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Research Paper

The investigation of the usability of GIS facilities for planning forest roads network in Iranian Caspian forest

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Abstract: One of the foundations of long-term management in the northern forests of Iran is the existence of forest roads network. Passing the roads through low to moderate slopes and areas with high level of stability, reduces the costs of excavation, earth filling, land stabilization, excavation gable roofs and earth filling, and thus reduces construction costs. This research was carried out in the Shafaroud forest in the west of Guilan province. The paper aims to develop a method using the GIS technology and MPSIAC model to produce the stability map for designing the new roads network in the study area. The results showed that the proposed road network with a length of 23908 meters compare to existing roads network with a length of 25280 meters, could generate a suitable coverage among the parcels. The length of the proposed roads network is 1372 meters less than the length of the existing roads and creates the highest percentage of coverage with the least length so that in addition to the reduction of costs the forestry plans could be directed in the way of sustainable development. Some 12% of the proposed road passes through regions with high stability more than the existing road and the passage of the proposed road through the unstable regions as compared to the existing road has reduced two times and has had a significant difference in the level of 99% and totally has reduced the corrosive effects of the road on the nature. Ultimately, the results yielded show that using the GIS can increase the accuracy of the designing and quality of the forest road network and reduce the costs.

Key Words: forest roads network planning, stability map, GIS and MPSIAD model, Iranian Caspian forest

Introduction

As a result of being located in the mountainous and steep regions, the forests of Guilan province in the northern Iran are among the sensitive and important areas in terms of natural disasters such as mass movements, earthquakes, floods etc. Sliding movement can be seen in different parts of Iran while human operations such as exploitation of the mines and building roads is effective in generating sliding masses; however, it seems that the current circumstances of sliding masses are more affected by the climatical and especially geological situations rather than human factors. The primary material of these regions is mostly consisted of unstable establishments such as marl and marl lime which are sensitive to sliding masses. In the construction of forest roads, the conduction of fundamental and basic studies including studies on geological, pedology, topographical features, physiography and factors related to the growth elements (type of the trees, capacity of growth lands) are taken into consideration (Sarikhani, 2000).

Failing to construct forest roads in a systematic way in some of the forestry plans as a result of inaccurate designing and the passing of roads through routes sensitive to slippage and landslide and the mass movements of the soil leads to the destruction of the road and transmission of a great deal of soil to the lower hand and the operation of designing and construction in this road will end in failure and become practically impossible. Failing to construct deposit in the routes where the woods are transferred imposes several damages upon the trees at the two sides of the road and the peripheral rivers and decreases the useful life of the road (Mostafanejad and Sadadi, 2007).

Designing and constructing networks of forest roads in the mountainous forest regions is among the executive fundamentals of scientific and accurate management of forest lands and opens the window to the sustainable development of the forest masses. From the other hand, the construction of roads in a forest and mountainous region is actually a major intervention in the unharmed and unknown nature of the forest which leads to natural disequilibrium. One should act multilaterally in designing and constructing forest roads and the natural features, and characteristics of the region in terms of topography, typology of the forest, geology, pedology, climate, forestry and forestology and the style of utilization and totally a deep ecological viewpoint should be taken into consideration for the designing and construction of the network of roads (Richardson et al, 1997).

In 2007, Houshyarkhah and co-writers concluded that the networking of forest roads can be considered as one of the important bases in executing the objectives of forest management. Given the high expenses of constructing roads in the forests, building a fundamental network which can generate the most coverage with the least density of length and minimum destruction is necessary. Designing and constructing a network of the roads with sufficient and appropriate density is necessary for justifying the utilization and plan from an economic viewpoint and performing the whole operations in order to preserve, renew and develop the natural resources and using them constantly will be enabled by RS and GIS (Hosseini, 2004). Hosseini (2004) investigated and designed the network of forest roads in the Kheyrood Kenar forest of Nowshahr using the GIS method. The results of the research led to an optimal design of network. By overlapping the maps through GIS, he could pass the conductive route using various descriptive maps such as slope, geology, zoology, density and pedology in such a way that the majority of the route will be included in the sustainable regions and in the form of optimal design for the assumed road.

In their studies, Haeri and Samiee (1998) demonstrated the role of the factor of slope and the type of soil and the bed rock in a variety of mass and seismic movements which confirm the importance of paying attention to these factors. Therefore, by preparing the sustainability map of the region, it would be possible to effectively contribute to the designing of the roads with lower construction and maintenance cost by specifying the unsustainable points facing the danger of slippage as the negative compulsory points and the sustainable points as the positive compulsory points. Today, with the expansion of using the GIS facilities, preparing and compiling the maps with less time and cost and more speed is made possible. Glendon and co-writers (2006) in the United States categorized the forest regions in order to specify the different applications of forest regions (such as preservation, utilization planning, ecotourism etc.) In this research, based on factors such as the typology of the forest, geographical situation, predominant soils, bed rock, the depth of bed rock, texture of the soil, drainage of the soil and the fertility of the habitats, the forest area has been divided into 39 land types. Using the produced maps was an effective help in this investigation. To model the utilizable forests and managing the region's wildlife, Abedi and co-writers concluded in their 2007 research that geographical specifications, the type of the soil and the geological conditions should be studied before setting up any installations in the mountainous regions. Eschner and Patrick showed in their 1982 study in the forests of the Utgan coastline that the road erosion is 30 times as much as the uninterrupted rupture erosion and its speed is three times as much as the latter which brings about heavy financial damages for reparation and considerable environmental harms. Therefore being acquainted with the geological, geomorphologic and mechanical features of the soil of the region which the road passes through is among the most important factors in taking proper decisions in order to reduce the heavy costs of building roads and selecting suitable methods for maintaining and reconstructing forest roads. The phenomenon of erosion and its negative impacts might not be too considerable and significant in short term but will be perceptible in the long run.

Materials and Methods

The studied region

The study area is located in district No 9 at Shafarood Forest, Guilan provice in northern Iran (latitude 37° 22' to 37° 25' N, longitude 48°27' to 48° 30' E), which covers 2402 ha with the dominant species of beech and hornbeam. The altitude ranges between 800 to 1800 m above sea level. The type of the forest is uneven-aged seed-borne which is run by individual selection method. The forest roads network in this district has a total length of about 25.280 km.

Figure 1. a) Guilan Province b) Shafaroud's series Reze

Methods

In the present research, given the intended objectives and due to the application of GIS system for the forest roads, all the required processes were used for the conduction of the research like the rest of research projects. In the present research, the available maps in the booklet of the Shafaroud's Series Reze forestry plan were first investigated and analyzed and the maps related to the land covering and pedology of the parcels were extracted (plan's booklet.) The map of the categorization of the series' lands or in the other words, the production of the map of identical units was put forward. For this reason, by preparing the topography map of the studied region with a scale of 1:25000 using the maps which were printed by the cartography organization, the layers of slope for the creation of the units of the land's formation using the descriptive model related to the topographical situation of the region and with a scale of 1:25000 and the 50 meter spacing of aligning lines using Arcview was prepared in three layers corresponding to the designing of the network of the road (Hosseini, 2004 and Makhdoum, 1994) (Table 1 and Figure 3). Geological maps, information on climate and the application of the lands in the studied region were extracted from the Guilan Province's drainage basin record (Bakhshipour, 1997).

In the issue of combining and mixing the data using MPSIAC model regarding the effectiveness of geological and pegological factors and maps, slope, climate, land coverage and the application of the lands in designing the network of forest roads and the connection of these factors with the studied region, the erosive nature of the abovementioned factors was encoded in designing the network of the roads (Table 1) and having in mind the formula, scoring would be done for each of the abovementioned factors (Table 2) (Refahi, 2004). Afterwards, the classified map of erosion was extracted, having in mind the maps of convergent units (the combination of geological and pedological maps, slope, climate, land covering and the application of the lands.) (Figures 2, 3). After preparing the classified map of erosion, the route of proposed road was sketched using the scale of the compass while in the existing forestry plans, it's only the region's slope (topographical map) which is used for preparing the network of the road. In the next stage, the overlapping of the map of the existing road and the designed road on the classified map of the region's erosion was studied. Thereby, the number of units through which the route of the existing and designed roads pass would be specified (Figure 5). For statistical analysis, the Chi square test and the SPSS application were used.

Table 1. Encoding of the studied maps in terms of sensitivity to erosion for the orientation of the road

Map	Code 1 (High sustainability)	Code 2 (Medium sustainability)	Code 3 (Unsustainability)
Geology	Base volcanic and volcanic tuffs	Limestone	Marlin, sandstone, serpentine, shale
Soil	Clayish limonite	Clayish loam	Loamy
Slope	0 – 5%	5 – 25%	> 25%
Climate	-----	Humid and cold	Very humid and ultra-cold
Land covering	Vegetative covering more than 70%	Vegetative covering less than 50%	-----
Application of the lands	The trees are recently cut and forage is limited	Less than 50% are under forage	-----

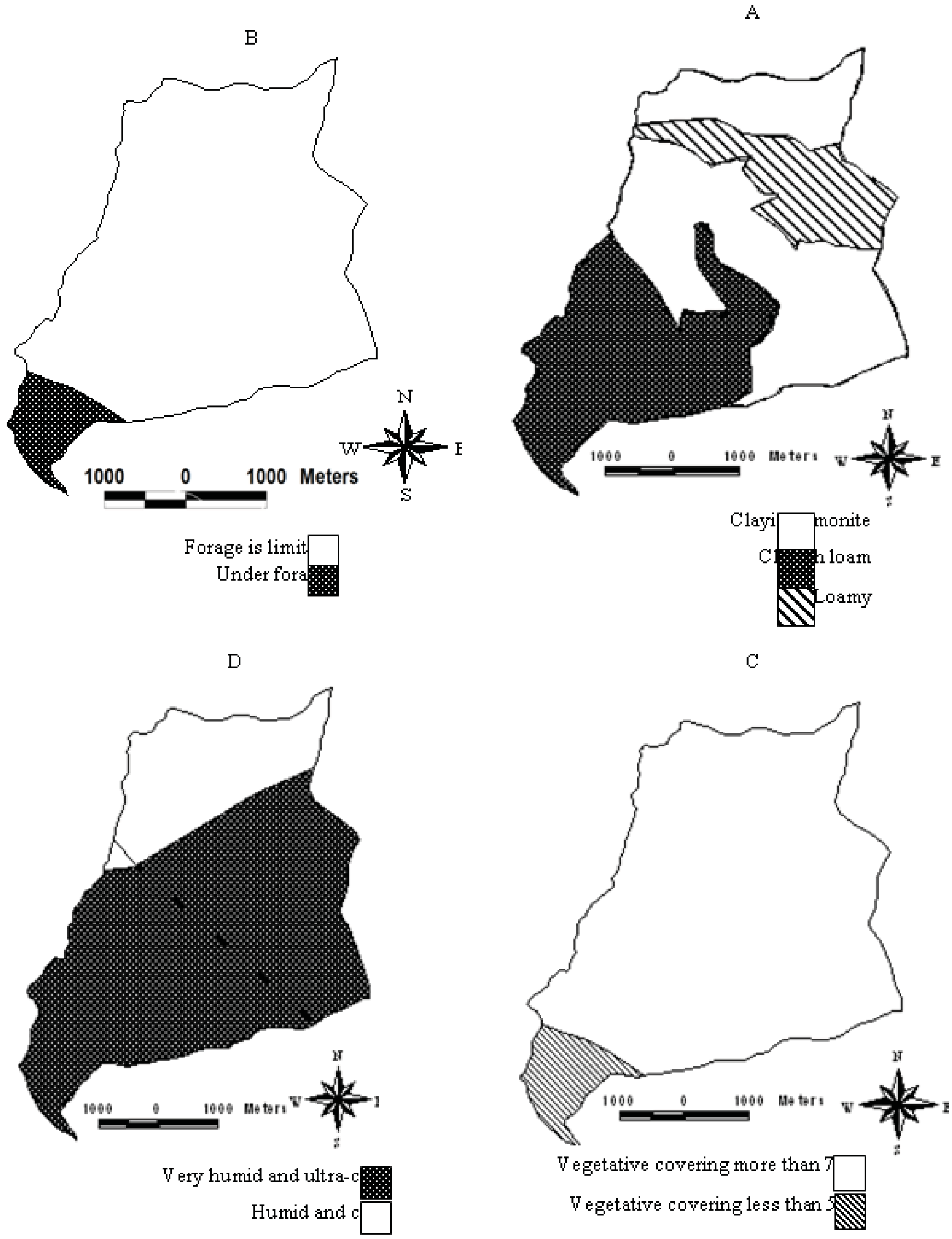

Figure 2. a) Pedological maps b) Application of the lands c) Land covering d) climate

Table 2. Scoring of the codes with the MPSIAC model

Map	Code 1 (High stability)	Code 2 (Medium stability)	Code 3 (Un stable)
Geology	2-4	4-6	8-10
Soil	4.16	5.16	7.33
Slope	1.65	4.95	11.55
Climate	----	0.14	0.17
Land covering	4	10	----
Application of the lands	5	11	----

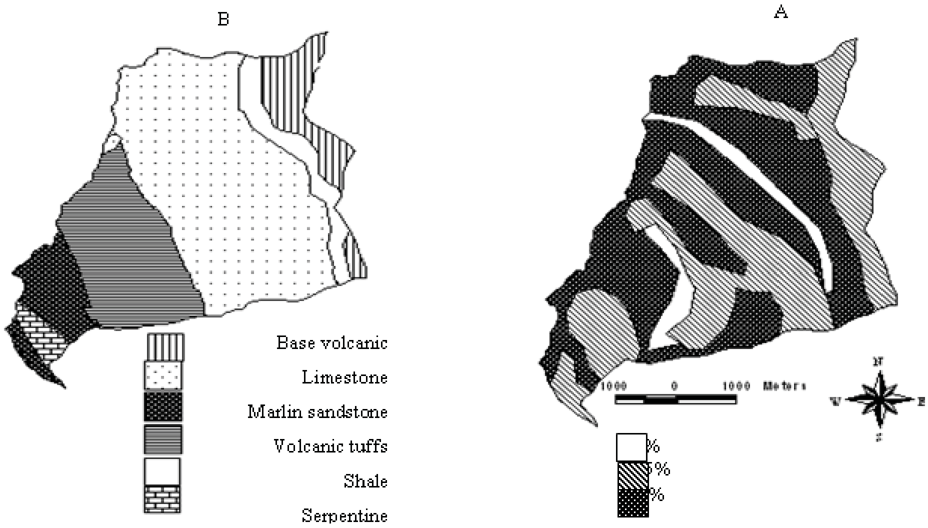

Figure 3. Maps of a) slope and b) geology

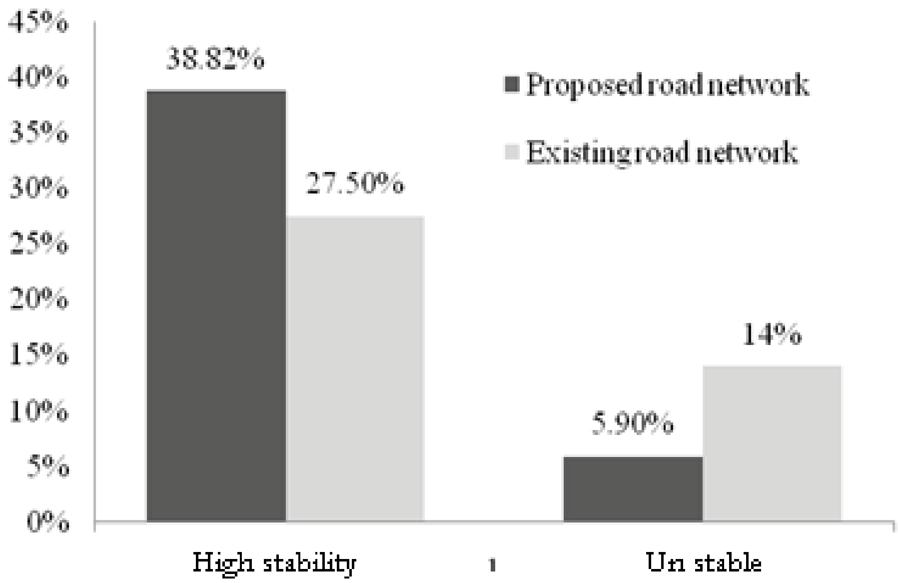

Figure 4. Comparison of the percentage of passage existing and proposed road network in the stable and un stable regions

Results

Results of the investigation of descriptive maps and the stability map concerning the six factors of MPSIAC model (geology, pedology, slope, climate, land covering and the application of the lands) specified the three regions in terms of their subjection to erosion. The analyses carried out indicated that the majority of passage of the network of suggested roads takes place in the regions with high stability and that the network of suggested roads passes through the regions sensitive to erosion (unstable regions) to a smaller extent as compared to the network of existing roads (Table 3 and Figure 4).

The results of the Chi square test between the network of existing road and the network of suggested road shows that the passage of the route in the network of suggested road in the regions with a power of one is significantly higher than the network of existing road in terms of statistics (it's significant in the level of 99%.) A comparison between the existing road and the suggested road in terms of geology in the regions sensitive to high erosion (code 3) was that the existing road and suggested road passed through these regions to the extent of 14% and 5.9% respectively (Figure 4). The execution of the designing of the network by using GIS technology and taking into consideration different maps along with the map of slope has better results as compared to the network design that only uses the slope map which overall reduces the harmful impacts of the road on nature in line with sustainable development.

Status of the road	**High stability (non-erosive)**	**Medium stability**	**Un stable (sensitive to erosion)**	**Total**
Existing road network	6950 meters	14790 meters	3540 meters	25280 meters
Proposed road network	9282 meters	13193 meters	1433 meters	23908 meters

Discussion

Since constructing roads is one of the most expensive managerial stages of forestry, it should be designed in such a way that it may generate the highest coverage with the least distance so that it can direct the forestry plans toward sustainable development as well as reducing the costs. Having in mind the data in the Table 3, it can be seen that the length of the existing road is 1372 meters more than the length of the suggested route. Houshyarkhah concluded in 2007 that the designed road with 1789 meters length vis-à-vis the 2100 meters of the existing road could generate the same amount of coverage among the passing parcels while dedicating a larger portion of the stability map to itself. As to the percentage of the passage of the existing and suggested roads from the highly stable and unstable regions, it can be seen in the Figure 4 that the suggested road has passed through the regions with high stability 12% more than the existing road and the passage of the suggested road from the unstable regions vis-à-vis the existing road has reduced by two times (Figure 4). In a 2006 research, Ghajar concluded that the passage of existing roads from the points with high sustainability is equal to 60% while this number would be 75.5% for the network of the designed road. The percentage of the passage of suggested road from classes with low firmness is less than the existing road. In the works of other researchers such as Hosseini (2004) and Mousa (2002), the percentage of the passage of suggested variants using GIS from the drainage degrees was good and the strength of the soil was high and the low-steep foothills had improved which in turn showed the effectiveness of GIS in the more accelerated and acceptable suggestion of the road.

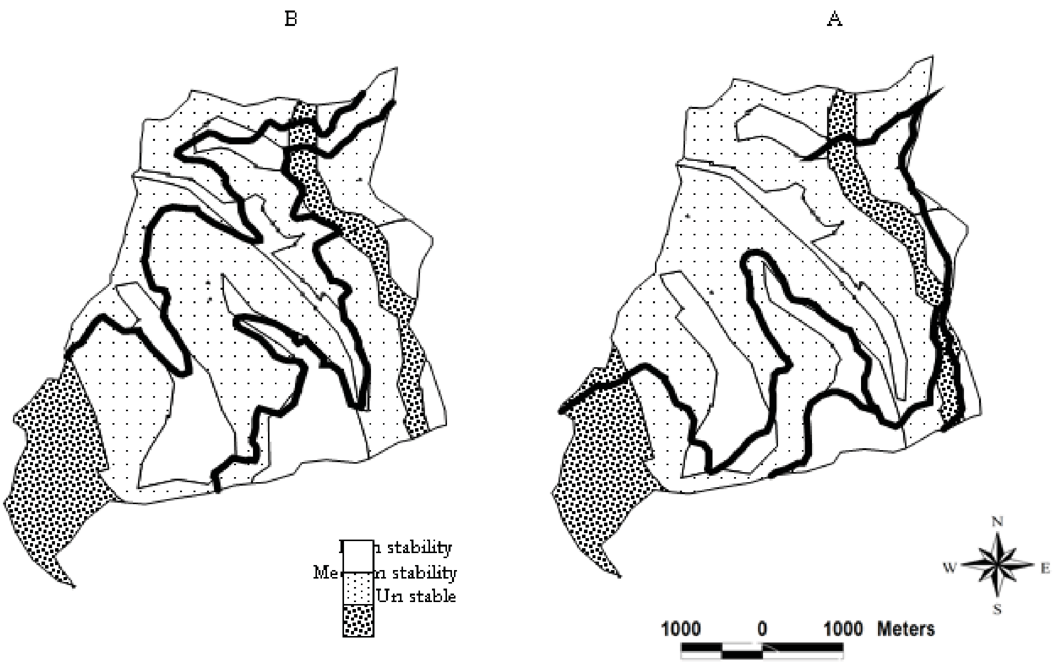

Figure 5. a) The situation of the existing road network and b) the proposed road network with regards to the stability map

Performing the designing of the road based on the specification maps and the power of the habitat and classification of the lands based on the important factors in constructing roads will have better results as compared to the designing of the network of road without this map (Figures 4 and 5). Ghajar showed in a 2003 study that using GIS can improve the accuracy of designing and quality of the network of forest road and reduce the costs. In another research, it was resulted that considering the factors of slope, direction and texture of the soil for designing the network of the road collectively lead to the minimization of the construction costs (Abdi, 2004).

Therefore using models and maps proposed such as the map of the habitat power and the region's relative stability and unstable map for orientation and ultimately creating and completing the networks of forest road in the forests of the northern Iran will be suggested. Using the precise situational and geographical information along with new technologies for designing forest roads should be made obligatory by the providers of the forestry plans so that the pattern of designing the road could be compatible to the natural conditions and phenomena and have the most effectiveness and lowest cost and destruction of the nature. Finally, the results show that using this system in such a level can be used in preparing the designed maps of the optimal routes by computer-assisted analysis.

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