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ASSESSING THE EFFECTS OF NATIVE PLANTS TO SLOPE STABILIZATION IN ROAD EMBANKMENTS: A CASE STUDY IN SIYAHKAL FOREST, NORTHERN IRAN

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ABSTRACT: Soil bioengineering is the low-cost way for slope stabilization in forest roads. Considering economic efficiency, the focus of the present study was to reduce environmentally destructive effects of roads by finding out the appropriate native plants for bio stabilizing slopes and also aiming at providing soil bioengineering decision making skills. The research was carried out through 30 systematic randomly distributed plots at two slope classes. In each sample plot, geological features (slope steepness, aspect and altitude) and various plant species were recorded. Three extra sample plots were taken in upland slopes to illustrate the success and failure of vegetation's presence. Geographical plan showed that roads were located at three land types where total existing land types were five. In total, five cores with 30 cm in diameter and 60 cm in depth created for laboratory tests of soil mechanical characteristics (liquid limit, solid limit and texture). Results revealed that there is a relation between plant species and variables such as land type, soil moisture, soil texture, aspect, slope, and soil depth of study area. The dominant tree species in the study area were *Carpinus betulus* with 24.5% followed by *Parrotia persica* with 17.3% which was followed by *Quercus castanefolia* (11.7 %), *Fagus orientalis* (8.2%), and *Alnus subcordata* (7.9%). Land type (A) is suitable for road structure, (B) is not suitable for road structure and (C) is relatively suitable for road structure.

Key words : *Soil bioengineering, slope, forest road embankments.*

Soil bioengineering is the use of living plant materials to construct structures that perform some engineering function. Often, soil bioengineering is used to treat sites where surface stability and erosion problem arise (Polster 8). Vegetation can play an important role in preventing erosion (Li *et al.,* 7). Cognition of appropriate native species for slope stabilization can economically increase by applying of bioengineering (using living plants engineering and ecological structures for soil stability) as a main structural factor. Soil bioengineering techniques can be used to restoration steep slopes, to treat seepage zones and to control surface erosion (Gray and Leiser, 4). One of the most common bioengineering techniques used for the stabilization of hill slopes, road cut and fill-slopes, and river banks are brush layering which is placing live cuttings or pieces of brush at the bottom of small benches excavated into the slope (Bischetti *et al.,* 2). Currently experiments (Petrone and Preti 9; Ploster, 8; Florineth and Gerstgraser, 3), approach consisted of the effects of native species (woody and herbaceous plants) on soil bioengineering. In some cases (Amman and Boill, 1) vegetation has been used in conjunction with civil engineering to prevent landslides and the social and practical aspects of planting on steep slopes to conserve soil on a large-scale in mainland. Composition of different bioengineering techniques can be utilized as road's steepest slope (Lewis *et al.,* 5) and river bed's stabilizer (Li *et. al.,* 6). Soil properties generally change dynamically over time due to the effects of plants, and increasing infiltration can reduce runoff, erosion and play main role in slope resistance (Zhao *et al,* 13; and *et al.,* 14).

This study aimed at reconnaissance natural plants (tree, shrub and herbaceous) which grows well at various existing land type with different characteristics, to introduce the best native widespread species in defined slope classes, that can be a useful guide in future road buildings as a low-priced slope stabilizer.

MATERIALS AND METHODS

Study area :

The research was started from June 2013 until June 2014 at Siyahkal forest, north of Iran between 36° 59'N and 37° 1'N and 50° 3'E and 50° 7'E. The characteristics of study stand was as follow; canopy cover 85%, average diameter 32.53 cm, average height 21.76 m, stand density 180 trees/ha. The altitude ranges between 100-1600 m. The average annual rainfall recorded at the closest national weather station, was 1200 mm. The maximum mean monthly rainfall of 120 mm usually occurs in October, while the

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minimum rainfall of 25 mm occurs in August. The mean annual temperature is 15° C, with the lowest values in February.

Sample plots :

Selective sampling system was used as a sampling method. Steepest slopes of cut and fill slopes and difficulty of performing round sampling, persuaded us to use rectangular plot shape.Research was done at three existing land types capable to stabilize: sandy loam (cut slope: 1:1, fill slope: 4:5), rocky (5:1), and cliffy (10:1) slopes. Frequency of tree, shrub and herbaceous species, percentage of dominant herbaceous and land features (slope, aspect and altitude) accumulated in each sample plot. The choice of plot size for soil bioengineering study comes from specific previous study on young stands (Zohrer, 14). Reference to preliminary inventory, the most appropriate plot size was discovered 7 m ×5 m.

Mechanical samples:

Land type plan demonstrated five diverse geology units, but roads only passes three land types, therefore, soil samples were taken from these three land types for soil mechanical analysis. Totally 15 samples were taken with 30 cm in diameter and 60cm in depth.

Statistical methods:

The data were analyzed with SPSS 18 statistical software. Initially all data were checked for normality by Kolmogorov-Smirnov test, the abnormal data were normalized. Study of residuals and means of analysis of variance (ANOVA), on a quantitative dependent variable and independent variables (factors) and t-test were applied for specifying existence or absence of meaning correlation among frequency of species and accumulated variables: slope, aspect, altitude, moisture, liquid limit and solid limit. In addition to determining that differences between the means exist, several post-hoc Duncan tests were considered on factor levels.

RESULTS AND DISCUSSION

In the initial phase frequency of plants in every plot were inventoried. *Carpinus betulus* was the dominant species (24.5%) which is followed by *Parrotia persica* (17.3%), *Quercus castanefolia* (11.7 %), *Fagus orientalis* (8.2%), *Alnus subcordata* (7.9%). Other species including *Acer insigne, Acer cappadocicum, Oxyacantha crataegus, Mespilus germanica, Ficus carica, Diospyros lotus, Paliurus spina-christi, Tilia platyphyllos* and *Cerasus avium* constitudes 30.4% (Fig. 1).

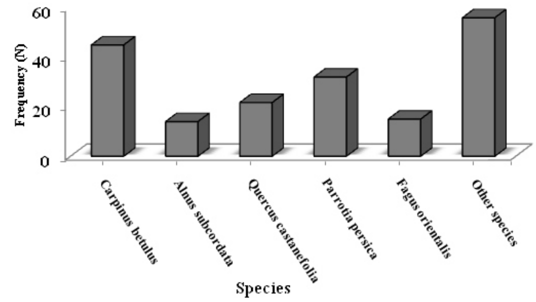

Fig. 1. Frequency of plants in every plot.

Comparing species frequency in land features at two slope classes and three land types, showed in Table 1.

Land type (A): is produced of lime stones and Marne in SM-ML and ML classes of soils. Soil liquid limit, solid limit and natural moisture ranged between 21-13, 9-14 and 8-10%, respectively. This land type is suitable for road structure. *Parrotia persica* and Carpinus betulus are dominant tree species in 15 plots of this site. In three plots, *Rubus fruticsos*, at two plots Carex brunna and at four plots, *Hypericum* and *Rosarium*, *Euphorbia helioscopia* and *Sumbusus ebolus* were dominant herbaceous species. Other plots did not have dominant herbaceous species.

Land type (B): is produced of Toof and volcanoes in CH class of soils. Soil liquid limit, solid limit and natural moisture are 78, 30 and 53%, respectively. This land type is not suitable for road structure. *Carpinus betulus* and *Quercus castanefolia* are dominant tree species at four plots of this site. At two plots, *Sumbusus ebolus* and in the other plot, *Rubus fruticsos* were dominant herbaceous species.

Land type (C): is produced of SC-CL class of soils. Soil liquid limit, solid limit and natural moisture ranged between 21-48, 11-26 and 7-25%, respectively. This land type is relatively suitable for road structure. *Carpinus betulus* and *Fagus orientalis* are dominant tree species at 11 plots of this site. Dominant herbaceous at two plots were *Rubus fruticsos*, Hypericum and *Rosarium* and *Sumbusus ebolus*, at five plots, *Euphorbia helioscopia* and *Pteridium aquilinum* and finally in the rest, herbaceous species were not dominant.

Table 2 shows the correlation of species with environmental variables.

However, it was not found statistically any relation between species and land type but the species diversity and frequency was not the same.

Table 1: Tree species and herbaceous species frequency in every land types.

Land type	Species	
	tree species	herbaceous species
A	*Parrotia persica*, *Carpinus betulus*	*Rubus fruticsos, Carex brunna, Hypericum, Rosarium, Euphorbia helioscopia, Sumbusus ebolus,*
B	*Carpinus betulus, Quercus castanefolia*	*Sumbusus ebolus, Rubus fruticsos*
C	*Carpinus betulus and Fagus orientalis*	*Rubus fruticsos, Hypericum, Rosarium, Sumbusus ebolus, Euphorbia helioscopia, Pteridium aquilinum*

Number 1 means the highest correlation and 4 means the lowest correlation.

In the five sample plots of cliffy slopes, only presence of tree and shrub species were studied which. Parrotia persica, Acer insigne, Carpinus betulus and Mespilus germanica were dominant species.This spatially explicit models are able to predict the state of vegetation cover over the land types with different characteristics.

Soil bioengineering is an inexpensive living system to remove or reduce maintenance cost and as well for regenerating forest sites, especially in areas with a high potential for mass wasting. In addition, these techniques can be efficient way of appeasing flooding and landslide hazard in forest lands. Soil bioengineering alternatives can be produce equal or better economic and environmental results than traditional solutions.

Locating species in different aspects, especially in north and south slopes, reference to sun light angle, is momentous. In north slopes, soil is moist, therefore reaches to high liquid and solid limit, which is the buoyancy motivation, will be more probable (Sun *et al.,* 11).

Slopes, which are capable to stabilize, are located in area with slope less than 80%

Soil moisture limits are efficient factors in stabilization. High moisture can increase probability of soil saturation and land slide probability. Experts have two opposite opinion about the effect of plants on stabilization:

1. Plants roots can prevent landslides, by draining and absorbing soil moisture.
2. In windy weather, vegetation covers especially shrubs and herbaceous make soils and slopes unstable because of their weight and producing permanent moisture condition surrounding their roots. So it is urgent using plants which are capable for creating deep roots.

Table 2: Species correlation with environmental features.

Characteristic / Species	North	South	West	East	Low LL < 30	Mid LL 30–50	High LL > 70	Low moisture	Mid moisture	High moisture	Mid SD5–15	SD 15–35 %	Slope < 80%	Slope > 80%
Carpinus Betulus	2	2	3	1	1	2	2	1	2	3	1	2	1	2
Alnus subcordata	4	3	–	1	3	1	1	3	1	1	2	1	2	1
Acer insigne	–	–	–	–	–	2	1	–	3	1	–	1	2	1
Acer cappadocicum	3	3	1	–	3	1	2	3	1	3	2	1	–	–
Quercus castanefolia	1	–	–	–	3	2	1	3	2	1	2	1	–	–
Diospyros lotus	1	–	–	2	–	4	2	–	3	–	–	1	–	–
Ficus carica	–	1	–	–	1	–	–	1	–	–	1	–	–	–
Parrotia persica	2	2	–	1	1	3	–	1	2	1	1	2	1	2
Fagus orientalis	3	3	–	1	–	1	–	–	1	–	–	2	2	1

*1 means highest correlation, **4 means lowest correlation.

When shallow and short time stabilization is needed, herbaceous species works better (Sun *et al.,* 11). In accordance with cut and fill slopes on roads' gap and handled sites, pioneer herbaceous specious like *Sumbusus ebolus, Hypericum* and *Rosarium* and *Rubus fruticsos* are plentiful.

Plant species given in Table 2 are adjusted based on species which have meaningful correlation with environmental factors (aspects, slope classes, soil moisture, liquid and solid limit). This correlation is evaluated from 1 to 4. Number 1 means the highest correlation and 4 means the lowest correlation. For example, in south aspect with slope over 80% and medium level of soil liquid limit, *Mespilus germanica* can be suitable species for stabilizing. In soils with high moisture and low liquid and solid limit, *Acer insigne* is an appropriate species. By quantifying bioengineering effects, we showed:

1. The on-going experience confirms soil bioengineering can works low cost, compared with classical stabilization methods. It is similar to results which obtained by Petrone and Preti (9).
2. Native plants can be adopted to achieve the needed stability on a particular slope in front of landslides; this result can be viewed through the previous studies: Polster (8), Lewis *et al.* (5) and Li *et al.* (6).
3. If slopes are not managed correctly, substrate mass movement can directly increase maintenance costs. This behavior is similar to the one observed by Rickli and Graf (10).

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