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Soil Bioengineering with Woody Vegetation for Slope Stabilization

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The denuding of lands whether due to agriculture, grazing or urban sprawl can lead to erosion and slope destabilization. Special problems can arise for ecological restoration projects that generally focus on native vegetation types and procedures that improve soil qualities and characteristics. The specific technique(s) used to stabilize a slope depend on many factors and may include slope gradient, aspect, soil structure, regional climatology, and project objectives or requirements. Slope Stabilization techniques work in one of five ways, by reshaping the landscape, improving soil cohesiveness, improving soil fertility, armoring the surface, or modifying velocity and direction of wind and rain.

The two main categories of techniques used in slope stabilization are bioengineering and synthetic structural engineering. The Soil Conservation Service defines soil bioengineering as the use of live woody vegetation to repair slope failures and increase slope stability (Wells 1994). Slope destabilization is often caused by the removal of vegetation from a slope which causes slope shear strength to decrease relative to shear stress. The focus of this paper is on bioengineering techniques that, by their nature, are more conducive to ecological restoration projects. Bioengineering techniques avoid the use of synthetic materials that may alter soil and vegetational qualities and characteristics. Because so many factors are involved, bioengineering techniques are more a set of guidelines than a strict set of procedures. A quality inspection and estimate of the site are needed so that these techniques can be combined and adapted to fit the individual needs of the situation.

When trying to stabilize the slope by restoring vegetation it is necessary to reduce the erosion caused by raindrop impact on bare soils, and to establish a penetrating root system to inhibit gully erosion and soil mass movements. Vegetation stabilizes a slope by physically increasing frictional forces and by removing the soil water through transpiration which results in lower pore water pressures and reduced weight of the soil mass (Brooks et al. 1991).

Bioengineering techniques used to combat gully erosion and slope destabilization include live staking, brush layering, live fascines, branch packing and combinations of these. These techniques increase shear strength and work to augment undercutting and nick points which create zones of weakness and undermine the shear strength of the slope (Brooks et al. 1991).

Live Staking

Live staking is a technique used in thin soils to combat shallow earth slides. The technique requires access to vegetation that is suitable for live cut and transplant techniques. The 1/2" to 1-1/2" diameter and 3' long live stakes are placed in the ground to a depth of 2-3' and are planted in a triangular pattern with 2-3' spacing. Stakes can be pounded in or inserted into a hole created by a planting bar. This technique of slope stabilization is often used along rivers where native vegetation and habitats are conducive to rootable vegetative growth from branch cuttings.

A bioengineering project constructed by the California Department of Parks and Recreation showed the limitations of live staking techniques to washout (Lucas 1995). The project was carried out on the Navarro river in Hendy Woods State Park. Project goals where to stabilize the slopes and meet the project requirement of 95% canopy cover of riparian trees after 5 years set out by the U.S. Fish and Wildlife Service. Native willow staves were planted with 3'spacing among a two 2' layer of riprap. Slopes of the river bank were leveled to 2:1. Although vegetational coverage requirements established by the U.S. Fish and Wildlife Service were meet, goals describing required soil aggregation or allowable loss were not. The failure was due to a large rainfall event before root establishment, and showed the importance of having proper knowledge of the vegetation and local climatic conditions for estimating project establishment time.

Brush Layering

Brush layering is a technique most effectively done by laying 1/2" to 1-1/2" diameter and 2-5' long branch cuttings down in trenches created to prevent nick points and headcutting. After placement of the branch cuttings the trench is back-filled to a point where the cuttings extend only 1/2' to 1' from the slope surface. Trench rows should run the entire length of the slope, with slope degree and soil texture influencing the spacing between rows (Schiechtl 1980) Requirements of this technique include immediate action, available soil material for fill, and native vegetation suitable to branch cuttings. It is very important not only to mix branches of different species, but also to use branches of different age and thickness groups. As a result roots will penetrate deeper and a variety of above surface growth will develop (Schiechtl 1980). Immediate action is needed to impede the process that leads from nick point to gully formation. The effective use of brushlayering is accomplished only when all factors are accounted for.

In the fall of 1993, the Ontario Ministry of Natural Resources used bioengineering techniques to successfully realign a stream. Typical gabions or riprap trapezoidal channels were deemed unacceptable. Realignment and stabilization of the slopes on the Tannery Creek River was accomplished by a combination of brush layering and log anchoring at the water line (Wraith 1995). Project requirements where rigorous and required a no net loss of habitat because the stream was classified as a cold water fishery. The trenches were spaced at 600mm intervals on a slope graded to achieve a 2:1 gradient. The brush layers were made up of available native willows approximately two meters long and placed at a density of 50 per linear meter. Broadcast seeding of native grass seed was done to complement the brush layering and log anchoring.

Live Fascine (Brush Wattles)

This technique works to mitigate shallow earth slides and gully erosion by increasing root area and positively affecting shear slope strength. Live fascines use 6-8" bundles of 1/2" to 1-1/2" vegetative cuttings. The bundles are placed into trenches leaving several stems exposed on the surface. These trenches are dug perpendicular to the slope. Planting the cuttings perpendicular to the slope serves to establish vegetation and a rooting system and physically impeeds runoff and erosion by slowing water runoff rates. Bundles are further anchored by wooden 2x4" stakes spaced at 3-4' intervals. Live staves are then inter-spaced among the 2x4s at 3-4' intervals on the down slope side of the bundles. Successive rows of bundles should be placed along the entire length of the slope surface. Spacing between rows of bundles depends on degree of slope, with no more than 2-3' between rows.

In areas of high average rainfalls additions to live fascines called brush mattress are used. Construction of brush mattresses is done to reduce raindrop impact, and is accomplished by burying the basal ends of woody vegetative cuttings under the fascine bundles. The cuttings are then laid down with the apical end towards the slope apex and secured by wire connecting the stakes along the slope length. This technique was used successfully in Northern Virginia by RUST Environment and Infrastructure who used brush mattresses to stabilize earthen mounds between meanders of a river (Thomas et.al 1995). The 3:1 slopes of the mounds were stabilized using a combination of live and dead brush mattresses. The live vegetative cuttings consisted of native willows in the lower reaches, with red osier dogwood (*Cornus stolonifera*), elderberry (*Sambucus canadensis*), blueberry (*Vaccinium corymbosom*), and strawberry bush (*Euonymus americanus*) in the upper regions.

Branch Packing

Branch packing is a method used to repair slopes with existing slumps, headcuts, or gullies. Dead 2x2" stakes are inserted 3 to 4 feet into the ground inside the slump or gully, leaving the tops of the stakes approximately level with the slope. Vegetative cuttings are then laid down horizontally in 4-6" layers. Succesive layers are separated by 1 to 2 feet of compacted soil. The technique creates a multi-layered structure that has high amounts of vegetation and will require large volumes of water to successfully establish itself. While bioengineering techniques of slope stabilization have the potential to be cost effective means of establishing vegetation and reducing erosion, they have limitations. The biggest limitation may be the availability of plant materials suited to the techniques. When restoring native vegetation to slopes it maybe necessary to shift the matrix of species unnaturally heavy towards species that are suitable. Another limitation is the susceptibility to project wash out during the root establishment phases. The length of the root establishment phase is dependent on species, soils, and climatic conditions.

Synthetic additions

If existing gullies and degraded topography are too great, techniques applicable to a larger scale may be required. In these situations, combinations of live vegetation and synthetic materials can be very effective. Examples include joint plantings, live crib walls, and vegetated rock gabions. In these techniques vegetative cuttings are used in conjunction with riprap, concrete, and wooden structures. Other options include synthetic constructed materials such as Woven Coir Semi-permanent Erosion Control Blankets. This method can be used to aid in the establishment of cover vegetation during the root establishment phase. This technique has a life span 5-10 years in the soil and is very successful in controlling erosion and maintains vegetative cover even during periods of high rainfall and heavy rain fall intensities (Austin 1995). Mat structures and erosion control blankets also perform well in areas receiving negligible rainfall where vegetative techniques of slope stabilization may not be feasible, in these conditions, structural engineering techniques inherently perform better. These synthetic techniques also have draw backs such as cost, reducing the type of usable vegetation, altered soil physical properties, and logistics of transportation, installation and permanency of the structures.

Literature cited

Brooks, K.N., P.F. Ffolliot, H.M. Gregerson, and J.L. Thames. 1991. Hydrology and the Management of Watersheds. Iowa State University Press.

Lauka Sautha, P.E., and Calista R. Santha. 1995. Effective Utilization of fully matured grass in Erosin Control.

Lucas, Andrea. (1995). Evaluation of a Biotechnical Protection Project on the Navarro River, California. In Proceeding Carrying the Torch for Erosion Control: An Olympic Task, (pp 41-50). International Erosion Control Association Steamboat Springs Co.

Schiechtl, Hugo. (1980). Bioengineering for land reclamation and conservation, University of Alberta Press.

Simpson, Ben. (1989). Effective Establishment of vegetation for erosion control. In Symposium Proceedings of Soil Erosion and it's control (pp 47-54). Geneva,Switzerland: Jason Consultants S.A.

Thomas, Michael R. et al. Stream channel stabilization using soil bioengineering-A case history.In Proceeding Carrying the Torch for Erosin Control: An Olympic Task, (pp 65-71). International Erosin Control Association Steaboat Springs Co.

Wells, Gary W. (1994). Soil Bioengineering: The use of dormant Woody plantings for slope protection. In Symposium Proceedings: Agroforestry and Sustainable Systems (pp.29- 36). Rocky Mountain Forest Experiment Station, Gen Tech Rep RM-GTR-261,USDA.

Wraith, J.G. 1995. Tannery Creek-Bioengineered Stream Realignment. In Proceedings Carrying the Torch for Erosin Control: An Olympic Task, (pp 75-86). International Erosin Control Association Steamboat Springs Co.