Research note

Using GIS to Evaluate and Design Skid Trails for Forest Products

Maryam Kooshki,[1] Elyas Hayati,[2,5] Nosratollah Rafatnia,[3]
Mohammad Taghi Ahmadi[4]

【Summary】

This study was performed to evaluate types of skid trails by considering the types of products (yield table) and to design skid trails in district 1 of Shast-Kallate Forests, Gorgan, northern Iran. Types of skid trails (machine skid trails and animal skidding paths) are very important for transporting forestry products. It is suggested that log products be extracted by machine skid trails and fuel wood and pulpwood by animal skidding paths. After determining the current skid trails by a global positioning system (GPS), a map of the skid trails was provided in a geographical information system (GIS); then harvest volumes and types of products in each compartment were extracted and gathered in a yield table. Types of current skid trails (machine skid trails and animal skidding paths) were evaluated by considering the types of products. According to the results of overlay maps, animal skidding paths were located in compartments with high harvest volumes and high slopes where trails were not suitable for extracting logs and lumber; therefore, machine skid trails should be designed for these compartments. The suggested skid trails were designed by considering harvest volumes, utilizable areas, slope, topography, soils and stream networks of each compartment. The advantage of this research is that the authors applied criteria of types of products to design and evaluate skid trails, which was not taken into account in previous research.

Key words: machine skid trails, animal skidding path, yield table, product type, forest transportation system.

Kooshki M, Hayati E, Rafatnia N, Ahmadi MT. 2012. Using GIS to evaluate and design skid trails for forest products. Taiwan J For Sci 27(1):117-24.

[1] Forest Engineering, Gorgan Univ. of Agricultural Sciences and Natural Resources, PO Box 386, Gorgan, Iran.

[2] Forestry and Forest Economic Department, Faculty of Natural Resources, Univ. of Tehran, PO Box 4314, Karaj, Iran.

[3] Faculty of Forestry and Wood Industries, Gorgan Univ. of Agricultural Sciences and Natural Resources, PO Box 386, Gorgan, Iran.

[4] Member of Young Researchers Club, Islamic Azad Univ., Karaj Branch, Iran.

[5] Corresponding author, e-mail:hayati_fe@yahoo.com 通訊作者。

Received March 2011, Accepted November 2011. 2011年3月送審 2011年11月通過。

研究簡報

應用地理資訊系統評估及設計林產物集材道

Maryam Kooshki,[1)] Elyas Hayati,[2,5)] Nosratollah Rafatnia,[3)]
Mohammad Taghi Ahmadi[4)]

摘 要

本研究的目的在於評估伊朗北部戈爾甘Shast-Kallate森林區不同類型林產物(收穫表)的集材道，據以設計適用的集材道。不同類型的集材道(機械式及動物式)，對於林業的產物是非常重要的，一般建議原木集材使用機械式索道，燃料及紙漿材使用動物式集材道。應用衛星定位系統定位、繪製目前的集材道地圖，將圖存放在地理資訊系統上，並將不同林班的各類林產物收穫量抽取、集中呈現於收穫表。針對林產物類型，評估目前機械式及動物式集材道。根據地圖的套跌分析結果，位在林班的高坡度的動物集材道並不適於段木及原木的收穫；因此在此地應設計機械式集材道因應。建議集材道設計時應考慮林班的使用面積、坡度、地形、土壤集及溪流網路。本研究的優點在於作者依據收穫林產物的類型之準則評估及設計集材道，這是過去的研究沒有考慮到的。

關鍵詞：機械式集材道、動物式集材道、收穫表、林產品類型、森林運輸系統。

Kooshki M, Hayati E, Rafatnia N, Ahmadi MT。2012。應用地理資訊系統評估及設計林產物集材道。台灣林業科學27(1):117-24。

INTRODUCTION

The greatest damage imposed on forests is a result of improper road construction; on the other hand, roads and skid trails are fundamental structures for logging and even conservation of forests (Su et al. 2009, Lu et al. 2010). Logging practices are an integrated process which takes place at a series of operation sites (Hui et al. 2005), so to prevent the distribution of extensive damage throughout the forest, a proper transportation network has to be developed. In order to provide access to the forest for wood production and logging processes, road and skid trail networks are fundamental structures (Abdi et al. 2009). Planning of a transportation network to access timber harvest sites, is a difficult and time-consuming task (Murray 1998), and also includes high costs in forest management units. Therefore the optimal road and skid trail density as well as suitable locations for road and skid trail development are very important. In determining the location of road and skid trail network development, technological criteria, slopes and other topographical features of the landscape should be taken into account when designing forest hauling roads under mountainous conditions (Tucek 1999).

Matthews (1942) was the first to present a model of forest road spacing and calculated the theoretical mean skidding distance. Segebaden (1964) and Lussier and Tardiff (1964) added a factor of sinuosity to this model because of the winding effect. Suddarth and Herrick (1964) presented a theoretical approach similar to Matthews (1942) to determine the effective skidding distance and optimum distance between landings for any geometric harvest setting.

In order to determine the optimum road and skid trail density, the harvest volume is an important parameter and should be considered in transportation network planning. Forest road spacing in dense stands is lower than that in open stands. Therefore, road and skid trail densities in a dense stand are higher (König 1970, Acar 1997). Sedlak (1983) computed road spacing with consideration of the volume of annual growth and stated that lower average road spacing would be required in parts of the forest with higher annual growth and harvest.

Previous studies were related to defining suitable locations of road development, road and skidding costs, and applying different parameters and methods for forest transportation network planning and assessment (Liu and Sessions 1993, Lihai et al. 1996, Zhixian and Zhili 1997, Murray 1998, Tucek and Pacola 1999, Kŏsir and Krč 2000, Audrey 2001, Chung and Sessions 2002, Heinimann et al. 2003, Chung et al. 2004). Kŏsir and Krč (2000) investigated the suitability of the terrain for designing and constructing forest roads and skid trails, and applied a method based on multi-criteria decision making for analysis of forest road and skid trail networks. Chung and Sessions (2002) used a mathematical programming method to design an optimal forest road network, and determined suitable locations for road construction based on road technical standards, logging and skidding costs (from economical and environmental points of view), and terrain conditions. Heinimann et al. (2003) designed a road network with minimum total costs, using the shortest path and Prim's algorithms, and reduced cut and fill volumes.

In addition to the above-mentioned factors, types of products which were not taken into account in previous studies, should be considered in transportation network planning. It would be better to design skid trails by considering types of products; in other words, it would be better to extract logs by machine skid trails and fuel wood and pulpwood by animal skidding paths.

In this study, we recognized the different kinds of current skid trails and evaluated them by considering types of products and other parameters (i.e., harvest volume, slopes, stream networks, etc.).

MATERIAL AND METHODS

This study was conducted in district 1 of the Shast-Kallate forest. The studied forest is a temperate deciduous forest located in northern Iran [Caspian Forests, also called the Hyrcanian Forests]. For more-detailed information about the Caspian Forests refer to Bonyad (2006) and Latifi and Oladi (2006). It covers 1714 ha and extends from 36º42′ to 36º44′N latitude and 54º20′ to 54º24′E longitude. The elevation range is 230~1010 m. A ground skidding system is the major method of harvesting in this mountainous uneven aged hardwood forest.

Recording of current skid trails of the district and providing maps

In order to determine skid trails, tapes, compasses, markers, and clinometers were used. It should be noted that horizontal recordings of current skidding trails were made at distances of < 20 m. Determined points were recorded with a global positioning system (GPS). To transfer the recorded points of skidding paths from GPS to a geographical information system (GIS), MAPSOURCE software was used. After providing maps of the current skidding paths, the types of skid trails (machine skid trails and animal skidding paths) were determined. Paths were encoded in the GIS, so that the machine skid trails were denoted by a code of 1 and animal skidding paths a code of 2; then maps of the types of current skid trails were produced.

Collecting data layers and providing yield tables of each compartment of the district

Yield tables of the study site were provided by defining the harvest volumes and types of products (Table 1). It is noteworthy that the required data for the yield tables were obtained from the Shast-Kallate forest plan. The required data layers, such as slope map, stream network map, and map of the harvest volume were prepared using ArcGIS (ver. 9.3).

Table 1. Types of products in each compartment of district1, Shast-Kallate forest

Compartment	Types of products	Harvest volume (m^3)	Type of path	Number of trails
1	Log, pulpwood, fuel wood	1580	-	-
2	Log, pulpwood, fuel wood	150	-	-
3	Log, pulpwood, fuel wood	50	-	-
4	Log, pulpwood, fuel wood	770	Skidding	4
5	Log, pulpwood, fuel wood	800	Skidding	2
6	Log, pulpwood, fuel wood	135	-	-
7	Log, pulpwood, fuel wood	1900	Skidding	4
8	Log, pulpwood, fuel wood	1190	Skidding	3
9	Log, pulpwood, fuel wood	1050	Skidding	1
10	Log, pulpwood, fuel wood	800	Skidding	2
11	Log, pulpwood, fuel wood	1620	Skidding	3
12	Log, pulpwood, fuel wood	1300	Skidding	1
13	Log, pulpwood, fuel wood	890	Skidding	3
14	Log, timber, pulpwood, fuel wood	1370	Skidding	2
15	Log, timber, pulpwood, fuel wood	1800	Skidding	7
16	Log, timber, pulpwood, fuel wood	1005	Skidding	2
17	Log, timber, pulpwood, fuel wood	1075	Skidding	2
18	Log, timber, pulpwood, fuel wood	1440	Skidding	1
19	Log, timber, pulpwood, fuel wood	1980	Animal path	2
20	Log, timber, pulpwood, fuel wood	1555	Skidding	2
21	Log, timber, pulpwood, fuel wood	1110	Skidding	2
22	Log, timber, pulpwood, fuel wood	1740	Skidding	2
23	Log, timber, pulpwood, fuel wood	1820	Animal path	2
24	Log, timber, pulpwood, fuel wood	2220	Skidding and Animal path	2
25	Log, timber, pulpwood, fuel wood	1645	-	-
26	Log, timber, pulpwood, fuel wood	650	Skidding	1
27	Log, timber, pulpwood, fuel wood	2160	Animal path	2
28	Log, timber, pulpwood, fuel wood	2365	Skidding	1
29	Log, timber, pulpwood	3080	Animal path	2
30	Log, timber, pulpwood	1405	Skidding	3
31	Log, timber, pulpwood	2815	Skidding	1
32	-	-	-	-
33	Log, timber, pulpwood	1875	Animal path	2

Evaluating the current skid trails and designing suggested skid trails

In order to determine proper skid trails for logs, and fuel wood and pulpwood, types of current skid trails were evaluated with respect to the kinds of the products available in each compartment. In the next stage, new skid trails were suggested and designed with regard to the harvest volumes (yield table), types of products, utilizable area, slopes, terrain, stream network, and soil texture of each compartment. The suggested and designed trails were also evaluated in terms of length and width of path, and longitudinal slope according to procedures of the Forest Organization, stream networks, and harvest volumes. Designed trails in the forest were controlled using GPS.

RESULTS

Results of the evaluation of the current skid trails showed that minimum, maximum, and average slope angles of current skid trails were 2, 64, and 33%, respectively, and the animal skidding paths were situated in areas with high-slope terrain and harvest volumes (Fig. 1).

In evaluating existing skid trails by yield tables, the results showed that, animal skidding paths were located in compartments with high volumes of harvest and high slopes, and also the type of product was logs. So, animal skidding paths are not adequate, and machine skid trails should be developed in these compartments.

In order to have a better assessment of existing skid trails, characteristics of the compartments of the district were collected. These characteristics included the utilizable area of the compartment, slopes and hydrographic features. According to the results of analysis of the compartments, existing skid trails were designed with minimum crossing of streams (only in exceptional cases did skid trails per-

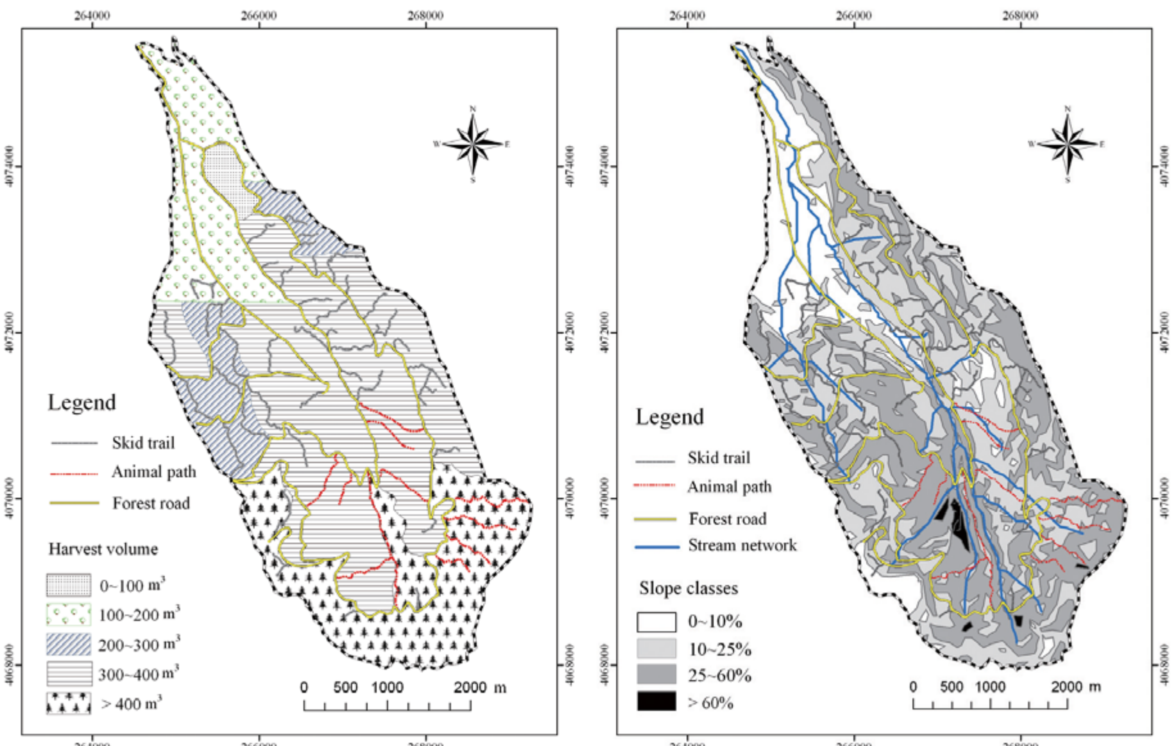

Fig. 1. Overlay maps of existing skid trails in district 1, Shast-Kallate forest.

pendicularly cross a stream), and slopes in high parts of the district were suitable for designing skid trails by procedures of the Forest, Range and Watershed Management Organization of Iran (up to 30%). For overall slopes of > 30% (class 25~60%), skid roads had to be developed with a minimum cut volume.

The designing of the suggested skid trails was carried out by considering yield tables, volumetric stand density of the compartments, terrain conditions, overall slopes, and stream networks. After adding the suggested skid trail layer to the existing skid trails, a map of the skid trails of the district was produced (Fig. 2).

DISCUSSION AND CONCLUSION

Extracting various forestry products is related to the types of skid trails; hence maps of skid trails were provided with regard to the products: 1) machine skid trails to extract logs and 2) animal skid paths to extract fuel wood and pulpwood. As shown in Fig. 1, in compartments with high log harvest volumes, types of skid trails were animal skid paths which are not adequate for extracting logs from the compartments. Thus, more attention has to be paid when designing skid trails. Obviously, it should be considered that the products are logs, but harvest volumes are rather

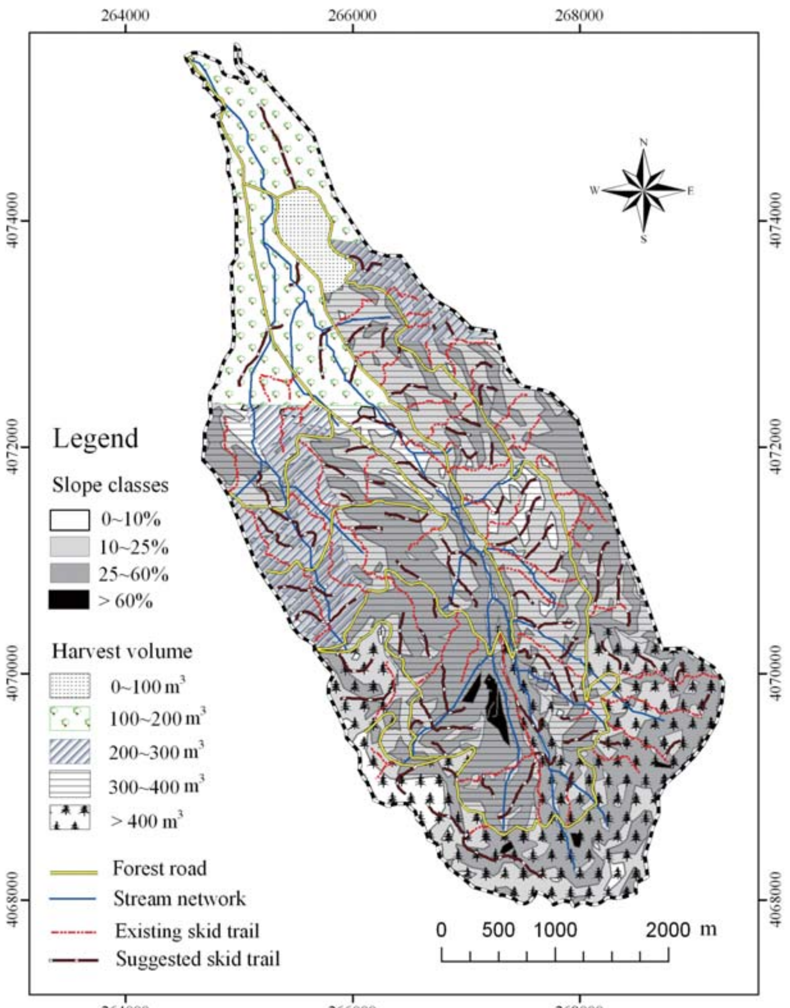

Fig. 2. Map of newly designed skid trails in district 1, Shast-Kallate forest.

low; as a result, there is no need for machine skid trails to extract forestry products.

As mentioned by previous studies, the harvest volumes is an important factor in forest transportation network planning, as higher road and skid trail densities are needed in parts of the forest which contain higher annual growth and harvest rates (König 1970, Sedlak 1983, Acar 1997); therefore, the harvest volumes should be considered.

To determine suitable locations for forest transportation network development, Tucek (1999) and Chung and Sessions (2002) considered some technological factors such as slopes, logging and skidding costs, and terrain conditions. For this study, different factors (i.e., slopes, terrain conditions, stream networks, and harvest volumes) were considered to locate newly designed skid trails. There were no difficulties in evaluating stream networks and terrain conditions of the area. In the course of evaluating current skid trails with consideration of product types, it was proven that with regard to high harvest volumes in certain compartments, the length and number of existing skid trails for transporting wood products were not adequate. Also, in designing skid trails with consideration of the harvest volume of each compartment, more skid trails were designed for compartments with high harvest volumes and vice versa. In compartments in which harvest volumes were low and skid trails densities were high, no new skid trails were designed.

Results of the evaluation of current skid trails when considering effective factors showed that suggested skid trails should be developed. In this study, angles of branching in the range of 30°~50° (according to the procedures of the Forest, Range and Watershed Management Organization of Iran, this range is considered optimum angles for branching in mountainous parts of Caspian forests) were considered in designing skid trails. We also attempted to provide suitable places for landing and prevented skid trails from intersecting streams (except in special cases). In order to reach a maximum volume of logs for extracting in each skidding period and also to reduce skidding times and costs, the authors attempted to make the direction of wood extraction be downward except in critical and exceptional cases. Also cut and fill volumes according to the procedures were minimized. The advantage of this research is that the authors applied criteria of the type of product when designing and evaluating the skid trails, which was not considered in previous research. Designing skid trails in terms of economic aspects is suitable because extracting wood products through skid trails quickly and less expensively results in increasing forest product accessibility, and in this case, damage to forest soils and residual stands are minimized.

ACKNOWLEDGEMENTS

This work was funded by the Faculty of Forestry and Wood Industries, Gorgan Univ. of Agricultural Sciences and Natural Resources, Gorgan, Iran (grant no: #8618013505). The study could not have been conducted without the cooperation of the managers and staff of Shast-Kalate Research Forest Station, so we particularly thank Drs. M. Malekshah and S.H. Shataei Joybari for their kind collaboration.

LITERATURE CITED

Abdi E, Majnounian B, Darvishsefat A, Mashayekhi Z, Sessions J. 2009. A GIS-MCE based model for forest road planning. J For Sci 55(4):171-6.

Acar HH. 1997. Preparation of forest transport plans in mountainous regions. Turk J Agric For

21(2):201-6.
Audrey MM. 2001. Development of environgentle routeing strategies for the management of forest access roads using GIS and GPS [dissertation]. Dublin: National Univ. of Ireland. 167 p.
Bonyad A. 2006. Silvicultural thinning intensity effects on increasing the growth of planted loblolly pine (*Pinus taeda* L.) stand in northern Iran. Taiwan J For Sci 21(3):317-26.
Chung W, Sessions J. 2002. Optimization of cable logging layout using a heuristic algorithm for network programming. Proceedings of the Council of Forest Engineering, 16-20 June 2002, Auburn, AL. 104 p.
Chung W, Sessions J, Heinimann HR. 2004. An application of a heuristic network algorithm to cable logging layout design. Int J For Engin 15:11-24.
Heinimann HR, Stückelberger J, Chung W. 2003. Improving automatic grid cell based road route location procedures. Proceedings of Austro 2003, 5-9 October 2003, Schlaegel, Austria. 76 p.
König W. 1970. The influence of optimum road-spacing on opening up the state forest of North-Rhein. Westphalia, Germany: Univ. Regensburg. p 21-31. [in German with English summary].
Kŏsir B, Krč J. 2000. Where to place and build forest roads. Int J For Engin 11(1):7-19.
Latifi H, Oladi D. 2006. Evaluating Landsat ETM+ data capability to produce forest cover type maps in the timberline of northern forests of Iran. Taiwan J For Sci 21(3):363-75.
Liu K, Sessions J. 1993. Preliminary planning of road systems using digital terrain models. Int J For Engin 4:27-32.
Lu SY, Liu CP, Hwang LS, Wang CH. 2010. Simulated flood frequency response to forest cover removal for an upstream watershed in central Taiwan. Taiwan J For Sci 25(2):136-53.
Lussier LJ, Tardiff G. 1964. Modern management techniques applied to forest industry. Quebec, Canada: Laval Univ. 401 p.
Matthews DM. 1942. Cost control in the logging Industry. New York: McGraw-Hill. 374 p.
Murray AT. 1998. Route planning for harvest site access. Can J For Res 28(7):1084-7.
Sedlak O. 1983. General principals of planning forest road nets. Rome, Italy: Food and Agriculture Organization publication. 14(1):17-36.
Segebaden GV. 1964. Studies of cross-country transport distance and road net extension. Stud For Sci 18:1-70.
Su DK, Jiang RC, Zhou L, Yu DP, Xie XK, Liu ZG, Dai LM. 2009. Effects of clearcutting on the tree species composition, structure, and diversity of a mixed broadleaf-Korean pine (*Pinus koraiensis*) forest on Changbai Mountain: implications for ecosystem restoration. Taiwan J For Sci 24(4):303-10.
Suddarth SK, Herrick AM. 1964. Average skidding distance for theoretical analysis of logging costs. Lafayette, IN: Research Bulletin of Purdue Univ. 789 p.
Tucek J, Pacola E. 1999. Algorithms for skidding distance modeling on a raster digital terrain model. J For Engin 10(1):67-79.
Wang H, Shao GF, Dai LM, Xu D, Gu HY, Wang F. 2005. An impacts of logging operations on understory plants for the broadleaved/Korean pine mixed forest on Changbai Mountain, China. J For Res 16(1):27-30.
Wang L, Ma F, Liu C, Gu Z, Sun J. 1996. Assessment of animal skidding and ground machine skidding under mountain conditions. J For Res 7(1):63-72.
Zhang Z, Feng Z. 1997. The method of calculating average skidding distance. J For Res 8(1):47-9.