EVALUATE AND DEVELOP AN EXISTING FOREST ROAD NETWORK BASE ON ENVIRONMENTAL FACTORS

Sattar Ezzati[1]*, Kyumars Mohammadi Sammani[2], Akbar Najafi[1], and Hamid Hasangholipour[3]

[1]Department of Forestry, Tarbiat Modares University, P. Box: 64414-356, Noor, Iran.
*E-mail: S.ezzati@modares.ac.ir, E-mail: a.najafi@modares.ac.ir
[2]Department of Forestry, Kurdistan University, Sanandaj, Iran.
E-mail: K.Mohammadi@uok.ac.ir,
[3]Department of Forestry, Guilan University, Rasht, Iran.
BSc gratuated in forestry. H.hasangholipour@yahoo.com

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Abstract

Designing the forest road network is a complex and specialized process including route selection, field investigation, data analyzing, and finally determining the best variant coping with the site-specific road locations. The present study was designated to evaluate the existing forest road network and to develop the existing forest road network in the mountainous forests, north of Iran (Savadkoh district). In order to find appropriate options for road routing, firstly the effective environmental factors were identified such as slope, aspect and elevation layers. In the next step, the Geographic Information System (GIS) was applied to evaluate and develop an existing forest road network. The length and density of the existing road network were about 1.75 km and 10.14 m.ha^{-1}, respectively. The new variant was developed with regard to forest and physiographic conditions using PEGGER software. The length and density of new variant were 1.38 km and 8 m.ha^{-1}, respectively. The development of the existing road network has been increased the total road density from 10.15 to 18.16 m.ha^{-1} and also could cover 55.5% of the forest area for timber harvesting operations. Approximately, 32.14% total length of the new variant was passed on 15–30% slope and 64% of the new variant was passed on 30–60% slope terrains, which is more likely to be minimal negative environmental impact. Moreover, the new variant has had a better performance than the existing road. The results showed that this method can be more helpful and road network can be designed quickly with less cost than traditional method. Also, it was confirmed by computer analysis that application of this system at such level can be effective in preparation of the optimum routes designing plans.

Key words: environmental impact, forest road network, GIS, PEGGER, Iranian forests.

Introduction

The Caspian forests located in the north of Iran cover the north facing slopes of the Alborz mountain ranges and are classified as temperate mountain forests. Consistent timber harvesting and protection of forests and making their direct benefits (economic, social, environmental etc.) (Gumus et al. 2008) available to public, primarily depends on a well arranged road network and transportation plan (Aykut et al. 1998). Forest functions are different in each country and depend on the culture and social life (Potocnik 1996), as shown in different studies (Hruza 2003, Demir 2007). Forest roads are the most important infrastructure for forestry operations, but without good plan, they could cause technical, economical and environmental problems (Demir and Oztork 2004). Therefore, in many studies there are attempts to compare the different variants of roads and finally to select the best one in order to enhance the accessibility of forest areas (Mohajer 2005). A suitable forest road network is necessary first to make a continuous forest harvesting and conservation, as well to use the direct benefits (Aykut et al. 1998). Timber harvesting being one of the main benefits, needs special attention during forest road network planning. Forest road network parameters change with regard to construction location requirements, different terrain conditions, particular technologies used and management activities. These requirements and the planning approach have to be related to management, economy and environmental ecology (Potocnik 1996). There are some other important factors that should be considered in forest road network design such as slope, elevation, aspect, type of bed rock, soil permeability and tree volume (Hosseini 2003). Not only costs has the main role in forest road planning, but also there are some other important factors, which should be considered such as forest road distribution, landscape patterns, forest hydrological role and soil conservation (Heralt 2002). The suitable distribution of the forest roads makes accessible all parts of the forest and thus all the processes like harvesting, plantation, silvicultural activities etc could be properly managed. The topographic condition is important not only for the design of the forest road network, but also can be effective for the forest road distribution among villages (ShiLiang et al. 2007). Appropriate and optimal distribution of forest road network from both economical and environmental viewpoint can help to meet the aims for sustainable development in forest management. A few of studies were conducted on the analysis of forest road network in the world. For example Akbari (1995) studied the existing forest roads in northern Iran and reported that the road density was 11.7 $m.ha^{-1}$, which was not enough to cover all district. Therefore, he proposed that road density should be developed to 16.5 $m.ha^{-1}$. Naghdi (2004) studied the planning of skid trail in planned and unplanned logging systems in a district in Mazandaran Province, nort of Iran, and found that the appropriate road density was 10.5 $m.ha^{-1}$. Pulkki (1992) described that the optimum road density in the different harvesting methods in Canada (log, tree length, whole tree) was 8.3–16.7 $m.ha^{-1}$. He stated that optimum skidding length was an effective factor on road structures. Picman and Pentek (1998) in Croatia stated that the optimum road density for ground skidding system was 14.7 $m.ha^{-1}$. Past studies developed forest road network with manual methods, while in the last few years the computer software and hardware is extensively and effectively used for the solutions of complex problem in forest areas, especially in the developed countries (Akay 2003, Rogers 2005, Demir 2007). Pentek et al. (2005) also analyzed the existing forest road network in Croatia investigating the mean skidding distance, its costs and suitable accessibility using GIS software. They showed that the average geometrical mean skidding distance was 158 m and the average existing real mean skidding distance was 250 m, whose factors of skidding wood assortment was 1.58. Today, the concepts like the digital map, digital terrain model, geographic information systems and the land information systems have gained an important role in design of the road network (Akay 2003, Demir and Oztork 2004, Aruga at al. 2005). The computer software is extensively used in many countries of the world for design of public and forest road networks. Thus, the aim of the present study was to investigate the forest road network with regard to road density and distribution, and to use this planning approach as a case study. Further, the aim was to compare the existing road network and new planned road segments according to environmental factors, to cover all studied district and to compare them by applying geographic information system.

Material and Methods

The study was carried out in a mountain temperate forest district covering 1722 ha of Mazandaran province, north of Iran. The area is located between 34˚3′40″ and 35˚1′00″ E, and 36˚08′00″ and 36˚11′40″ N (Fig. 1). The length of the existing road is 1.71 km. The road density was obtained refers to reference and road spacing was determined as theoretically road density

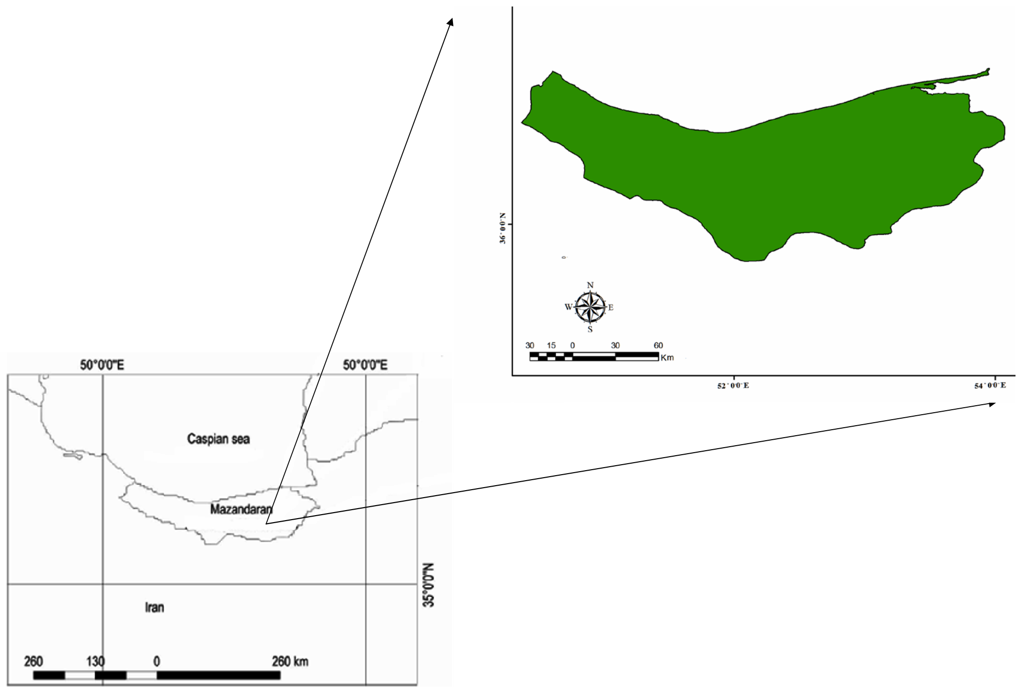

Fig. 1. General location of the study area.

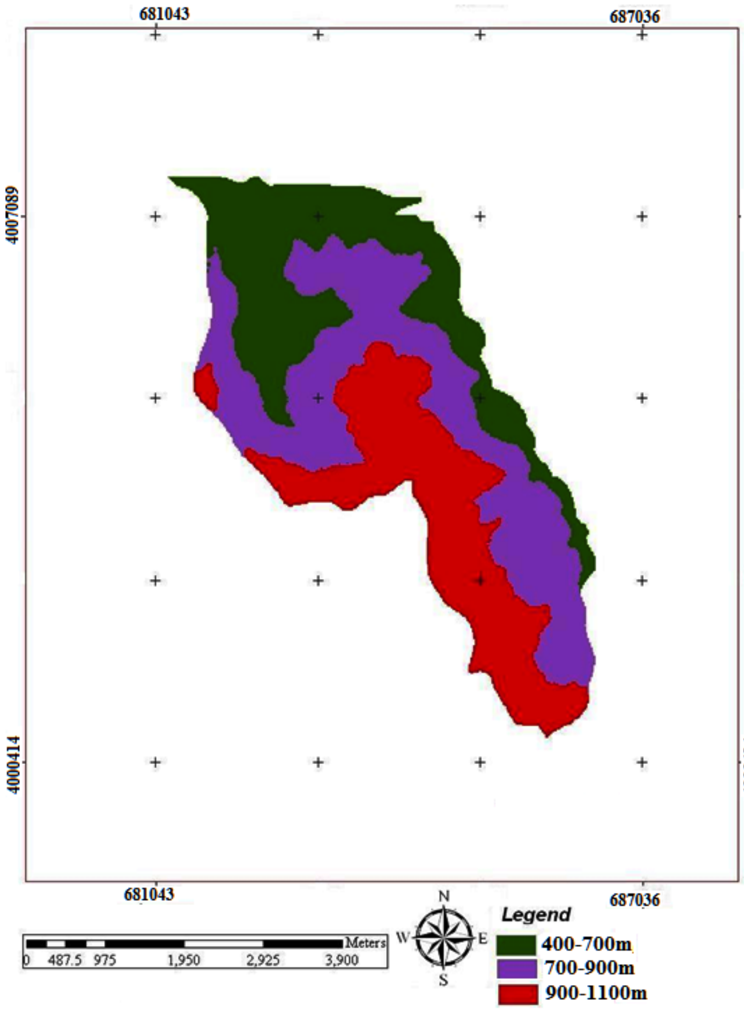

Fig. 2. Elevation map of the study area.

ume ($m^3.ha^{-1}$) maps were produced. The maps were elaborated by inventory data from field study. Tree volume ($m^3.ha^{-1}$) is one of the suitable factors for road density. In fact, when volume is less than 250 $m^3.ha^{-1}$ appropriate road density is 10 $m.ha^{-1}$ and when volume is more than 250 $m^3.ha^{-1}$, appropriate road density is 20 $m.ha^{-1}$ (Demir 2007). Majority of the study area had more than 250 $m^3.ha^{-1}$ volume. Therefore, the district studied needs about 20 $m.ha^{-1}$ road density. After determining of the existing roads (Pentek et al. 2005) new road segments were designed in accordance with the management plan. At this stage, the parameters were slope, aspect, stability maps overlaid and the critical points based on environmental considerations were determined. At the next stage, we tried using PEGGER software in GIS environment to propose the new variant additional to the existing road, which passes more positive and pass less negative points.

(Backmund 1968) and for the existing road it was 10.15 $m.ha^{-1}$. All road segments in the study area were recorded by reconnaissance using GPS (Garmin 60CX brand) and study of topographic maps. Then, by using Digital Elevation Model (DEM) in Geographic Information System (GIS), the affecting map factors were produced. In fact by using DEM, slope, aspect and elevation, also tree vol-

Results

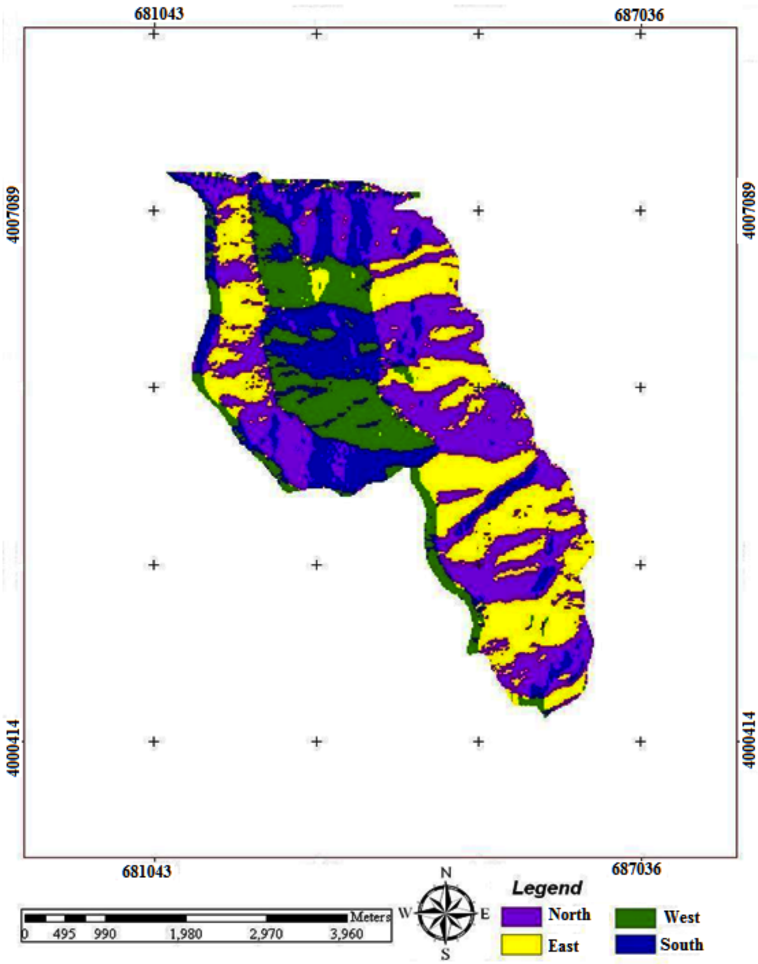

Fig. 3. Aspect map of study area.

To evaluate and develop the existing road, firstly the important maps e.g. (aspect, elevation and volume) were provided in GIS (Fig. 2, 3 and 4, respectively). In the next step, developed and existing road started. As you seen in the Fig. 5 the new variant has included two sections. First section is started almost in the middle of existing road, and another is started in the end of the existing road network. These two segments were previously planned to cover the uncovered part of the study area. Total the length of road 510 km (2.9 km) of the existing roads' longitudinal slope was more than 0–15%, while new variants do not pass such slopes.

The proportions of the existing and newly planned road network passing slope of 15–30% were 15.7% and 32.14%, respectively. Except these, 69.92% of existing roads and 63.90% of newly planned ones passed slopes 30–60% (Fig. 5 and Table 1). Finally, 11.47% of the existing roads' length and 3.96% of the new variant roads passed slopes more than 60% steep. The length and density of the existing road network was 1.75 km and 10.14 m.ha^{-1}, respectively. The new variant developed the road length to 1.38 m, and as consequence, the road density was 8 m.ha^{-1}. So total road density of the area was increased to 18.15 m.ha^{-1}. The total percent of road network (both existing variant and new variant) passing slopes of 0–15%, 15–30%, 30–60%

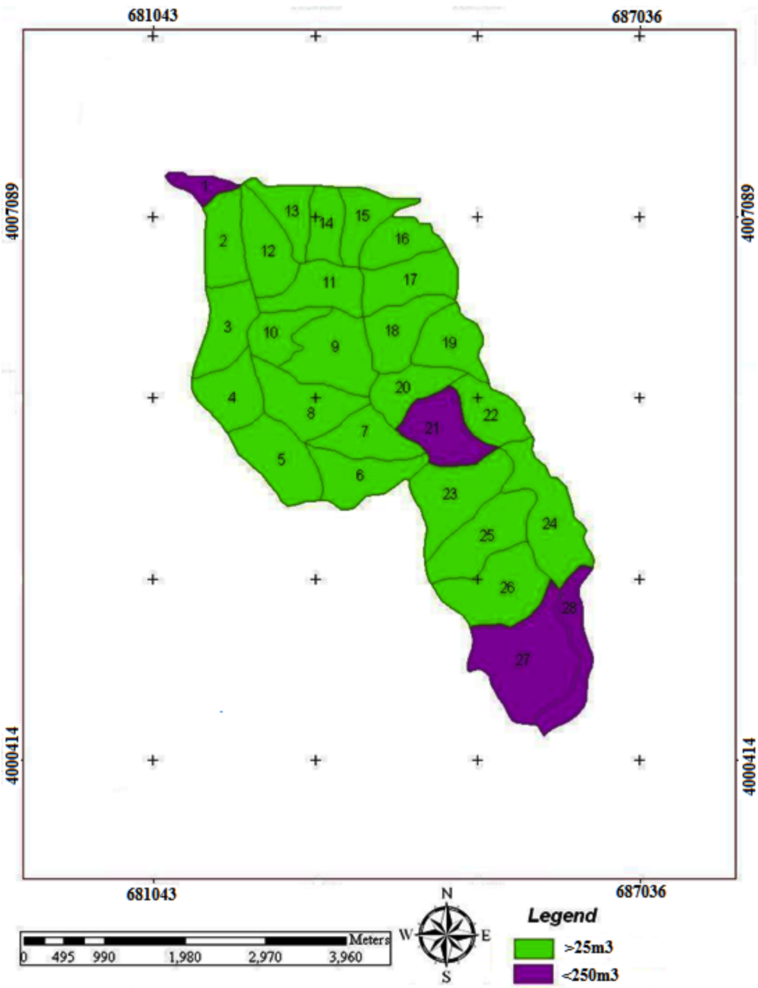

Fig. 4. Volume map of the study area.

and > 60% were 1.63%, 22.92%, 67.29% and 8.16%, respectively.

Discussion

The present study showed that environmental parameters such as longitudinal slope, aspect and elevations affected significantly the road network planning. When tree volume was less than 250 $m^3.ha^{-1}$, appropriate road density was 10 $m.ha^{-1}$ and when volume was more than 250 $m^3.ha^{-1}$, appropriate road density was 20 $m.ha^{-1}$ (Demir 2007). The existing road network plan is not capable of activating all management plan activities according to the calculations, moreover majority of study area has more than 250 $m^3.ha^{-1}$ tree volume, and so the existing road density (10.15 $m.ha^{-1}$) is not enough. If the management activities were carried out within the existing area, the density of forest road network would be increased only with 18–20 $m.ha^{-1}$ or a rate of 50% (Sobhani and Stuart 1991). In contrast, the new variant could increase the road density from 10.14 to 18.14 $m.ha^{-1}$ and cover area by about 55%, which is more acceptable (Akbari 1995, Lotfalian 2001, Demir 2007). With the road network to be constructed, the forest will be used in the optimal way and through utilization at maximum level, could be very beneficial in terms of environment. Because, by way of digital terrain modeling and assessment of slope thereat, the usage of a land in an impropriate way will be prevented and besides, the most beneficial road will have been planned in technical, economical and ecological aspects. As it is obvious in Table 1, the new variant does not pass from 0–15% slope because of topographic condition. In fact, there is no area with 0–15% slope in this section of study area (Fig. 5). The areas with 15–30% slope have a good condition to road building and we should try to design the forest road in this slope (Hosseini 2003). New variant is passed on this segment about 32.14% more than existing road (15.7%), so new variant has been a better situation than the existing road in this segments. We should try to design the forest road in the safe area and low slope, because, when slope increase, not only the cost increase but also soil erosion occurs, as well as it cause the stability of road reduces (Lioyd and Swift 1985). Approximately 63.94% and 3.96% of new variant are passed on 30–60% and over 60% slopes, respectively. New variant was passed on more than 60% slopes less than existing road respectively 3.96% and 11.47%. In contrast new variant has the better design than existing road, which not only can cover the most study areas but also passed more than existing road in the gentle slopes than existing road network. Total road network (the exist-

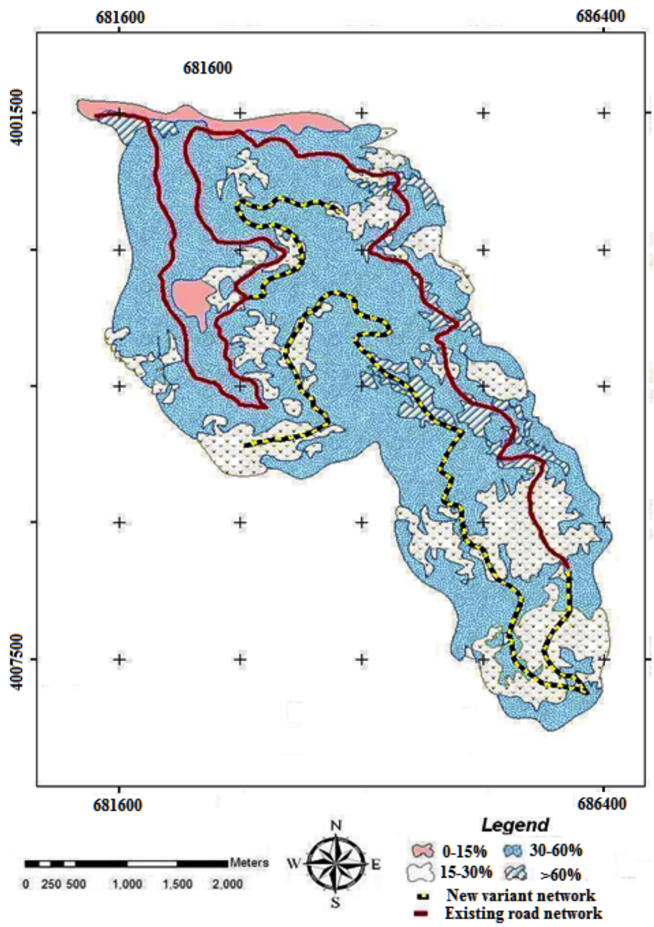

Fig. 5. The existing and new variant roads in different slope classes.

Table 1. The existing and new proposed road which are passed in different slopes.

Slope groups, %	Existing road			New variant			Change, %		Total road		
	Road length, km	Propo-rtion, %	Road density, $m.ha^{-1}$	Road length, km	Propo-rtion, %	Road density, $m.ha^{-1}$	Incre-ased (+)	Decre-ased (–)	Road length, km	Propo-rtion, %	Road density, $m.ha^{-1}$
0–15	0.51	2.91	0.29	0	0	0		2.96	0.51	1.63	0.29
15–30	2.746	15.7	1.59	4.422	32.14	2.57	16.4		7.168	22.92	4.16
30–60	12.229	69.92	7.1	8.816	63.90	5.11	5.98		21.045	67.29	12.20
>60	2.006	11.47	1.16	0.547	3.96	0.31		7.51	2.553	8.16	1.48
Total	17.491	100	10.14	13.785	100	8			31.276	100	18.14

ing and new variants) has 18.14 $m.ha^{-1}$ road density which is acceptable for north forests of Iran (Sobhani and Stuart 1991, Lotfalian 2001). With propose a new variant and passing more in the low slopes and avoid from high slopes, now total road in 4 classes of slope 0–15%, 15–30%, 30–60% and more than 60% was passed 1.63%, 22.92%, 67.29% and 8.16% respectively which has better situation than existing road.

Conclusion

The new forest road network plan was achieved by the addition of a total of 3.13 km forest roads designed for successful timber harvesting activities. The development of the existing road network increased the total road density from 10.14 to 18.14 $m.ha^{-1}$ and also covered 55.5% of the forest area available for logging. The length of new variants' longitudinal slope was more than 15–30% in about 32% of the cases. Comprehensive GIS database and research led to this success. Forest road networks aimed at enhancing timber operations must be implemented to meet the targets of the management plan. 20 $m.ha^{-1}$ road density, which is a conservative measure need not be a criterion for forest network plans. A geographical information system should be more used as a tool for functionally based forest road network plans by reason of its geographical data storage, updating, and number of possible analyses.

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