Calculating the correction factor of skidding distance based on forest road network

M. Lotfalian[1], E. H. Zadeh[1], S. A. Hosseini[2]

[1]*Department of Forestry, Faculty of Natural Resources, Sari Agricultural Sciences and Natural Resources University, Sari, Iran*

[2]*Faculty of Natural Resources, Mazandaran University, Sari, Iran*

ABSTRACT: Average skidding distance for forest stands is an important parameter for the determination of the optimum road density and spacing. In this research the real mean skidding distance and theoretical mean skidding distance were measured to calculate the correction factor of skidding distance for Chafrood forest in Hyrcanian zone. The length and azimuth of skid trails from road and depot junction to forest interior were measured. Moreover, the position of skid trail was recorded by GPS. These skid trails with a buffer of 140 m were designed on a topographical map using Arc GIS software. Results indicated that the road spacing of 500 m in the study area resulted in a theoretical mean skidding distance of 125 m. For a real mean skidding distance of 525.9 m and for the mean slope of 40%, the correction factor was estimated to be 4.2.

Keywords: real skidding distance; theoretical skidding distance; correction factor; Chafrood forest

In the Hyrcanian forest located in the north of Iran, extraction with ground-skidding equipment is the most common system (Jour Gholami, Majnounian 2008). Three types of roads are built for selective logging in these areas: (a) major access roads to be used by trucks carrying logs to a sawmill; (b) temporary local roads into individual logging areas; (c) skid trails made by bulldozers dragging logs to truck loading areas. The first two types usually have a gravel surface protection, while the latter are simply a loose soil. Skid trails are defined as tertiary roads that are used by skidders that move logs from the point of felling and bucking to log landings (Demir et al. 2008).

In Iran it was estimated that the skidder productivity rate in uphill skidding was 16.31 $m^3 \cdot h^{-1}$ and greater than its productivity in downhill skidding (12.32 $m^3 \cdot h^{-1}$). Changing of the logging system from shortwood system (8.88 $m^3 \cdot h^{-1}$) to combined system (tree-length, longwood and shortwood systems depending on different situations) with 14.31 $m^3 \cdot h^{-1}$ productivity rate gives rise to an increase in productivity rate. The TIMBERJACK 450C production cost which was working under contract was 11 € · m^{-3} (Pir Bavaghar et al. 2007). The mean of skid trail density in northern forests of Iran is estimated to be 30 $m \cdot ha^{-1}$. Ghaffarian and Sobhani (2008) demonstrated that the minimization of total skidding and road construction costs is useful for determining optimum road spacing and logging planning in Kheiroudkenar forest of Nowshahr in the north of Iran. Najafi et al. (2008) showed that the forest road networks can be evaluated by GIS and a dense grid of field observations as well as the skidding cost is reduced using linear programming.

Wheeled skidders appeared in the early 1970's and are now the most widely tractors used in Hyrcanian forests (Bagheri, Naghdi 2009). The major problem with wheeled skidders in selective logging methods is their requirement for a dense network of roads and skid trails (Naghdi, Bagheri 2009). One crucial decision in road network planning in this area is to determine under what terrain conditions ground-based extraction systems should be applied. Slope and topography which affect the forest road network were considered as correction factors (terrain factors) by Segebaden (1964).

Mean skidding distance is the main factor that should be considered when we calculate the formula of a reasonable forest road network (Zhixian, Zhili 1997). Kanzaki et al. (1990) described a high-density path network in a steep mountain area which supports intensive, high-quality forest in Osaka, Japan. In this network, the road density was 222.94 m·ha^{-1}, correction factor of the real skidding distance was 1.215 and the development percentage was 77.9%. Data showed that the correction factors approach 1.0 as the road density increases. Heinimann (1998) reported that the road spacing on slopes depends on the underlying off-road transportation technology.

In mountainous forests of Guilan province in Iran, the correction factor of skidding distance for the mean slope of 50% has been determined 2.72 (Mohammadalizadeh 2001). Lotfalian (2001) used the coefficient of 3.1 to correct the theoretical skidding distance in Sangdeh forest of Iran. Segebaden (1964) in Sweden proposed the correction factor of 2.5 for the low lying area to 4.5 for the mountainous area. According to Abegg (1978) in Switzerland the correction factor of skidding distance for the flat area, hilly area and mountainous area is suggested to be 2, 2.5 and 3.5, respectively, and according to FAO (1974) the correction factor was defined in the range from 1.6 to 2 for the flat area to more than 3.6 for the steep slopes.

The aims of this paper were to measure the real mean skidding distance and theoretical mean skidding distance and to calculate the correction factor of mean skidding distance for Chafrood forest of Hyrcanian zone.

MATERIAL AND METHODS

Description of the site

The study was conducted in compartments 109, 110, 111 and 112 in Chafrood forest (1,775 ha). The area extends from 37°23'00" to 37°31'05"N in latitude and from 48°46'40", 49°06'00"E in longitude (Fig. 1). The general aspect of Chafrood forest is northern. The mean slope is about 40% (min. 5% and max. 80%). The climate is moist and cold with average annual temperatures 7.5°C. The altitude ranges from 150 m a.s.l. to 1,050 m a.s.l. The structure of growing stock was 6.4% of beech, 47.6% of hornbeam, 3.5% of oak, 6.1% of alder and 36.4% of other hard broadleaves. Total length of roads in Chafrood forest was 41.15 km and their density was 23.18 m·ha^{-1}. The road length in the study compartments was 3,275 m with a density of 19.97 m.ha^{-1}. The terrain consists of limestone and conglomerated stone.

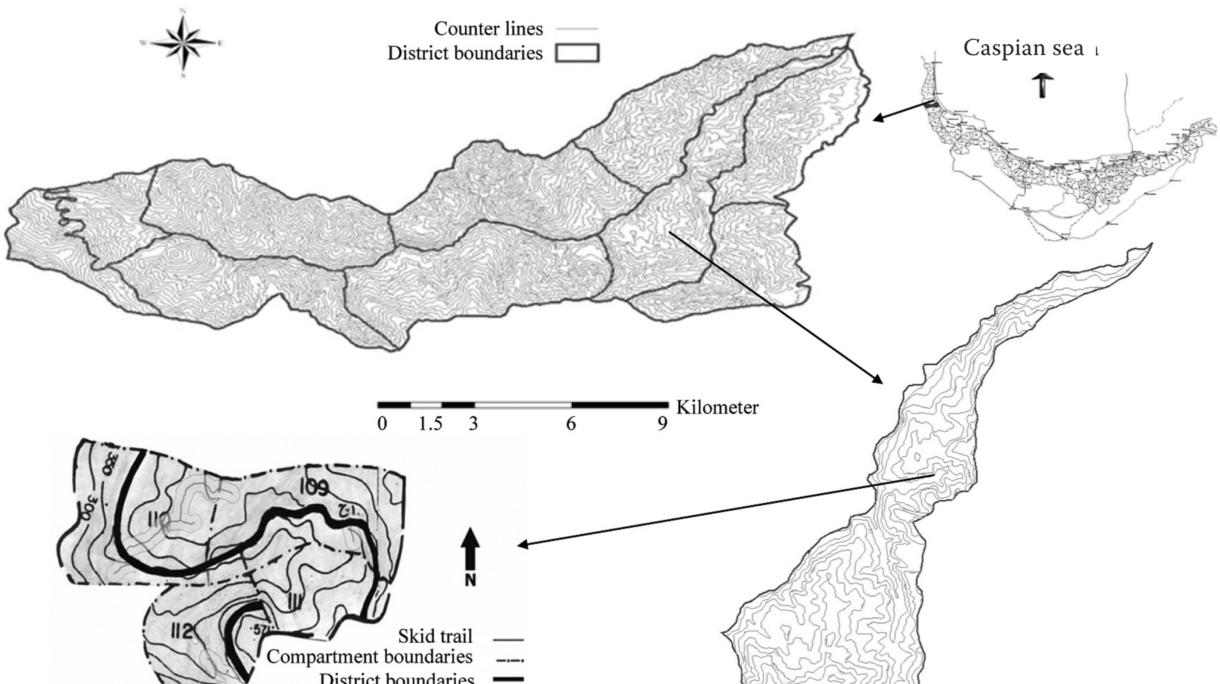

Fig. 1. The geographical location of the study area

Measurements

The azimuth of skid trail direction from road and depot junction to forest interior was measured by a compass on each node. Real (on slope) and horizontal distance between two stakes was taken after every 20 m by a meter. Moreover, the position of the skid trail junction on road and depot was recorded by GPS. These skid trails were designed on a topographical map using Arc GIS software. The maximum distance of winching for skidders is 70 m. So, for each skid trail a buffer of 140 m was considered on the map based on the scale. The optimum shape and density of forest roads are influenced first of all by the terrain configuration and by the used skidding machines (Beneš 1991).

Calculations

A special criterion is introduced for evaluating the effectiveness of access to the forest, expressed by the ratio of the theoretical and geometrical skidding distances (Beneš 1989). The road density, road spacing and theoretical mean skidding distance in our study area were calculated using the formula:

$$RD = \frac{L}{S} \tag{1}$$

$$RS = \frac{10{,}000}{RD} \tag{2}$$

$$SD = \frac{2{,}500}{RD} \tag{3}$$

where:
RD – road density (m·ha^{-1}),
L – total length of forest road (m),
S – area of study forest (ha),
RS – road spacing (m),
SD – theoretical mean skidding distance (m).

The real mean skidding distance in our study area was calculated using the formula:

$$ASD_r = \frac{\sum_{i=1}^{n} d_i \left(\frac{Md_i + md_i}{2}\right)}{\sum_{i=1}^{n} d_i} \tag{4}$$

or

$$ASD_r = \frac{\sum_{i=1}^{n} L_i \times D_i}{\sum_{i=1}^{n} D_i} \tag{5}$$

where:
ASD_r – real mean skidding distance (m),
Md_i – farthest distance of skidding to depot (m),
md_i – nearest distance of skidding to depot (m),
L_i – mean skidding distance in each depot (m),
D_i – total length of skid trails diverged from each depot (m).

The correction factor of mean skidding distance (μ) was calculated from the division of real mean skidding distance by theoretical mean skidding distance (Equation 6):

$$\mu = \frac{ASD_r}{SD} \tag{6}$$

The real mean skidding distance in our study area was compared to values obtained from different coefficients of *a* in Segebaden's equation:

$$S = \frac{a}{RD} \tag{7}$$

RESULTS AND DISCUSSION

The costs can be reduced by constructing roads and skid trails of suitable density (Bagheri, Naghdi 2009). Results indicated that the road density and road spacing in our study area were 20 m·ha^{-1} and 500 m, respectively. Optimal road spacing is an important factor in logging planning to help minimize the total cost of harvesting and roading (Ghaffarian et al. 2009). The value of road density and road spacing was obtained as follows:

$$RD = \frac{L}{S} = \frac{3{,}275}{164} = 20 \text{ m·ha}^{-1}$$

$$RS = \frac{10{,}000}{RD} = \frac{10{,}000}{20} = 500 \text{ m}$$

Optimal road spacing can be influenced by logging method, price of products, taxation policies, landing costs, overhead costs, equipment opportunity costs, road width and size of landing, skidding pattern, profit of logging contractor, slope and topography and soil disturbance (Segebaden 1964; Smith 2003; Ghaffarian, Sobhani 2007). These parameters were not considered in the present study because it is difficult and time-consuming to measure them correctly.

Planning of individual roads within proposed logging blocks is more focused on technical considerations such as detailed terrain conditions and on achieving optimum skidding distances (Klas-

SEN 2006). In this study the theoretical mean skidding distance and real mean skidding distance were 125 m and 525.9 m, respectively.

$$SD = \frac{2.500}{RD} = \frac{2,500}{20} = 125 \text{ m}$$

$$ASD_r = \frac{\sum_{i=1}^{n} d_i \left(\frac{Md_i + md_i}{2}\right)}{\sum_{i=1}^{n} d_i} = \frac{1,199,259.69}{2,280.4} = 525.9 \text{ m}$$

or

$$ASD_r = \frac{\sum_{i=1}^{n} L_i \times D_i}{\sum_{i=1}^{n} D_i} = \frac{1,199,261.93}{2,280.4} = 525.9 \text{ m}$$

In this research the real mean skidding distance and theoretical mean skidding distance were measured to calculate the correction factor of skidding distance. According to the results of the study, this factor for Chafrood forest in Hyrcanian zone was 4.2. This result is in agreement with SEGEBADEN (1964) and FAO (1974) reports. They proposed the correction factor of more than 3.6 for steep slopes in the mountainous area. LOTFALIAN (2001) used the coefficient of 3.1 to correct the theoretical skidding distance in Sangdeh forest of Iran.

$$\mu = \frac{ASD_r}{SD} = \frac{525.90}{125} = 4.2$$

PENTEK et al. (2005) believed that the correction factor of the theoretical mean skidding distance enables to use the theoretical model which includes the parallel and equal distribution of forest roads in hilly and mountainous areas where such a distribution is not possible. Some researchers emphasized that the maximum real skidding distance should be used in steep and difficult terrains. Results of the mean skidding distance recorded for the depots are presented in Tables 1 and 2. The real mean skidding distance obtained from different coefficients of *a* in Segebaden's equation is shown in Table 3.

The skidding distance models including *Down, Up, Strdown, Strup* programmed in the Turbo Basic language to work with a raster Digital Terrain Model are tools to help the road planners to judge the efficiency of existing or planned road networks while considering the real skidding distance and the proposed technology of skidding (TUCEK, PACOLA 1999). BENEŠ (1989) indicated that it is harmful for the environment to build skidding trails in the mountains, because such a skidding network must be dense, its use is not frequent, and its contribution to potential soil erosion is high. It is recommended to skid the logs the shortest way from the stump to the road, preferably down the slope.

Table 1. Mean skidding distance in depots

Depot number	Total length of skid trail (m) (D_i)	Real mean skidding distance (m) (L_i)
1	141	70.5
2	189	94.5
3	1,547.4	704.6
4	403	201.5

Table 2. Real mean skidding distance in depots

Skid trail number	Real length of skid trail (m)	Distance of skidding (m)		Real mean skidding distance (m)
		nearest	farthest	
1	141	0	141	70.5
2	189	0	189	94.5
3	1,407.4	0	1,407.4	703.7
3.1	140	644	784	714,0
4	403	0	403	201.5

Table 3. Real mean skidding distance based on Segebaden's equation

Coefficients of *a*	4	5	6	7	8	9
Real mean skidding distance in Segebaden's equation (m)	200.3	250.4	300.4	350.5	400.6	450.7

CONCLUSION

Average skidding distance for forest stands is an important parameter for the determination of the optimum road density and spacing. Overall, the road spacing of 500 m in Chafrood forest resulted in a theoretical mean skidding distance of 125 m.

For the real mean skidding distance of 525.9 m and for the mean slope of 40% in our study area, the correction factor was estimated to be 4.2.

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Corresponding author:

Associate Prof. Majid Lotfalian, Sari Agricultural Sciences and Natural Resources University, Faculty of Natural Resources, Department of Forestry, P. O. Box 737, Badeleh, Sari, Mazandaran Province, Iran
e-mail: mlotfalian@sanru.ac.ir