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A survey of forest harvesting on stand destruction and regeneration

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Abstract

Harvesting in any way will damage the residual stand and regeneration; however reasonable efforts to mitigate the intensity of these damages will lead to a sustainable forest. This study examines the damages in District 2 Series 2 of Neka - Zalemrood. In order to estimate harvesting injuries, two separate forms were prepared for stand injuries and regeneration damages and sampling were done in two phases, after cutting and after extracting wood. First, the data follow was investigated in normal distribution and data analysis was performed using SPSS software and paired t-test. Results showed that with 95% probability damages on stand after cutting were 8.2% and after extracting wood were 5%. In regeneration section after cutting 2.9% of stand were damaged and 3.2% were destroyed and after extracting timbers 1% Were damaged and 10.2 % were destroyed.

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Introduction

Forest harvesting includes cutting operations, transferring loads from stump to roadside depot and transferring loads from roadside to consumption place or factory and the outcome of these steps bring about the forestry operations and products are sent to markets. Harvesting has always had harmful effects on forest ecosystem operations. Damage to residual trees, natural regeneration and destruction of topsoil are the most important impacts of harvesting operations and extracting wood from forest stand (Naqdi, 2004). Due to wrong cut, a number of trees in the path of the falling trees will be damaged severely. Then skidder across skidding logs and multiple transferring on the skidding paths, will damage the path side stem. Hoseini (1994) on his Master's thesis entitled "A review of harvesting injuries on forest stand" observed that ground skidding systems in Shelter wood cutting forestry practices damage more than 39% of the residual trees in the stand.

Tashakori (1996) on his Master's thesis entitled "A review of harvesting injuries on forest stand trees of Golendrood" with traditional way of harvesting, examined injuries on regeneration and standing trees. Injuries to the regeneration includes browsing seedlings and saplings with 51.4% of the total number of seedlings and saplings, crown and stem bending of saplings and thicket with 7.4% of the total number of them and destruction of saplings and thickets stems with 4.2% of the total sample, which were measured. Naghdi (2004) on his study evaluated parcel 75, 76 and 77 District 2 Series 7 of Neka with industrial procedure by skidder Timberjack, and compared the Injuries in two sections of tape winching and skidding paths by two methods of whole cutting harvesting and log harvesting. He concluded that the injuries in regeneration were 10.6% on seedling growth, 16.2% on sapling and 18.5% on thicket.

Ghafarian *et al* (2005) in their study of the training forest of Kheyroudkenar with 5 meters wide and 45 meters long which was affected by traditional skidding by means of mule and carrying timber, concluded that seedling injuries was 58% which Injured trees were 31% and destroyed ones were27%. He eventually estimated the level of damage to seedling, regarding parcels, in sum 3.2%.

Lotfalian (2005) performed his study in Parcel 17 and 28 of Watson series and Parcel 7 of Alandan Series in Mazandaran Forest of Wood and Paper industry with industrial procedure by skidder HSM and Timberjack (both rubber wheeled) and came to the conclusion that damage was 3.2% on the regeneration of seedlings, 10.5% on sapling , 17.7% on thicket, and the total amount of damage was 4.8 percent. Meanwhile, he also found that by increasing the diameter and height of trees, the degree of damage was also added. Lamson *et al* (1985) in their study of the injuries caused by the use of a single selection mode by manual cutting(chain saw) and ground skidding systems in twelve hectares of Broadleaf stand, evaluated injuries on four groups of destructed and eradicated trees, injuries on skin and outside part of wood, seedlings bending, crowns and branches breaking. In this study, eradication and complete destruction damage of trees by an average was 47 trees per acres, injuries associated with trees bending was by an average 33 trees per acres, damages to injuries on bark were by an average 79 trees per acres, and the crowns and branches losses were 34 trees per acres.

Dayled and Granhus (1998) in their research entitled "Harvesting injuries in multistoried spruce stands and the impacts of operational systems and operation severity" evaluated mechanical damage of single selection mode in Norway multistoried spruce stands that was done by manual, motor and cable methods. The maximum difference between two systems regarding the severity in harvesting was more in stands with high balance. The greatest damage was related to the mechanical harvesting of a stand that is affected by trees control.

Newton *et al* (2006) in a study, entitled "Effects of harvesting on regeneration of two-storied Douglas-fir stands" in West Oregon showed that harvesting was carried out by cable and ground equipment with whole cutting method. They had found that 40 percent of planted seedlings were damaged due to harvesting and also 18 to 30 percent of survived seedlings during harvesting were buried under the remained wood chips. In addition, 13 to 16 percent of trees were broken or bent by an angle of 45 degrees. Stokes *et al* (2009) in a study titled "Seedling height and the impact of harvesting operations on advance regeneration of conifer species in upland Britain" performed their evaluation at three different sites that showed short-term thinning operations impacts on survival or regeneration damages in various heights of seedlings. In one of the sites with the dominant species of Sitka spruce, destroyed small size (less than 50 cm) and medium size (200 to 50 cm) seedlings during harvesting were significantly higher than the number of large seedlings (More than 200 cm). Also at the sites with the dominant species of Japanese Larix the state of injuries were not related to the size of seedlings but were significantly related to the distance from the nearest tape of extracting wood. In any case, harvesting forest is an imperative. Yet we know that the machinery transportation for transferring timbers on the forest floor causes some damages to residual stands. Therefore, to identify the damage resulting from harvesting, to specify the parts of stands with greater injuries, and the steps which are taken to prevent or reduce the effects of harvesting on forest, we had decided to conduct this study.

By investigating the damages of harvesting, the parts of stands that is most vulnerable, and the steps of harvesting which has taken, we can accurately, efficiently and virtually with no cost and just by improving adopted methods, lessen harvesting and regeneration injuries, and perform harvesting operation used in accordance with accepted standards.

The aim of this study is a Survey Of forest harvesting on stand destruction and regeneration in the Neka – Zalemrood forest in Hyrcanian forest (north of Iran).

Materials and methods

Study area

This study was conducted in district 2 Series 2 of Nekachoob. Series 2 has 25 parcels and the used parcels in the current year were parcels 9 and 24, and the specifications are as follows:

Parcel 9 is called Gavazn-Kheyl forest which has an area of 40.5 hectares and useable area of 26 hectares. Minimum and maximum altitude from sea level is 580 and 710 meters, respectively. The general characteristic of forest is elderly and middle-aged high forest with artificial middle regeneration. Earlier cuts made in this parcel were single-selection mode and whole cutting.

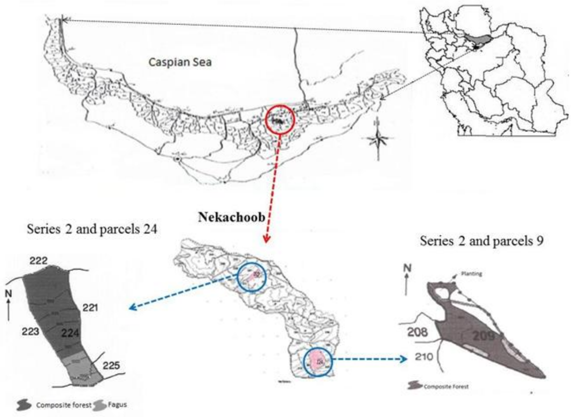

Fig. 1. Location of study area in the Mazandaran province (north of Iran).

Parcel No.
24 is called Kooran-Geli which has an area of 60.3 hectares and useable area of 56.3hectares. Minimum and maximum altitude from sea level is 750 and 1060 meters, respectively. The general characteristic of forest is elderly and even-aged high forest with poor regeneration.

For the evaluation of damages on stand and regeneration, a systematic random sampling technique was used. For this purpose, circle shaped plots were used, which had respectively an area of one R with 5.64 meters radius and 10 R with17.84 meters radius in the horizontal plane. Number of plots according to equation $n=\frac{t^2 \times (sx\%)^2}{(E\%)^2}$ for Parcel 9 and 24, is evaluated 20.Then put the network on the map, and GPS coordinates into the map so the damages of harvesting and regeneration parts were identified that during the operation 5pieces of samples were removed because of being in the open area with no vegetation. As far as we were considering harvesting damages, we had to evaluate damaged stands and regeneration once after cut and once after extracting timbers so the first stage of sampling was performed in August and the second stage in late September. In order to assess the regeneration residual trees damage measured the tree and regeneration information include: Stem quality, Healthy, Injury class, Dimensions, Proportion to environment, Height, Shape, Cause and Crown injury.

To avoid ambiguity the way of considering parameters are listed below some of them are as follows:

Stem quality: to evaluate the studied trees, they were considered from breast height to approximately 6 meters (given that the highest quality of a tree belongs to its first 6 meters) and the classification is as follows:

Class 1: has a smooth body without twisting or big nodes, suitable for veneering
Class 2: has a little twisting and nodes, suitable for timber extracting
Class 3: knotted trunks, probably worn and proper for firewood and cellulose industry

Injury Category: for diagnosis of type and importance of injuries, were divided into four classes:
Class 1: Change of the color caused by any contact or collision with tree
Class 2: Bark damage but no damage to the cambium layer
Class 3: Complete detachment of bark with a layer of cambium
Class 4: Detachment of bark and cambium layer and damage to the peeled xylem

Dimensions: The dimensions of each injury length and width in this column are listed in cm in order to calculate the area of injury. In the case of many injuries on each tree, the area of total injuries is registered.

Environment proportion: along the length of the tree, the tree will not see much damage. 4 classes for this purpose, the extent of the injuries were considered:
Class 1: less than 10%
Class 2: 10 to 30%
Class 3: 30 to 50%
Class 4: More than 50%

Height: The height of the damage median from collar is measured in centimeters and recorded with the following classes:
Class 1: Injuries on along roots
Class 2 Injuries to the height of half a meter
Class 3: Injuries in the height of half to one meter
Class 4: Injuries in the height of one to two meter
Class 5: Injuries in the height of over two meters

Shape: Injuries figures are in different shapes that are round shaped (or oval), band (or rectangular) and irregular (or star).

Cause: The most important part of the inventory is at this column, because the aim of this study is to modify job procedures and prevent damages.

1-Dropping tree, preventable (Inappropriate falling direction, improper cutting method, not using the right tools, etc.)
2-Dropping tree, unpreventable (cutting direction for suitable skidding, properly cutting, stand density, etc.)
3-Log transferring
4 –lopping
5- Winching, preventable (improper choice for winching path, improper cutting direction, etc.)
6-Winching, non-preventable (proper choice for winching path, proper cutting direction, etc.)
7 -The skidder movement, preventable (bad road design, cross slope, skidder deviation from the path, etc.)
8- The skidder movement, non-preventable (right path design, no skidder deviation from the path, etc.)

Canopy damage: for injury assessment of trees, their levels of injury were also examined and recorded with the following classes:
Class 1: less than 10% canopy fracture
Class 2: between 10 to 50% of fracture
Class 3: more than 50% fracture
Class 4: the complete destruction of the crown or trunk fracture

To assess the natural resurgence damage after determining the plot and its range, regeneration is studied and the columns were written and filled in form.

Amount: in regeneration there are many seedlings with the same species which are near to each other and all of them are healthy, in such cases we do not have a specific number for each and no column will be filled, but a number will be given and their amount is listed in the last column.

Results

Damages to the stand: By recording data, it can be comprehended that some data are qualitative information and they need to be converted to numeric ones. Therefore, all data were converted to quantitative ones using Excel software.

After cutting:

$$P_i = \frac{\Sigma Y_i}{\Sigma X_i} \rightarrow P_i = \frac{28}{338} = 0.082$$

$$S_y^2 = \frac{\Sigma y2 - \frac{(\Sigma Yi)2}{n}}{n-1} \rightarrow S_y^2 = \frac{78 - \frac{(28)2}{15}}{14} = 1.83$$

$$S_x^2 = \frac{\Sigma x2 - \frac{(\Sigma xi)2}{n}}{n-1} \rightarrow S_x^2 = \frac{9088 - \frac{338}{15}}{14} = 105.12$$

$$S_{xy} = \frac{\Sigma xy - \frac{\Sigma x \Sigma y}{n}}{n-1} \rightarrow S_{xy} = \frac{633 - \frac{338*28}{15}}{14} = 0.147$$

$$SPi = \sqrt{\frac{1}{\bar{x}2}\left[\frac{Sy2 - Pi2Sx2 - 2PiSyx}{n}\right]}$$

$$SP_i = \sqrt{\frac{1}{(22.53)2}\left[\frac{1083 - (0.082)2(105.12) - 2(0.082)(0.147)}{15}\right]} = 0.012$$

$$\%SP = \frac{SPi}{Pi} \times 100 = \frac{0.012}{0.082} \times 100 = \%14.63$$

$$E = \pm t \times SPi = 1.96 \times 0.012 = 0.02$$

$$P = pi \pm E \rightarrow 0.082 \pm 0.02 \quad \rightarrow \quad 0.062 < P < 0.102$$

So with 95% probability, the rate of the stand damages after cutting was between these two values:

After extracting:

$$P_i = \frac{\Sigma Y_i}{\Sigma X_i} \rightarrow P_i = \frac{17}{338} = 0.050$$

$$S_y^2 = \frac{\Sigma y2 - \frac{(\Sigma Yi)2}{n}}{n-1} \rightarrow S_y^2 = \frac{23 - \frac{(17)2}{15}}{14} = 0.26$$

$$S_x^2 = \frac{\Sigma x2 - \frac{(\Sigma xi)2}{n}}{n-1} \rightarrow S_x^2 = \frac{9088 - \frac{(338)2}{15}}{14} = 105.12$$

$$S_{xy} = \frac{\Sigma xy - \frac{\Sigma x \Sigma y}{n}}{n-1} \rightarrow S_{xy} = \frac{412 - \frac{338*17}{15}}{14} = 2.07$$

$$SPi = \sqrt{\frac{1}{\bar{x}2}\left[\frac{Sy2 - Pi2Sx2 - 2PiSyx}{n}\right]}$$

$$\rightarrow SP_i = \sqrt{\frac{1}{(22.53)2}\left[\frac{0.266 - (0.050)2(105.12) - 2(0.050)(2.067)}{15}\right]} = 0.005$$

$$\%SP = \frac{SPi}{Pi} \times 100 = \frac{0.005}{0.05} \times 100 = \%10$$

$$E = \pm t \times SPi = 1.96 \times 0.005 = 0.0098$$

$$P = pi \pm E \quad \rightarrow \quad 0.040 < P < 0.0598$$

So with 95% probability, the rate of the stand injuries after extracting timbers was between these two values:

Table 1. the rate of the stand damages after cutting.

	Amount	Percentage	*P*	*Spi*	*E*	*Limit % P*
Healthy	310	91.7	–	–	–	–
Injured	28	8.3	0. 082	0.012	0.02	6.2 - 10.2
Total	338	100	–	–	–	–

To compare the data, first the data follow of a normal distribution were evaluated by chi-square test that the data showed normal results. The average stand damages after harvesting were compared with the same region before harvesting using a paired t-test (t Test). For this purpose the number of trees was calculated by converting all trees to a medium quality multiplied with stock per hectare. Then, the damaged trees caused by harvesting were converted to medium quality ones, after that the value is deducted from the initial numbers and they will be compared in order to calculate their meaningfulness or non-meaningfulness with SPSS software.

Table 2. Rate of the stand injuries after extracting timbers.

	Amount	Percentage	*P*	*Spi*	*E*	*Limit % P*
Healthy	321	94.9	–	–	–	–
Injured	17	5.1	0.05	0.005	0.0098	4 - 5.98
Total	338	100	–	–	–	–

Table 3. Results of paired t-test and quality condition of tree.

of tree			paired t-test (t Test)				
Change sources	Average	Standard deviation	Change sources	Freedom degree	Mean Square	*F*	*sig*
Number of trees converted to medium quality	23/35	12/22	Between groups	1	346/56	0/065	0/800
Number of trees converted to medium quality after harvesting	26/66	26/36	In the groups	28	5599/85		

Regeneration damages

For this information after naming the plots, other columns were recorded with code.

-After cutting

$$P_i = \frac{\Sigma Y_i}{\Sigma X_i} \rightarrow P_i = \frac{70}{1144} = 0.061$$

$$S_y^2 = \frac{\Sigma y2 - \frac{(\Sigma Y_i)2}{n}}{n-1} \rightarrow S_y^2 = \frac{736 - \frac{(70)2}{15}}{14} = 29.23$$

$$S_x^2 = \frac{\Sigma x2 - \frac{(\Sigma x_i)2}{n}}{n-1} \rightarrow S_x^2 = \frac{170042 - \frac{1144}{15}}{14} = 5913.78$$

$$S_{xy} = \frac{\Sigma xy - \frac{\Sigma x \Sigma y}{n}}{n-1} \rightarrow S_{xy} = \frac{10165 - \frac{1144 * 70}{15}}{14} = 344.73$$

$$SPi = \sqrt{\frac{1}{\bar{x}2}\left[\frac{Sy2 - Pi2Sx2 - 2PiSyx}{n}\right]}$$

$$SPi = \sqrt{\frac{1}{(76.26)2}\left[\frac{29.23 - (0.061)2(5913.78) - 2(0.061)(344.73)}{15}\right]} = 3.97*10^{-4}$$

$$\%SP = \frac{SPi}{Pi} \times 100 = \frac{3.97*10-4}{0.061} \times 100 = \%0.65$$

$E = \pm t \times SPi = 1.96 \times 3.97*10\text{-}4 = 0.77*10\text{-}3$

$P = pi \pm E \rightarrow 0.061 \pm 0.77*10^{-3}$

$0.060 < P < 0.061$

So with 95% probability, the rate of regeneration damages after cut was between these two values:

After extracting timbers

$$P_i = \frac{\Sigma Y_i}{\Sigma X_i} \rightarrow P_i = \frac{187}{1675} = 0.111$$

$$S_y^2 = \frac{\Sigma y2 - \frac{(\Sigma Y_i)2}{n}}{n-1} \rightarrow S_y^2 = \frac{9065 - \frac{(187)2}{15}}{14} = \frac{6734}{14} = 481$$

$$S_x^2 = \frac{\Sigma x2 - \frac{(\Sigma x_i)2}{n}}{n-1} \rightarrow S_x^2 = \frac{436643 - \frac{187041}{15}}{14} = 17828$$

$$S_{xy} = \frac{\Sigma xy - \frac{\Sigma x \Sigma y}{n}}{n-1} \rightarrow S_{xy} = \frac{49713 - \frac{1675 * 187}{15}}{14} = 2059.38$$

$$SPi = \sqrt{\frac{1}{\bar{x}2}\left[\frac{Sy2 - Pi2Sx2 - 2PiSyx}{n}\right]}$$

$$SPi = \sqrt{\frac{1}{(111.66)2}\left[\frac{481 - (0.111)2(17827) - 2(0.111)(2059.38)}{15}\right]} = 1.04*10^{-3}$$

$$\%SP = \frac{SPi}{Pi} \times 100 = \frac{1.04*10-3}{0.111} \times 100 = \%0.93$$

$E = \pm t \times SPi = 1.96 \times 1.04*10\text{-}3 = 0.002$

$P = pi \pm E \rightarrow 0.111 \pm 0.002$

$0.109 < P < 0.113$

So with 95% probability, the rate of regeneration injuries after extracting wood was between these two values:

Table 4. the rate of regeneration damages after cut.

	Amount	Percentage
Healthy	1074	93.9
Injured	33	2.9
Destroyed	37	3.2
Total	1144	100

Table 5. Rate of regeneration injuries after extracting wood.

	Amount	Percentage
Healthy	1488	88.8
Injured	17	1
Destroyed	170	10.2
Total	1675	100

To compare the data, first the data follow of a normal distribution were evaluated by chi-square test that the data showed normal results. The average regeneration damages after harvesting were compared with the same region before harvesting using a paired t-test (t Test). For this purpose the number of initial regeneration per hectare was compared with deducted amounts of harvesting injuries in order to calculate their meaningfulness or non-meaningfulness with SPSS software.

Discussion and conclusions

In this study with 95% probability the rate of stand damages after cutting is between 6.2 and 10.2 percent, in other words cutting and converting operation is damaged 8.2% of residual trees that 35% of them were preventable. 7% of damaged trees in the cut plots were beech, 68% hornbeam and 25% were other species like alder, oak and maple trees. Naqdi *et al* (2007) in their review assessing stand injuries with 100% inventory, concluded that 21.8% of trees have been damaged as a result of cut that 84 percent of injured trees were beech, 8.9 percent hornbeam, and 7.1 percent other species. Difference in excessive amounts of injury differentiation is caused by variation in forest type, in this study forest type is mixed but in Naqdi's it was beech. Lotfalian *et al* (2007) in their study concluded that 13.6% of residual tree were injured due to cut and convert operation that these little difference is caused by stock per hectare. Jorgholami and Rizvandi (2011) in their study of the short log harvesting concluded that 16.4% of trees were damaged, but the severity of damages in diverse species is different. Naqdi *et al* (2008) in their study evaluated residual trees damages in cut openings and concluded that 17.5% of residual trees are damaged and increase in damages amount is caused by 100% inventory. Majnounian *et al* (2009) in their study entitled "A survey of harvesting damages impacts on regeneration and standing stand" came to the conclusion that after cutting 7 percent of trees were injured. In Their research the dimension of network was 50 × 50 and sample plot was 5 R but in this study the dimension of network is 250 × 250 and sample plot is 10 R.

In our study we concluded that 95% of damages to stand after extracting wood is between 4 and 5.98 percent, in other words extracting wood operation damaged 5 percent of residual trees. Among the studied trees, 12% of them had grade 1 injury, 47% grade 2 injuries, and 41% injury. Lotfalian *et al* (2007) estimated total harvesting injuries as 15.5% and by knowing the amount of stand injury after cutting, the percentage of stand injury after extracting would be 1.9 %. Majounian *et al* (2009) in their study evaluated standing trees injuries in Shelter wood cutting method and concluded that among studied trees 10.5 percent had grade 1 injury (scratch and bark color change), 29.8% had grade 2 injury (damaged bark without peel off), 59.7% had grade 3 injury (bark peeled with cambium).

Naqdi *et al* (2007) in their study assessed the damage to residual trees in extracting wood path and concluded 42.5% of the residual trees were damaged. They also reported that damages resulting from load piling operation have larger area than injuries resulting from cutting operation. Indeed in this study after piling and extracting wood 53 percent of injuries are class 2(10 to 30 percent proportion to environment), 47 percent of injuries are class 3 (30 to 50 percent proportion to environment), however after cut 32 percent of injuries are class 2, 57 percent are class 3 and 11 percent are class 4 (more than 50 percent proportion to environment). The results showed the most damages included small area ones, which is in accordance with Majnounian *et al* (2009) research.

Table 6. results of paired t-test and regeneration condition of tree.

regeneration condition			paired t-test (t Test)				
Change sources	Average	Standard deviation	Change sources	Freedom degree	Mean Square	*F*	*sig*
Number of initial regeneration	74/20	77/45	Between groups	1	346/56	0/065	0/800
Number of regeneration after harvesting	67/22	72/11	In the groups	28	5599/85		

Damage to regeneration

Due to close to nature forestry practices for the management of northern forests, reducing residual stand and regeneration damages become more important. Hence, this study also aimed to determine the damage to regeneration. The results of study after cutting showed that with 95% probability the rate of regeneration damage is 2.9% and destroyed one is 3.2% which 14.8% of it is preventable. 2% of seedlings are damaged and 4.5% are destroyed. 7.1%of saplings are damaged and 1.9% is destroyed completely. Lotfalian *et al* (2007) in their study of regeneration damage after cut reported 3.2 percent that 5% of them were preventable. Majnounian *et al* (2009) in their study of harvesting damages on regeneration ad standing mass concluded 22 percent of regeneration is damaged after cut. They have also found that the amount of damage to seedlings is lower than saplings and thickets group that is consistent with the present study.

The results of damage to regeneration after timber extracting also showed that with 95% probability the rate of damaged regeneration is 1% and destroyed one is 10.2% which 12% were preventable. Ghafarian *et al* (2005) in their study entitled “A survey of forest injuries caused by extracting wood by traditional method” concluded that 27 percent of seedlings are injured and 31 percent are completely destroyed. Jorgholami and Majnoonian (2010) investigated traditional method in their study and concluded that 22 percent of forest revitalization is injured for extracting wood with mule. They have also concluded that cable tapes injured regeneration 44 and 36 percent; in short log and long log method, respectively. Lotfalian et al (2006) in their study reported the rate of regeneration after winching and extracting wood as 4.8 percent that 8% of them were preventable.

For the prevention of damages caused by cutting:

-Cutting team has to be trained frequently, the number of them should increase and it is necessary for them to spend more time for cutting.

- Cutting team performance should be rewarded or punished for their work quality not work hours.
- Tirfor and proper training is essential in times of need. Cutting team should have proper equipment for cutting trees.

It is needed to be more careful in the design and construction of skidding path, for this purpose:
Skidding path standards should be met. Skidding path design should be examined carefully and should be performed by several alternatives. Only in times of need bulldozer should be used in skidding path.

It is necessary for skidding teams to be trained in the following:

Skidder should never deviate from the skidding path. The chokerman have to specify winching path before skidder.

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