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DESIGNING OF FOREST ROAD NETWORK BASED ON TECHNICAL AND ECONOMICAL CONSIDERATIONS USING GIS & AHP

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ABSTRACT

Designing of forest road network is a complex engineering problem. Therfore, the economic and environmental issuuse should be considered in forest road network designing. The aim of paper is to develop a method using GIS and Analytic Hierarchy Process (AHP) to design a forest road network with the lowest construction cost while maintaining other technical requirements. First of all, the required data was collected from the study area. Then the necessary maps including slope, aspect, altitude, soil, geology and standing volume was determined as well as the importance coefficient of each layer of maps was determined via Expert Choice (EC) software. Then, road planning potential map was prepared by overlaying these layers. Finally, the proposed road network techniqually evaluated by merging the planned road network and road planning potential map based on Backmund criteria. Results indicated that the proposed road network with density of 10.67 m/ha and 81.6% road coverage is preffered to the existing road.

KEYWORDS: Forest Road Network Planning, GIS-AHP Method, Expert Choice, Iranian Caspian Forests

INTRODUCTION

Forest roads are an essential inferstructure for accessibility and logging practices, management, afforestation, transportation, forest protection and recreation activities (Akay and Session, 2005). Inadequate road construction and poor maintenance has the most potential to cause more environmental damage than other operation associated with forest management (Skaugest and Allen 1998). Passing the roads through low to moderate slopes and areas with high level of stability reduces the costs of excavation, land stabilization, excavation gable roofs and earth filling, therefore reduces construction costs (Kunwoo, 1990). Several different optimization techniques have been used in forest road planning such as: 3D forest path finding model named “TRACER” for rapid evaluation of different paths, aiming to help the planners to plan the primary roads (Akay and session 2005), software entitled “ROUTES” to estimate the longitudinal slope length, forest length and routing possible variants using DEM (Reutebuch 1988), GIS technique for designing the skid trail network and providing some primary data such as stand productivity, timber volume and cost and other weighty layers (Tan 1992), PEGGER software to automatically trace the forest roads using GIS- PEGGER which is a strong tool for rapid analyzing of various road variants (Rogers 2005). Finally, decision support system is used to improve the transportation planning in landslide prone terrain (Wing et al 2001). Hence, using more modern techniques such as GIS application for

forest road network planning could reduce costs and environmental damage. The challenge is to use the GIS-AHP model based on environmental, techniqual and ecological conditions. Using GIS as a decision making system can be an efficient method for offering appropriate alternatives in forest road locating.

Field surveys and empirical modelling indicated that slope stability, observing road geometric principles and choosing the safe and stable regions for routing road by GIS, reduces the cost of excavation, earth filling, land stabilization and road maintenance (Zaitchic and Van Es 2003, Musa and Mohammad 2002, Nghdi and Babapour 2009).

The present study considers various factors such as slope, aspect, altitude, soil, geology, volume and forest type using AHP to present a GIS-AHP method for planning road network in northern mountainous forest of Iran, consequently to compare the result of this approach with the existing road network.

MATERIAL AND METHODS

Study Area

The study area is located in district No 10 at Shafarood Forest, Guilan provice in northern Iran (latitude 37°45'N, longitude 48°54'E), which covers 1812 ha and 28 compartments (Fig. 1). Forest roads in this district have been designated based on traditional methods. The road length is 11167meters. The existing road density (RD) is 6.16 m/ha. Regarding to the selection management system, it is not sufficient (Iranian Plan and Budget Organization 2000), thus additional roads are required. The altithude ranges 20 to 650 meters and the slope generally ranges 10 to 60%. . The aspect is northern and north estern. Forest type is managed under unevenaged sylvicultural system with hornbeam and iron wood species. The geological foundation is volcanic stone with lime lode. The soil texture is lome and clay lome.

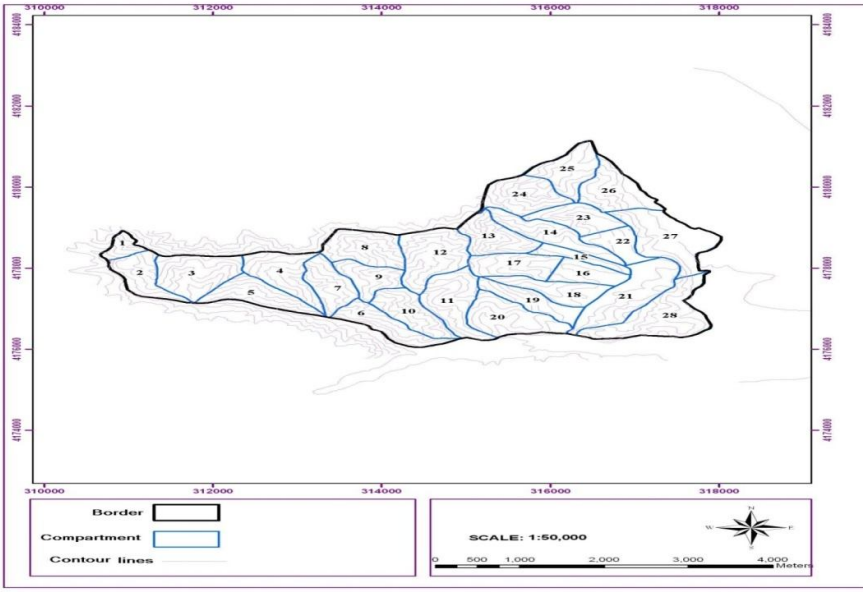

Fig. 1: The Map of Study Area

METHODS

The contour line layer of the area was extracted from 3D DGN files and it was used to generate a digital elevation model to design road alternatives. For road network planning, different effective factors maps of the study area including slope, aspect, altitude, soil, geology and volume were mapped using Arc GIS ver 9.3 and AHP method by Expert Choice software (Malczewski, 1999). For implementing AHP method, the questionnaire was distributed between forest

engineering experts to obtain the relative weight for each criterion. Each of prepard maps possess categorized in suitable, unsuitable and mid suitable areas for road network planning. By overlaying the weighted maps of affective factors, road planning potential map was prepared. An ArcView GIS extension called PEGGER (Rogers 2005), which automates the route projection, was used to design road network alternatives regarding to forest road standards. To do this, both road planning potential and hydrographic maps were considerd.

Comparision of Designed Road with Existing Traditional Road

The existing traditional road was compared to the designed road network based on the coverage percent criterion of Backmund (Backmund. 1968) and accessibility of wood volume by road (tonage of wood volume per km of road).

The Bakmund criterion of forest roads are most commonly quantified only by length and road density. First of all, the road density was calculated according to function (1).

$$D = \frac{L}{A} \tag{1}$$

Where, D is road Density, L is total length of roads (meter) and A is the forest area (hectare)

Then, the road network percentage (R) of each road network was determined and compared according to function (2):

$$R = \frac{A_L}{A} * 100 \tag{2}$$

A_L is the area thas is covered by forest roads.

Stock and location of harvested trees are necessary for determining “ton per km” of roads. It entails using dot grid network in traditional method, however, the technique of GIS, not only is more accurate, but also rapidly determines the “tone per km”by converting vectore maps to raster one. Algebric some of cell values identify the “tone per km” of each road.

RESULTS

The results of AHP revealed that slope and stand type had the highest and the lowest weights, respectively (Fig.1).The consistency ratio (0.07) was acceptable (Eastman, 1995). By overlaying weighted maps of affective factors (slope, forest tyope, stand volume (m^3/ha), aspect, altitude, soil and train condition) the forest road construction potential map was produced. The later map disclosed five classes included: very good, good, average, bad and very bad.

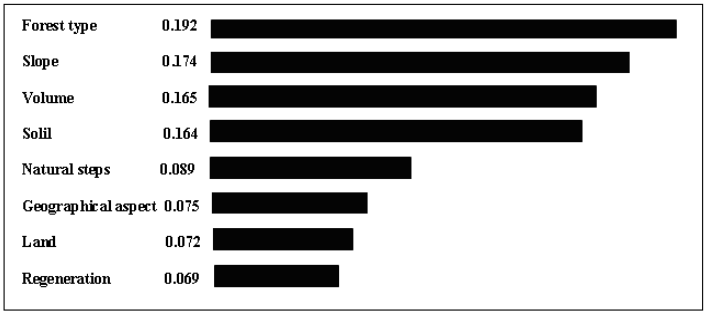

Fig. 1: Results of AHP Method

A road network was designed on road planning potential map instead of using topographic map as a base mape. Proposed road has been shown in Fig. 2.

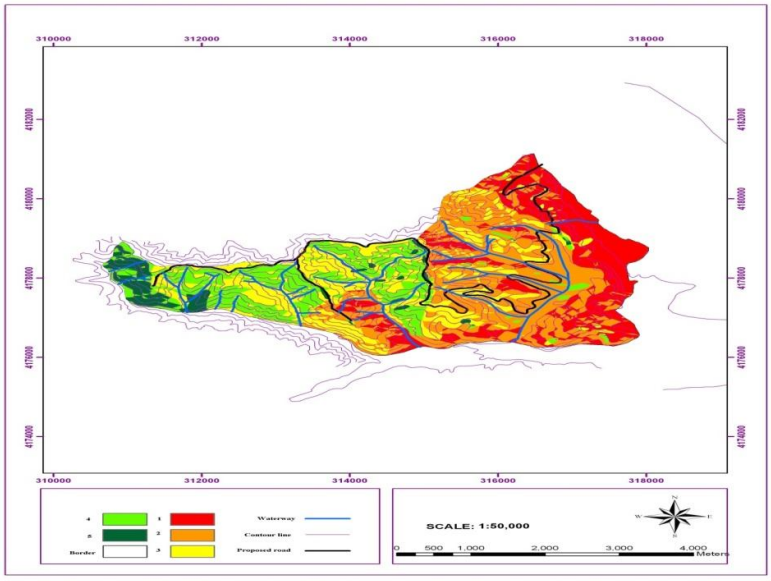

Fig. 2: Proposed Road Pass Map at the Study Area

Comparison and Evaluation of Road Variants

Data was manipulated in GIS environment. The results indicated that the average slope of the district is 35.18 and the district area is 1812 ha. The existing road had the following properties: road length was 21614 m, area coverage was 70.8%, road density was 6.16 m/ha and skidding distance (with corrected slope from each side of road) was 471.2 m. The planned road had the following properties: road length was 20498 m, area coverage was 81.6%, road density was 10.67 m/ha and skidding distance (with corrected slope from each side of road) was 496.8 m. The results indicated that the modified "tonage per km" was 878,779,972 and 6,702,637,410 for existing and planned roads, respectively. Both roads and potential map of road construction were overlapped in order to study the environmentally differences of existing and planned roads (Fig. 3).

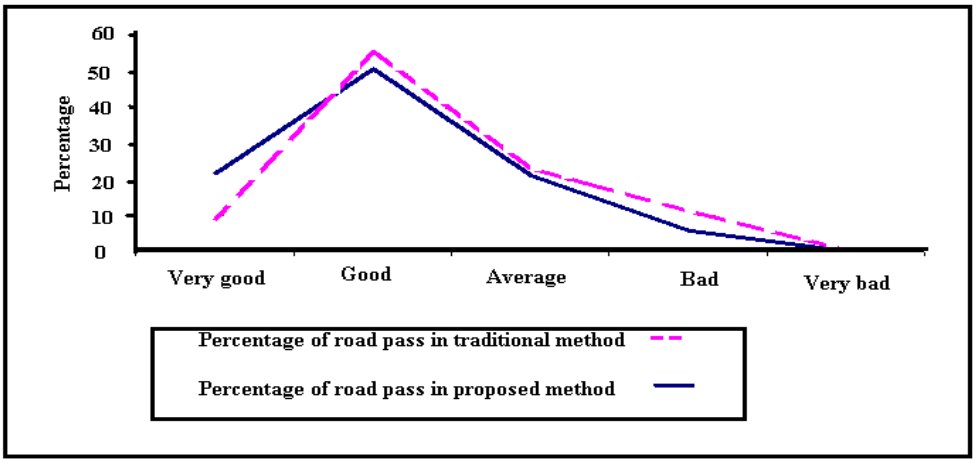

Fig. 3: Comparison of Road Pass Percentage in Existing and Proposed Road Network Planning

DISCUSSIONS & CONCLUSIONS

Forest road network planners often need to make a decision between several objectives. Therfore, one of the most useful models could be GIS-AHP method. Using GIS-AHP qualitative and quantitative criteria can be used and incorporated in decision making (Eastman 1995). Forthermore, GIS software systems provide the basic tools for forest road network planning. GIS offers a number of advantages compared to the traditional hard and time consuming methods. However, a pleasent model for planning and selecting road between more alternatives should be simple and easy to understand and use. Haung et al. (2003) used socio- economic characteristics, risk rate, traffic rate, and the possibility of aiding in emergencies for road routing and also evaluated those using AHP to prepare the efficiency map for rout planning. Using a GIS in designing and evaluating the forest road variants is very effective (Majnounian et al, 2007) and not only it causes the simplicity of using AHP method, but also can help in computing and analyzing as well as it is proposed as a good method in forest road network allocation.

This research is a new method to link the traditional and advanced road network planning where as it proposes the combination of two methods. Tan, 1992; Session et al., 2001; Dudhani and Sinha, 2003, Malczewski, 1999 and Naghdi and Babapour, 2009 also suggested that applying GIS technique has more prefference in comparing to traditional method. The techical accuracy aspect of the proposed GIS-AHP method is higher than the traditional method. The advantage of this challenge is that it is possible to apply the results of this study based on Iiranian Forests and Rangelands Organization (IFRO) with high accuracy. Therfore, it is superiour to traditional road network planning method. Hence, if the technical prespective is considerd in road netwok planning it should reduce the cost of excavation and embankment. For example, if the designed road passed from slope of 60% instead of passing from slope of 30%, the volume of excavation and embankment increase 2.2 times and the cost of road construction increase 2.2 times (Naghdi and Mohammadi Limaei, 2009). Consequently, a proper road network planning not only is better in terms of technical and environmentally, but also it imposes less road constraction and maintenance costs. In addition, a proper road network planning may be reduce the skidding trace; this could decrease the environmental impact of skidding trace construction and reduce the skidding trace construction cost. The length of road in proposed planning method is less than other methods while it has higher capability. Therfore, this advantage will reduce both environmental damage and construction costs.

This paper presented a quantitative method in order to propose a forest road network using GIS and AHP. The capabilities of GIS in spatial analysis enable the forest road planner to combine different factors and identify them to improve the results. Using AHP will permit the derivation of relative weights. However, the results depend on data precision, the innovative method is proper for initial planning. This procedure will allow the manager to incorporate construction costs and environmental factors.

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