi (Limbeck-Lilienau 2003). With an increase of damage category the probability of an infection also increases.

Table 1: Description of damage categories (DC 1 – 4)

Damage characteristics	**Damage Category**			
	DC 1	**DC 2**	**DC 3**	**DC 4**
Location of damage	> 1 m	0.3 – 1 m	Stump	root
Size of damage	< 10 cm^2	11 – 50 cm^2	51 – 200 cm^2	> 200 cm^2
Intensity of damage	Bark damaged	Bark squeezed	Wood visible, not damaged	Wood visible, damaged

According to Meng (1978) damages in the size-class DC 1 (< 10 cm^2) are irrelevant and as a rule there is no risk of an infection by wood-destroying fungi. With a wound area more than 10 cm^2, the stage of decay increases in relation to the size of injury.

When an external damage to bark occurs, a fungal infection could not be expected (Butora und Schwager, 1986). If the bark gets squeezed, the tree would only rarely be infected by fungi. Infection and the following decay mostly occur when the wood is visible (DC 3). In the cases of real wood injury (DC 4), the probability, that wound rot fungi appear, raises by 40 to 50 percent compared with DC 3.The highest risk for decay is given for trees with injuries in the area of the felling cut and the root collar (Figure 2). Damages on superficial roots and above the root collar (> 0.3 m) get less often infected by wood-destroying fungi (Meng, 1978).

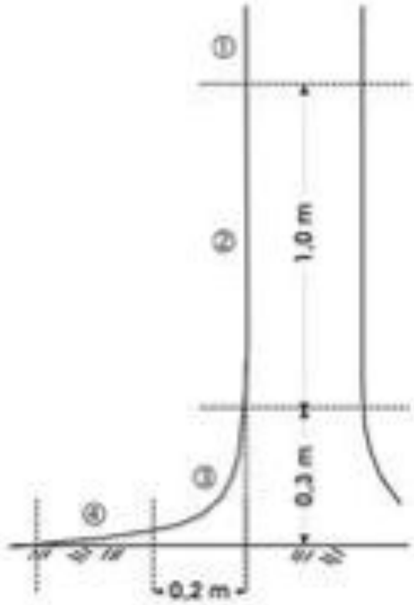

Figure 2. Classification of damages according to location on the root and stem (Meng, 1978)

3. Results and discussion

3.1 Damage frequency and distribution

A total of 760 live stems were sampled throughout the stand and incidents of new damage, caused by the skidding, have been recorded on 151 trees. A total of 206 tree injuries has been recorded (Table 1). Almost two thirds (66.2%) were evident on beech and the rest on oak trees.

Table 1. Distribution of the damages according to species

Species	Number of injuries (N) (%)
Beech	134 (65%)
Oak	74 (34.5%)
Chestnut	1 (0.5%)

Almost one fifth (19.7%) of the monitored trees were damaged, a result which does not exceed the findings of other previous studies on residual stand damage. McNeel and Ballard (1992) reported less than 5% residual stand damage as a result of a thinning operation in a Douglas-fir plantation in a flat to rolling terrain (0 to 17% terrain slope). Bacher (1999), in a literature review, found an average value of 10% wounded trees as an impact of harvester-forwarder systems on the residual stand. Bettinger and Kellogg (1993) told about 39.8% damaged trees after a harvester-forwarder operation in a 47-year-old Douglas-fir and western hemlock stand, while Han and Kellogg (1997) also found high damage percentages between 31.9% and 41.3% of wounded trees by a similar harvesting system. Trees along the trailside have been reported to suffer more damages than non-trailside trees (Han and Kellogg, 2000, Heitzman and Grell, 2002).

Average wounds per damaged tree is 1.34 (sd±0.59) for beech and 1.42 (sd±0.61) for oak. The distribution of wounds per damaged tree is described in Table 2.

Table 2. Distribution of number of wounds per tree according to species

Species	Number of wounds per tree			Total
	1	2	3	
Beech	72 (47.7%)	22 (14.6%)	6 (4.0%)	100 (66.2%)
Oak	32 (21.2%)	15 (9.9%)	3 (2.0%)	50 (33.1%)
Chestnut	1 (0.7%)	0 (0%)	0 (0%)	1 (0.7%)
Total	105 (69.5%)	37 (24.5%)	9 (6.0%)	151 (100%)

Research was conducted in a buffer zone of two meters along the main and secondary skid trails, therefore the distance of the residual damaged trees ranged from 0cm to 200cm (Figure 3). Mean damage distance was found to be 37.8cm (sd±25.5cm). The majority of the damages (more than 94 percent) were found in a distance range of 0-100 cm from the edge of the skidding trails.

Han and Kellogg (2000), on their research on damages in young Douglas-fir stands with four timber harvesting systems, found that damaged trees were more concentrated along the skid trails for tractor logging than for skyline and cut to length logging. About 56% of the total damage (any size scar) in skyline, 64% in cut-to-length, and 80% in tractor thinning units was observed within 5m of the centerline. The greatest damage occurred within the first 3m from the centerline of the skid trails or the skyline corridors. In another study on skidding damages, Froese and Han (2006) found that 67.7% of the damaged trees were located within 4m from the center of the skid trail. Considering the fact that, in our case, the width of the skid trail ranged from 3.4m to 4m, it is safe to conclude that the majority of damages occurred within the first 3-4m from the skid trail centerline.

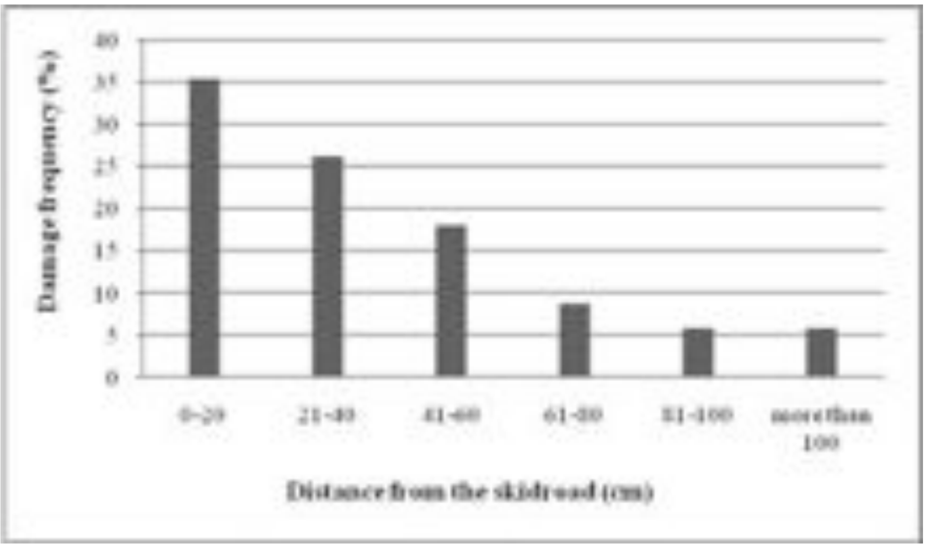

Figure 3. Distribution of the tree damages according to their distance from the skidding track**.**

3.2 Damage characteristics

The large majority of damages were evident either on the root area (39.5%) or at stem heights between 31-100 cm (39%) (Table 3). Solgi and Najafi (2007) reported damages located on the root system of only 12%. Harvesting systems seem to have a profound effect on the locations of damages on the residual trees. Limbeck–Lilienau found that the combination of wheeled harvester and forwarder caused more damages on the roots (38% in summer, 6% in winter) than the combination of tracked harvester and forwarder (10% in summer, 1% in winter). Han and Kellogg (2000) after comparing four harvesting systems and damages to residual trees found that the amount of scarring below 60 cm was 2% in helicopter, 17.5% in skyline, 29.3% in cut-to-length, and 64% in tractor units. Scar height has a significant effect on the extent of decay; frequency of infection and amount of decay decreased as wound height increased.

Table 3. Distribution of the damages according to their location on the tree

Location	Frequency	Percent	Cumulative Percent
Root	81	39,5	39,5
1-30	27	13,2	52,7
31-100	80	39,0	91,7
More than 100	17	8,3	100,0
Total	205	100,0	

The majority of damages (68.5%) have an area of more than 200cm^2 (DC 4) (Table 4). In the case of beech, 90 out of the 133 damages measured, had damaged areas belonging to DC 4. This is a very important finding, considering that most of the damages were located in the root area. This result, in combination to the fact that beech has a "heart-shaped" root system, explains the extensive damages, often combined with wood decay. Solgi and Najafi (2007) refer to 40% and 42% damage with an area of 51-200cm^2 and more than 200cm^2 respectively, while Limbeck–Lilienau (2003) reported that in her study in the summer 47% of all damages were bigger than 200cm^2.

Table 4. Damage area per species

Species	**Damage area class**				**Total**
	<10cm^2	**10-50cm^2**	**50-200cm^2**	**>200cm^2**	
Beech	5 (2.4%)	12(5.8%)	26 (12.6%)	90 (43.7%)	133 (64.6%)
Oak	2(1%)	3 (1.5%)	18 (8.7%)	49 (23.8%)	72 (34.9%)
Chestnut	0(0%)	0 (0%)	0 (0%)	1 (0.5%)	1 (0.5%)
Total	7 (3.4%)	15 (7.3%)	44 (21.3%)	140 (68.5%)	206 (100%)

The analysis of data showed no significant differences with regard to the distribution of damages in area classes on the residual beech and oak trees of the study area (χ^2= 2.78, dF=6, p= 0.836). The majority of damages belonged to DC 4 class (area wider than 200cm^2), while damages of the DC 3 class (50-200cm^2) represent 21.3% of the total number of damages.

Higher slope has been recognized as a potential factor leading to higher damage levels (Stampfer et al., 2001). However, this assumption was not justified in our findings (Table 5). No statistically significant differences have been found between the damage area class and the slope class according to the Pearson Chi-square test (χ^2= 5.30, dF=9, p= 0.81).

Table 5. Damage area class distribution in slope classes

Slope_class	**Damage area class**				
	DC 1	**DC 2**	**DC 3**	**DC 4**	**Total**
0-10%	4	6	21	71	102
11-20%	3	9	22	56	90
21-30%	0	0	2	8	10
More than 30%	0	0	0	4	4
Total	7	15	45	139	206

4. Conclusions

Assessment of harvesting systems is done in multiple levels; economical, ergonomical and ecological among others. The current study examines the impacts of skidding operations on residual trees along the skid trails. Skidding damages result in exposed sapwood and can possibly lead to degradation of the future forest products. These wounds may function as entry points for insects and diseases. Therefore, the potential loss of tree value underlines the importance of the skidding damages examination from the managerial point of view.

The findings of this study agree with those in other studies with regard to the frequency of damaged trees and the damage area. The frequency of damage location depends on the harvesting system used, while no relationship was statistically found between slope and damage area. These preliminary results should not be generalized for all the beech forests in Greece, since the study is still ongoing with data from different areas. This study should be further expanded to other species nationwide.

Useful suggestions to reduce skidding damage are provided by FAO (2004) and Solgi and Najafi (2007). These include planning the trails, utilizing the optimum trail spacing, keeping the trails straight and directional felling of trees on an angle towards trails. It is also important to keep the skidders on the trails, limit skidding operations during wet periods, use the correct size of skidder (i.e. not too large and not too small) as well as utilize bumper trees where required.

Another very important factor, on which great attention should be paid, is the forest workers. None of the above mentioned findings and conclusions will make a difference unless actions and initiatives, aiming at increasing the professional capacity of the people involved in forest operations, take place. Only well trained forest workers and machine operators can guarantee increased productivity, safety during work and reduced environmental impacts during the forest operations.

References

Bacher, M. (1999). Literaturstudie Bestandesschäden. Versuchsbericht der Forstlichen Versuchs- und Forschungsanstalt Baden-Württemberg, Abteilung Arbeitswirtschaft und Forstbenutzung, Nr. 6. 13p.

Bettinger, P. and Kellogg, L. D. (1993). Residual stand damage from cut-to-length thinning of second growth timber in the Cascade Range of western Oregon. Forest Products Journal, 43, 59-64.

Butora, A. and Schwager, G. (1986). Holzernteschäden in Durchforstungsbeständen. Bericht der Eidgenössischen Anstalt für das forstliche Versuchswesen, Nr. 288, Schweiz. 47 p.

Dvorak, J. and Cerny, S. (2003). Injuries on Forest Stands in Krusne Hory Mountains Caused by Utilization of Logging Systems. Proceedings of FORTECHENVI Brno, May 2003.

Efthymiou, P.N. (2009). Harvesting of Forest Products - University Lectures. Aristotle University of Thessaloniki, Greece. 210 p.

FAO, (2004). Reduced Impact Logging in Tropical Forests – Literature synthesis, analysis and prototype statistical framework. Forest Harvesting and Engineering, Forestry Department - Working Paper 1, Rome.

Ficklin, R.L., Dwyer, J.P., Cutter, B.E. and Draper, T. (1997). Residual tree damage during selection cuts using two skidding systems in the Missouri Ozarks. Proceedings of the 11th Central Hardwood forest conference (Robert A., Garrett H.E., Johnson P.S., Pallardy, S.G. and Cecich, R.A. eds.) March 23-26, Columbia, MO, 36-46.

Froese, K. and Han, H.S. (2006). Residual stand damage from Cut-to-Length thinning of a mixed confifer stand in Northern Idaho. Western Journal of Applied Forestry, 21, 142-148.

Han, H.S. and Kellogg, L. D. (1997). Comparison of damage characteristics to young Douglas-fir stands from commercial thinning using four timber harvesting systems. Proceedings of the Council on Forest Engineering, Rapid City, South Dakota, USA, July 28 – 30, 1997. 10 p.

Han, H.S. and Kellogg. L.D. (2000). Damage characteristics in young Douglas-fir stands from commercial thinning with four timber harvesting systems. Western Journal of Applied Forestry 15, 27-33.

Heinimann, H.R. (2004). Forest Operations under Mountainous Conditions. Encyclopedia of Forest Sciences (Jeffery Burley, ed.), Elsevier, Oxford, 279 - 285.

Heitzman, E. and Grell, A.G. (2002). Residual tree damage along forwarder trails from cut-to-length thinning in Maine spruce stands, Northern Journal of Applied Forestry 19, 161-167.

Limbeck-Lilienau, B. (2003). Residual stand damage caused by mechanized harvesting systems. Proceedings of Austro2003: High Tech Forest Operations for Mountainous Terrain, October 5-9, 2003, Schlaegl - Austria.

McNeel, J. F. and Ballard, T. M. (1992). Analysis of site stand impacts from thinning with a harvester forwarder system, Journal of Forest Engineering, 4, 23-29.

Meng, W. (1978). Baumverletzungen durch Transportvorgänge bei der Holzernte – Ausmaß und Verteilung, Folgeschäden am Holz und Versuch ihrer Bewertung. Schriftenreihe der LFV Baden-Württemberg, Band 53. 159 p.

Shaffer, R.M. (2009). Farm Tractor Logging for Woodlot Owners. Virginia Polytechnic Institute and State University - Virginia Cooperative Extension.

Solgi, A. and Najafi, A. (2007). Investigating of residual tree damage during ground-based skidding. Pakistan Journal of Biological Sciences 10, 1755-1758.

Stampfer, K., Steinmüller, T. and Svaton, R. (2001). Grenzen der Steigfähigkeit, Österreichische Forstzeitung (Arbeit im Wald), 112, 1-3.

Vasiliauskas, R. (2001). Damage to Trees due to Forestry Operations and its Pathological Significance in Temperate Forests: a Literature Review. Journal of Forestry, 74, 319-336.