Effects of Skid Trail Planning, Landing Construction and Directional Felling on Normal Selective Logging in Caspian Forest

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Abstract:
Sustainable natural forest management in the Caspian forest of Iran require that cost –effective measures be identified to help maintain timber stand quality and reduce damage to advance regeneration during logging operation. This study considered economical and environmental analysis of including three best management practice- plans and flagging skid trail before felling, directional cutting and landing construction- in adjacent 70-ha plot, in conjunction with conventional planned logging in Caspian forest of Iran.
Data on the two logging operations were collected under almost identical conditions. Work and time studies on logging activities in both systems, and post-harvest assessments of environmental impacts, were carried out. The average time required to fell a single tree was greater in the current logging system (6.12 min) than in planned logging (5.47min) due to the time spent by the chainsaw operator for delays .Skidding time for a turn under the conventional system was significantly greater (18.94 min) than under planned logging (15.43). A similar result was found when comparing the productivity of the two logging systems. For skidding under planned logging, productivity averaged 15.97 m³/h of workplace time, whereas skidding productivity under conventional logging averaged only13.33 m³/h of workplace time. Timber logging as carried out in the planned logging system, not only decreased cost of logging but also reduced impact in felling gaps, winching lines and skid trails 23%, 26 % and 21% respectively. For the planned logging system an average of about 1% of the area harvested was affected by skid trails, whereas in conventional logging the corresponding value was 2.62%. The most important finding of this study is that planned timber logging can reduce costs significantly by comparison with conventional logging.

Keywords: Planned logging, Skid trail, Directional felling, Caspian forest

1 Introduction

Despite noteworthy advance, damage to residual stand during logging in thought to be one of the largest silvicultural challenges facing sustainable management in Caspian forest. Recent data reported by Naghdi et al (2005) from Neka Timber Concession for example indicate that logging operation kill or severely damage and average 8% of residual stand. While some damage is unavoidable during logging operation and acceptable level of damage have yet to be defined for natural forest management in Caspian forest, this finding suggest that current logging practices may not sustain timber yield through a series of cycles given the Caspian forest .for this reason there is a perceived need among forest manager to identify additional RIL practices that can reduce residual stand damage in a cost effective manner , it has been suggested that careful planning, marking and flagging skid trail before logging , using from directional felling and planning of logging deck can help reduce damage to residual stand ,soil and forest road , but this practices are not currently employed in the most Caspian forest management operation, the main objectives of this investigation were to (1) quantity current harvest cost and benefit associated with careful skid trail planning and marking before felling, using from benefit of directional felling and deck planning and construction.(2) estimate the extent to how much of residual stand damage can be mitigated during logging operation and (3) identify cost effective best management that might increase the timber value of post harvest stand .

2 Material and methods

2.1 Site description and research approach

This study was conducted in the 3700ha Asalem timber concession located in the Shafarood forest region, Guilan province, Iran. The site is classified as mountain forest with a mean annual temperature of 18/8 ^{oC} and mean annual rainfall of approximately 1038/7 mm that the majority of which falls in November to April, a peak of rainy season. Skidding activity should be cease almost entirely during wet season. Providing forestry plan for this concession started in 1995 for logging of hardwoods like Beech (Fagus orientalis Lipsky), Oak (Quercus castaneaefolia C. A. Mey. Sub sp. Castaneifolia) Maple (Acer insigne Boiss. et Buhse) Hornbeam (Carpinus betulus L) Alder (Alnus subcordata C. A. Mey).The annual harvest area in approximately 370 ha with harvest volume ranging from 20-30 m^3/ha. subsequent logging entries are scheduled at 10-years intervals. Comparison between current logging operation and planned logging systems were conducted in adjacent 72ha parcels. Forest road to reaching harvest area constructed 3 years ago .logs from two parcels were skidded to this road in current logging but in planned logging landing constructed. The height of parcels ranged from 100 to 1600m above of sea level and maximum of slops were 25-50%: Harvest volume ranged from 20-30 m^3/ha in the two parcels. All logging occurred between June and September 2006.

2.2 Normal logging operation – parcel 319

The logging system employed in parcel 319 was representative of Caspian forest normal management. Logging was based on selective cutting for all species except endangered (Mohajer, 2006). Trees were selected, marked for logging 6 month prior to felling using a systematic pre-harvest inventory. Felling operation was conducted by two sawyers (feller and helper) with STIHL with 90 cm saw bars. Felling group felled the trees without any processing. Processing was performed during skidding. The same sawyer and skidder operator performed the logging in the two parcels. The skill of sawyer is considered to be similar to other experienced sawyer in the region, typical of logging practices in the region. Felling wedge rarely used in the concession. Sawyer received a flat salary each month. One driver and 3 helpers compose skidding group. They performed all skidding all processing and skidding operation in the study , tree length logs were skidded individually or on rare occasions, in bunches of two or three road side landing. The rubber tire skidder (Timberjack 450C) was equipped with an Arch and 50m of cable were used for skidding. Typical of logging practices in the region, the skidder operator used the line cable to hook logs. Skidder operation are paid flat salary each month

2.3 Planned logging

Typical Caspian forest management, however, doesn't include planning and marking skid trail before felling. Because of landing absence, logs store along of road. Movement of skidding machine causes damage on forest road and increase its repair and maintenance cost. The FRWO instruction for planning of skid trail and landing suggests that damage to residual trees; soil and forest road can be reduced by marking skid trail before felling, landing construction and transporting logs to landing instead along of road (Sobhani and Naij Noori 2006). According to FRWO instruction best place for landing was selected and skid trails planned for harvested area and demarcated by blue stock. Marking skid trail before felling provide visual reinforcement for felling crew for doing directional cutting with wedge. Logs skidded to landing instead of along forest road.

2.4 General assessment of felling technique

The implication of directional felling requires those sawyers are fully capable of felling trees in any predetermined direction (ITTO 1996b). To assess the technical ability of the district sawyer both were observed in the felling of approximately 100 trees selected at random. Before starting of felling, appropriate direction of felling determined and its azimuth of the trees actual fall was recorded (Krueger, 2003). The difference between the appropriate direction and actual direction of the tree's fall was then calculated for each observation.

2.5 Felling efficiency

Mean cycle times and production rates (including delays) in m^3 felled per hour of machine operation was estimated for both logging systems by measuring log volume over 95 cycle (Jorgholami, 2005).

Mean cycle times were broken down into component parts as follows (modified from Wang, 2004):

- ⇒ Walk to tree: Begins when the feller starts toward the tree to be cut. Ends when the feller reaches the tree
- ⇒ Acquire: Begins when the feller starts clearing around the tree and judges where the tree will fall. End when the feller is ready to cut the tree.
- ⇒ Undercut: Begins when the feller starts cutting the edge of the tree. End when the snipe extracted from the undercut face.
- ⇒ Backcut: starts when the faller moves to back of tree for starting cutting, ends when the faller moves to another tree.
- ⇒ Delays: There were three kinds of delays in this study, operational delay, technical delay and personal delay.

Volume of harvested trees was estimated by using of rural volume table. Mean diameter of harvested trees was 69 cm in Parcel 319 and 65 cm in Parcel 331; thus, it was assumed that trees diameter did not contribute to observed differences between treatments in mean cycle times. F-tests were employed to test the assumption of homogeneity of variances, and equal- or unequal-variance t-tests were used to determine the significance of differences observed between treatments in mean cycle times and their components.

2.6 Assessing residual stand damage associated with felling operation

Approximately 30 single tree fall sites were selected at random from both the current and planned logging, and the residual stand damage incurred at each site was tailed (method modified from Naghdi et al (2005)). Damage to residual trees recorded according to the location and severity of wound (table1, modified from Jackson et al (2002)). F tests were used to test the homogeneity of variance and equal variance t-tests were used to test for difference in residual trees damage between logging systems. Differences were considered statistically significant at $P \leq .0.05$.

2.7 Skidding efficiency

Mean cycle time and production rate (including delays) in m^3 yarded per hour of machine operation were estimated for both operation by measuring log volume over a 25 skidding cycle (method modified from Wang, 2004). Mean cycle time was broken down into component parts as follows:

- ⇒ Travel empty: Begins when the skidder leaves the landing with an empty cable. End when the skidder arrives at the felled stems to be extracted.
- ⇒ Maneuvering. Start when the skidder reach to the suitable location and ended when the skidder maneuver and prepare for winching
- ⇒ Release: Begins when the hooker pull out the cable and ended when cable reach to the log
- ⇒ Hook: the time that hooker positioning a choker at the end of the log
- ⇒ Winch: Began when the chooser sat the choker and ended when the load was winched to the arch;
- ⇒ Travel loaded: Begins when the skidder starts toward the landing full of felled stems. End when the skidder reaches the landing with the logs.
- ⇒ Unhook: Begins when the skidder operator gets out unhooking felled stems. Ends when the skidder starts piling
- ⇒ Pile: start when skidder tries to move logs with skidder's blade, finish when logs put down on the other logs along side of forest road or landing.

Mean volume hauled per skidder cycle was m^3 in parcel 319 and m^3 in parcel 331. F-tests were employed to test the homogeneity of variance, and equal- or unequal- variance t-tests were used to determine the significance of difference observed component. Difference were considered statistically significant at $p \le 0/05$.

2.8 Trees impacted by winching operations

The sample plots were 50 winching lines pulse a 3 m buffer strip on each side of winching lines (Jackson et al. 2002). Lengths of winching lines were measured and tree damage was tailed along each buffer according to location and severity of the wound (Table1, (modified from Jackson et al. 2002). To adjust for differences in pre-harvest trees density among stands and individual winching lines lengths, the percentage of trees damaged per unit length of winching lines was calculated

Table 1: Classification of damage sustained by residual tree's along skid trail and in felling gaps (modified from Jackson et al. (2002))

Damage type	Bole	Root	Crown
Severe	Snapped at base, bent, or severely leaning	uprooted	Loss of entire crown; loss of less than entire but more than two third of crown
Moderate	Exposed and damaged cambial tissue	Exposed and damaged cambial tissue	Loss of less than two-thirds but more than on third of crown
Minor	Exposed cambial tissue but no damage, bark scrape	Exposed cambial tissue but no damage, root scraped	Loss of less than one-third crown

2.9 Assessing residual trees damage associated with skidding operations

All skid trails in each of parcels were mapped and delineated into two classifications (modified from Whitman et al (1997)). (1) Primary skid trails that constructed with bulldozer with cut and fill; (2) temporary pathways used to shuttle logs and trees out of the woods to a deck or landing area by skidder operator without any cut and fill. The lengths of individual skid trails were measured, and trees damage was tallied along the entire length of all primary and secondary skid trails plus a 2 m buffer strip on each side according to location and severity of the wound (Table 1, modified from Jackson et al. 2002)). To adjust for differences in pre-harvest trees density among stands and individual skid trail lengths, the percentage of trees damaged per unit length of skid trail constructed was calculated.

2.10 Additional costs of landing construction in planned logging and conservation and maintenance of road in current logging

All of extracted logs were delivered alongside of forest road in parcel 319. Using from forest road as a landing disturbed surface of road. According to forestry plan about 20% cost of forest road construction will be used for forest road repair man maintenance. For this purpose we calculated the volume of extracted wood in parcel 319. Cost of forest road repair and maintenance estimated for each m^3.

Two landing was designed and constructed in parcel 331. Therefore all of extracted logs delivered in planned landing. Cost of landing construction for each $m^3$of timber estimated by dividing volume of extracted wood per cost of landing construction.

3 Results

3.1 General assessment of felling operation

A mean tree felling error of ± 75.14° (SE. =5.38, n=100) was observed for felling operation in current logging and ± 45.42° (SE.2.29 n=100) for planned logging. Applying planned logging significantly reduced felling error about 29.32° Marking skid trail and create a visual condition for felling crew helped to decreasing felling error in planned logging.

3.2 Felling efficiency

A comparison of the time distribution of work elements that occurred in felling a single tree under the two logging systems reveals the following:

The average time spent to fell a single tree under current logging is more than in planned logging with considering delay time. but difference was not significant (F=10.824, df=188, P=0.405).Mean acquire times significantly increased in planned logging compared with current logging (F= 10.557, df =188, P= 0.0001). Identifying the best path for direction of felling with due attention to skid trail, residual stand and regeneration increased acquire times in planned logging .Delay time in planned logging decreased compared with current logging but difference was not significant (tale 2 student's t-test; P=0.136). Personal delay time, technical delay time(in this study, most of delay time in felling was related to this type of delay ,include changing the chain on chainsaw, pinching and filing) and performing delay time (is related to inappropriate planning or incorrect management such as borrowing wedge or other tools of other groups) are the common type of delays in current logging delay time decreased 9% compared with current logging by using felling pattern and equipped felling crew with new felling tools in planned logging . No significant differences were observed in adjusted mean walk to tree, undercut and back cut between treatments (Student's t-test; P ≥ 0.05).

The estimated production rates for felling operations under both current logging and planned logging are based on the total time used to produce a certain volume of timber. Volume per tree harvested has been calculated volume table according to diameter of each species. Times used in the calculations are workplace time excluding meal time.

Table 2: Comparison of felling efficiency data between treatments [a]

Treatment	Mean cycle time components (second)					Mean diameter	Mean cycle distance	Replication
	Walk to tree	Acquire	Undercut	Back cut	Delays			
Normal logging	52^a	23^a	96^a	111^a	76^a	69^a	31^a	95
Planned logging	41^a	53^b	88^a	112^a	39^b	65^a	29^a	95

Means with the same letter within columns are not significantly deferent (Student's t-test; P > 0:05)

3.3 Residual tress damage by felling operation

Decrease of felling error in planned logging and ability of felling crew to accurately and consistently fell trees in the desired during felling caused damage to residual trees due to felling was significantly reduced in planned logging (Student's t-test; p = 0.018). Current felling operation damaged nearly 13.6% of residual trees, while felling in planned logging damaged only 10.4% of residual trees. The results support the idea that accurate directional felling of trees necessarily involves the use of felling wedges (ITTO, 1996b).

3.4 Skidding efficiency

Table 3 shows the mean cycle time required to skid a turn and its distribution among various work elements. Mean skidding cycle time decreased in planned logging compared with the normal logging but difference was not significant (table 3; student's t-test; P= 0.059). In planned logging skidder operator restricted to leave the skid tail, therefore chooser spent more time for pulling cable to the end of logs .Also winching distance in planned logging increased compared with normal logging but difference was not significant. Accidental pattern of normal felling increased winching time compared with planned logging (table 3; student's t-test; P=0.259) .sometimes logs hit to another stump or felled tree therefore winching time increased. Designing skid trail before felling and landing construction significantly decreased travel loaded and delay time in planned logging (table 3; student t-test; P=0.008) adjusted for standard travel distance. Logs decked along of forest road in current logging and in each turn operator should search location for extracted logs. Sometimes he obliged to skid the logs on the forest road until finding suitable location for piling therefore travel loaded time increased .Also skidding logs on the forest road can demolish forest road. Planning and construction of landing not only reduce travel loaded time but also prevent forest road from demolition. No significant difference were observed in adjusted mean travel empty, maneuvering, release, and hook, winching, unhook and pile time between treatment (table 3; student's t-test; p ≥ 0.05).

Table 3: Comparison of skidding efficiency data between treatments [a]

Treatment	Mean cycle time components (second)									
	Travel empty	Maneuvering	Release	Hook	Winching	Travel loaded	Unhook	Pile	Delay	Mean cycle time
Normal logging	172[a]	35[a]	67[a]	82[a]	90[a]	262[a]	42[a]	107[a]	279[a]	18.94[a]
Planned logging	163[a]	35[a]	103[a]	85[a]	74[a]	163[b]	46[a]	90[a]	167[b]	15.43[a]

Means with the same letter within columns are not significantly deferent (Student's t-test; P > 0:05)

3.5 Trees impacted by winching operations

Using from directional cutting and herringbone pattern for felling decreased impact to residual stand in winching line. Prevent from log turning in planned logging significantly decreased residual impact to trees in winching line (student's t-test; P=0.012).Table 4 shows results.

Table 4: Comparisons of the percentage of trees damaged per 100 meters of winching line in two logging method. Average length of winching lines in parcel 331 (24m) was longer than parcel 319 (20m)

Study area	Number of total trees	Number of impacted trees	Percent
Normal logging	12.76	4.16	32.60
Planned logging	11.61	2.8	24.12

3.6 Trees impacted by skidding operation in skid trails

The lengths of individual skid trails and residual damage along them plus 2 m buffer were measured. Then trees damage was tallied along the entire length of all skid trails according to location and severity of the wound. A summary of tree damage incurred along skid trails is presented in Table 5. If the total imputed trees of current logging are assigned an index value of 100%, then the impacted trees for planned logging, as applied on sample unit Parcel 331, is 79%. It is important to note that this significant reduction in impact was achieved with designing skid trail and using maximum capability of winching of skidder.

Table 5: Total length of primarily and secondary skid trail and related impact to alongside trees

Skid trail classification	Current logging	Planned logging
length Primary skid trails	2101.3	1797
length of Secondary skid trails	1835	0.00
number of trees along Primary skid trail	232	276
number of trees along secondary skid trail	203	0.00
number of impacted trees along Primary skid trail	131	163
number of impacted trees along secondary skid trail	100	0.00
total impacted trees	231	163

3.7 Economic consideration

Economic considerations from this study are summarized in Table 6. Improved skid trails helped the felling group to guide direction of felling toward them. Forest manager didn't spend any cost for this work only changed the time of planning from after to before of felling. Estimated production costs are based on the logging production rates and the hourly costs for the logging workforce involved in logging activities. To obtain hourly costs for the skidding and felling crew, the monthly costs in Table 6 were divided by 176 working hours, assuming 22 working days per month and 8 working hours per day. Table 7 summarizes the labor cost per cubic meter of logs delivered to the landing for two logging method. Forest road was used as a landing in normal logging. Therefore repair and maintenance cost of road was estimated. According to district action plan annually 2,500,000 Rial (270.27$) spent for repair and maintenance of 1 km forest road. About 1.1 km of district road used for log landing in parcel 319 and 2290.89 m^3 wood extracted from this parcel therefore repair and maintenance cost of forest road per cubic meter of logs was 1200 Rial (0.13$).

Table 6: Summary of economic considerations associated with modified logging practices in Caspian forest

Activities	Normal logging		Planned logging	
	Productivity [m³/h]	Cost [Rial/m³]	Productivity [m³/h]	Cost [Rial/m³]
Felling	53.17	4514=0.49$	49.09	4893=0.53$
Skidding	13.33	63159=6.83$	15.97	52768=5.70$
Cost of Forest Road Maintenance		200 =0.13$	Cost of Landing Construction	485 =0.05$
Total costs		68873=7.45$		58146=6.29$

1$=9250 Rial

Table 7: Forest employee compensation levels for this study according to Shafarood 2005*

Category	Job title	Compensation[Rial** / month]
Felling		
	Operator	4850000 = 524.32 $
	Assistant	4250000 = 459.45 $
Skidding		
	Operator	5500000 = 594.59 $
	Assistant	4350000 = 470.27 $
	Chooser	4150000 = 448.65 $
Other		
	Cook	3750000 = 405.41 $
	Driver	5100000 = 551.35 $

*Data in this table is the average forestry worker salary in Caspian forest .they may receive some premium and gratuity in month. The salary of forestry worker depended to work experience. Worker with more experience will receive more salary.

**1$=9250 Rial

For estimating cost of landing construction, machine rate (bulldozer) per each hour was 181955 Rial (19.67$). About 3000 cubic meter wood extracted from parcel 331 therefore construction cost of landing per each cubic meter was 485 Rial (0.05$).

Those logging activities that are carried out differently in the two systems were considered. These include felling and skidding operations. Costs for equipment and other costs such as road infrastructure and long-distance transport are not included. Skid trail flagging also hold great potential for mitigationing damage caused by felling operation in this study area. It means that it will be yield economic return only in the next cutting cycle. Skid trail planning, landing construction and directional cutting as a best management practice not only reduced cost of operation about 15.35% but also be expected to yield financial benefit in the next harvest through a 23%, 26% and 21% reduction residual damage in felling gap, winching line and along skid trail. Also study of disturbed area in this study showed that in planned logging with designated skid trails and landings marked in the field before felling commenced, the area used for primary skid trails amounts to 1% of the 74ha harvested on parcel 331, whereas in current logging the corresponding figure is 2.62 of the 74 ha harvested on Parcel 319. Therefore the implementation of planned logging systems, where the skidding machines remain on the designated skid trails at all times, is deemed highly necessary to permit the attainment of a significant reduction in soil disturbance and soil compaction. Unnecessary damage to residual trees and advance regeneration is also avoided by keeping the skidding machinery on the skid trails. This rudimentary estimate should provide sufficient incentive to justify investing planned logging.

4 Discussion

Damage to residual stand caused by normal logging could be reduced in Caspian forest in a cost-effective manner. As a first step forest manager should be planned all skid trail and landing prior to felling operation. Marked skid trail will help to felling crew for directional cutting. Felling crew try to fall trees toward or opposite skid trail. This will result in increased skidding efficiency and reduced residual tree's damage (Gerwing et al. 1996; Johns et al. 1996; Barreto et al. 1998; Boltz et al. 2001; Holmes et al. 2002).

Designed skid trail will reduce disturbed area and residual stand damage along of skid trails. Landing construction helped to skidder operator for finding suitable place for pilling. Log piling in designed landing will increase skidding efficiency and help forest road for preserves from demolish and erosion caused by log landing along of them.

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