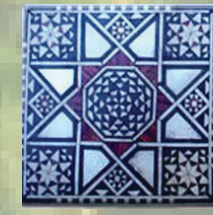




THE WORLD BANK  
IBRD • IDA



GFDRR  
Global Facility for Disaster Reduction and Recovery

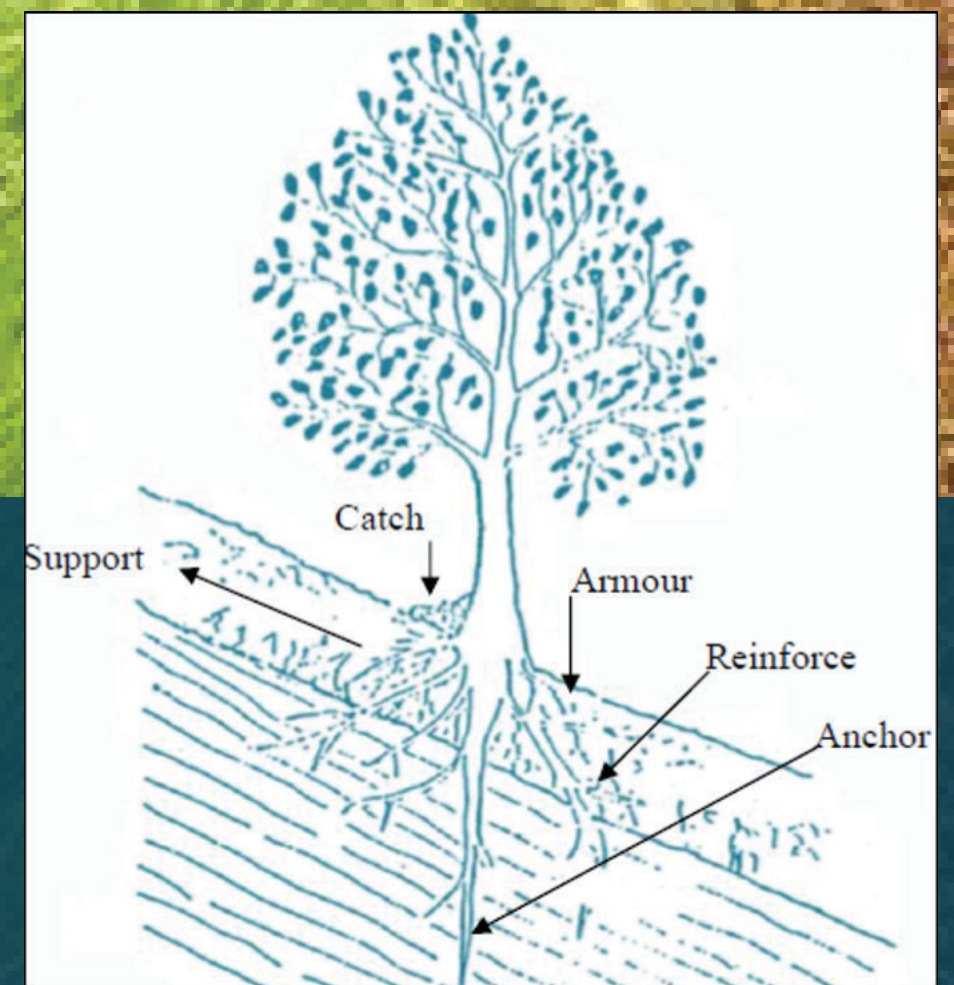


META  
META



# Bioengineering

Bioengineering is a subset of green infrastructure that uses vegetation (trees, shrubs, grasses) to serve engineering functions – combined with civil engineering measures. Bioengineering helps to reduce soil/slope instability and erosion, increases the slope's factor of safety, is versatile in its application and cost-effective.



## Key Points

- 1 Integrate bioengineering systematically into rural road designs, especially in flood-prone, erosion-prone, and hilly areas.
- 2 Tailor the different functions of bioengineering to the specific location.
- 3 At sensitive / dangerous areas, strategically combine bioengineering with grey infrastructure for optimal impact of both.
- 4 Consider bioengineering as a Building Back Better option when the initially employed stabilization method failed or did not perform
- 5 Promote co-benefits.

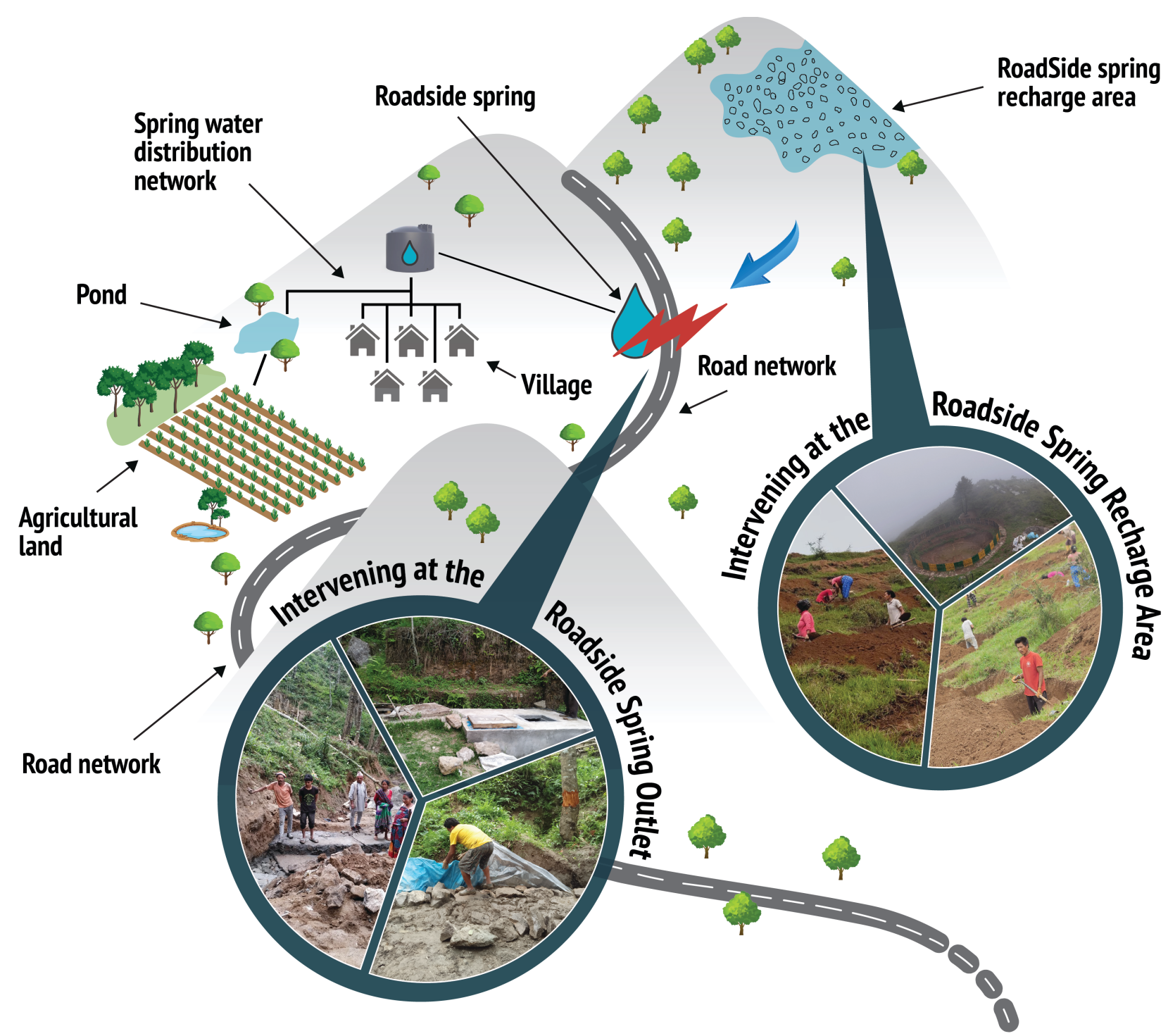
## Specific guidance:

Engineering function	Bio-engineering measures	Civil engineering measures
<b>Catch:</b> Stop material from falling or sliding down a slope	<ul style="list-style-type: none"><li>- Contour lining of grasses, brush layers</li><li>- Live check dam</li><li>- Stems of shrubs and bamboo</li></ul>	<ul style="list-style-type: none"><li>- Check dams</li><li>- Catch walls</li><li>- Jute netting</li></ul>
<b>Armour:</b> Protect the surface from erosion	<ul style="list-style-type: none"><li>- Storeys of mixed plants providing complete cover</li><li>- Grass carpet of clumping or spreading grass with dense and fibrous roots</li><li>- Use green soil bags</li></ul>	<ul style="list-style-type: none"><li>- Revetment wall</li><li>- Stone pitching</li></ul>
<b>Reinforce:</b> hold particles together and reduce the risk of shallow-seated movement	<ul style="list-style-type: none"><li>- Grasses, shrubs, and trees that are densely rooting</li><li>- Most vegetation structures</li></ul>	<ul style="list-style-type: none"><li>- Soil nailing</li><li>- Reinforcing earth</li></ul>
<b>Anchor:</b> reduce risk of deeper-seated movement	<ul style="list-style-type: none"><li>- Trees and shrubs that are deeply-rooting with long string roots</li></ul>	<ul style="list-style-type: none"><li>- Rock anchors by bolting</li></ul>
<b>Support:</b> hold material on the slope	<ul style="list-style-type: none"><li>- Large trees and bamboos having deep and dense root system</li></ul>	<ul style="list-style-type: none"><li>- Retaining walls</li><li>- Prop walls</li></ul>
<b>Reduce:</b> reduce material and water movement	<ul style="list-style-type: none"><li>- Strong, numerous, and flexible stems</li><li>- Many strong, fibrous roots</li></ul>	<ul style="list-style-type: none"><li>- Check dams</li><li>- Catch walls</li></ul>
<b>Drain:</b> remove excess water	<ul style="list-style-type: none"><li>- Down slope and diagonal vegetation lines</li><li>- Angled fascines</li></ul>	<ul style="list-style-type: none"><li>- Surface drains</li><li>- French drains</li></ul>

Table 1. Bioengineering function: Bioengineering systems and civil engineering systems (based on Developing Bio-engineering Capacity for the Local Government Engineering Department Operations in the Chattogram Hill Tracts, Bangladesh, ADB)

## Spring protection

- 1 In hilly areas springs and seeps are opened up with road development. This can cause the 'emptying' of local aquifer systems
- 2 We need to intervene at the new spring outlet and capture and protect the spring
- 3 We need to intervene in the spring shed and enhance recharge of the spring



Increasing Resilience of Rural Infrastructure and Local Communities through Green Roads Concept