Bio-engineering Practices for Soil and Water Conservation

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Objective

- To provide an overview of the concepts, knowledge and practices in bio-engineering technologies, and to highlight the low-cost and sustainable measures used for combatting watershed degradation processes

Definition

Bio-engineering connotes different things to different users and implementors. However, in general, the term bio-engineering is used to mean a technique in which living vegetation, either alone or in combination with non-living plant materials, or soft engineering structures are used to stabilise and protect slopes from erosion and landslides. In other words, bio-engineering practices are the integration of vegetative methods with normal engineering practices in order to protect the land. Terms like bio-engineering, vegetative engineering or vegetative structures are used synonymously.

Why bio-engineering practices in PIWM?

Past experience and knowledge from erosion and landslide control programmes have led us to believe that engineering practices alone are not always the solution to problems of slope stabilisation. In many cases, engineering practices are expensive and need high levels of skill and technology that are not always affordable by the users and implementors. Living vegetation can be used for their engineering, hydrological and ecological properties.

What are the functions of bio-engineering practices?

Vegetation or plants used for bio-engineering can be woody and non-woody. Both woody (trees, shrubs, bamboos) and non-woody (herbs and grasses) plants perform engineering, hydrological, and ecological functions.

Engineering function

Engineering functions of plants resemble the functions that civil engineering structures provide to support and protect the slope. These engineering functions of plants are as follow.

Catch - Process for holding a thin layer of moving soil particles and debris by multi-stemmed shrubs and bamboos.

Armour - process for protecting soil surface and soil particles from movement by providing protective cover (grass carpets).

Reinforce - mechanism for providing strength to bind the soil particles by densely rooted trees and grass.

Anchor - process for firmly fixing the soil particles and debris by the anchoring action of deep, long and strong roots of trees and shrubs.

Support - mechanism for providing support to soil mass and rocks from the mechanical action of the root systems of plants.

In bio-engineering systems, vegetation provides additional strength to the engineering structures with which they are integrated. Vegetation and engineering structures, if used in combination, co-exist and are compatible.

Hydrological function

The multiple stems and trunks of bio-engineering plants trap soil particles and debris moving down the hill slope. Root systems bind and hold soil particles, rocks and debris and reduce the rate of erosion and landslides.

Hydrology is important for slope stabilisation and erosion control. Vegetation plays a major role in manipulating the hydrological regime by changing the quantities of water circulating from land and water bodies to the atmosphere. Vegetation influences elements that are responsible for enhancing erosion and landslides. These elements are

- interception,
- leaf drip,

- stem flow,
- evaporation,
- transpiration,
- infiltration,
- soil water storage, and
- sub-surface flow.

Vegetation intercepts raindrops and protects the ground surface from the direct impact of falling rain. Leaf drip and stem flow reduce the velocity and direct impact of raindrops. Water evaporates from the leaf surface and some water is stored in the canopy and stems. Vegetation loses water from the surface of leaves through transpiration. Vegetation decreases surface runoff and overland flow and increases the infiltration process, soil water storage, and sub-surface flow.

Ecological function

Unlike engineering structures, bio-engineering performs an ecological function by tranforming the harsh environments of degraded slopes into better ecological conditions. Bio-engineering improves soil and moisture conditions, which, in turn, generate better micro-environments for the establishment and growth of plants, micro-organisms, and small animals. It also helps increase the biodiversity of the site.

What are the common bio-engineering techniques?

Various bio-engineering techniques can be used depending upon site conditions and availability of resources. Possible combinations or integration of vegetative methods with light and small-scale engineering structures are endless. However, some techniques that are commonly used are follow.

Planting trees, shrubs and grasses. Trees, shrubs and grasses can be planted on degraded slopes, either alone or in combination. A dense network of roots in the soil and a canopy overhead helps to protect the slope from erosion. Methods of planting should be selected depending upon the purpose, site condition and availability of resources. However, on hill slopes, contour line planting at regular intervals is the general practice.

Planting stumps/woody stems. Stump cuttings or woody vegetation can be planted along the contour to trap soil particles and debris falling down the slope.

Seeding grass, trees and shrub. Seeds of grass, trees and shrubs can be sown directly on site either alone or in combination. Methods and timing for seeding depend upon site condition and availability of resources. Seeds can be broadcast to cover large areas in a short time and at a low cost. This method can be used on steep, rocky and unstable slopes where seedlings and cuttings can not be planted directly.

Bamboo/amliso-broom grass (Thysolena maxima) planting. Rooted-culm cuttings, rhizomes and wild seedlings of bamboos and *amliso* can be planted directly on slopes. Bamboo and *amliso* perform slope stabilisation work effectively once they are established.

Wattling. Bundles of live branches with buds are put into a trench along the contour and covered with a thin layer of soil. When the branches put out roots and shoots a strong vegetative barrier is formed that is effective in holding soil particles moving down the hill slope. This technique is not popular since it is expensive and works only on gentle slopes.

Brushwood check dams. Brushwood check dams using bamboo and wood are commonly used to stabilise gullies on slopes. After the construction of check dams, grass and shrubs are planted on side slopes and on the gully head.

Vegetated rip-rap. Side slopes of gullies and gully beds are sometime protected by constructing dry stone walls and then grass seeds are sown or planted in the gaps between the stone in order to reinforce toe walls and gully beds.

Loose stone and gabion check dams. Construction of loose stone and gabion check dams is very common for stabilising slopes. After the construction of check dams, seedlings of trees, shrubs and grasses are planted either separately or in combination on gully heads, side slopes, gully beds, and in and around the structure for reinforcement.

Brushwood embankments/spurs. Construction of brushwood embankments and spurs helps to protect stream banks from erosion. Bamboo and wood are used to construct the embankment and spurs. On the backside of the structures, trees, shrubs, grass seedlings or woody cuttings are planted to provide vigour and anchorage to the brushwood structures. These techniques have shown effective and promising results in the torrents and small rivers of the *Churia* and *Terai* regions.

Jute netting. jute netting is another way to protect the slopes using grass slips or seedlings. This method can be useful on steep and hard slopes where establishment of vegetation is difficult. Although this method is expensive it is commonly used in Nepal. Results have not been evaluated yet.

Lifespan/longevity of bio-engineering systems

In bio-engineering systems, soft engineering structures and vegetation should be integrated. This is because soft engineering structures are temporary; they loose strength over time and re-construction is always necessary. However, vegetative structures are permanent once the plants are established. Plants will reproduce and rejuvenate. If there is no human interference vegetation serves its bio-engineering purposes permanently.

Selection of appropriate plant species for bio-engineering

The correct selection of suitable plant species is essential for the success of bio-engineering practices. Identification of engineering function and structural characteristics of the plant is required before selection for bio-engineering. The following criteria should be taken into consideration while selecting the plants suitable for bio-engineering.

- Purpose, site condition and local situation
- Physical and climatic factors
- Engineering function required
- Bio-engineering techniques required
- Structural characteristics of plants
- Availability of planting materials
- Identification of various alternatives (species choice, methods, etc)

Selection of plants should be based on careful studies of engineering functions such as armouring, anchoring, reinforcing, matting, etc and the structural characteristics of plants such as size, shape, form and structure of leaf, canopy, stem, root, etc.

General characteristics of degraded land are a low level of soil nutrients, stoniness, drought and harsh environment. Plants selected for bio-engineering should be able to withstand these stresses. They should

- establish rapidly,
- grow vigorously,
- have dense and deep root systems,
- resist drought,
- propagate easily,
- resist insect and diseases, and
- withstand harsh environment.

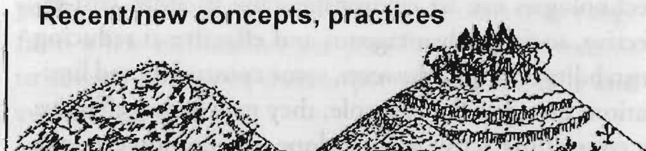
The most suitable plants are usually pioneer/xerophytic species, leguminous species and local species.

How to plan and manage bio-engineering programmes?

Planning bio-engineering programmes is complex. It needs careful study and design of both vegetative and soft engineering techniques. The interaction and interrelationship of these two techniques in terms of time

Conventional/old concepts, practices

Recent/new concepts, practices



and space and their primary and secondary functions should be well understood. Planning aspects such as application, site condition, technical requirements, geographical circumstances, scope of benefits, cost sharing, participatory mechanism, resource availability, human interference, etc should be assessed. The following also need to be considered.

- Causes of instability and consequences
- Outline of landslide/erosion
- Site condition and description
- Severity of problem
- Technical mechanism
- Alternatives

Planning should also evaluate the cost-effectiveness of the bio-engineering programmes. For example, the selection of unpalatable plants will reduce the cost by avoiding the problem of grazing. Similarly, plant species that generate income or have an economic value will yield benefits to the people. People's cooperation and their participation can be obtained if species' selection contributes to solving socioeconomic problems.

What are the lessons learned?

Although the establishment of bio-engineering measures on degraded land following erosion is not easy, the technologies can be environmentally friendly, cost-effective, socially advantageous and effective at reducing instability of slope. However, some constraints and limitations do exist. For example, they may be less effective at controlling active gullies, slope stabilisation can take a long time to establish and yield intended results, and they may need extra care and frequent replacement of plants. One great advantage is that measures are based on indigenous knowledge and local resources can be used widely. The best possible way to replicate and disseminate such technology is through the 'seeing is believing' approach by conducting study tours and on-site training to technicians and farmers.

Bio-engineering techniques should not only be based on technical aspects, but should also address socioeconomic aspects. Techniques should be selected in such a way that they help uplift the socioeconomic condition of the rural poor by providing fuelwood, fodder, fruits and nuts, and biomass for compost making, and by reducing drudgery for women farmers.

Suggested further reading

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