Forest Road Stabilization Using Bioengineering Methods in Caspian Forest, Iran

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Abstract:
One of the most important parts in road fortification is stabilizing roadside slopes. The old method of establishing a roadside slope is geotechnical structure. Today forest vegetation is known to increase hill slope stability by reinforcing soil shear resistance. Hence it can be said that the bioengineering methods can be an alternative approach for stabilizing roadside slope. For this, it is necessary to know the biotechnical characteristics of the species. In this study two important biotechnical characteristics of the root system of Alder (Alnus subcordata) namely root area ratio (RAR) and tensile strength were investigated. Eight alder trees growing on hilly terrain near forest road in northern Iran were selected randomly for the study. RAR values of the roots were obtained from profile trenching method in 10 cm layers. Also 39 root specimens were analyzed for tensile strength using a standard Instron. The results indicated that, RAR decreases with depth and in most cases, the maximum RAR values were located in top soil depth (0.1 m). The minimum and maximum RAR values along the profiles were 0.0002% and 0.448%, respectively .The relation between number of roots and depth was a logarithmic function. The penetration depth of above 90 percent of the roots was at soil depth of 90- 100 cm and maximum rooting depth was 1.0 m. The results of Pearson correlation showed no significant correlation between the RAR values with tree diameter and slope gradient. The mean roots diameter was 1.14 and means value of root tensile strength was 16.29 ± 3.10 MPa and root tensile strength decreased with increase in root diameter. The results augment the knowledge about biotechnical characteristics of root systems of Alder species in order to be used in bioengineering.

Keywords: forest road; biotechnical properties; Alder (*Alnus subcordata*); root area ratio (RAR); root tensile strength; Caspian Forest.

1 Introduction

Although forest road construction is an important part of forest management but occasionally results in hillslope instability. This hillslopes need stabilization, nevertheless for road maintenance it is also essential to stabiles hillslopes. Vegetation affects slope stability both hydrological processes and mechanical structure of the soil (Bischetti et al. 2005). Plant roots provide additional cohesion to the soil and root-permeated soils are thus much stronger than soils alone to withstand soil erosion processes such as mass movement (Ziemer1981, Operstein and Frdman 2000, Mickovski and Van Beek 2009). The extent to which root reinforce the soil depends on several variables including root system morphology, such as root biomass, root number, root diameter or rooting depth (Wu et al. 1979), root system architecture (stokes et al. 1996, Mickovski et al. 2007) and root system mechanical properties such as root tensile strength (Wu et al. 1979, Operstein and Frdman 2000). Knowledge of these characteristics helps us in selecting species for erosion control. Therefore number of root, RAR (Root Area Ratio) and root tensile strength were investigated. In order to stabilize the slope against landslides, the number of roots which cross the slip surface is extremely important (Cammeraat et al. 2005, van Beek et al. 2005, Reubens et al. 2007). RAR provides a measure of root density in the soil (Abernethy and Rutherford 2001) and it is strongly influenced by the local soil, climate characteristics and associated vegetation communities and randomness (Bischetti et al. 2005). Root tensile strength is important index for considering soil reinforcement and it can affect plant anchorage (genet et al. 2005). In this investigation we focused on root of alder that is found in hillslopes study area.

2 Material and methods

This research was carried out in district 1 of Tanian forests in northern Iran, on the west part of the Caspian forests. The site is located 100 - 1400 m above sea level, longitude is between $49^{\circ} 4' 5''$ to $49^{\circ} 8' 20''$ and latitude is between $37^{\circ} 15' 35''$ to $37^{\circ} 16' 10''$. The weather is moderate in winter and warm and humid in summer and annual precipitation is 1557 mm and rainfall is mostly in autumn and lowest in summer. The maximum temperature is 31.7° C and minimum temperature in is 2.1 ° C. The soil texture is loam with low percent clay in the surface layers and clay in the bottom depths, and slope commonly ranging from 30% to 60 %. Sallow landslide sometimes occurs in this area. Dominant species is hornbeam and alder in the area that we focused on Alder. This stand was plantation and next to forest road. Eight trees were randomly chosen from compartment number 8. Their diameter at breast height (DBH), gradient of the slope on which they were growing, total number of roots and penetration depth of root was measured. The data were analyzed with SPSS 13 statistical software. Differences were considered to be significantly different for $P < 0.05$. Initially all data were checked for normality by kolmogrov-smirnov test, the abnormal data were transformed to normality.

2.1 Root area ratio measures

In order to obtain root distributions two methods are generally adopted: core-break sampling (Babu et al. 2001; Burke and Raynal 1994, Hendriks and Bianchi 1995, Schmid and Kazda 2002, Xu et al. 1997) and counting roots by profile trenching (Burke and Raynal 1994, Schmid and Kazda 2001, 2002, Vinceti et al. 1998, Xu et al. 1997). In this study profile trenching method was used. The trenches were dug in down slope and a distance of one meter from of sample trees. RAR values were obtained at each depth of 10 cm measuring all roots diameter.

2.2 Tensile strength test

Live roots were collected from soil besides trees at depth of about 30 cm below the soil surface (Cofie and Koolen 2001). In order to avoid any root damage, the roots were put in bags with alcoholic solution at 15% (Meyer and Go¨ttsche 1971) and transported to the laboratory in a refrigerated box. The tensile tests were carried out on fresh roots within one week from sampling. The roots for the test with a length of about 10 cm were cut (Zhou et al., 1999). Before the test root diameter was obtained by measuring the diameter at three different positions along the length of the roots. Testing was performed with standard Instron device with constant strain rate of 10 mm/min. Tests subject to slippage, or those roots that broke due to crushing at the jaw faces, were disregarded (Bischetti et al. 2005) and only specimens which broke about in the middle were taken in to consideration.

3 Results

3.1 Root area ratio

RAR values showed a great variability with soil depth although the general behavior of RAR with depth is decreased (Fig. 1). In most cases, the maximum RAR values were located in soil depth of top 0.1 m, the minimum and maximum RAR values along the profiles were 0.0002% and 0.448%, respectively. The result of Pearson correlation showed no significant correlation between the total RAR with diameter at breast height (DBH), slope gradient, and crown canopy.

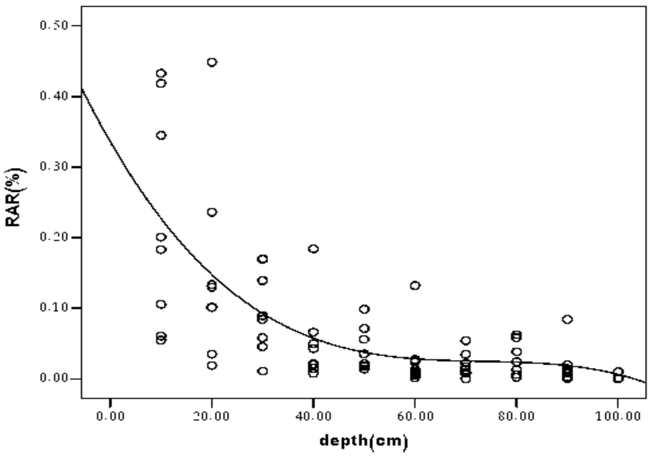

Figure 1: Scatter plot for RAR values at different depths and fitted cubic function

3.2 Number of root

Total number and maximum depth of roots for each sample were summarized in table 1.

Table 1: Total number and maximum penetration depth of root for each sample

Sample	Total root	Depth (cm)
s1	143	100
s2	108	70
s3	190	100
s4	210	90
s5	165	100
s6	134	90
s7	212	100
s8	235	90

Generally number of root was decreased with increased depth in a following logarithmic function (Fig 2). The penetration depth of above 90 percent of the root was at soil depth of 90 - 100 cm and maximum rooting depth was 1 m. No significant correlation was found between number of roots, with DBH and gradient of slope

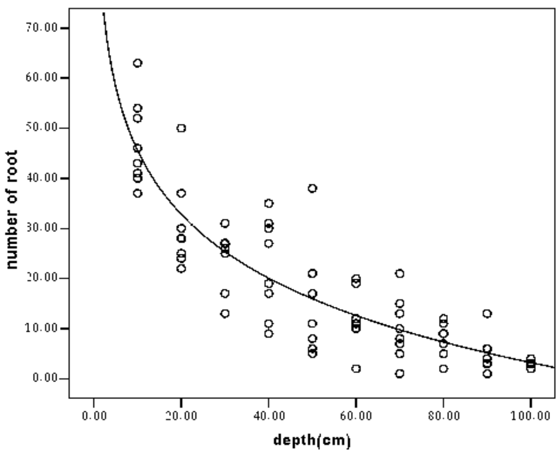

Figure 2: Scatter plot for number of roots at different depth and fitted logarithmic function

3.3 Tensile strength test

In total 39 root specimens were tested correctly. The result showed a great variability of measured root tensile strength among the specimens. The diameter of roots analyzed varied between 0.17 mm and 3.12 mm. The mean strength value was 16.29 ± 3.10 MPa and the minimum and maximum values recorded were 3.37 MPa and 114.48 MPa, respectively. The relation between tensile strength and diameter was significant at 95% level ($P < 0.05$) and following a power function (Fig. 3).

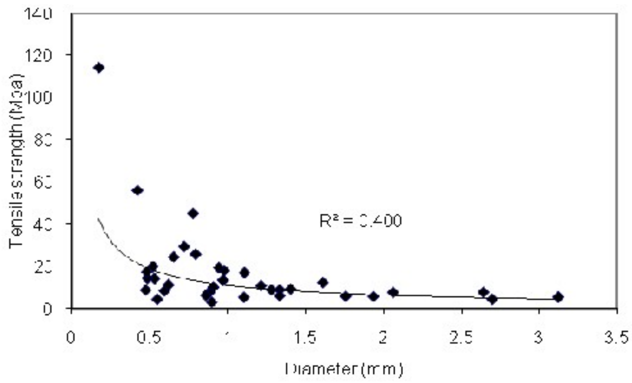

Figure 3: Correlation between root tensile strength and diameter that following power function. $y= 11.36x^{-0.75}$

4 Discussion

RAR strongly influenced by genetics, local soil and climate characteristics and forest management, in addition randomness must be accounted for (Bischetti et al. 2005). As observed in this study, in general, RAR decreased with depth. This decrease is of lower nutrients and aeration, and presence of more compacted lower layers (Bischetti et al. 2005). The decrease of RAR with depth is documented by several authors (Abdi 2009, Green way 1987, Nilaweera 1994, Schmid and Kazda 2001, Shields and Gray 1993, Zhou et al. 1998).Simon and collision (2002) suggest that a useful measure of root distribution is to calculate the depth above in which 90 percent of all roots are found. They reported 38 cm and 56 cm depths for their investigated species. This study showed penetration depth of 90 percent of the root is at above soil depth of 80 cm. The number of roots distribution with depth was satisfactorily approximated by a logarithmic function, although Abdi, (2009) showed correlation between the two parameters is a power function in the hornbeam species. This difference in results may be due to species differences. This study showed no significant correlation between the number of root and gradient of slope, (Abdi 2009) showed same conclusion.

The result of strength tests confirmed the power law relationship between strength and diameter roots. This well-known relationship (e.g. Abdi et al. 2009, Bischetti et al. 2005, Burglo et al. 2001, Mattia et al. 2005, Norris 2005) reveals that thin roots are more resistant to tensile stresses than thick roots. The values of the power law parameters α (scale factor) and β (decay coefficient) obtained 11.36 and -0.75, respectively. Nilaweera (1994) suggested for hardwood roots α (between 29.1 and 87.0) and β (between -0.4 and -0.8) that in this study α do not follow the range suggested but β is in the range. Bischettia et al. (2005) for 6 hardwood species reported α (between 29.33 and 60.15) and β (between -0.69 and -1.11). Vergani et al. (2012) for 5 hardwood species reported α (between 14.83 and 26.39) and β (between -0.46 and -0.2). These differences may indicate and necessitate more studies in the future to gain more precise models. The mean tensile strength of investigated species was 16.29 MPa that is comparable with the result of Bischetti et al. (2005) in *Alnus viridis,* 20.42 MPa although it is different from the result of *Alnus incana* (32 MPa), Quercus robur (32 MPa) (Greenway 1987), *carpinus betulus* (31.51 MPa) (Abdi et al. 2009).

In conclusion the data presented in this study expanded the knowledge on root tensile strength and root area ratio in Iran Caspian forests and are suitable to be used in hillslope stability in forested areas.

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