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## Research Article

# Estimating of Volume and Weight of Logging Residue from Selection Cutting Under Different Ground Slopes in Hyrcanian Forest

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**Abstract:** In this research volume and weight of logging residue were estimated in two compartments with different ground slopes (upper and lower than 50%) in Hyrcanian forest of Iran. The results showed that the means of volume, weight and number of logging residual was significantly higher in the slopes of > 50% than slopes of < 50% ($P < 0.05$). The mean of logging residual volume in the slopes of < 50% and > 50% were 3.56 ± 0.38 and 4.62 ± 0.45 $m^3.ha^{-1}$. The mean of pieces volume, weight, length and diameter in slopes of > 50% was significantly higher than slopes of < 50%. The ratio of residue volume to logging volume in the slopes of > 50% were estimated 21.2%, while in the slopes of < 50% were estimated 17.1%. In the northern forests of Iran each logging planning should be assessed regarding feasibility residue collection and transportation. Utilization of logging residue requires careful planning.
**Keywords:** Logging residue, Selection cutting, Ground slope, Cable skidding, Uneven aged stand, Nav forest

## INTRODUCTION

Logging residues are the most challenging bio-energy resource and a raw material for forest products industry. Currently, wood contained in logging residues is suitable for use in many engineered wood products and potentially, for other value-added products in future markets. The potential for energy production from logging residue exist. One source of woody material receiving much attention is logging residue. Logging residues are woody materials that left in the forest after timber harvesting [1]. Logging residues includes the tops of harvested trees, branches, wood that has an underdeveloped market or is a poor form and thus not marketable [2-4]. Logging residues on the base of size, quality and species can use in different wood industries such as particle board, parquet, paper, box making and chemical conversion or fuel uses. On the other hand, future site productivity can be impacted by the additions or removals of logging residues. There are few major issues for retention logging residues on sites: providing wild life habitat, minimizing soil erosion, protecting soil productivity and protecting riparian areas. Increased demand for woody biomass is considered to generally have potentially positive silvicultural, environmental and economic benefits [5]. Economic factors are the main determinant to decide about logging residues. The amount and condition of forest residues varies widely from stand to stand. The amount remaining after harvest also depends on utilization standards and harvesting techniques [6, 7]. However, harvest and collection costs are site specific and differ not only due to regional and local differences in input costs and machinery complements, but also are highly dependent on site characteristics (slope, distance to road), material characteristics (tree size and species), harvest type (clearcut, thinning, selection cutting), among other factors [1, 6, 8]. The Hyrcanian forests of Iran are known as one of the most basic resources for wood production and have a big share in supplying wood to the related industries. Commercial logging in these forests is accomplished within the legal framework of forestry management plan and annual removal is around 1 million $m^3$ per year. This amount is not sufficient for needs of internal wood industries and predicted in future years to increase imports of wood [9]. Selection cutting is the main silvicultural method in the northern forests of Iran. In these forests, logging operation is generally performed by using ground based skidding system. Chainsaw and cable skidder are two main logging machines for wood harvesting in these forests. One source of woody material receiving much attention is logging residue. To the land manager, utilization of logging residues can reduce the costs of postharvest treatments. The amount of logging residues on a particular harvest area or for a given year is directly related to economic conditions and export markets. For the economic and technical feasibility of using logging residue more detailed information is needed about the characteristics of residue materials. Estimation of costs, equipment, handling, and transportation of logging residues require a data base providing information about size, number of pieces, distribution and quality of these materials. Regardless of the source, an understanding of the amount and characteristics of the material is important to decisions concerning utilization or onsite retention to enhance other resource values [1, 3]. The aim of this study was to estimating the volume and characteristics of logging residue under different ground slopes in Hyrcanian forest.

## MATERIALS AND METHODS

### Study area and logging operation

The study area is located in two compartments 37 and 38 from district 2 in Asalem Nav watershed in the Hyrcanian forest of Iran. The Nav watershed is located between 37° 38' 34" to 37° 42' 21" N and 48° 48' 44" to 48° 52' 30" E. Elevation of the study area is ranged from 800 to 1200 m with average annual precipitation of 950 mm and is dominantly covered by *Fagus orientalis* and *Carpinus betulus* stands. During December and January of 2009, marked trees were felled using manual chain saw, topped at merchantable height or 20 cm DIB (Diameter inside Bark) and skidded in the shape of full length or long logs from stump area to roadside landings using Timber jack 450C wheeled skidder. Shafaroud Company was harvesting performance in the study area. The ground slope condition and logging intensity is shown in table1.

**Table1: The ground slope condition and logging intensity in study compartments**

| Study Compartment | Ground slope condition | | | Logging intensity | | |
|---|---|---|---|---|---|---|
| | Area (ha) | | | Number of trees | Industrial volume ($m^3$) | Fuel volume ($m^3$) |
| | < 50 % | >50 % | Total | | | |
| 37 | 35 | 6 | 41 | 248 | 606 | 192 |
| 38 | 3 | 31 | 34 | 253 | 547 | 171 |

### Sampling design and collection of data

The line intersect sampling has been widely used for estimating volume of logging residue and has been demonstrated to be efficient and unbiased [1, 2, 10-13]. The sample design used in this study consisted of 100 m line transacts located at each of 30 points on a systematic grid. Both the initial starting point and the base line for the grid system were randomly selected to reduce bias. To reduce bias associated with piece orientation, each of the 30 line transects was randomly oriented along 45 degree azimuths. All qualifying residue intersected by the 100 m line transects was measured. Only pieces at least 4 cm in diameter inside bark and 30 cm long were considered measurable. Older dead pieces that were rotten to the point of losing their original form were excluded. Measurements recorded for each piece of residue were diameter (by 2 cm class) inside bark at the point of intersection with a transect line, at the middle of piece, large end and small end diameter and length of piece. The volume and weight of logging residues in each line transect was computed by equations of 1 and 2 [11]:

$$V_i = (\pi^2 / 8L) \sum_{j=1}^{n_i} d_{ij}^2 \quad \text{..............} (1)$$

$$W_i = (S\pi^2 / 8L) \sum_{j=1}^{n_i} d_{ij}^2 \quad \text{............} (2)$$

Where, $V_j$ is volume ($m^3$/ha) in line transect j, L is length of line transect (100 m), $d_{ij}$ is diameter inside bark (cm) of piece i in line transect j, n is number of pieces intersected in line transect j, $W_i$ is weight (ton/ha) in line transect j, S is specific gravity of pieces ($g.cm^{-3}$). The number of pieces was computed by equation of 3 [11]:

$$N_i = (\pi n_i)/(2 L l_i) \quad \text{..........} (3)$$

Where, $N_i$ is number of pieces per hectare in length class *i*, $n_i$ is number of tallied intersections in length class *I*, L is length of sample line and *li* is midpoint of length class *i*. The volume of each piece was computed by Huber formula as following (4) [11, 14- 16]:

$$V = (d_m^2 / 4)\pi . L \quad \text{...........} (4)$$

Where, *V* is volume ($cm^3$), $d_m$ is diameter inside bark at the middle of piece (cm) and L is length of piece (cm). The weight of each piece was computed by equation of 5 [15]:

$$W = (V) \times (GD) \quad \text{...............} (5)$$

Where, W is green weight of piece (kg), V is volume of the piece ($m^3$) and GD is green density of the wood ($kg.m^{-3}$).

The ratio of residue volume to logging volume (RRL) was computed as R/L= (RV/LV) × 100, where RV is residue volume ($m^3.ha^{-1}$) and LV is logged volume ($m^3.ha^{-1}$). The ratio of residue volume to number of harvested trees (RRN) was computed as R/N=RV/NT, that RV is residue volume ($m^3.ha^{-1}$) and NT is number of selected trees. The means of volume, weight and number of logging residue in two compartments were compared by t test at $\alpha$=0.05 level.

## RESULTS AND DISCUSSION

The results of this study showed that the means of volume, weight and number of logging residual was significantly higher in the >50% slopes than <50% slopes (Table2). The mean of logging residual volume in the <50% and >50% slopes were 3.56±0.38 and 4.62±0.45 $m^3.ha^{-1}$ (Table2). Hesselink indicates that in northern Ontario approximately 25% of harvesting residue is left as standing residuals and on the ground as slash [17]. According to a research in three parcel that harvested by selection silviculture method volume of logging residue were reported 2.78, 4.86 and 5.32 $m^3.ha^{-1}$ in northern forests of Iran [18]. The amount of logging residues on a particular harvest area is directly related to logging intensity and site condition such as size and number of felled trees, topography and soil condition and forest road density.

**Table 2: The Mean (Standard error) of logging residues in different slopes**

| Logging residues | Ground Slope* | |
|---|---|---|
| | **< 50%** | **> 50%** |
| Volume ($m^3.ha^{-1}$) | 3.56 (0.38) B | 4.62 (0.45) A |
| Weight ($Ton.ha^{-1}$) | 2.48 (0.25) B | 3.19 (0.30) A |
| Number ($Pic.ha^{-1}$) | 195 (10.0) B | 233 (15.0) A |

*: Different letter in rows indicated significant difference at α=0.05 level.

**Table 3: The Mean (Standard error) of pieces of residues in different slopes**

| pieces | Ground Slope* | |
|---|---|---|
| | **< 50%** | **> 50%** |
| Volume ($m^3$) | 0.0141 (0.001) B | 0.0222 (0.002) A |
| Weight (kg) | 9.37 (0.34) B | 15.32 (0.53) A |
| Length (cm) | 117 (5.6) B | 151(6.8) A |
| Middle diameter (cm) | 12.3 (0.22) B | 14.1 (0.38) B |

*: Different letter in rows indicated significant difference at α=0.05 level.

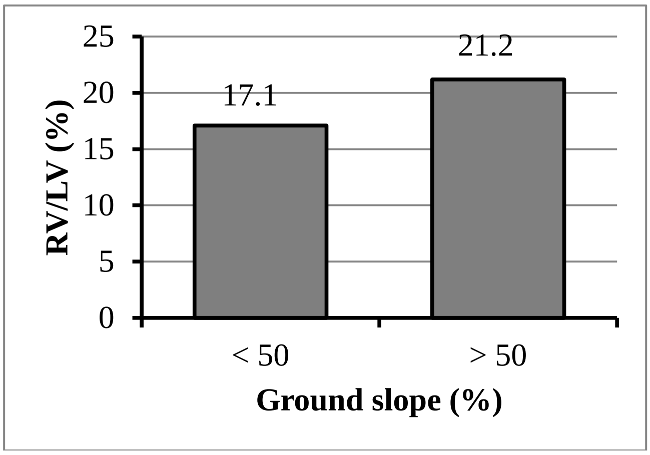


**Fig.1: The ratio of residue volume to logging volume (RV/LV) under different slopes**

The mean of pieces volume, weight, length and diameter in >50% slopes was significantly higher than <50% slopes (Table 3).

The ratio of residue volume to logging volume (RV/LV) in the slopes of > 50% was higher than slopes of < 50% (Fig.1).

This ratio in > 50% and < 50% slopes were 21.2% and 17.1%. Eker (2011) reported the available logging residue ratio was 3.67% for the total volume, while the average potential of residues was 6.6 tones, air dried per hectare for the studied stands in Turkey [3]. Takashi *et al*. investigated the dry weight of logging residues in thinned stands of Japanese cedar (*Cryptomeria japonica*) of various ages and reported the dry weight of the logging residue in each stand was estimated at 13.1-38.4 $ton.ha^{-1}$ from plot inventories [19]. A large volume of woody biomass has traditionally remained on site after logging operation in the northern forests of Iran.

The ratio of residue volume to number of harvested trees (RV/NT) in the >50% slopes was higher than <50% slopes (Fig. 2).

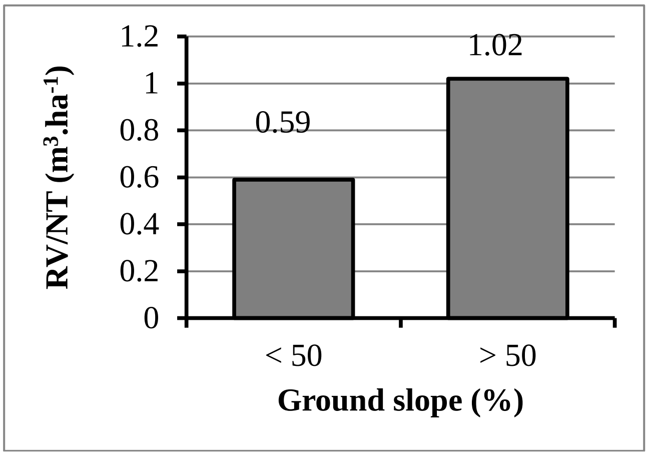


**Fig. 2: The ratio of residue volume to number of harvested trees (RV/NT) under different slopes**

This ratio in >50% and <50% slopes were 1.02 and 0.59 $m^3.stem^{-1}$ (Fig.2). These results indicated that by felling and extraction of each selected tree about 0.59 and 1.02 $m^3$ woody materials was remained in <50% and >50% slopes in the study area. This amount is considered without of stump volume and branches of lower than 4 cm in diameter. Tvankar and Eynollahi investigated volume and weight of logging residuals in a selectively logged compartment in the Hyrcanian forest and reported the residual volume was estimated 2.34 $m^3$ and 1.66 tons per hectare [20].

Eker in Turkey forest harvesting suggested that coarse logging residues can be available as firewood in traditional utilization manner, but a thin material is left in the forest because of high collection and extraction costs [3]. Ground slope is a main factor in limiting of logging operation, specially, in the skidding systems. In steep slopes power and mobility of skidders are reduced. In the steep slope area and dens stands winching and skidding operation are difficult.

## CONCLUSION

Commercial forests in the Iran are low and limited. The Nav forest is one of the best forest stands in the northern Iran, which plays an important role in national wood production. Remaining 17 to 21 percent marked volume in the forests of the study area is noticeable. These logging residue with a diameter and suitable lengths are useable in many wood industries. Due to shortage of wood in the Iran, collection and extraction of logging residue can have economic value. Suitable design of roads and skid trails based on the selective logging provided access to all parts of the harvested compartment and can collect and extracted logging residues. Before marketing studies and economic analyses of the feasibility of residue utilization can be made, it is first necessary to learn something about the quantities, characteristics and accessibility of the residue. Leaving logging residuals in forest stands result to infested insects in production forests [21] and increase fire hazard [7]. Iran is a country with relatively poor forest resources. The utilization of logging residues could support energy resource, fuel reduction in forest floor, employment and site preparation [3]. Logging residues contribute to the diversity and cover resources of a logged site [22]. For this reason, we do not recommend complete utilization, but we should strive to use a greater portion of this valuable resource. Harvest managers should consider integrated residue collection during logging operations in order to avoid re-trafficking sites after the original commercial logging activity.

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