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Slope stabilization with *Gleditshia caspica* and *Parrotia persica*

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ABSTRACT: The stabilization roles of two species, *Gleditshia caspica* and *Parrotia persica*, were studied on slopes in northern part of Iran. Landslides developed in this area because of incorrect land use and clear cutting of forest to change to agriculture land. Spread planting of *Gleditshia caspica* and *Parrotia persica* can help to control instability of soil in this area. Bishop's method was used to calculate the safety factor of slopes. This calculation was studied for the following conditions with vegetation cover of *Gleditshia caspica*, with *Parrotia persica* and without vegetation cover. *Parrotia persica* helped to stabilize slopes with 45-60% grades and *Gleditshia caspica* helped for slopes with 25-40% grades.

Key words: *Gleditshia caspica, Parrotia persica, slope, forest, landslide*

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INTRODUCTION

In recent years, the increased population in the world has led to an increase in exploitation of renewable natural resources. This has caused the destruction of forests, especially over the last ten years. Numerous natural disasters such as floods, droughts and the rise of the sea level affect human activities and welfare. Iran has a long history of landslides and these landslides cause significant damage to houses, agriculture lands, roads and installations and loss of human life. It is very difficult and expensive to remediate slopes following a landslide due to the particular conditions of geology, topography and climate. Furthermore the occurrence of landslides is a geomorphologic phenomenon that is influenced by numerous factors such as climate, ups and downs, vegetation cover, geology and tectonic activity. (Ahmadi, 1993) In Gilan Province landslides can be prevented rather well, because it has special condition for topographical and geological of landslides producer. (Habibi, 1999) This order, and with due attention to that, landslides in Gilan has not been studied now, we have taken a decision to study on part of landslides in Roudsar township, and hoping to make a use of the results on the same part of province, and propose different solution to use decrease landslides in this area. Therefore we have studied the effects of landslides producer. But another aim of this research specifies roles of vegetation cover on stability of soil on the slopes. This study have been done in Roodsar of Iran in 1999.

MATERIALS AND METHODS

This area is in northern part of Iran from latitude 36°, 15′N to 37°, 30′N and longitude 50°, 15′E to 51°, 10′E. The area is about 228 ha. In this area, 32 ha are covered with *Gleditshia caspica* and 28 ha *Parrotia persica*. The entire area is sloped.

The aide of analysis of slope is to calculate the safety factors on the critical landslide surface, defined by: (Baker, 1981 and Brunsden, 1987)

$$\text{Safety factor (F)} = \frac{\text{Cutting stress}}{\text{Cutting resistance}} \qquad (1)$$

General analysis of soil stability on a slope can be based on the following procedure: (Drannikov, 1963)

- Assume the surface of the landslide is part of a circle, and the failed mass of soil rotates around the center.

- Study equilibrium of forces on the surface of the landslides.
- Calculation and operation are repeated to determine the critical circle.

There are various methods for the analysis of slope stability such as Bishop's method; Fellenius's method, Morgenstern's method. Bishop's method is used in the study reported here. (Baker 1981). Software using this method was used to analysis slope stability of area. Safety factor in Bishop's method can be calculated from the fllowing equation: (Behniya, 1993 and Baher, 1994)

$$F = \frac{L}{\sum w.\sin\alpha}.\sum[\{c'.b + (w - u.b)\tan\phi'\}.\{\frac{\sec\alpha}{L + \frac{\tan\alpha.\tan\phi'}{F}}\}] \quad (2)$$

In which: F= safety factor, α= angle of surface with horizon (degree), w= weight of soil on the slope (N), c= adhesive coefficient of soil (KN/m^2), L= length of chord of slide (m), u= pore pressure (KN/m^2), b= width of area (m), ϕ= angle of internal friction (degree).

In this research, random sampling was used. Plot was rectangular form, with 8×10 m dimensions and 3.5% of area was sampled. Of a total of 78 plots, 43 were in *Gleditshia caspica* and 35 in *Parrotia persica* forest. In addition to ground cover measurement, soil profiles were dug. In these profiles, one undisturbed soil sample was taken for soil mechanic test and numbers of roots in one square meter were counted (in one, 0.8 and 0.4 cm diameter classes).

Characteristic of soil mechanic can be obtained from the soil samples of the area. The triaxial test is used to determine soil characteristic such as angle of internal friction and cohesion of the soil.

Bioengineering is used to stabilize soil landslides. Bioengineering is a composition of biology and soil mechanic sciences, and is alive and changeable. It can assist in increasing slope stability.

The following equation is used to determined increase of shear resistance of soil with vegetation roots: (Pedram, 1992 and Ovnagh, 1993)

$$\Delta SR = 1.15 TR \frac{AR}{A} \quad (3)$$

Where TR= tension resistance of root, AR= total surface area of roots in A, A=surface of soil. On the basis of amount ΔSR, it is possible to calculate the angle of internal friction of soil (ϕ_2) and safety factor (F_2) with vegetation roots.

Root tensile strength was studied in one, 0.8 and 0.4 cm diameter classes for determination of increase soil safety factors.

RESULTS

F1 (safety factor without vegetation) was calculated with soil properties (u, ϕ_1, c, and dan.) and area characteristic (b, α, l and h) with equation 2, and additional soil resistance with roots (ΔSR) was calculated with equation 3, then angle of internal friction with vegetation (ϕ_2) was calculated. F2 (safety factor with vegetation) was calculated with soil properties (u, ϕ_2, c, and dan.) and area characteristic (b, α, l and h) with equation 2 (Tables 1 and 2).

Table 1: Soil properties in C12 area

Class	b	u	ϕ_1	c	α	l	h	dan
	m	KN/m^2	deg	KN/m^2	deg	m	m	g/cm^3
1	25	0.4	23.5	0.3	31.9	15	3.5	1.45
2	20	0.3	26.4	0.2	29.3	15	3	1.5
3	15	0.3	22.9	0.2	30.2	15	3.5	1.55
4	12	0.4	23.8	0.3	28.4	15	2	1.88

Table 2: Safety factor in C12 area. 1= *Gleditshia caspica* and 2= *Parrotia persica* , F1= without vegetation and F2= with vegetation

Class	F_1	Sp.	Dia cm.	n	TR Kg/cm^2	ϕ_2 Deg.	F_2
			1	1	501		
1		1	0.8	30	558	36.6	
			0.4	42	591		
			1	1	501		
2		1	0.8	32	558	38.9	
			0.4	39	591		
			1	-	350		
3		2	0.8	15	262	25.7	
			0.4	24	248		
			1	-	350		
4		2	0.8	16	262	28.6	
			0.4	23	248		
Total	1.2945						1.3618

Relationship between angle of internal friction (ϕ') and safety factor of soil without roots (F1) was shown for angle of slope 15, 18, 23, 27, 30 and 33 degrees (Fig. 1). Relationship between angle of internal friction (ϕ') and safety factor of soil with different ground cover of *Parrotia sp.* (F2) was shown for angle of slope 15 degrees (Fig. 2). Effective of different roots of 20-40%

vegetation on F2 was compared with F1 on angle slope 15 degrees (Fig. 3). Effective of different slopes (18, 23, 27, 30 and 33 degrees) on F2 was compared with F1roots of *Parrotia sp* vegetation with ground cover above 60% (Fig. 4). Finally, the least ground cover of different vegetation could be stabilized soil on slope with different amount of angle of internal friction (ϕ') and different angle of surface with horizon, was shown in Tables 3 and 4.

Table 3: Safety factor of slopes with slope percent (Tanα×100 and angle of internal friction (Degree) for *Gleditshia caspica* ground cover. (U= Unstable, S= Stable)

	Tanα100					
	25	32	38	42	51	58
Angle of internal Friction (degree)						
16	S	<20%	40-60%	40-60%	40-60%	>60%
18	S	S	<20%	20-40%	40-60%	40-60%
20	S	S	<20%	<20%	40-60%	40-60%
22	S	S	S	<20%	20-40%	40-60%

Table 4: Safety factor of slopes with slope percent (tanα×100 and angle of internal friction (degree) for *Parrotia persica* ground cover. U= Unstable, S= Stable

	Tanα×100						
	25	32	38	42	51	58	65
Angle of internal Friction (degree)							
16	S	20-40%	U	U	U	U	U
18	S	S	>60%	U	U	U	U
20	S	S	20-40%	40-60%	U	U	U
22	S	S	S	20-40%	U	U	U

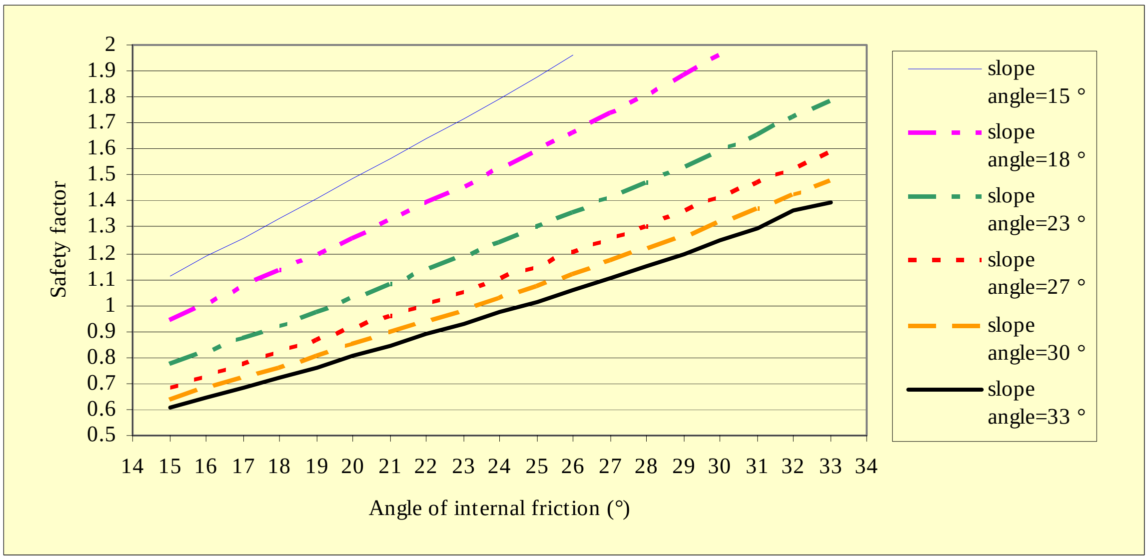

Fig. 1: Calculated safety factor of soil without vegetation cover on different slope angles

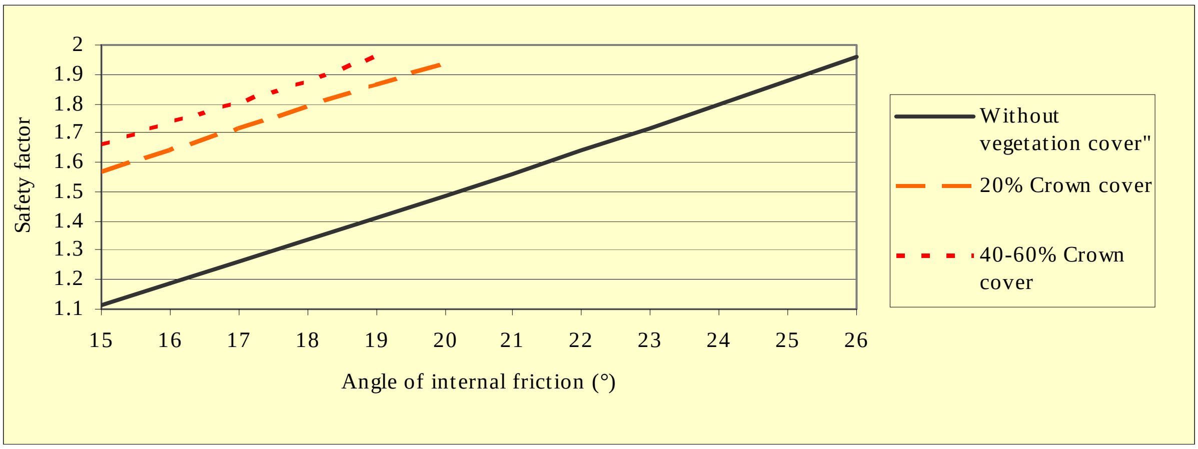

Fig. 2: Calculated safety factor of soil with *Parrotia sp*. on a 15° slope. The safety factor was calculated with different % crown covers

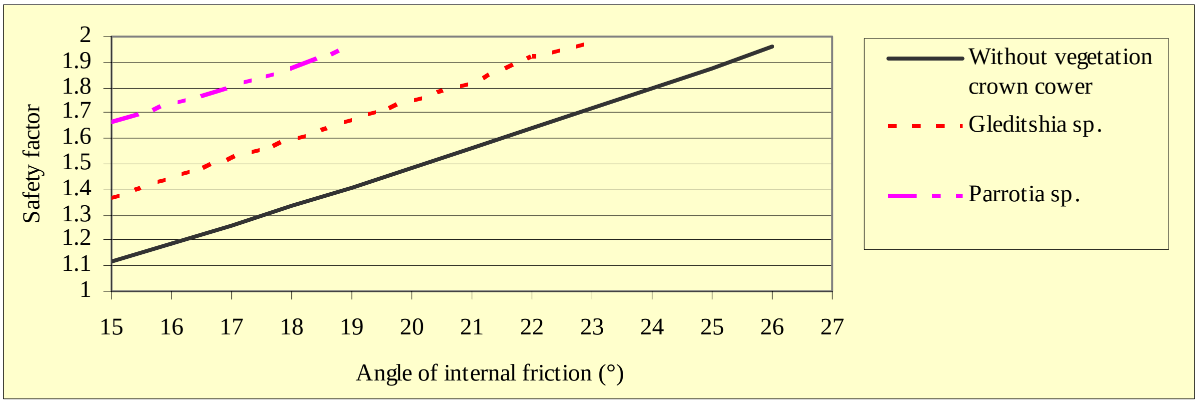

Fig. 3: Calculated safety factor of soil with different species on a 15° slope. The safety factor was calculated with different 20 – 40 % crown cover

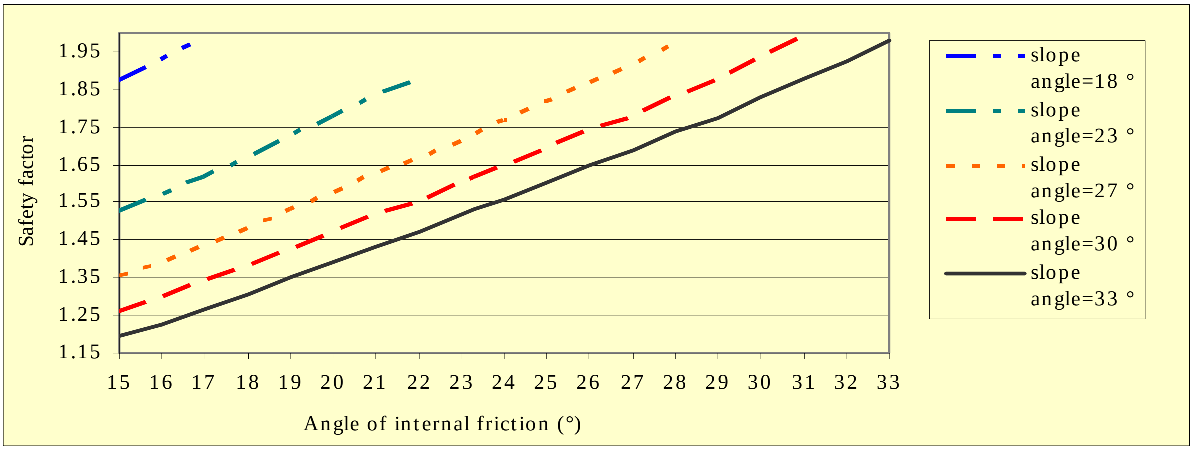

Fig. 4: Calculated safety factor of soil with *Parrotia sp.* plants on slopes with different angles and >60% crown cover

DISCUSSION AND CONCLUSION

Although there are several factors which may affect slope stability and lead to landslides in the study area, it is clear that the main factor is the removal of the natural forest cover of the slopes, to create tea plantations and citrus orchards. In order to increase the F of slopes in this area with gradients greater than 25%, the least F that can be established for different vegetation cover with attention to the angle of internal friction of soils (ϕ) and the gradient of the slope (α) in order to the least safety factor (F=1.3).

The main contributory factors which affect slopes stability are as follows; (Watson, 1995)

- Angle of slope.
- Angle of internal friction
- And percentage of vegetation covers.

Other factors may also play a part in the slope stability and these are as follows;

- Soil moisture content.
- Weight of soil mass and vegetation cover.
- Internal adhesion of soil particles.
- Wind loading on the soils and vegetation.
- Location of any underground water table.
- Earthquake and tectonic forces.

These factors have not been considered in this study. In addition to angle of intern al friction, cohesion and pore pressure of soil, other factors were studied such as soil density and angle of surface with horizon. Data from the 78 test plots were preparation to distinguish the lowest *Gleditshia caspica* and *Parrotia persica* ground cover for slope percent and angle of internal friction (degree) to stable slope. *Parrotia persica* helped to stabilize slopes with 45-60% grades and *Gleditshia caspica* helped for slopes with 25-40% grades. Decrease ground cover and increase heavy precipitation in one day decrease soil safety factor on slope above 60% grades for *Parrotia persica* and 40% grades for *Gleditshia caspica* and occur landslides in these slopes.

This study has revealed and quantified the effect of the *Parrotia persica* and *Gleditshia caspica* trees in the Roudsar township forest lands, a phenomenon by means of which the tree stabilizes the slopes in the Gilan State and probably also in other areas where the *Parrotia persica* and *Gleditshia caspica* are growing. It is a pioneer study, and the results have given estimations of the root force of these trees for the first time in Iran. The findings and methodology of the study may be applied in other areas and to other trees.

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