Tools and Technologies for Climate Change Adaptation and Disaster Risk Management in Asia and the Pacific

Application of the Bioengineering in Bhutan: Tools for Landslide Disaster Risk Reduction

Joint Webinar

Tools and Technologies for Resilient Transport Sector

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ADB BROWNBAG WEBINAR SERIES
Brown Bag Seminar Series 5th on 14 March 2024

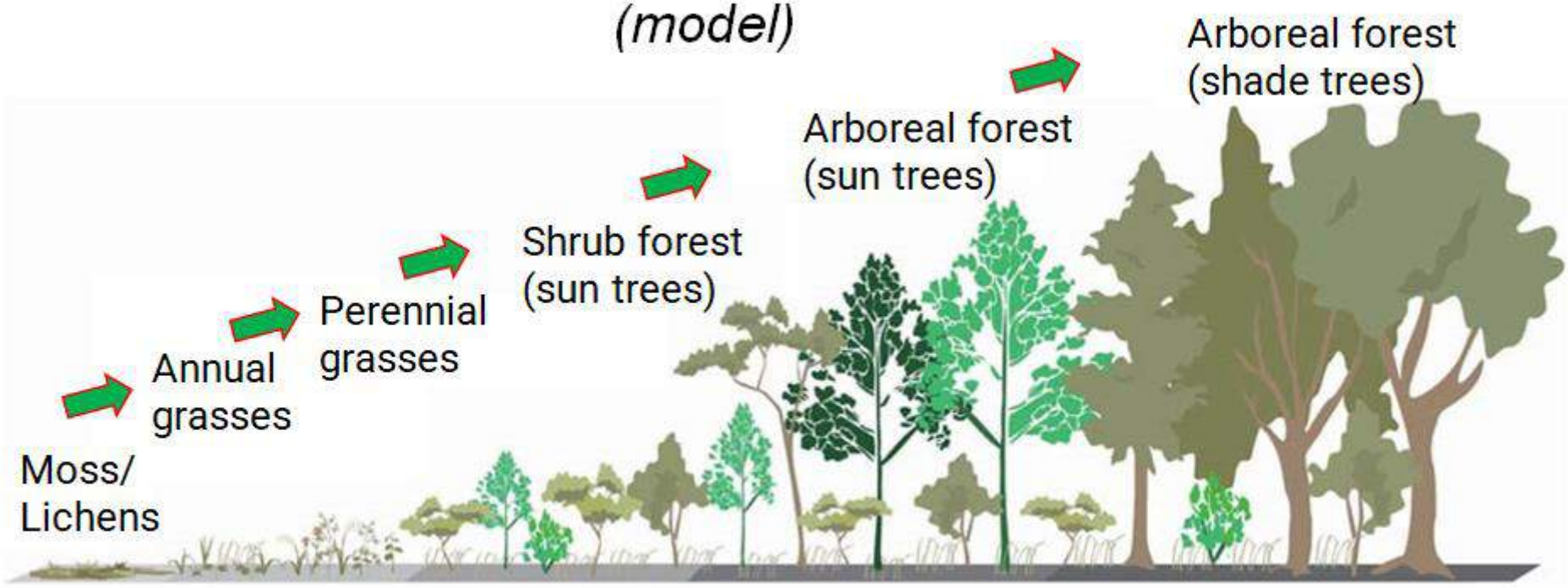
Contents

Introduction

General concepts

A process of plant transition at the slope as bare land

(model)



Bioengineering at the soil slope considering the conservation of regional ecosystem (modified figure in the document No.743 of National Institute for Land and Infrastructure Management, Japan)

What is Bioengineering?

Purpose of the Bioengineering for cut slope

- Slope Stability by the suitable bioengineering for the protection against “Soil Slope Failure”

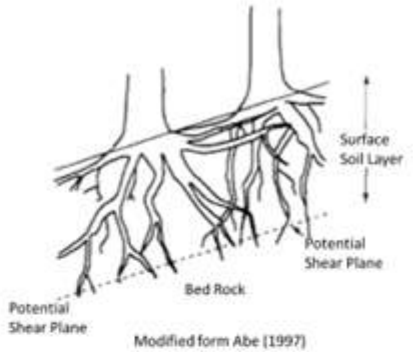
Bioengineering
according to purposes

- Stability of overburden at the slope
- Protection of the erosion of the cut slope surface
- Environmental protection at the slope

According to **purposes**

- Stability of overburden at the slope

  by root system



- Protection of the erosion of the cut slope surface

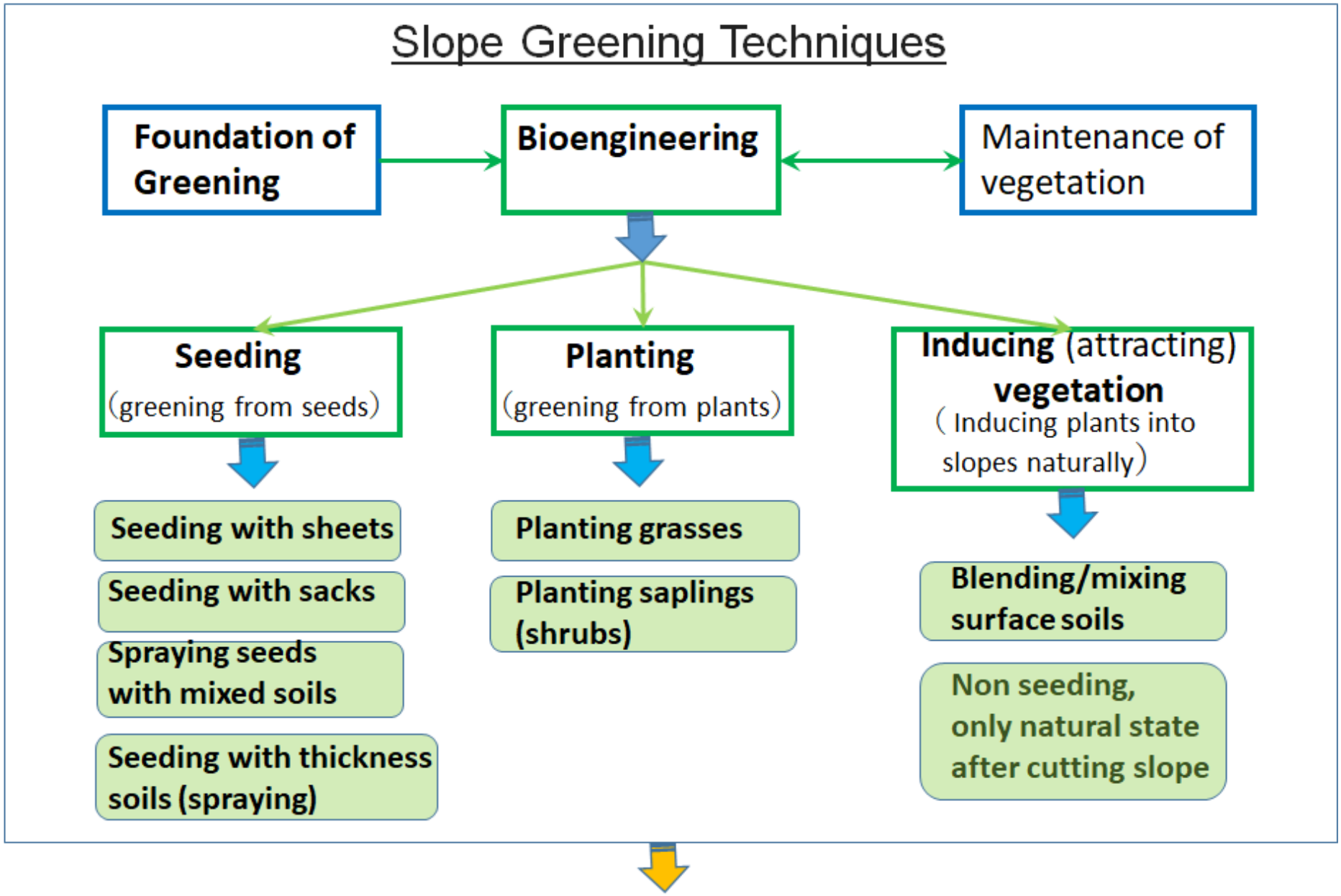
  by plant coating

- Environmental protection at the slope

  by natural plants from the neighbor slope

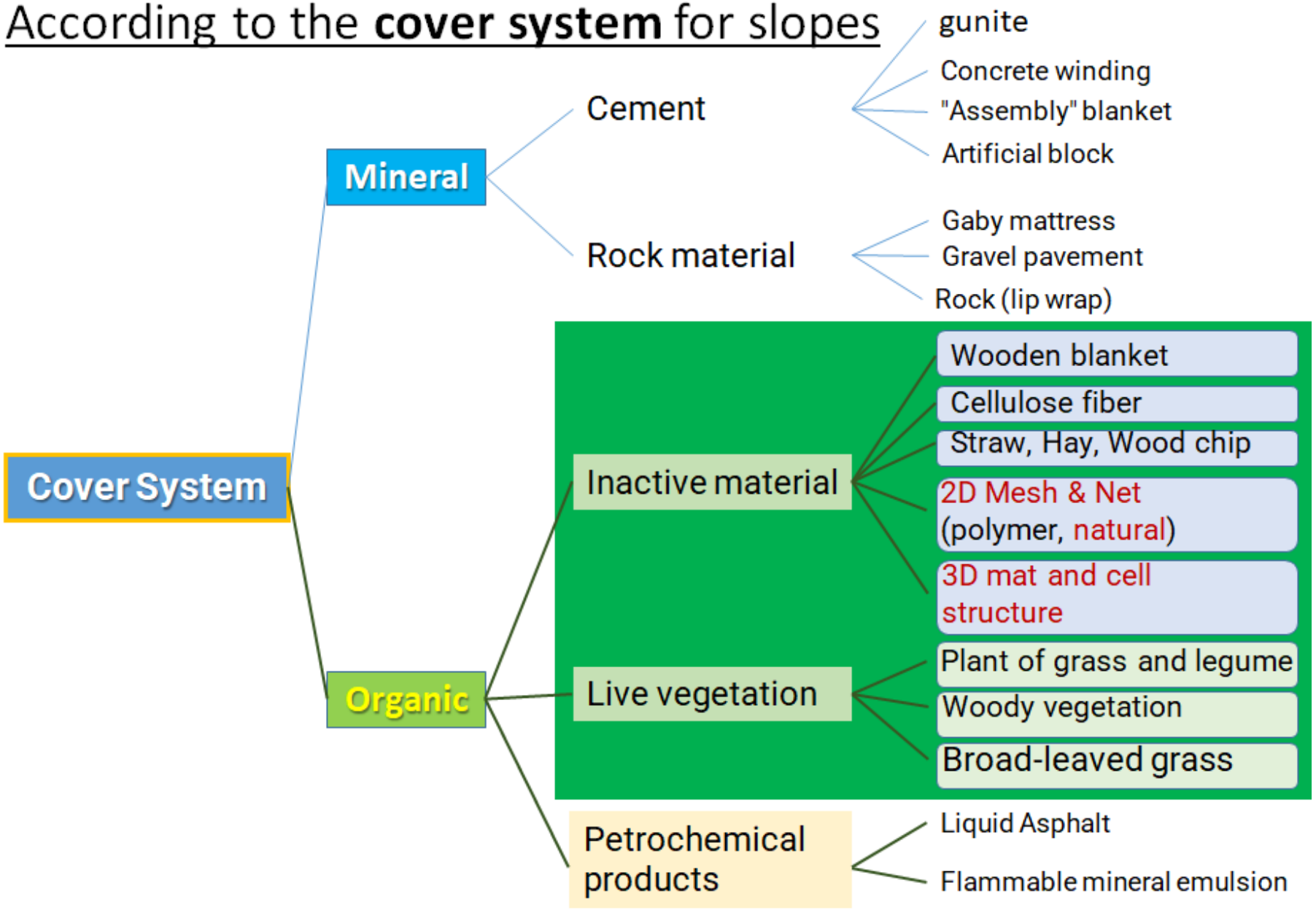
According to **greening techniques**

Ground cover materials for protection of erosion at slopes
(modified from *Biotechnical and Soil Bioengineering*)



Manual for bioengineering in Bhutan

According to the **cover system** for slopes

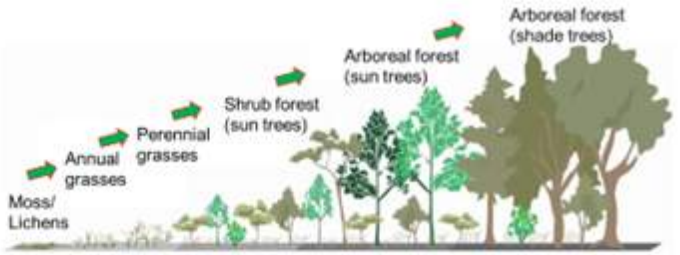


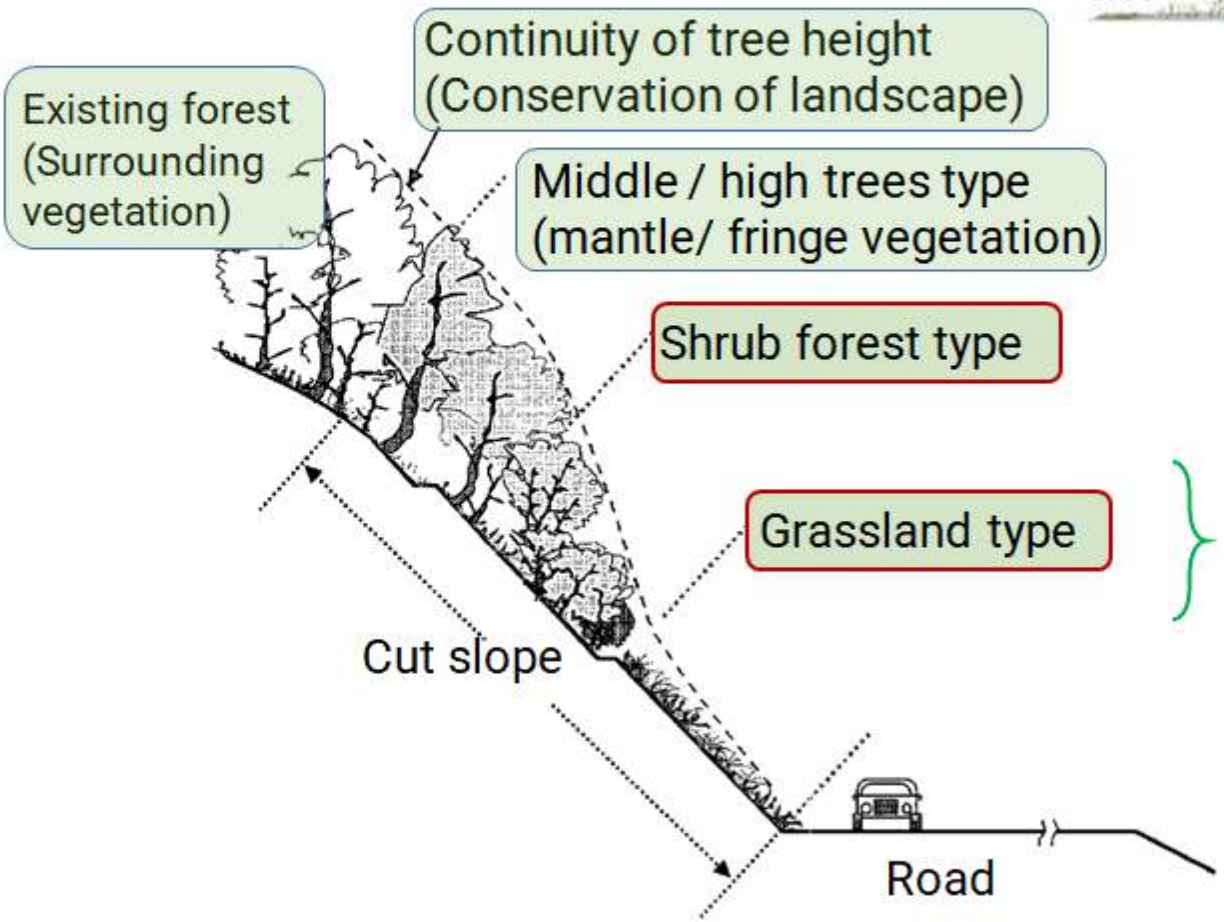
Ground cover materials for protection of erosion at slopes
(modified from *Biotechnical and Soil Bioengineering*)

Variation of the Bioengineering

(in cut slope)

A process of plant transition at the slope as bare land





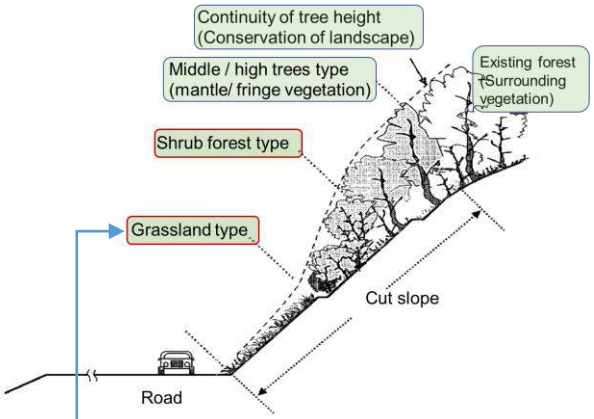
Natural recovery vegetation

Bioengineering in this project

Example of type combination for appearance of each vegetation target

(modified figure after the Japanese Society of Revegetation Technology)

Bioengineering examples by three target types



Bioengineering in this project

Target (bio-Eng.)	Examples	
Arboreal forest type (using surface soils)	After 3 months	After 6 years
		
Shrub forest type (using surface soils)	After 5 months	After 5 years
		
Grassland type (using surface soils)	After 6 months	After 7 years
		

Bioengineering of JICA project in Bhutan

Added https://dlca.logcluster.org/23-bhutan-road-network#id-2.3BhutanRoadNetwork-Overview (20230529 viewed Bhutan Road Network)

The 1st test construction site, Gangthanka Slope

The 2nd Pilot site, Yangkhil Slope

The 3rd Pilot site, Gopini Slope

Project for Capacity Development on Countermeasures of Slope Disaster on Roads in Bhutan

Output 2, Suitable bio-engineering works are selected against "debris slope failure"

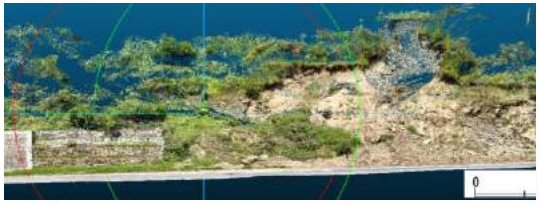
MINISTRY OF WORKS AND HUMAN SETTLEMENT

Test construction sites

Slope Site introducing construction methods

① Lobeysa R. O. 2020

② Trongsa R.O. 2022



③ Phuentholing R.O. 2024

Under construction at Gopini slope in Samtse in March 2024

Purpose and application

The introducing vegetation works are being carried out as bioengineering test construction on three cut slopes on Bhutan's national highways: *Gangthangka* slope, *Yangkhil* slope, and *Gopini* slope, but the goal is to apply the work to other regions.

To stabilize the surface soil on the cut slope with vegetation, it is necessary to install an adequate drainage system.
However, in this Joint webinar, the drainage system will not be explained.

Types of vegetation work and selection of vegetation methods

Construction method used from the first trial slope to the third trial slope for Bioengineering

Vegetation wok/ methods	1st trial slope Gangthangka	2nd trial slope Yangkhil	3rd trial slope Gopini	memo
1 **Linearly planting**	Done	—		Long term
2 **Overall planting**	Done	Done		Highly versatile
3 **Transplantation of a germination bed**	Done	—		Effective
4 **Gabion cap planting**	—	Done		Effective
5 **Stepped planting**	—	Done		Effective
6-1 **Laminate sheet planting without seeds**	—	Done	Under construction	Long term effective
6-2 **Laminate sheet planting with seeds**	—	—	Under construction	Long term effective
7 **Pot planting**	—	—	Under construction	Effective
8 **Sand bag planting**	—	—	Done	Effective

Methods

Introduce the contents as an applicable construction method as follows:

1st trial slope Gangthangka

1 **Linearly planting**

2 **Overall planting**

3 **Transplantation of a germination bed**

2nd trial slope Yangkhil

4 **Gabion cap planting**

5 **Stepped planting**

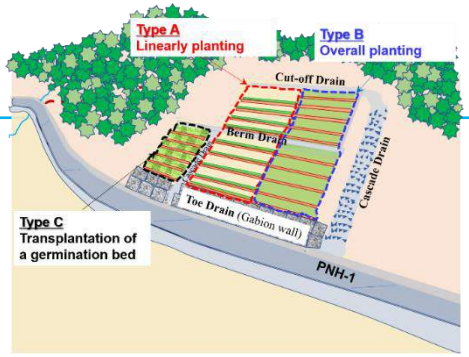
6-1 **Laminate sheet planting without seeds**

1st trial slope Gangthangka

1 **Linearly planting**

2 **Overall planting**

3 **Transplantation of a germination bed**



A: Slope before vegetation works on May 29, 2019

One month later

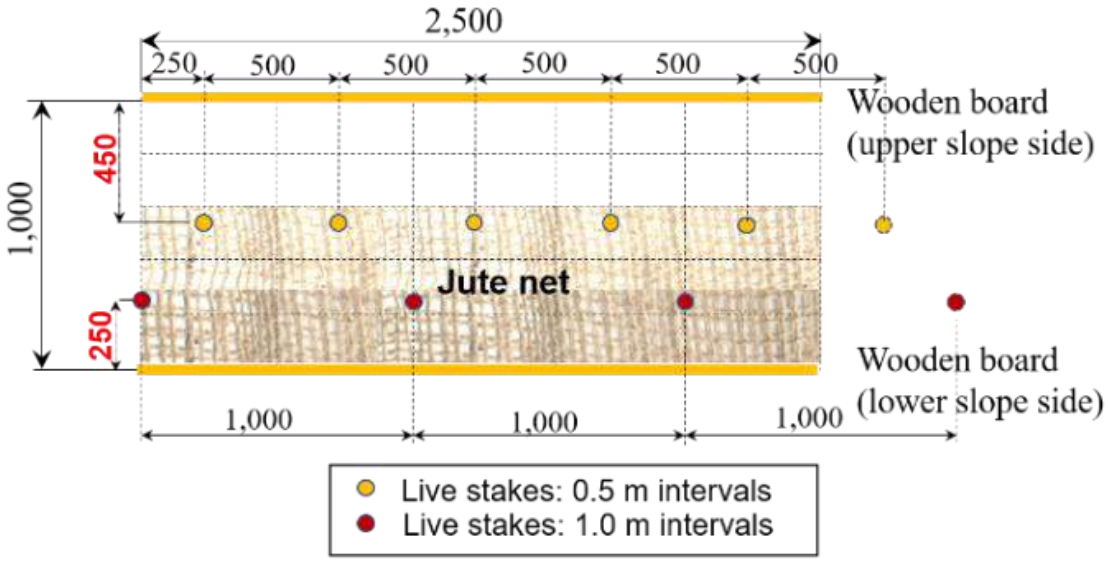
C: After the vegetation works, taken photo on June 26, 2020

B: Finished vegetation works on May 30, 2020

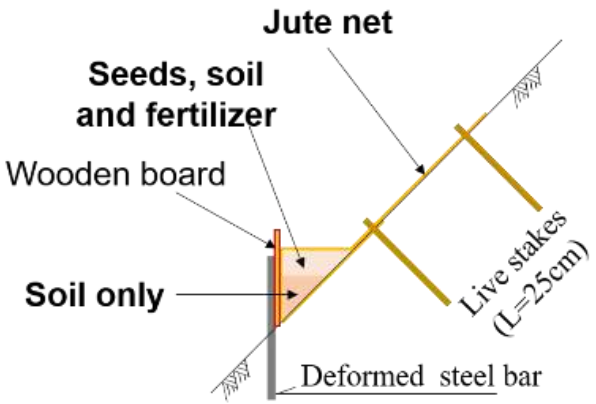
Four months later

D: After the vegetation works, taken photo on October 31, 2020

1 Linearly planting



Front view



Section view

Procedure of Type-A

1) Installing deformed steel bar
2) Installing wooden board
3) Placing jute net
4) Premixing seeds, soil and fertilizer
5) Placing soil portion
6) Placing soil with seeds and fertilizer
7) Folding and covering with jute net
8) Fixing jute net with live stakes

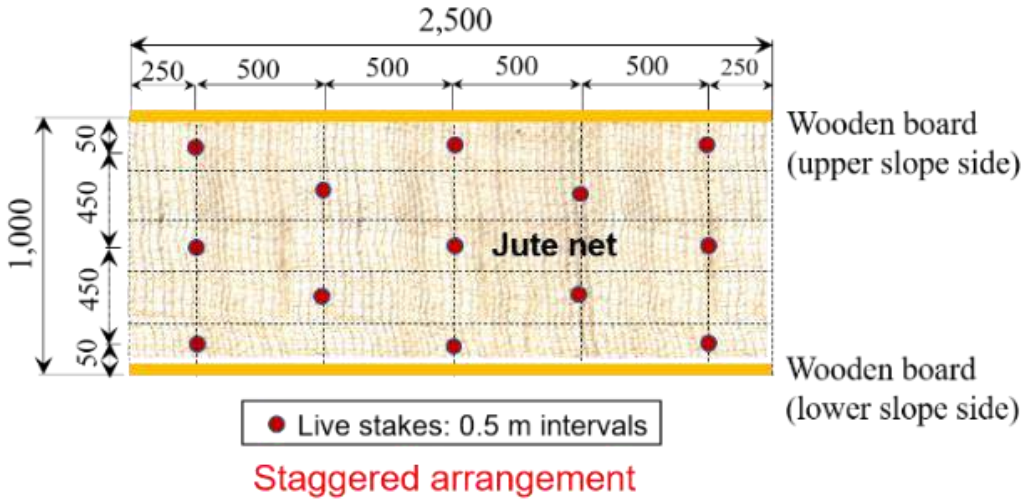
Method and function:

Prevents infiltration by creating streaks of vegetation, prevents erosion, and promotes plant invasion and establishment.

Application issues:

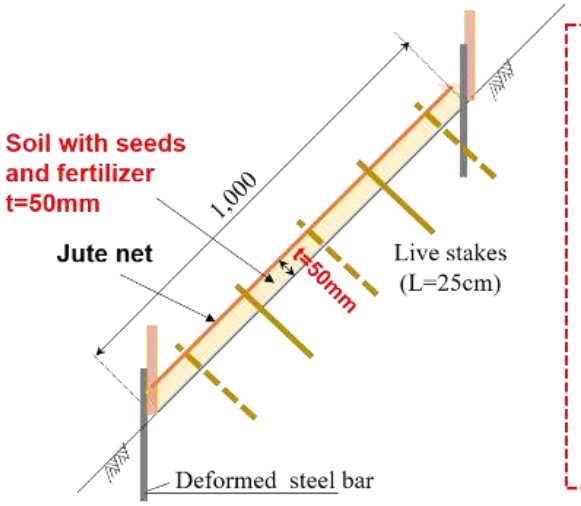
This construction method is basically carried out on embankment slopes and requires careful maintenance for vegetation.

2 Overall planting



Staggered arrangement

Front view



Section view

Procedure of Type-B

1) Installing deformed steel bar
2) Installing wooden board
3) Premixing seeds, soil and fertilizer
4) Placing soil with seeds and fertilizer with a thickness of 5 cm at every 20 cm
5) Placing jute net and covering soil
6) Fixing jute net with live stakes
7) Repeating the process from 4 to 6

Method and function:

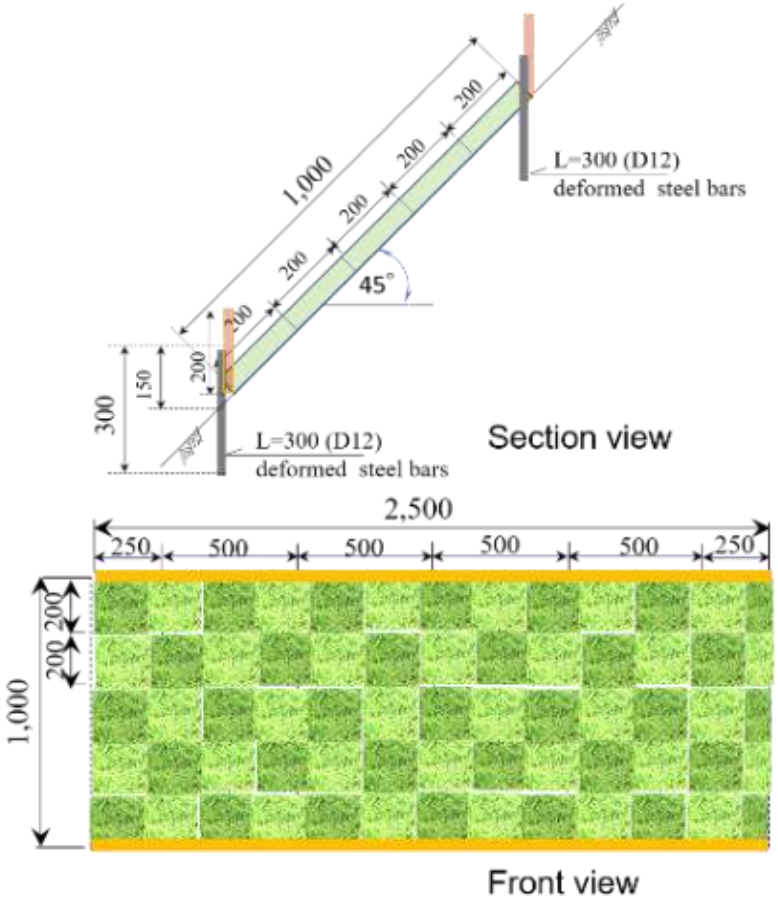
Cover the entire area with vegetation at an early stage to prevent erosion and suppress collapse due to frost heaving. For this reason, grass seeds are first used with the aim of early germination.

Application issues:

Pay attention to dryness of the slope surface and perform water sprinkling during maintenance.

3 Transplantation of a germination bed

Cut into square size after germination test at the yard of Lobesa R. O.



Procedure of Type C

1) Cut the long grass at the yard of Lobeysa R.O.
2) Cut into 20cm square size with at least 5cm thickness of soil and transport to the construction site
3) Install deformed steel bars and wooden boards as same as Type A & B.
4) Sprinkling water on the slope to moisten the soil
5) Place the grass on the slope regularly

Method and function:

Transplant existing vegetation. This ensures that the plants take root on the slope. This method is basically carried out on embankment slopes, but this time it was constructed on cut slopes.

Application issues:

The issue is whether it is possible to obtain a germinating bed that is equivalent to the vegetation coverage on the slope.

2nd trial slope Yangkhil

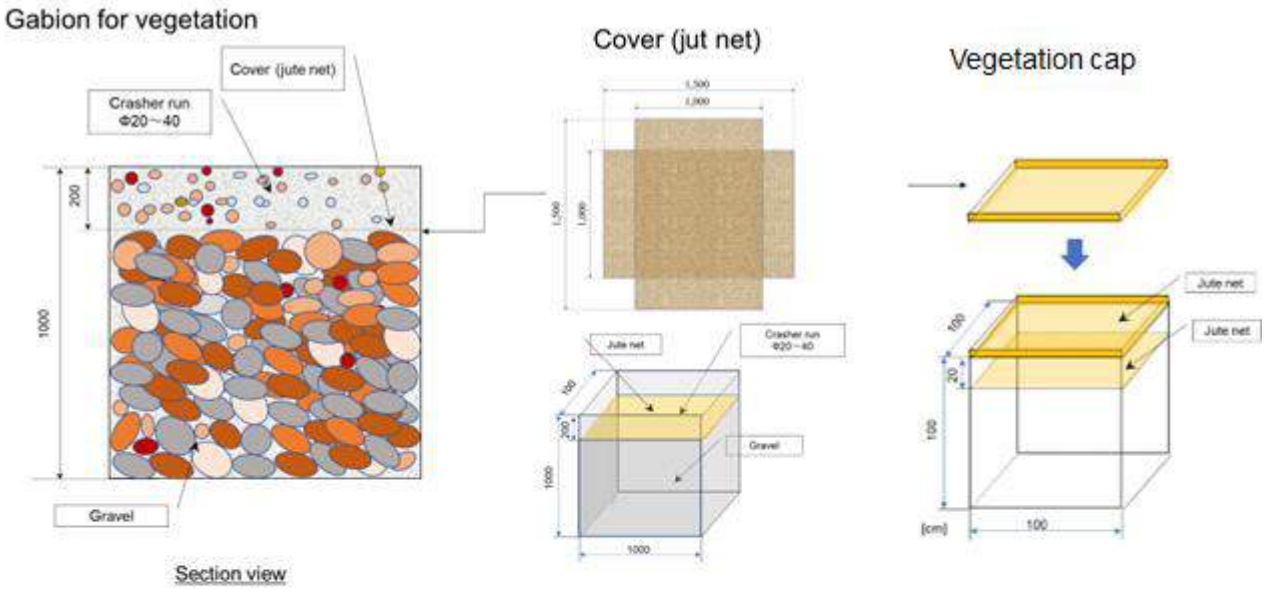
4 **Gabion cap planting**

5 **Stepped planting**

6-1 **Laminate sheet planting without seeds**

20230525 Yangkhil (Resort) Slope

4 Gabion cap planting



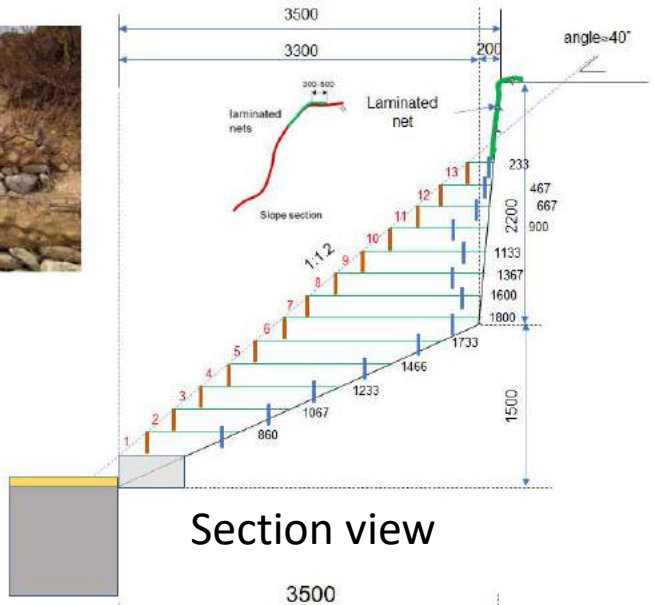
Method and function:

Place jute net and ϕ20-40 crusher run on the 20 cm upper part of the gabion and put a cap with soil, seed, and fertilizer on the gabion. This allows for vegetation to grow on top of the gabion, and the gabion itself does not receive direct rainfall.

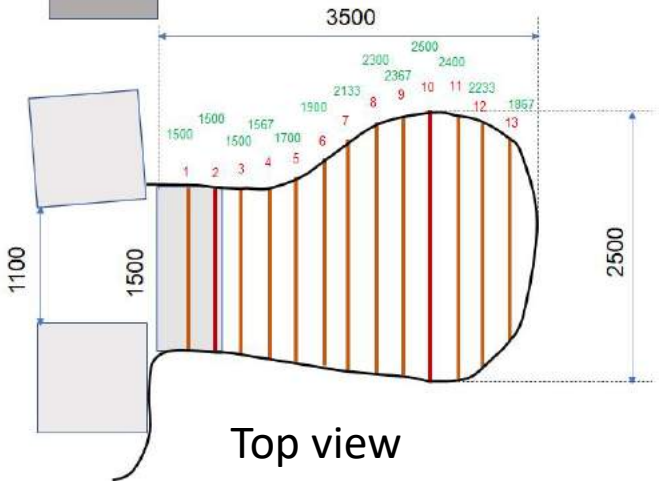
Application issues:

Deformed steel bars are inserted into the ground to strengthen the foundation of the gabion.

5 Stepped planting



Section view



Top view

Method and function:

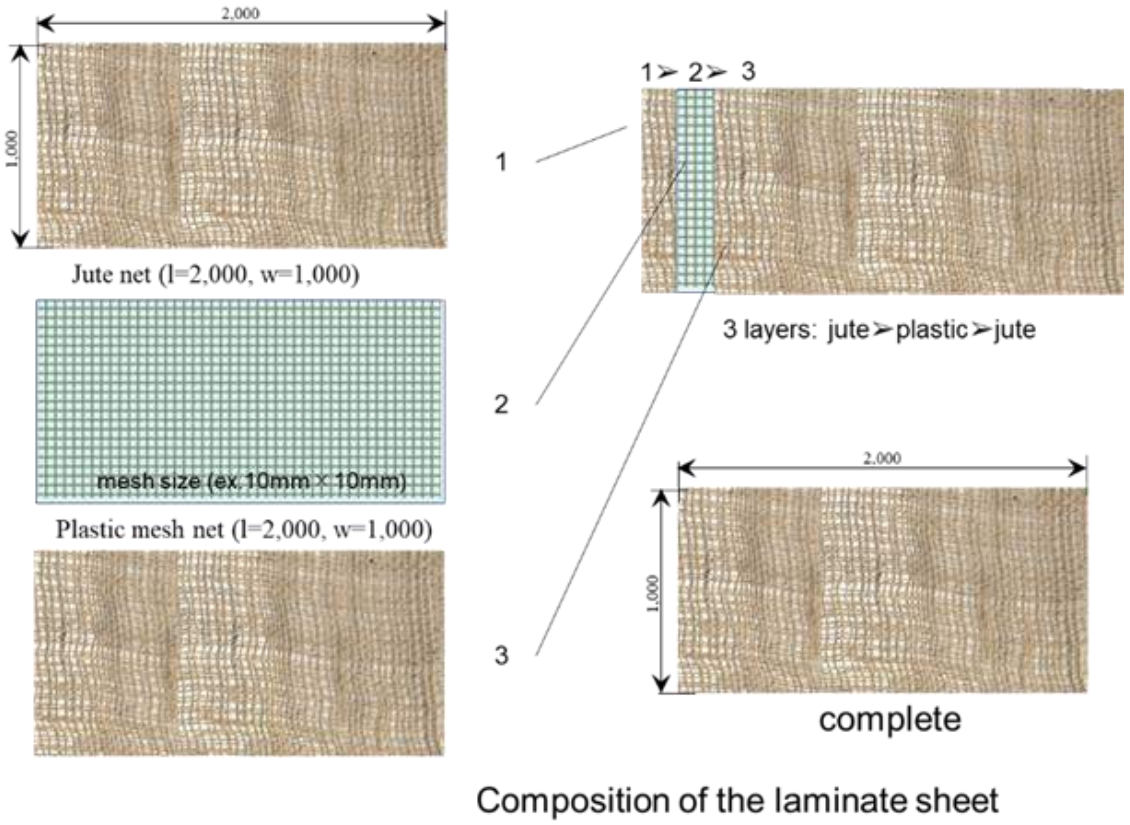
Steps with a height of 10 cm will be installed at a slope of 1:1.2, and the exposed areas will be planted with vegetation. It keeps small high angle slopes stable.

Application issues:

The slope gradient and range must be determined according to the site conditions. It is best to lay non-woven fabric on the installation slope to provide drainage functionality.

6-1 Laminate sheet planting without seeds

6-2 Laminate sheet planting with seeds



Composition of the laminate sheet

Method and function:

Create a 3-layer laminate sheet with plastic mesh net sandwiched between Jute nets. These are installed in areas that are prone to collapse, such as the shoulders of slopes, to prevent erosion and collapse.

Application issues:

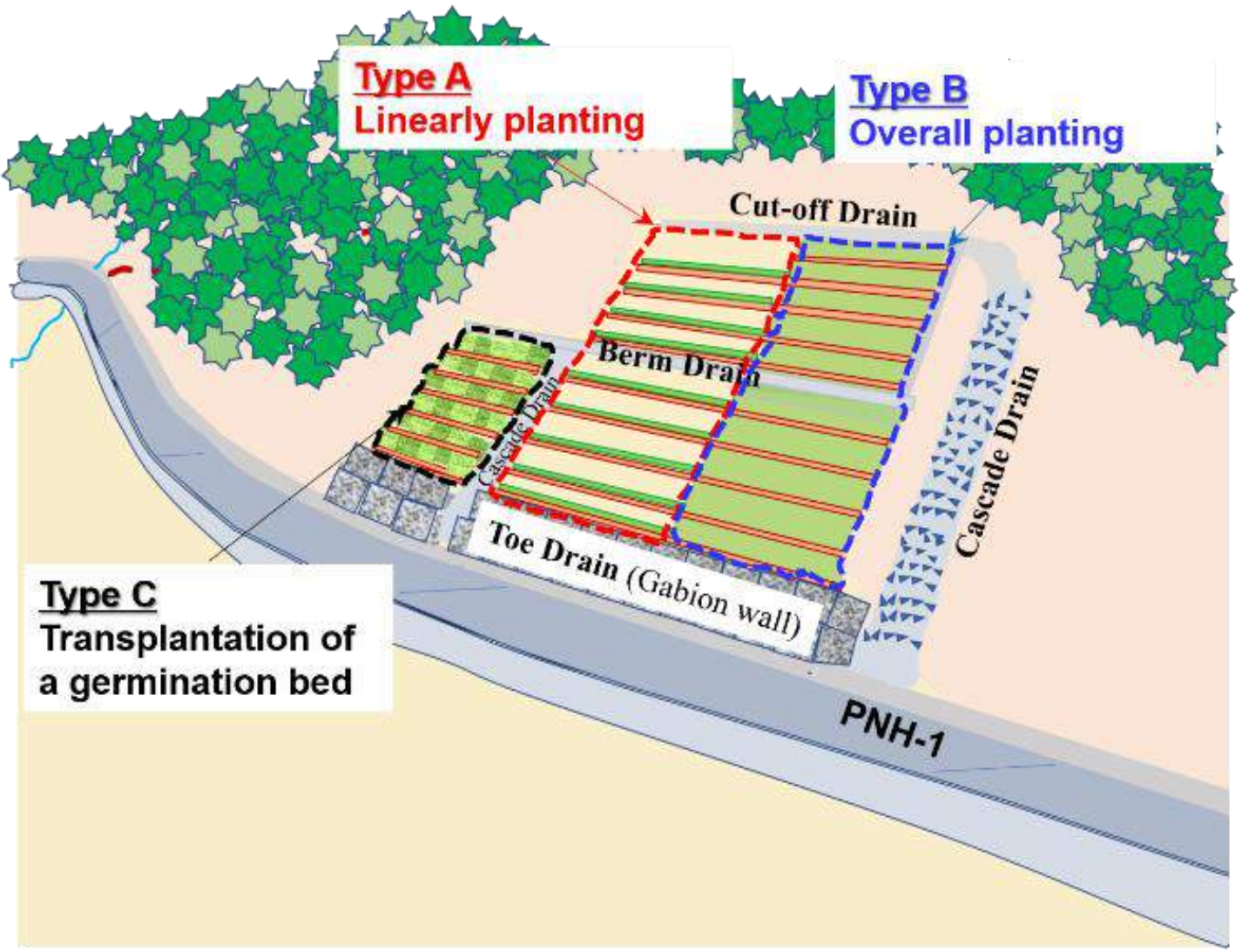
The product introduced here does not contain seeds in a laminated sheet. Currently, I am planning to try putting the seeds in a laminated sheet at the 3rd trial site, *Gopini*.

Thank you for your attention

Trongsa

Appendix 1: The 1st Pilot site, *Gangthanka* Slope

Image diagram of the Vegetation Works



Process

Selection of
a **Target slope**

Seeds

Vegetation type

Design

Construction

Cut Slope
Drainage S.
Vegetation W.

A: Slope before vegetation works on May 29, 2019

B: Finished vegetation works on May 30, 2020

C: After the vegetation works, taken photo on June 26, 2020

D: After the vegetation works, taken photo on October 31, 2020

Appendix 2: Video Guidance at the 1st Pilot site, *Gangthanka* Slope

Refer to "Kiyoharu Hirota, Yasuhisa Suganuma, Tomoharu Iwasaki, and Takeshi Kuwano (2022): How to Teach Remotely the Vegetation Works to Protect Slopes Against Mass Wasting: A Case of Using Video Materials in Bhutan. 361-370, Alcántara-Ayala et al. (eds.), Progress in Landslide Research and Technology, Vol.1, Issue 2, 2022, Progress in Landslide Research and Technology."

Video teaching tool is a separate document.

Appendix 3: The 2nd Pilot site, *Yangkhil* Slope

20230503 Yangkhil (Resort) Slope

20230503 Yangkhil (Resort) Slope

20230423 Yangkhil (Resort) Slope

20230525 Yangkhil (Resort) Slope

20230704 Yangkhil (Resort) Slope

20230817 Yangkhil (Resort) Slope