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Research article/Araştırma makalesi

The design of forest roads network in compliance with the environmental issues using GIS and AHP

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Abstract

Forest roads are one of the basic infrastructures for the management of forest areas. Ensuring the stable operation of forest roads network and maintaining initial capital spent on construction of forest roads requires proper estimation of the volume of earthworks is the construction of forest roads. Today, by using the Geographic Information System (GIS), simultaneous information management with consideration of factors affecting routing, predictive and rapid assessment of directions became possible. The aim of this study is to provide a method to optimize the design of forest roads network by considering the environmental, technical and economic criteria and utilizing the capabilities of GIS and Analytic Hierarchy Process (AHP), so that a greater number of these criteria entered in the design process. The study conducted in series 7 of Sherwood. After obtaining information layers on environmental characteristics affecting the forest road network design, based on technical principles and by using Pegger software, 4 roads were designed. After classification and valuation of the different layers of maps, for environmental evaluation, AHP pairwise comparison method used in the process. The results of this research proved the hypothesis that GIS and AHP have many capabilities in road design based on ecological principles. The study area has high topography so designing a proper road was not possible and given the proximity of road congestion, road 3 was chosen due to its environmental priorities. At the end, the ability of its implementation in the areas studied and approved.

Key words: forest road, considerations of environmental, technical and economic, multi-criteria assessment, GIS, AHP

1. Introduction

Forests are the main natural resources of the planet and their functions have an essential role in maintaining ecological balance. Forest health in each location is an indicator of the common ecological conditions in the area (Zhang& Chen, 2007). Forest roads are necessary to administrate many parts of the forest (Dimitrios etal.,2016). The roads are a necessity to make ideas and principles and design managements come to reality in the forestry unit. The road networks are like a vital artery for forest products and services. Today, due to the importance of other forest values, the rest of non-production services such as tourism and considering the vision and perspective discussed and considered in the design of the road network (Sepahvand, 2005). In design of forest roads, basic and fundamental studies including research of geology, soil characteristics, topography, soil and vegetative cover and wildlife and habitat for animals elements related factors (Type of tree, Plant capacity) are considered (Sarikhani, 2008). With the appropriate planning of the road network, network efficiency increased and at the same time, manufacturing costs reduced. Since the network design by using traditional methods are costly and time-consuming, reducing cost design time will reduce the number of evaluating options and this will hurt the quality of design. On the other hand, the new methods of design using GIS technology and data processing facilities has the ability to analyze high volumes of digital data for different layers with high speed and accuracy, so it can improve the quality, speed, cost, and accuracy of design (Audi, 2005). In 2007, by studying on forest roads and valuation networks designed by GIS and RS, Shiba compared routes with directions designed by this software with traditional methods and showed that routes that designed by GIS have more advantages over the roads that were designed by traditional methods. Gumus *etal*., (2007) designed 59.067 kilometers of roads using GIS in their study on forests of Turkey. The results of this study showed that 90.3% of the way passed from the places that had the least negative points. Forest roads network designed to meet the performance targets. Since the cuts, disturbs the natural balance and stability, if they are not made technically correct and from natural balance point of view they are not made in an acceptable form and their stability are not considered, it can cause damage and disorder in the

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structure and balance of the road, which it can ultimately cause slip from the mountains to the surface or body of the road valley side (embankment). With regard to the above, forest road, network design should be such that all terms are considered. The aim of this study is to provide a method to optimize the design of forest roads network, by considering the environmental criteria, and taking advantage of the capabilities of GIS and AHP, so that more of these criteria entered in the design process.

2. Materials and methods

2.1 Study Area

The study area is in 25 northern forests area. In terms of geographic location, this series is located between49º 47′ 50″ of longitude and latitude of 36 º 55 ′ 30 ″. Its elevation ranges from 700 to 2100 meters and the general slope faces north. In the present series, there are 74.28 kilometers of roads, including paved and graveled and their general appearance are in a funnel from and the soil texture is medium to slightly heavy(Figure 1).

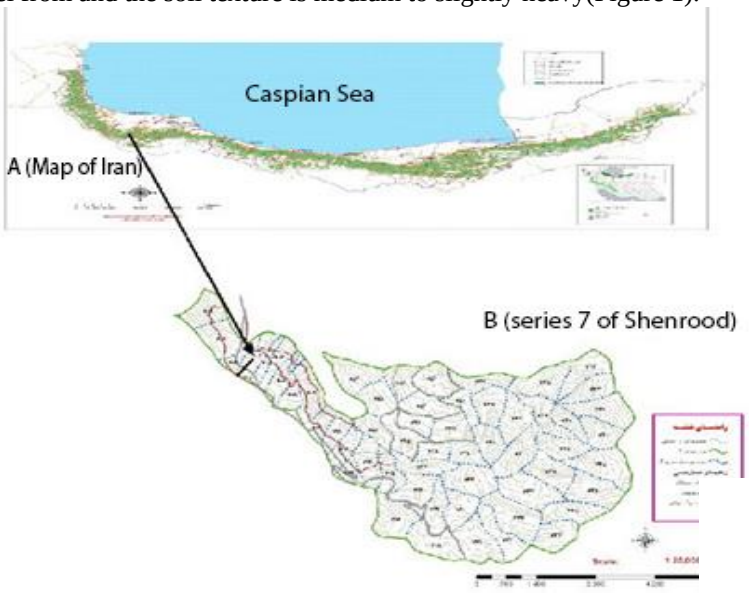

Figure1. Location of deries 7 in area of 25 (Case Study)

In the first step in this research, basic knowledge and overall assessment of the region's road network design was discussed using GIS. For this purpose, at first, by extracting the topographic lines from three-dimensional dgn digital map, digital elevation model was prepared. According to the study and congestion, the 50 meters was determined. Using DEM, slope map in Idrisi was prepared. By taking aim reviews, geomorphology, the study of the earth, and scale of the map, the study area was divided into four floors slope including 0-10%, 10-25%, 25-60%, and more than 60%. Then use the DEM, map directions were provided. By using this map, the southern and eastern classes that were more appropriate to pass were identified and priorities in the design of the road network. The four cardinal directions (North, East, South, West) and a floor as flat areas (undirected) were considered that includes all areas with less than 10% slopes. After preparing the final plan for land crossing capability, the road was designed in Arc View by using Pegger (Rogers, 2005). The road was designed in such a way that as far as possible, it would be in compliance with the allowable slope for roadwork and by considering the appropriate forest cover, it passes through areas with high and medium potential road constructability that arguably has greater stability. Then, given the importance of the slope, the designed road was correct on the slope map. After that, the road network map was transferred to Arc GIS and the necessary corrections including changing fractures to curves, was imposed on it. In this study, the method of pairwise comparison using AHP function in ArcGIS was used as a method to determine the weight of evaluation criteria (Map Descriptive) in a multi-criteria decision.

3. Results

Acording to, the slope map was prepared both in four classes of (0-10, 10-25, 25-60, and more that 60 percent) to mapping the crossing ability of the road and stability map of the region. It was prepared in a way that 27.4% of the area of the series were less than 30%, 55.2% of the area has between 30% to 60% slope, and 17.04% of the area has more than 60%. The altitude of study area fluctuates from 600 to 2104 meters above the sea level and were prepared in three classes(600-1200,1200-1800 and 1800-2104) (Figure 2).

27 percent of Sri less than 30% and 2/55 percent of the area between the slope of 30 to 60 percent, 17.4 percent higher than the slope angle is 60 percent.

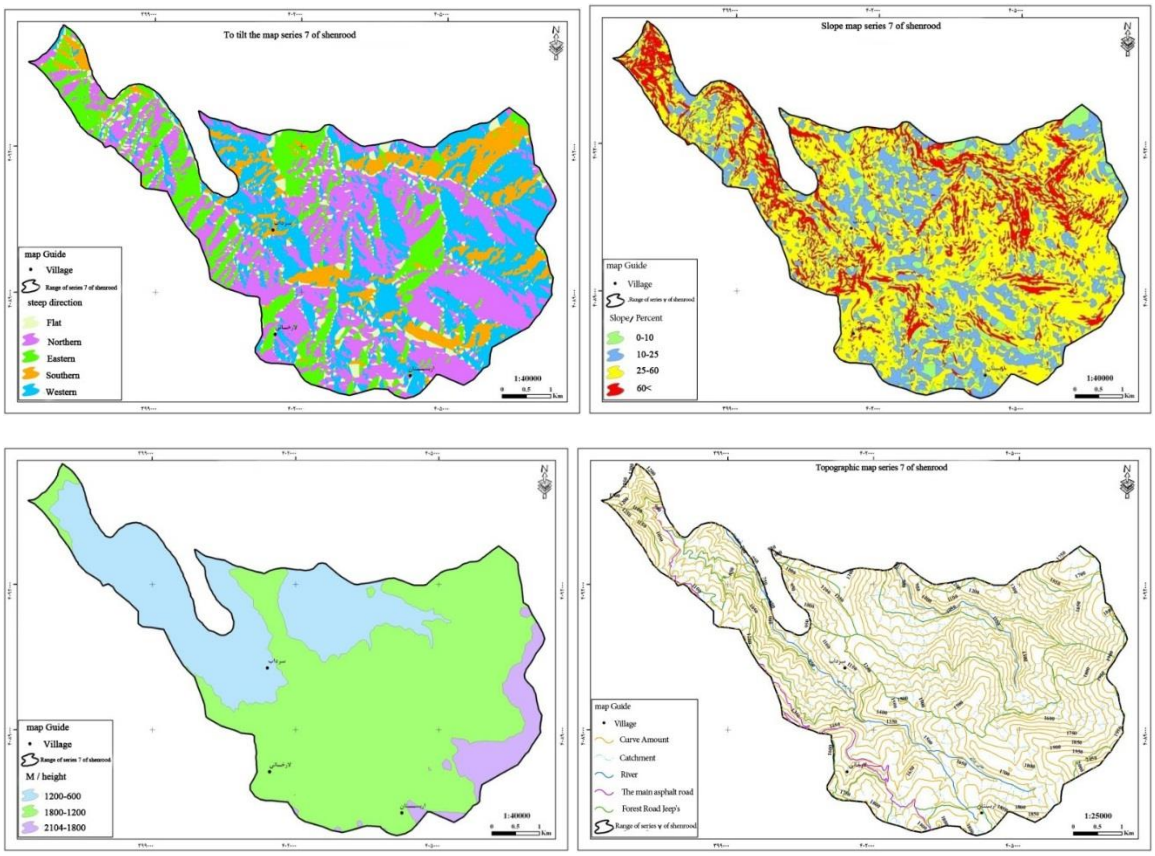

Figure 2. A) The slope map, B) map directions, C) topographic map, and D) elevation map

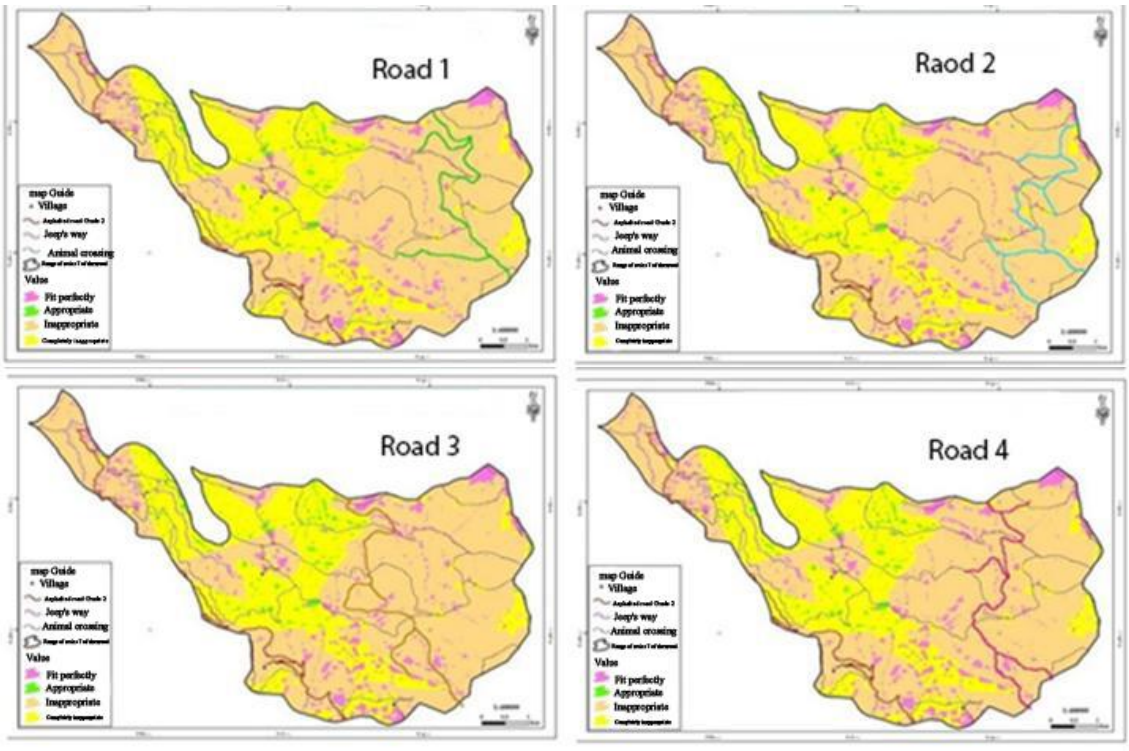

Figure 3. Map of new designed road based on the location of valued

Using the attached software, Pegger, 4 options with respect to all layers of the road network, designed and then evaluated environmentally and technically. Design options shown in Figure 3.

3.1Technical evaluation by Sagbuden method

In the method the index of total distance × length of the road used, which the smaller amount of the index in terms of technical evaluation is desirable. Therefore, the road 3 is the most desirable roads (Table 1).

Table 1. The results of the technical evaluation of alternatives by Sagbuden method

Rank	Total skidding distance × Road length	Road length (km)	Total skidding distance	Road
1	1131302	26.236	43120.216	1
2	1192172.1	7.396	43516.285	2
3	1189244	28.427	41835.016	3
4	1224727	28.895	42385.430	4

3.2Environmental Assessment of roads

The results of the environmental assessment for various road shows that in environmental terms, road 3 has the first priority and in environmental terms, road 1 has the last priority (Table 2).

Table 2. The results of the environmental assessment for different road

Variants	Total multiplying the percent passing through the respective classes multiply in the coefficient for each of the classes valued
1	200.8
2	203.4
3	220
4	205

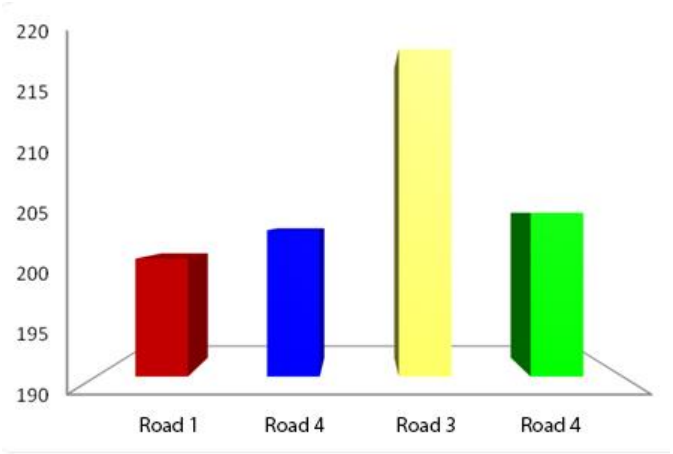

Figure 4. Environmental prioritizing of designed options

Road 4 with the minimum length has the highest desirability and road 2 with a maximum length has the lowest desirability (Table 3).

Table 3. The results of the environmental assessment for roads based on road congestion

Rank	The value of length	Road length (km)	Road congestion (m / ha)	The extracted value	Road
4	312.06	26.236	7.05	6301	1
3	403.26	27.396	7.36	6390	2
2	309.45	28.427	7.46	6630	3
1	294.34	28.895	7.77	6415	4

In Figure 5, it is clear that most road congestion is in road 4 and the lowest road congestion is in road 1.

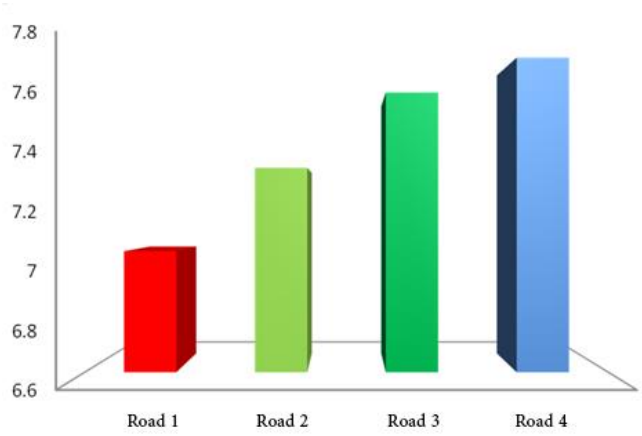

Figure 5. That most road congestion is in road 4

4. Conclusions and discussion

Forest road network should be designed based on complete information of management method, situations of forests, forest management methods, operation units, methods of extraction of timber and other forest service so transport system can be developed with minimal cost. In designing of forest roads network, from designing of single roads to its completion, multiple technical issues should be decided in a rational way. The basis for these decisions is having the right information and enough knowledge of the region. Due to the heterogeneous forests environment, particularly northern forests, seeing all angles and sides and turning them into numbers in order to analyzing and evaluating of them is not possible by traditional techniques and surveying forest or it is costly and time-consuming. Use GIS a lot of information can be processed with lower cost and spending less time. Using GIS for mapping potential areas for the road by using the PEGGER program in GIS presented acceptable results in this study. Firoozan(2006) ,Rogers et al.(2001) ,Abedi (2006), reached the same conclusion about designing road maps by using PEGGER. Contour map and based on properties of percent slope in the design route between two points, different routes can be suggested quickly and according to map of appropriate areas for routes based on ecological principles and characteristics of the network of forest roads and mountainous, evaluated routes and select the appropriate one with high speed and accuracy. While in this method, there is no need for suggesting different variants and by quickly offering different routes and analyzing them in GIS, a right exclusive route chosen. In this study, environmental factors influencing road design process identified and for weighting the criteria, pairwise comparison used in AHP. The results showed that this method would provide good results. Using AHP for weighting, give the possibility of using various quantitative and qualitative criteria at study and use of relevant experts' opinions will increase accuracy of the study and give the study better results. It is noteworthy that in weighing the slope criteria, below 10 percent classes has top points and slopes over 60 percent has the lowest points in locating of designing roads. For criteria of the slope, the South and East had the highest points and the West and North had the lowest points in in locating of designing roads. By overlapping the existing roads with valuation places and prioritizing the series 7 of Shenrood, it seen that due to the extreme topography of the area designing of new roads in the area were in poor value ranges and among four roads, road No. 3 has a top environmental priority. Study on forest roads and evaluating networks designed by GIS and RS, start to compare roads that were designed with these software and the roads that were designed in the traditional way and showed that roads designed by help of GIS has advantage over the roads that are designed in the traditional way(Shiba,2007). The results of this study proved the hypothesis that GIS and AHP have many capabilities in road designed based on ecological principles. The study area has high topography and there was not any possibility to design a proper road and given the proximity of the congestion of roads, road 3 was chosen in terms of environmental priorities.

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