Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences 6 (6): 1020-1023, 2007
ISSN 1682-3974

Soil Stabilizing Characteristics of Rangelands Vegetation in Northwest Iran (Misho Rangelands Protected Location of Shabestar)

[1]Ghassem Habibi Bibalani, [1]Abolfazl Aghajanzadeh Golshani, [2]Shahriar Sobhe Zahedi and [3]Zia Bazhrang
[1]Islamic Azad University, Shabestar Branch, Shabestar, E. Azarbayjan-5381637181, Iran
[2]Natural Resource Research Center of Gilan State, Iran
[3]Pardis Amayesh Technical Engineering Co., Chaboksar City, Zip Code 448711165, Gilan, Iran

---

Abstract: Roots of plants stable soils on slope and provide resistance against the forces that improve slope instability. In northwest of Iran (East Azarbayjan state), rangelands were changed to agricultural land use; this vegetation is unsuitable vegetation on slope to stable them. Restoration of rangelands vegetation effects, largely to improve slope health, is focussed on replacing agricultural plants with rangelands species, but little is known about their slope stabilizing characteristics. We studied 4 rangelands plant species to determine these characteristics. Data available for 2-and 3-year-old shrub plants indicate that Gavan (*Astragalus raddei*) has high root spread and rooting depth. Data for older plants of this species will be used in improve landslide threshold models for vegetated slopes.

Key words: Acontholimon, *Astragalus*, *Cundella*, Iran, landslide, rangelands

---

INTRODUCTION

The composition of rangelands vegetation influences how well a rangelands area functions and hence has an important effect on the state of a slope. In northwest Iran, much rangelands vegetation was cleared for agricultural land use consequently ecosystem services provided by rangelands vegetation have been lost or seriously changed.

The ecosystem services provided by rangelands vegetation are vital and vary from stabilizing slopes and filtering runoff, through shading and protection of animal habitats, to enhancing aesthetics and controlling downstream flooding (Collier *et al.*, 1995). Of these, slope stabilization is often regarded as being of high importance because, without it, many of the other functions may be limited by erosion and its consequences, e.g., undesirable changes in rangelands slope morphology and excessive in-stream sedimentation (Naiman and Decamps, 1997).

The stabilizing role of rangelands vegetations depend on increase the shear strength of slopes soils, protect surface soil, take water from the soil (via transpiration and evaporation), increase filtration of soil, support the toe of slope (buttressing), protecting it from shear failure. These functions can be affected by the rangelands slope scale and slope steepness.

Though the role of vegetation in improving slope stability and preventing landslide is well recognised (Gray and Sotir, 1996; Phillips and Watson, 1994) the study on the below-ground root data for rangelands vegetation and shrub species used in landslide control is limited.

We have been examining the characteristics of 4 plants for their ability to stabilize slopes. We consider a plants have stabilizing roles on slope stability.

MATERIALS AND METHODS

Four species, that grow naturally in east Azarbyjan of Iran and commonly found in rangelands areas, were selected for test (Table 1). Plant age was determined from the time they were pricked-out into planter bags. Nursery stock was used for the 2-year-old and most of the 3-year-old biomass data and therefore in some cases root depth and lateral spread were restricted by the planter bag.

Eight plants of each species were measured for height, canopy spread, root collar diameter and maximum root depth and lateral root spread. To obtain canopy spread the maximum diameter of the foliage was measured in both an E-W and N-S direction and averaged. Each plant was photographed to record general above- and below-ground morphology/architecture prior to being dissected into its component parts to determine biomass. Above-ground biomass was measured by separating the foliage, branches and stem. Each component was

---

Corresponding Author: Ghassem Habibi Bibalani, Islamic Azad University, Shabestar Branch, Shabestar, E. Azarbayjan-5381637181, Iran Tel: +98-471-2225834 Fax: +98-471-2224927

Table 1: Plants on slopes stabilization trial

Common name	Botanical name
Cangar	*Cundella tournefortii*
Gavan	*Astragalus raddei*
Gol Keh	*Acontholimon trayacanthinum*
Kolah Mirhasan	*Acontholimon bracteatum*

oven-dried at 80°C for 24 h then weighed. Below-ground biomass was determined by hosing roots clean of soil, then cutting and grouping parts according to diameter (size classes: <1 mm (fibrous), 1-2, 2-5, 5-10 and 10-20 mm, root bole). The total length of roots in each diameter size class was measured before they were oven-dried at 80°C for 24 h. The dry weight of each plant component was recorded to the nearest 0.1 g.

To obtain growth data for older-aged plants we established a trial plot (50×25 m) on flat alluvial land on Shabestar city, northeast Shabestar, Northwest Iran. The topsoil is a black, very friable sandy loam with a weakly developed structure of fine granules, with a layer of loose sand beneath. The soil is free draining to a depth of 1.5 m and requires irrigation in summer.

Before planting, the plot was sprayed, ploughed and covered with weed mat. Eight shrubs of each species have been planted randomly in blocks, 5 of which will be extracted each year for the next 3 years according to age. The 3- and 4-year-old blocks are planted at 1.5 m spacing and the 5- and 6-year-old blocks at 2-2.5 m spacing. The shrubs were irrigated for the first three months after planting.

RESULTS AND DISCUSSION

Data were available for 2- and 3-year-old plants. Mean root depth varied from 170-480 mm in year 3 and for most of the plants was around 350 mm. Gavan exhibited the greatest root depth, 480 m, after 3 years (Fig. 1). Nursery conditioning was responsible for the relative consistency of results both within and between species in years 2 and 3.

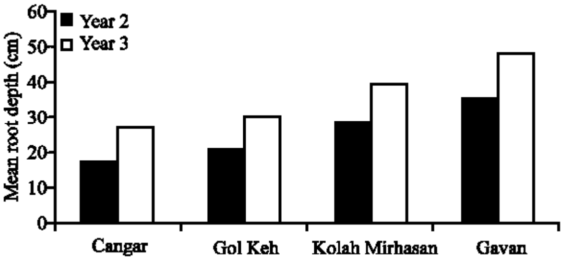

Fig. 1: Mean root depth for 2- and 3-year-old species (n = 8 per species) sorted on year 3 data

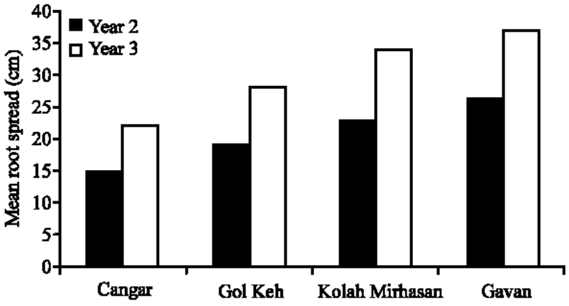

Fig. 2: Mean root spread for 2 and 3 year old species (n = 8 per species) sorted on year 3 data

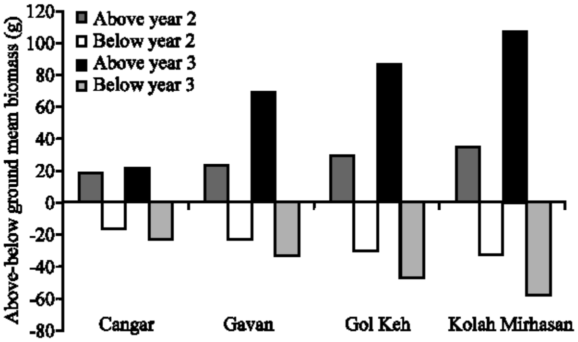

Fig. 3: Mean above-below ground biomass for 2 and 3 year old species (n = 8 per species) sorted on year 2 below-ground data

Root spread in year 3 rangelandsd from 150-370 mm, with most species averaging about 270 mm. Gavan had about twice the root spread of the other species, around 370 mm (Fig. 2).

Biomass varied among species, with Kolah Mirhasan slopes being the top performer (Fig. 3).

For an individual plant species, its performance position relative to the other species changes according to the parameter in question. While most of the trial species exhibited similar values for each parameter, Gavan outperformed all the species for two parameters-above-below ground biomass-and in lateral root spread. This was not surprising as Gavan is one of species that have a high growth rate, which reflects their birch-like growth form. As is common in root studies of plants less than 3 years old, factors such as wrenching, root training and constriction in planter bags may have contributed to the differences seen in the data, rather than representing a true inter-species difference. From our root studies of other rangelands and agricultural plants, we would expect differences to emerge once the plants are about 4-5 years old.

In general terms, the more information that is known about the plant and its root system and the environmental conditions that limit growth, the better will be the estimate of that plants contribution to stabilization effectiveness. However, it is not always possible to have complete information about a plant, largely because collection of these data is both time consuming and expensive. In this case we want more easily obtainable measures that can be used as surrogates for stabilization effectiveness. From earlier research in Azarbayjan state of Iran we have to use vegetation that governs plant performance for stabilizing land prone to landslides. It would seem reasonable that these parameters might also be useful in gauging the effectiveness of plants for slopes stabilization. Such parameters include canopy occupancy, root occupancy, root depth, root biomass and root cross-sectional area per shear area (Table 2). (Note: here we focus on structural roots, i.e., those greater than 2.5 mm diameter).

The rate a site is occupied by a shrub canopy depends on species growth rate and planting density. Canopies of individual shrubs, i.e., circles, are grown at the selected planting density, increasing their diameter over time until canopy closure is attained and canopy site occupancy occurs.

Intuitively, treatment options that promote the quickest canopy closure are likely to be the most effective in terms of reducing sediment generation. Canopy closure is a useful surrogate for landslide control effectiveness, particularly when no other data are available, as it intrinsically takes account of lateral root spread, which we have found precedes canopy spread.

As shrubs grow, their contribution to site stability increases as a function of the speed and ease at which roots colonise the soil. This depends on the root content, the roots' material properties and the morphology or architecture of the root system that develops.

Root studies of a number of species of different ages (Watson *et al*., 1999) indicate that root architecture and root morphology are determined by the physical soil conditions, particularly stoniness, drainage conditions and depth to water-table, bedrock or impermeable substrata. In many species, the majority of the roots we have observed are within 1.5 m radius of the stump.

Structural root biomass has been measured only in a limited number studies. Bibalani (1999) found in a study of Iron-wood (*Parrotia persica*), a scrub species, about 90% of the root mass of all the age classes were confined to the top 2.5 m of soil. As with other parameters, plant density is an important factor in determining plant effectiveness. Treatment or restoration options that promote greatest root biomass, particularly in the early years following establishment, are likely to be the most effective in terms of reducing sediment production caused by landslide. However, root biomass alone is a poor predictor of stabilization effectiveness.

Table 2: Definitions of plant stabilization effectiveness parameters determined from slope stability studies

Parameter	Definition
Root biomass	Total dry weight of roots present in the soil (for structural roots as defined in landslide studies the root diameter >2.5 mm).
Root depth	The maximum depth a root of 2.5 mm diameter reaches.
Root morphology	Architecture, shape, or structure of a plants root system.
Root site occupancy	Projection of the root system as a circle, in the same manner as for canopy occupancy.
Root strength	Root tensile strength, i.e., force per unit area required to snap a root.
Vegetation site occupancy	When a circle representing the plant canopy projected onto the ground touches circles from adjacent shrubs.

Root site occupancy is related to plant density and lateral root growth rates. Root site occupancy occurs when root systems of adjacent plants overlap. The concept projects the root system onto the ground as a circle, in the same manner as for canopy occupancy. The faster a site is occupied by roots, the greater the reinforcement to the soil and the more effective the plant treatment is. However, as many species have root systems that are confined to shallow depths they have little influence on the critical failure surface. Lateral root site occupancy is, therefore, not in itself a good indicator of effectiveness.

Root growth in the vertical plane largely reflects the site environmental conditions and any difficulty to vertical root growth. Thus stabilization effectiveness is a function of the roots' ability to anchor soil to bedrock or to layers within the regolith or surficial cover deposits that might be prone to failure. Root depth does not give a strong indication of the expected performance, but it can be indicative of the potential for effective control if enough data from the same species across a rangelands of site conditions is obtained.

A method for assessing how roots contribute to soil or slope stability is to determine the strength of individual shrub roots. Most studies measure tensile strength of individual roots, usually in a laboratory (Phillips and Watson, 1994). Data have been gathered for a number of rangelands species in east Azarbayjan by Bibalani *et al.* (2006). Root tensile strength varies both with growing environment and species. Root strength alone is not a good predictor of the effectiveness of a particular species for erosion control, because the soil may fail around the root long before the root actually breaks.

Physiology and ecology of shrub have been developed to approximate the contribution of shrub roots to slope stability (Gray and Ohashi, 1983; Wu and Erb, 1988). Although these models are useful to estimate and compare the strength contribution from shrub roots between different species, none are available to estimate the actual thresholds for the initiation of landslides. Many such approaches use the tensile strength differences between species as a surrogate for the additional cohesion factor in a stability analysis (Montgomery *et al*., 2000).

Location of the critical shear plane plays a major role in determining an initiation threshold for a landslide. Depth to the Critical shear plane increases as the soil shear strength increases. Shrub roots provide a significant strength contribution to soil shear strength. The objective of this study is to understand how vegetation can be used to increase landslide or slope failure thresholds by changing the location of the critical shear plane.

The critical shear plane location is estimated using an energy approach, which has been developed to take into account the roots contribution to soil strength (Ekanayake and Phillips, 1999a).

A composite model combining these two approaches may then be used as a simple tool to choose the most appropriate plant density to maximise the stability of a given slope.

The approach incorporates the ability of a soil-root system to withstand strain (Ekanayake and Phillips, 1999b). It is based on a consideration of the energy consumed during the shearing process of the soil-root system. The method uses characteristics of the shear stress-displacement curve of a soil-root system obtained from *in situ* direct shear tests under simulated overburden pressure and pore-water pressure conditions. The model is well suited to the conditions found in east Azarbayjan state are frequent and share common features such as similar shear surface depth, rainfall conditions and soil characteristics. The method is limited to vegetated slopes where the stability analysis can be approximated by a simplified infinite slope model.

The model will help identify different combinations of species and plant densities to suit the landscape and climatic conditions of the area of interest. The generalised method for stability analysis described may be used as a simple tool to compare and select the most appropriate species and densities to increase the stability of a given slope.

Quantitative data on root characteristics of plants are needed if this factor is to be incorporated into any stability or cost-benefit analysis aimed at determining the safety factor. The problem that faces ground bioengineers is a lack of data for the common species used in rehabilitation or restoration projects. We are addressing this and our observations of species used in slope stabilization and the preliminary results on rangelands vegetation show that there are differences for the parameters that determine a plants stabilization effectiveness.

Results from studies of landslide initiation on vegetated slopes suggest that similar vegetation performance assessment methods and modelling procedures may be applied to vegetated slopes.

Given growing international interest in using plant materials in engineering projects, we believe it is important to renew efforts to collect these fundamental data for rangelands plants.

REFERENCES

Bibalani, G.H., 1999. Research of protection and support from forest of Rahimabad and Eshkevarat, Gilan provinces of Iran. J. Agric. Sci., 4: 81-94.

Bibalani, G.H., A.A. Golshani and K.A. Najafian, 2006. The traction effect of lateral roots of Gavan (*Astragalus raddei*) on soil reinforcement in Northwest Iran (rangelands of the Shanjan area of Shabestar). Can. J. Soil Sci., 86: 493-499.

Collier, K.J., A.B. Cooper, R.J. Davies-Colley, J.C. Rutherford, C.M. Smith and R.B. Williamson, 1995. Managing riparian zones: A contribution to protecting New Zealand's rivers and streams. Department of Conservation, Wellington July 1995, pp: 2.

Ekanayake, J.C. and C.J. Phillips, 1999a. A method for stability analysis of vegetated hillslopes: An energy approach. Can. Geotech. J., 36: 1172-1184.

Ekanayake, J.C. and C.J. Phillips, 1999b. A model for determining thresholds for initiation of shallow landslides under unsaturated conditions in the E. Coast region, New Zealand. J. Hydrol. NZ., 38: 1-28.

Gray, D.H. and H. Ohashi, 1983. Mechanics of fibre reinforcement in sand. J. Geotech. Eng. Division ASCE, 109: 335-353.

Gray, D.H. and R.B. Sotir, 1996. Biotechnical and Soil Bioengineering Slope Stabilization. John Wiley, New York, pp: 425.

Naiman, R.J. and E. Decamps, 1997. The ecology and management of aquatic-terrestrial acetones. UNESCO Paris France and Parthenon Carnforth UK, pp: 372.

Phillips, C.J. and A.J. Watson, 1994. Structural tree root research in New Zealand: A review. Landcare Research Science Series 7 Manaaki Whenua Press, pp: 70-75.

Watson, A., C. Phillips and M. Marden, 1999. Root strength, growth and rates of decay: Root reinforcement changes of two tree species and their contribution to slope. Plant Soil, 217: 39-47.

Wu, T.H. and R.T. Erb, 1988. Study of soil-root interaction. J. Geotech. Eng., 114: 1351-1375.