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ASSESSMENT OF FACTORS AFFECTING FOREST ROAD ROUTING AND LANDSLIDE OCCURRENCE IN NORTH OF IRAN

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ABSTRACT
The objective of this research was to evaluate the factors affecting forest road routing and landslide occurrence in Dalakkheyl forest in North of Iran. Factors which influence on forest road routing were prioritized with analytical hierarchy process (AHP) in Expert Choice software. Dalakkheyl landslide and precipitation data for years of 2001 to 2010 were collected from company of wood and paper industries in sari city and Mazandaran climatology station, respectively. Results of this study indicated that the priorities of the various factors for forest road routing was slope (0.254)> geology (0.215)> soil (0.169)> geographical aspect (0.104)> volume per hectare or store (0.076)> drainage canal density (0.074)> protected species (0.057)> landscape (0.052), respectively. Moreover, another factor which influences on landslide and consequently forest road routing is rainfall. In this study there was significant correlation between the landslide frequency and rainfall intensity. The number on landslide occurrence increased with increasing rainfall intensity.

KEYWORDS: Forest road, Landslide, Rainfall, AHP, North of Iran

INTRODUCTION

The precipitation is being regarded as a significant controlling factor on landslide (Waters et al., 2010). Indeed, The rainfall/landslides relationship forms the basis for real-time prediction of landslide occurrence (Keefer et al., 1987; Dai and Lee, 2001). These are two different rainfall patterns relate to landslide occurrence including without antecedent rainfall (high intensity and short duration rains) and with antecedent rain (moderate intensity precipitation) (Corominas and Moya, 1999). Polemio and Sdao (1999) in their research highlighted the complex and changing nature of the phenomena governing the effects of meteoric precipitation on slope stability.

The water level change and rainfall intensity have much influences on the slope stability. In the circumstances of strong rainfall and underground water level going up and down, the stability coefficient of slope is reduced sharply (Lu-ming et al., 2009). Over the years, many models describing landslide-triggering rains were analyzed, generally found to be of no practical use for the purpose of preventing calamities (Polemio, 1996). Advances in geographical information systems over the last decade mean that quantifying regional relationships between slope stability and landslide risk is now possible.

As rain infiltrates into the soil, it increases the pore-water pressure within the soil, which in turn reduces the shear strength of the soil. High intensity and short duration rainfall are major causes of the landslide generation in many cases (2005). In mountainous areas such as Hyrcanian forests, quantifying landslide hazards and other risks associated with heavy rainfall is increasingly important. Landslide hazard map should be quantified towards landslide risk assessment and management for rainfall triggered flow-like landslide also which decisively provides fruitful upshot to early warning system of flow-like landslide disasters (Dahal et al., 2006).

A study was carried out to see the possibility of building a warning system for landslides along A-Li San Highway by the real-time rainfall data. A survey was done on the relation- ship between the rainfall data and landslide record. Results showed that warning system with probability of occurrence was more probable (Chen et al., 1995). Landslides are commonly observed in mountainous areas after intensive or long rainy periods, often leading to significant topographic changes (Chen and Lee, 2003). A chronology of recent landslides in the upper basin of the Llobregat River, Eastern Pyrenees in spain, has been reconstructed from technical reports, field reconnaissance and dendrogeomorphological analysis (Corominas and Moya, 1999).

Roads can clearly increase landslide hazard by making slopes steeper and directing drainage to steep locations. Road-associated landslides are usually larger than landslides associated only with vegetation removal (Anonymous, 2001). Beside, the road network is also impacted upon by landslides. These landslides occur most frequently as shallow and localized slope failures in roadside cuttings. These failures can give rise delay to traffic and also require ongoing investment in debris clearance, repairs to walls and roadside drains and road pavement (Hearn et al., 2007).

The objective of this research was to evaluate the factors affecting forest road routing for log transportation. Besides, this paper deals with a correlation between precipitation factor and instability or mass movements of hill slopes along mountain forest roads constructed in a part of North Iran.

MATERIALS AND METHODS

Site description: Dalakkheyl forest with an area of 1657 hectare is located in 5 km of the company of Mazandaran wood and paper industries in Sari city, Mazandaran province, Iran (36˚ 21′ 00″ to 36˚ 26′ 30″ N, 53˚ 03′ 00″ to

53˚ 05′ 35″ E and elevation 180-765 meter at sea level). In this forest, there are 36 landslides with a total area of 46.02 hectare. The soil is washed forest brown with classic horizon and its depth is 90 cm. The bed rock is marl, calcareous sandstone and limestone. The general aspect of the hillside is east and its average slope is 10-25%. The average temperature of Dalakkheyl forest is ranging from 29.8˚C in August to 1.8 ˚C in February. The region receives 808 mm of precipitation annually. The average growing season lasts 240 days from April to November. Mean road density is 16.1 m ha^{-1}. Fig. 1 shows the geographical position of the study area.

Research method

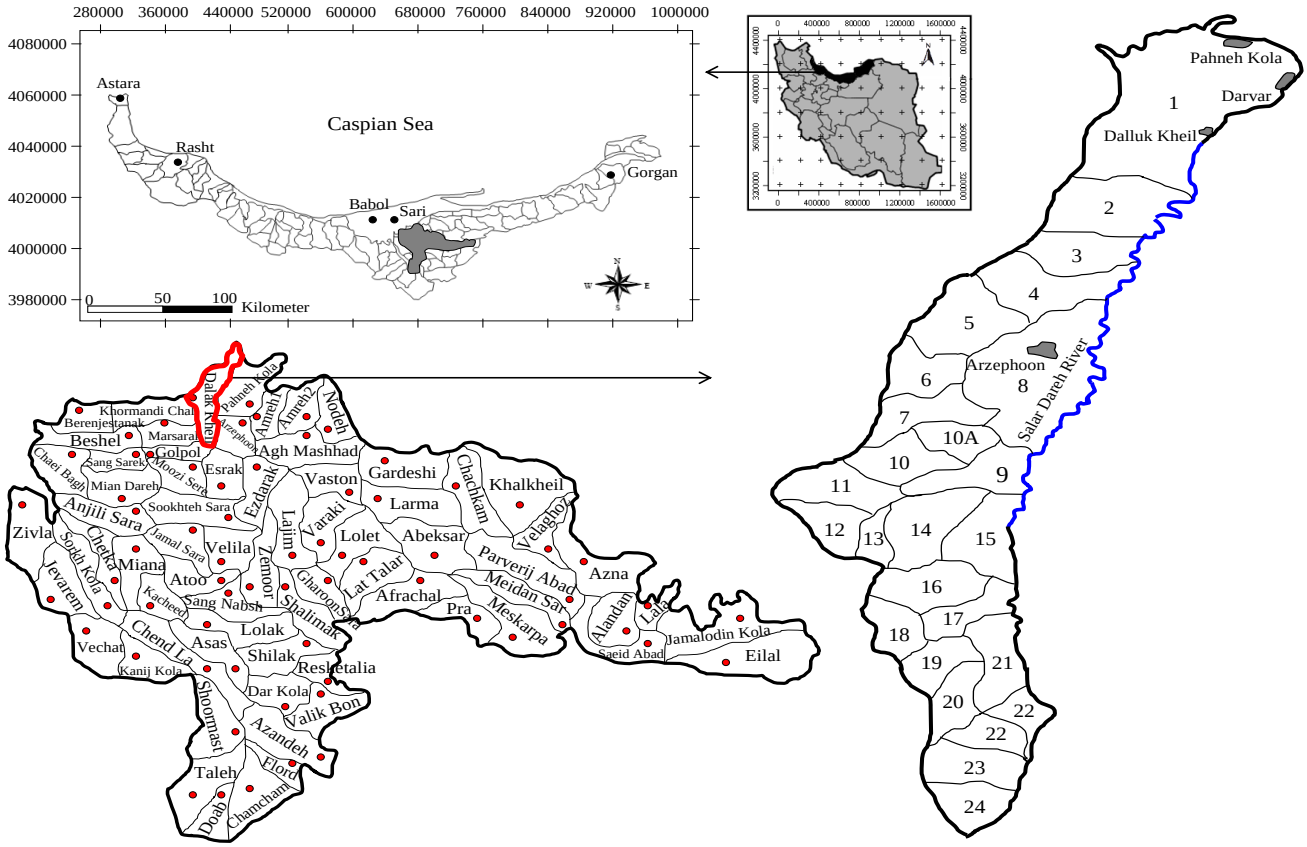
Factors which influence on forest road routing were prioritized with analytical hierarchy process (AHP) in Expert Choice software. AHP developed by Saaty (1980), is a method that enables reaching a decision by using quantitative and qualitative data. As the problem is stated in the hierarchical tree structure in this method, the problem becomes easy to understand. AHP is based on determining the relative priorities (weighting) of the criteria by pairwise comparison (Table 1). Dalakkheyl landslide and precipitation data for years of 2001 to 2010 were collected from company of wood and paper industries in sari city and Mazandaran climatology station, respectively. Data were analyzed in SPSS software version 16 based on Pearson correlation.

TABLE 1: Scale for pairwise comparison

Definition	Degree of importance
Equal	1
Moderate	3
Strong	5
Very strong	7
Extreme	9

2, 4, 6 and 8 can also be used.

FIGURE-1: The map and geographical position of study area (Dalluk kheil forest district)



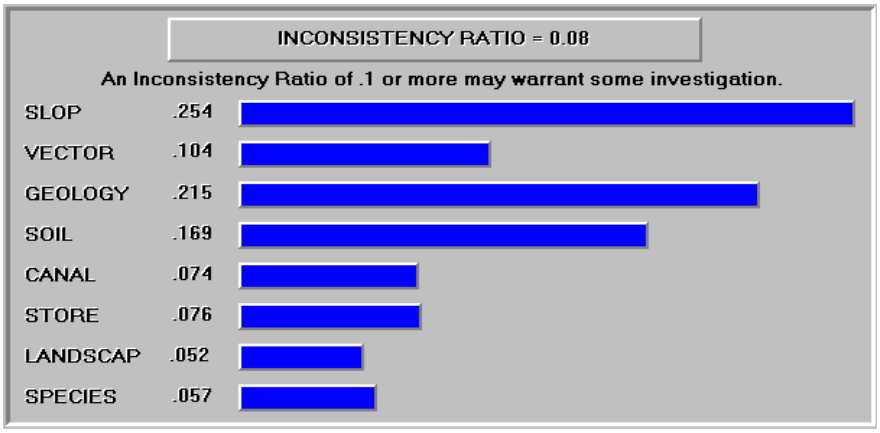
RESULTS AND DISCUSSION

Factors Affecting Forest Road Routing: Forest road routing is carried out according to the geological and soil conditions, drainage characteristics, slope gradient and configuration and vegetation. Results of this study indicated that the priorities of the various factors for forest road routing was slope (0.254)> geology (0.215)> soil (0.169)> geographical aspect (0.104)> volume per hectare or store (0.076)> drainage canal density (0.074)> protected species (0.057)> landscape (0.052) (Table 2, Figure 2). Landslide may occur almost anywhere, from man-made slopes to natural, pristine ground. Slope Assessment System (SAS) for estimation of the probability of occurrence and likely severity of landslides in a given area can be carried out by various approaches (Huat and Jamaludin, 2005).

TABLE 2: Pairwise assessment of criteria affecting forest road routing (AHP in expert choice)

[Best Fit]	VECTOR	GEOLOGY	SOIL	CANAL	STORE	LANDSCAP	SPECIES
SLOP	← 6.0	1.0	1.0	4.0	4.0	5.0	2.0
VECTOR		1.0	1.0	2.0	1.0	2.0	1.0
GEOLOGY			2.0	4.0	4.0	4.0	3.0
SOIL				4.0	3.0	3.0	3.0
CANAL					2.0	2.0	2.0
STORE						2.0	3.0
LANDSCAP							2.0

FIGURE 2: Final priorities of the criteria



Landslides in mountainous areas of the Hyrcanian forests are major hazard for roads often causing economic losses, property damages and high maintenance costs, as well as injuries or fatalities (Das et al., 2010). Mass movements like soil slides, debris slides, rock slides and debris flows are incorporated into the term landslides (Regmi et al., 2010). There are many references about successful applications of methods for the investigation of the landslides. Prokešová et al. (2010) analyzed the landslide using quantitative data extracted from sequential sets of vertical aerial photographs in order to better understand the reactivation dynamics of landslides in low slope areas.

Factors Affecting Landslide Occurrence along Road

The number of landslides and rainfall data for our research area is shown in Table 3. The number on landslide occurrence increased with increasing rainfall intensity (Figure 3 and Figure 4). Results of this study showed that there was significant correlation ($P< 0.05$) between the landslide frequency and rainfall intensity (Table 4). Hydro-climactic factors like air temperature, rainfall, rate and its distribution are important for anticipating or forecasting the landslide events. Thus, the hydro-climactic thresholds can be used as an empirical basis for issuing warning in areas highly susceptible to snow melt-season landslides. Other measures can be the deployment of field instrumentation to monitor hazardous landslides, timing avoidance of mitigation strategies, scheduling construction projects in sensitive areas and anticipating highway maintenance needs (Nikandish, 2000).

TABLE 3. Number of landslides and rainfall data from 2001 to 2010

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Rainfall (mm)	698	697	818	960	897	781	901	900	605	803
No. landslide	2	3	4	7	3	4	6	4	2	1

FIGURE 3. Rainfall data from 2001 to 2010

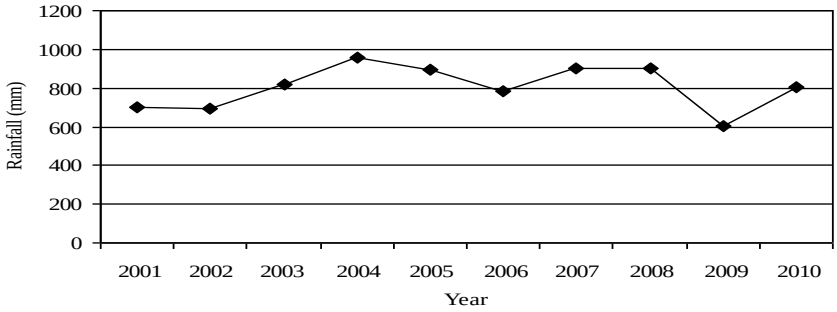


FIGURE 4. Number of landslide occurrence from 2001 to 2010

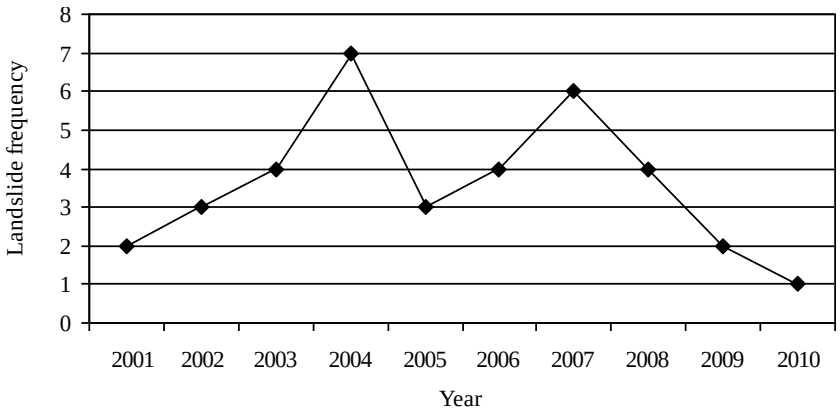
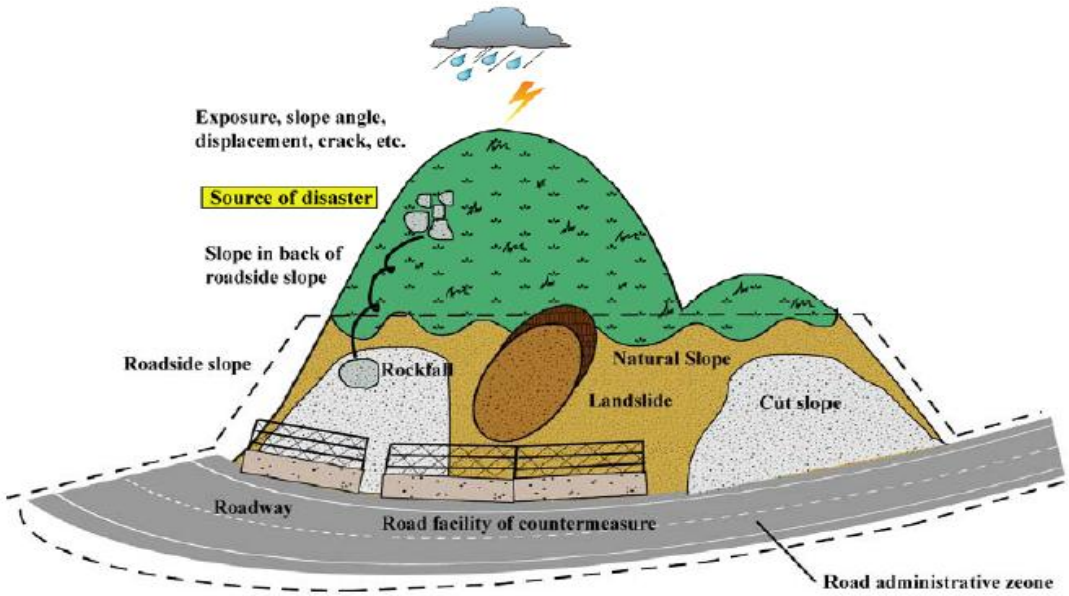


TABLE 4. A correlation between landslides and rainfall along forest road

Sources	Dalakkheyl	landslide
rain	Pearson Correlation	0.695*
	Sig. (2-tailed)	0.026
	N	10

Landslides are related to geo-environmental factors such as terrain morphology, geology, climate, land use and vegetation (Figure 5). Most landslides are classified as active or dormant (Chen and Lee, 2003). Moreover, forest management practices may alter both physical and biological slope properties that influence slope stability and the occurrence of landslides. Most physical alterations are the result of roads, skid trails, and landings.

FIGURE 5. Illustrate of landslide sources along a road (Kurahashi et al., 2008)



CONCLUSION

Results of this study indicated that the priorities of the various factors for forest road routing was slope (0.254)> geology (0.215)> soil (0.169)> geographical aspect (0.104)> volume per hectare or store (0.076)> drainage canal density (0.074)> protected species (0.057)> landscape (0.052), respectively. Dalakkheyl region is built up Marl and limestone. The soil is non development randzin, forest brown soil and washed brown soil with pseodoglay. Besides, the hill slopes are generally steep (More than 30 %). So, our study area was sensitive to slope failure and it must be especially considered for routing. Along road it was observed that more landslides were occurrence where the hill slope angle and slope length was more (from 2001 to 2010). Moreover, another factor which influences on landslide and consequently forest road routing is rainfall. In this study there was significant correlation between the landslide frequency and rainfall intensity. The number on landslide occurrence increased with increasing rainfall intensity. Rainfall runoff should be properly controlled and available potential slopes should be maintained in order to avoid any unexpected landslide hazard in the future.

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