



# How to Teach Remotely the Vegetation Works to Protect Slopes Against Mass Wasting: A Case of Using Video Materials in Bhutan

Kiyoharu Hirota, Yasuhisa Suganuma, Tomoharu Iwasaki, and Takeshi Kuwano

## Abstract

This paper describes the outline of the video tutorial prepared for vegetation workers and relevant officers in Bhutan to learn how vegetation works are to be done in remote areas. The Japan International Cooperation Agency (JICA for short) took a project on cutting unstable slopes in Gangthangkha, Wangdue, Bhutan, so that they should be gentler than  $45^\circ$  to improve slope stability with vegetation works. Particularly stabilizing slopes along Prime National Highway No. 1 (PNH-1 for short) was the overriding priority because slope failures along this highway have reportedly occurred in rainy seasons. Before vegetation works were carried out on the studied slope of the project, the authors conducted germination tests to choose seeds and methods suitable for the vegetation works. They chose *Paspalum Atratum*, Ruzi grass, and GM mixed (Grass Mixture seed formulating of Cock's foot 70% and Italian Ryegrass 30% of 100 kg) based on their test results. The soil thickness associated with sowing was set at 5 cm. The authors tried the following types of vegetation methods on the studied

site. Type A is arranging on the slope stripes of soil mixed with seeds and fertilizer, Type B is spreading out a five cm-thick seeds-mixed soil layer over the slope, and Type C is transplanting germination beds. In conclusion, Type C is the best in terms of its performance because the whole slope is quickly covered with already grown plants. In Type B, it is not until grass covers the entire slope that the slope is finally stabilized. Type A is good for seeds-mixed soil stripes, but it takes time for the grass to spread gradually over the whole slope.

## Keywords

Vegetation works • Cut slope • Video materials

## Supplementary Information

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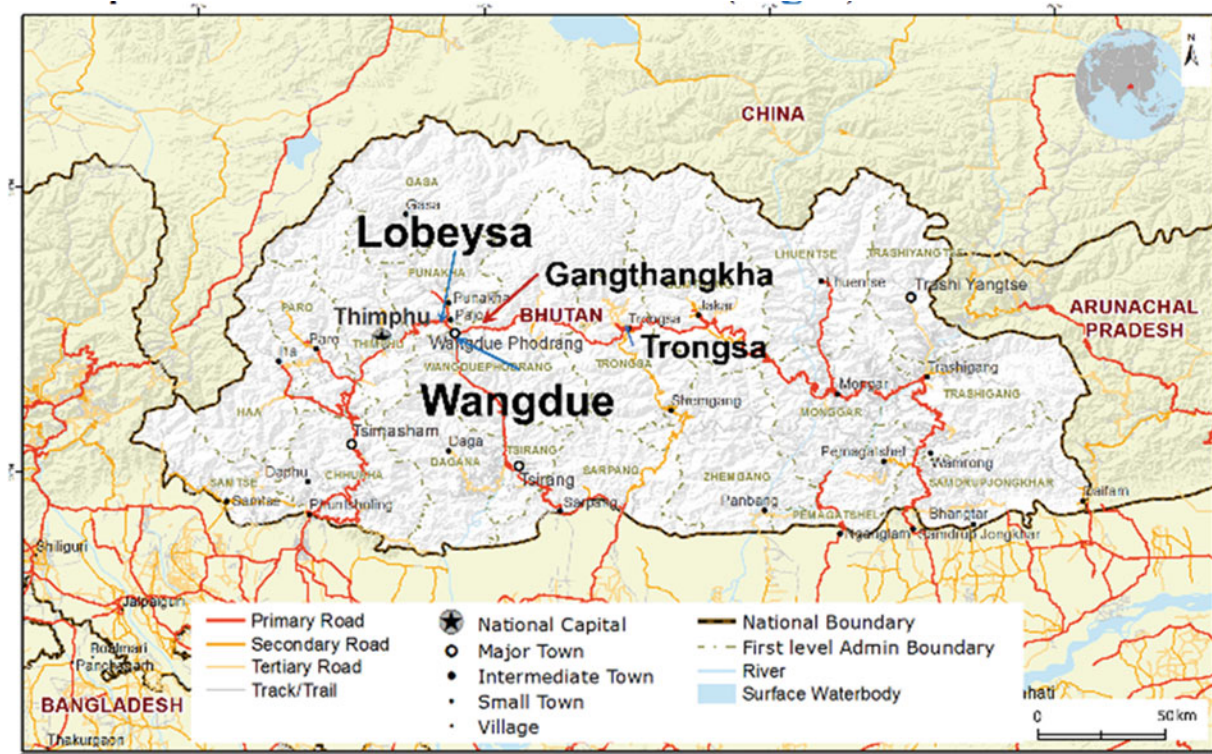
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## 1 Introduction

This teaching tool is a video medium that can help workers to learn how to perform vegetation works on cut slopes. The video has been prepared as a part of the JICA's Project "The Project for Capacity Development on Countermeasures of Slope Disaster on Roads in Bhutan." Behind this video production was the impact of the COVID-19 pandemic, which forced the JICA expert team including the authors to return to Japan in February 2020, during the project. The video was successful in enabling on-site vegetation works management remotely. This article introduces the outline of the vegetation works.

## 2 Outline of the Vegetation Works

The site of the vegetation works is in Gangthangkha, Wangdue where Lobeyisa Regional Office (Lobeyisa RO) of the Department of Road in Bhutan (Fig. 1).

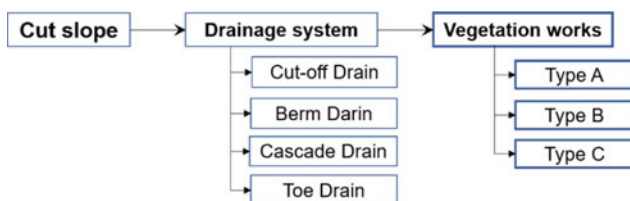


**Fig. 1** Map of Bhutan with locations relevant to the JICA project (based on Bhutan Road Network Map (World Food Programme 2017))

The vegetation works were part of the output of the JICA's bioengineering project, which began with cutting a slope at a stable angle for it and then installing drainage works as shown in Fig. 2.

Three planting methods were examined: Type A is linearly planting, Type B is overall planting, and Type C is the transplantation of a germination bed. For all, jute nets were stuck over the germination beds with wooden stakes to stabilize them (Fig. 3).

The Department of Livestock of the Ministry of Agriculture and Forests, Bhutan, provides a list of perennial grass seeds suitable for vegetation works (Table 1). The authors have chosen (1) *Paspalum Atratum* Var.CIAT 26986 (*Paspalum atratum*), and (2) Ruzi Grass (*Brachiaria ruziziensis*) (Fig. 4). Also used were (3) GM mixed seeds composed of 30% Italian ryegrass (*Lolium multiflorum*) and 70% Cock's-foot, var. Amba (*Dactylis glomerate*) (Fig. 5).



**Fig. 2** Vegetation workflow chart (Type A: linearly planting, B: planner planting, and C: transplanting of germination bed)

The table says the altitude appropriate for planting GM mixed seeds would be 2000–3000 m above sea level (MaSL for short) from an agroecological viewpoint. This altitude is higher than the study site. However, the seeds are widely used in Bhutan's farmlands.

### Methods for Germination Test

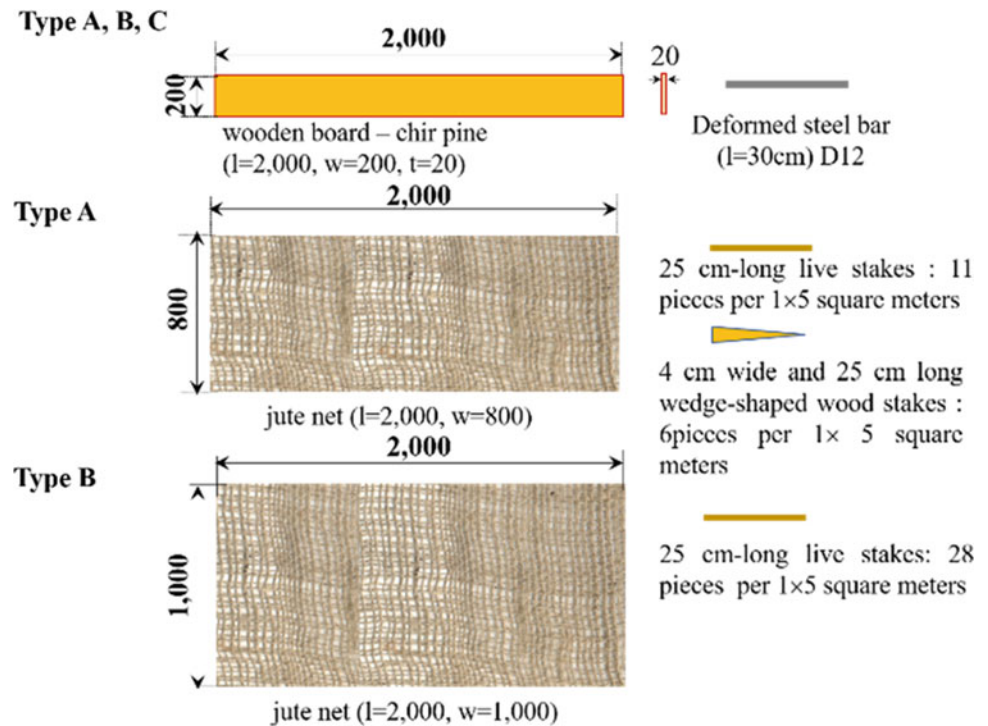
Before starting the vegetation works, the authors conducted 8 different germination trials, using three seed types to determine the suitable seed and soil thickness for the vegetation works (Fig. 6).

Beginning the germination test, all three seed types were well germinated for a little two weeks (Fig. 7). In particular, 5 cm thick seedbed shows a good sprouting condition (left side of Fig. 7b).

After cutting the slope, the vegetation works, Types A, B, and C, were carried out. Figure 10 (in Video Narration) illustrates these three types of planting. As said, Type A places stripes of seedbeds on the slope, Type B covers the slope with a wide seedbed, and Type C transplants germination beds. In each type, two kinds of seeds, i.e., *Paspalum atratum* and Ruzi grass were planted on the upper and lower parts of the slope, respectively.

In Type C, the grass to transplant was first removed in stripes from the plant bed (Fig. 8).

**Fig. 3** Materials to stabilize soil beds containing seeds and fertilizer



**Table 1** List of seeds for vegetation works (Data provided by DoL)

Seeds (Scientific name)	Yield potential (Dry matter)	Maturity for grazing	Recommended agro-ecology (MaSL)
Paspalum Atratum Var.CIAT 26986 ( <i>Paspalum atratum</i> )	2.9–3	1 yr (Perennial)	< 1500
Ruzi grass ( <i>Brachiaria ruziziensis</i> )	2.8–3.2	1 yr (Perennial)	500–2000
Italian Rye grass Var.Lipo ( <i>Lolium multiflorum</i> )	1.2–2.2	1 yr (Perennial)	2000–3000
Cocks foot Var.Amba ( <i>Dactylis glomerate</i> )	0.8–1.2	1 yr (Perennial)	2000–3000

DoL: Department of Livestock, yr: year, MaSL: meter above sea level



**Fig. 4** Photos of seeds (left: Paspalum Atratum, right: Ruzi grass)

In Type C, scraping grass is done before transplanting (Fig. 9).

### 3 Video Narration

**Narration 1** (see Fig. 10)



**GM mixed:** Italian Ryegrass 30%, Cock's foot, var. Amba 70%.

**Fig. 5** Photos of seeds for GM mixed (left: Italian Ryegrass, right: Cock's foot grass)

There are three types of planting method (Fig. 10).

Type A is linearly planting, Type B is overall planting, and Type C is the transplantation of a germination bed.

**Type A** is a method that wraps all containing seeds and fertilizer with a Jute net.

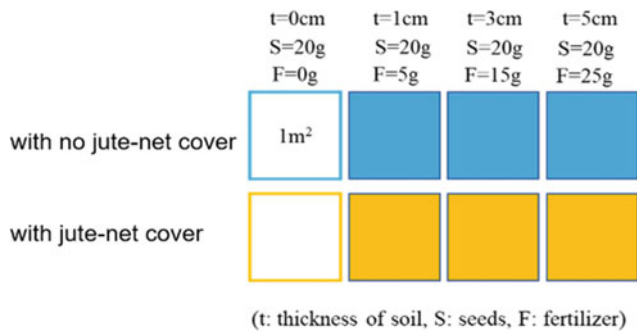


Fig. 6 Germination test cases

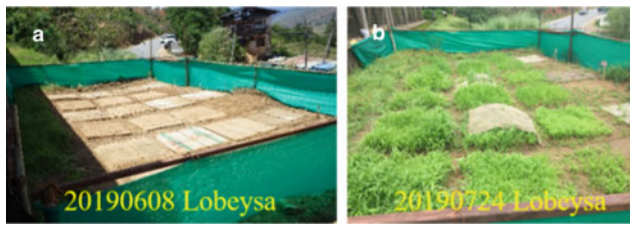
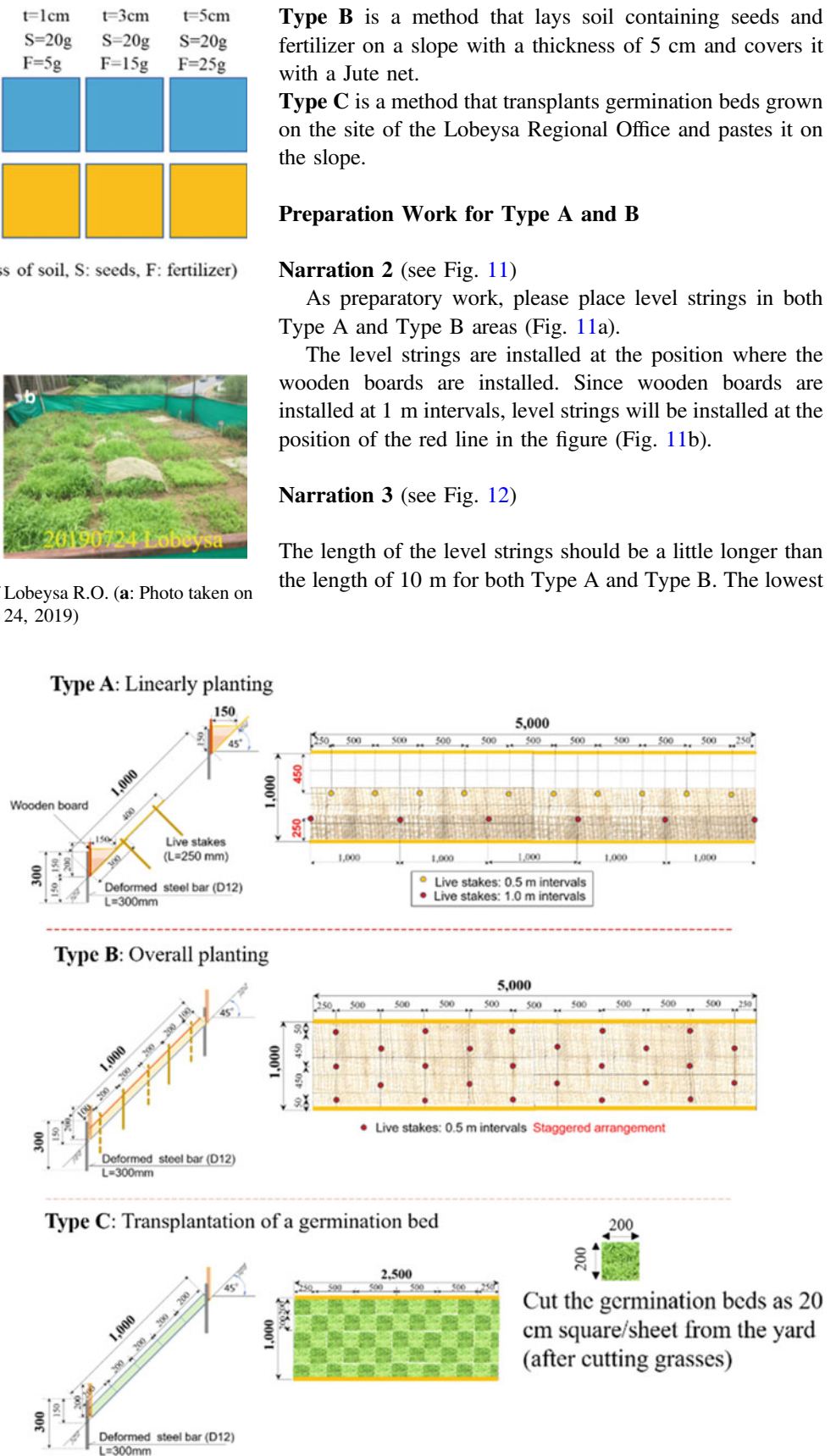


Fig. 7 Germination test at the yard of Lobeysa R.O. (a: Photo taken on June 8, 2019, b: Photo taken on July 24, 2019)

Fig. 8 Details of three vegetation works (left: cross-sections, right: front views)



**Type B** is a method that lays soil containing seeds and fertilizer on a slope with a thickness of 5 cm and covers it with a Jute net.

**Type C** is a method that transplants germination beds grown on the site of the Lobeysa Regional Office and pastes it on the slope.

**Preparation Work for Type A and B**

**Narration 2** (see Fig. 11)

As preparatory work, please place level strings in both Type A and Type B areas (Fig. 11a).

The level strings are installed at the position where the wooden boards are installed. Since wooden boards are installed at 1 m intervals, level strings will be installed at the position of the red line in the figure (Fig. 11b).

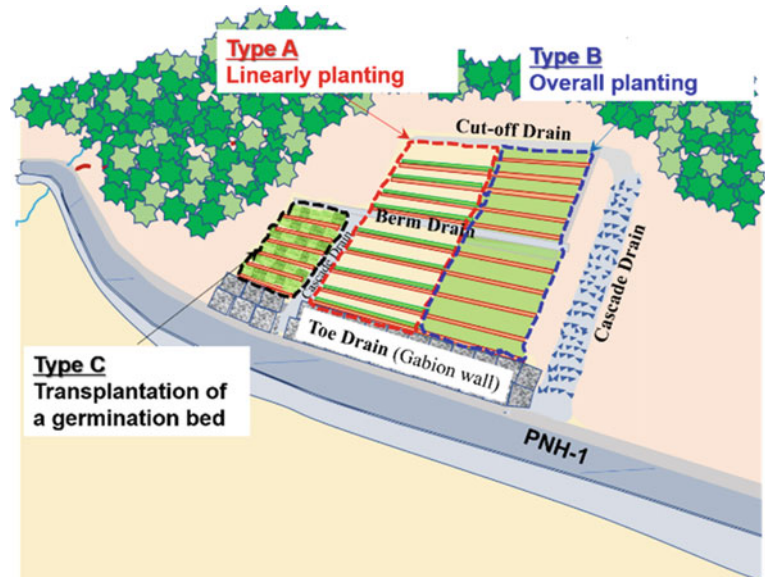
**Narration 3** (see Fig. 12)

The length of the level strings should be a little longer than the length of 10 m for both Type A and Type B. The lowest

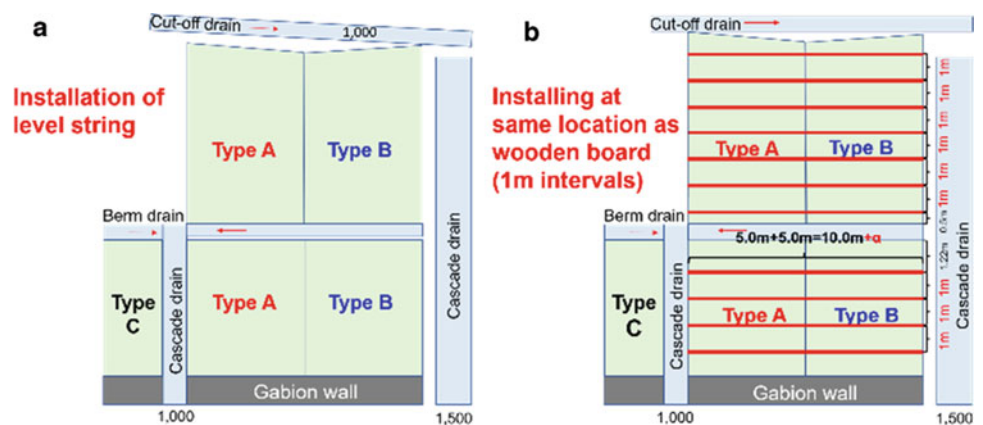
**Fig. 9** Plant bed for Type C vegetation works. The grass to transplant is first removed in stripes from the plant bed



**Fig. 10** Bird's-eye view of Types A, B, and C



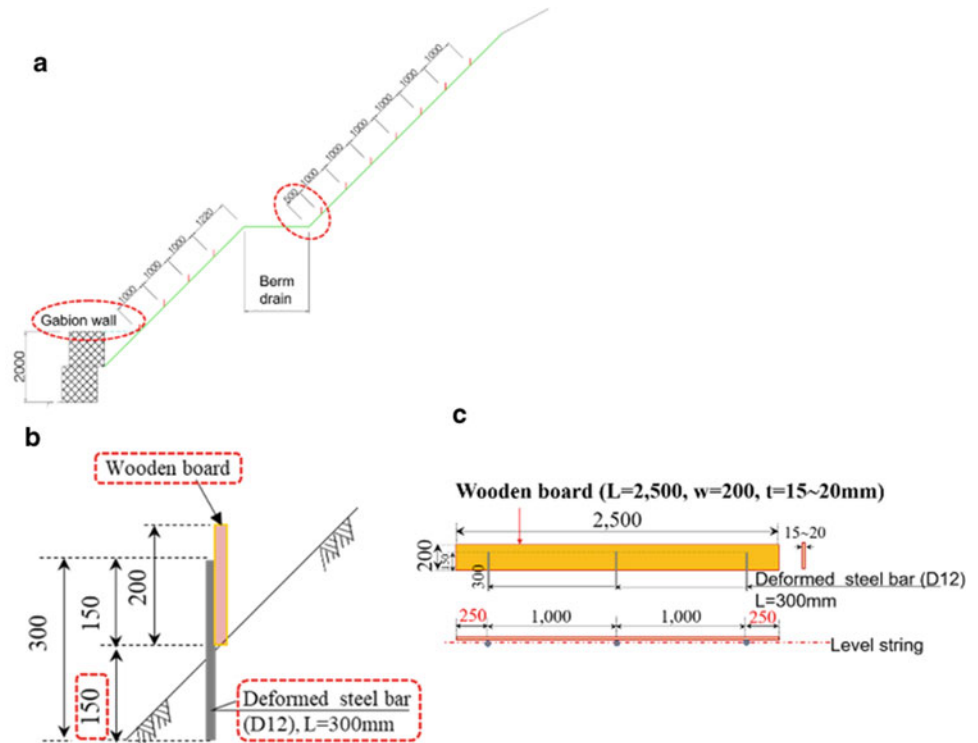
**Fig. 11** Layout of Types A, B, and C preparatory works



level string of the lower slope is installed at the same elevation as the top of the gabion wall.

The lowermost level strings of the upper slope are installed 50 cm higher than the elevation of the berm drain (Fig. 12a). Next, please install deformed steel bars. The purpose of installing the deformed steel bar is to fix the wooden board on the slope, so please install it below the

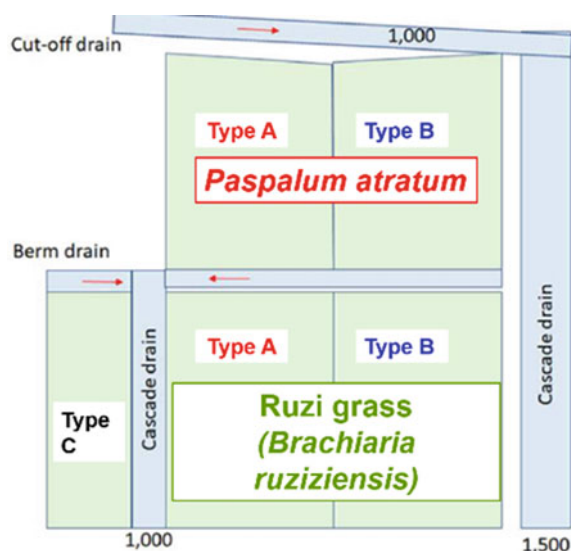
wooden board. All deformed steel bars are D12 and the length is 30 cm. Please set half of the bar 15 cm inside the ground (Fig. 12b). The deformed steel bar is installed every 1 m. The total length of type A and type B is 10 m, so if you install four 2.5 m long wooden boards, please use three deformed steel bars for each wooden board. Therefore, there will be a space of 25 cm at both ends of the wooden board

**Fig. 12** Details of Type A

(Fig. 12c). Please prepare the soil for Type-A by mixing soil, seeds and fertilizer in advance. The mix proportion is 400 g of seeds, and 500 g of fertilizer per cubic meter of soil.

**Narration 4** (see Fig. 13)

Two types of seeds are used for both Type A and Type B: *Paspalum atratum* and Ruzi grass. As shown in the figure,

**Fig. 13** Vegetation pattern with three different plants

*Paspalum atratum* is planted on the upper slope and Ruzi grass is planted on the lower slope (Fig. 13).

#### Instruction-1 How to Install “Type-A”

**Narration 5** (see Fig. 14)

Type A is a method of wrapping a triangular soil containing seeds and fertilizer with a Jute net, as shown in Fig. 14. Procedure of Type A is as shown here.

Firstly, installing a deformed steel bar, installing wooden board, placing a jute net, premixing seeds, soil, and fertilizer, placing soil portion, placing soil with seeds and fertilizer, folding and covering with jute net, and finally fixing jute net with live stakes.

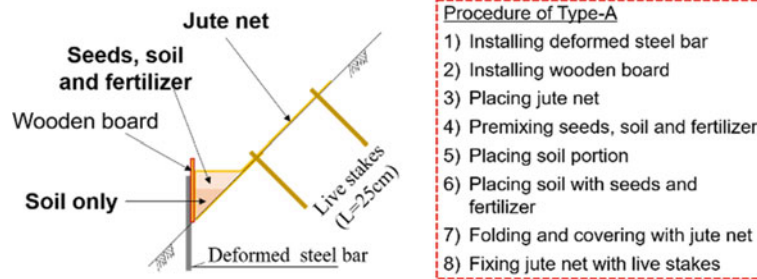
**Narration 6** (see Fig. 15)

Since the width of the jute net is 1 m, the dimensions when wrapping the soil are as shown in Fig. 15.

**Narration 7** (see Fig. 16)

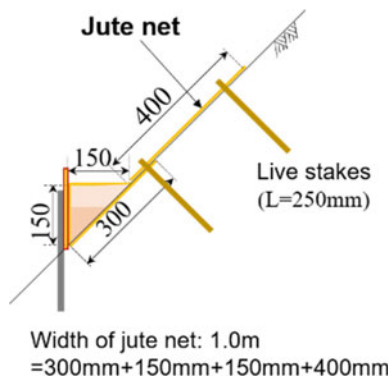
First, please place it 30 cm on the slope (Fig. 16a).

Next, please put the soil on the Jute net. The total depth of the soil is 15 cm. Please place only soil in the lower 10 cm part and then place mixed soil with seeds and fertilizer in the upper 5 cm part (Fig. 16b).



**Fig. 14** Details of Type A. Contents of Type A-procedure are as follows: (1) Installing deformed steel bar, (2) Installing wooden board, (3) Placing jute net, (4) Premixing seeds, soil and fertilizer, (5) Placing

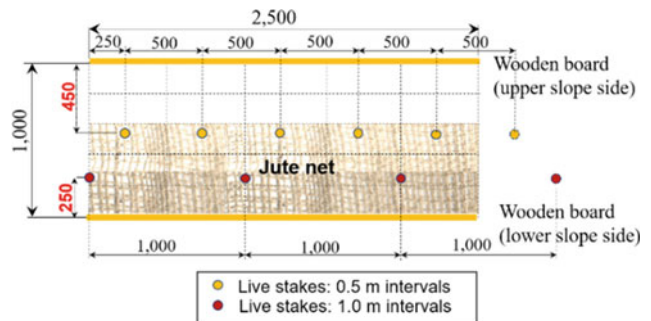
soil portion, (6) Placing soil with seeds and fertilizer, (7) Folding and covering with jute net, and (8) Fixing jute net with live stakes



**Fig. 15** Section view of Type A

Next, please fold the Jute net toward upper side and cover the soil on the slope (Fig. 16c).

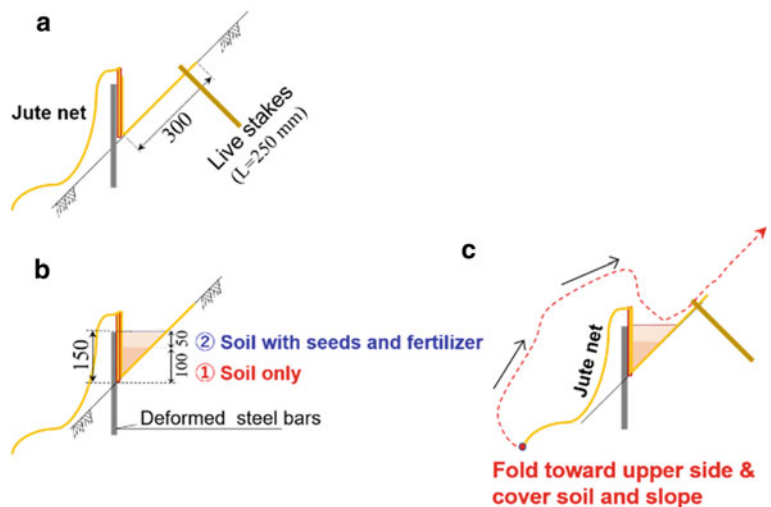
**Narration 8** (see Fig. 17)



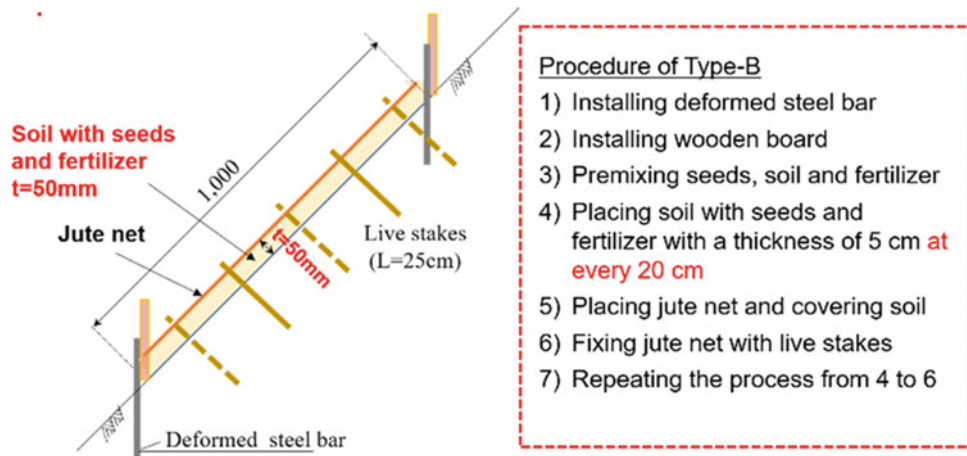
**Fig. 17** Front view of Type A

Live stakes are installed to fix the Jute net on the slope. As shown in this figure, please install them at 50 cm intervals at 45 cm below the wooden board of the upper slope side. On the other hand, please install them at 1 m intervals at 25 cm above the wooden board of the lower slope side. You can also use wood stakes instead of live stakes (Fig. 17).

**Fig. 16** Section view of Type B (a: setting a jute net, b: placing soil with seeds and fertilizer, c: folding a jute net)



**Fig. 16** Section view of Type B



**Fig. 18** Section of Type B. Contents of Type B-procedure are as follows: (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, and (7) Repeating the process from 4 to 6

**Video Performance 1:** Demonstration-1 How to install “Type A”

**Instruction-2** How to Install “Type-B” (title)

This part of the video is only subtitled with no voice.

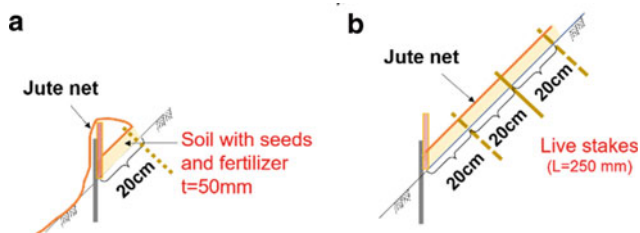
**Narration 9** (see Fig. 18)

In Type B, we use a jute net to cover and stabilize a 5 cm thick soil bed containing seeds and fertilizer, as shown in Fig. 18. The work can be done following the steps shown below:

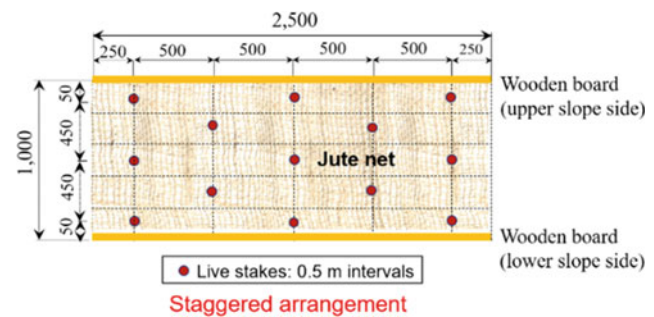
(1) makeup frames for a soil bed with deformed steel bars and wooden plates, (2) place a 5 cm-thick 20 cm-wide seeds/fertilizer-mixed soil stripe one after another at every 20 cm interval, (3) cover and stabilize the whole soil bed with a jute net.

**Narration 10** (see Fig. 19)

Please spread the soil with seeds and fertilizer with a thickness of 5 cm evenly on the slope, and cover it with a



**Fig. 19** Outline of Type B in section (Image a is the first stage of work and Image b shows a continuous work process)



**Fig. 20** Front view of Type B

jute net. Please conduct this procedure at every 20 cm interval (Fig. 19a). After installing the Jute net, please put live stakes to fix the Jute net on the slope (Fig. 19b).

Live stakes should be installed at 50 cm intervals in a staggered arrangement, as shown in Fig. 20.

**Video Performance 2:** Demonstration-2 How to install “Type B”

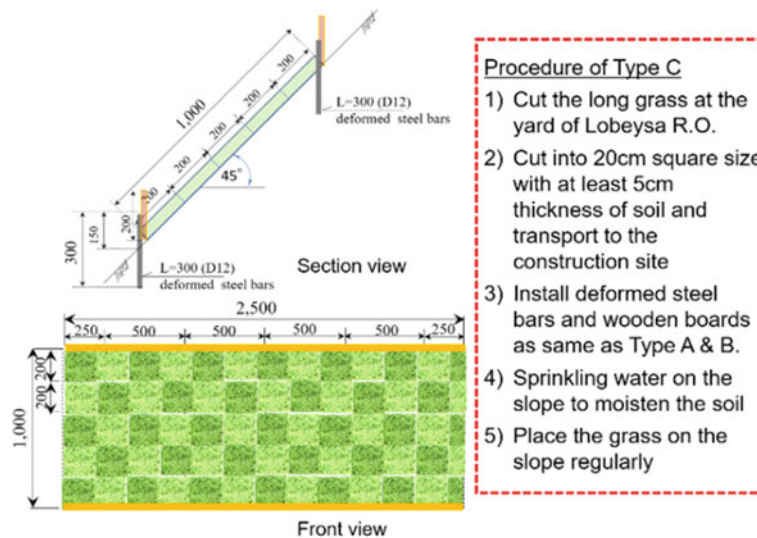
**Instruction-3** How to Install “Type-C” (title)

This part of the video is only subtitled with no voice.

**Narration 11** (see Fig. 21)

Type C is a method that transplants germination beds grown in the yard of the Lobeyasa Regional Office and pastes them on the slope. Procedure of Type C is as shown here. Before transporting the grass materials, please cut the long grass at the yard on Lobeyasa Regional Office. And then, please cut the grass into 20 cm<sup>2</sup> with at least 5 cm thickness of soil and transport it to the construction site. As preparation work,





**Fig. 21** Section and front views of Type C vegetation works. Contents of Type C-procedure are as follows: (1) Cut the long grass at the yard of Lobeyssa R.O., (2) Cut into 20 cm<sup>2</sup> size with at least 5 cm thickness of soil and transport to the construction site, (3) Install deformed steel

bars and wooden boards as same as Type-A and B, (4) Sprinkling water on the slope to moisten the soil, and (6) Place the grass on the slope regularly



**Fig. 22** Sequence of events at the site of vegetation works, Gangthangkha, Wangdue (lat 27° 29' 4.87" N, long 89° 54' 17.24" E, alt 1309 m, **a** slope before vegetation works on May 29, 2019, **b** finished

vegetation works on May 30, 2020, **c**, and **d** photos on June 26, 2020, about a month after the vegetation works, and on October 31, 2020, respectively)

please install deformed steel bars and wooden boards like Type-A and B. And please sprinkle water on the slope to moisten the soil, and finally, please the grass on the slope regularly (Fig. 21).

**Video Performance 3: Demonstration-3 How to install “Type C”**

This part of the video is only subtitled with no voice.

## 4 Sequence of Works

The target slope at Gangthangkha had occasionally been collapsing little by little due to mass wasting over time (Fig. 22a). The slope had an average angle of about 40° with its upper part much steeper. The slope could have been cut at a gentle angle of less than 40°, but it could have yielded a huge amount of soil to cut, making the work unrealistic. Therefore, the slope was cut to stay below the upper limit of 45° for vegetation works, and gabions retained the toe part of the cut slope. This work was then followed by vegetation works (Fig. 22b). Almost one month after the vegetation works were completed, germinations were observed at all the vegetation work sites for Types A, B, and C (Fig. 22c). Grasses have grown remarkably over three months since the vegetation works completed (Fig. 22d).

## 5 Summary

The video medium that was prepared during JICA's project successfully helped workers to learn how to perform vegetation works on cut slopes in Bhutan. In this project, three types of vegetation methods, Type A, Type B, and Type C, were examined. Out of these three methods, Type C was proven to be the most efficient in terms of its performance, transplanting germination beds directly on the target slope, though it requires a suitable nearby grass plant bed. In both Types B and C, it takes time for the target slope to be

covered with grass. However, Type B would be preferable, because bare earth can remain exposed for a long time in Type A where only seed-and-fertilizer-mixed soil stripes are placed on the slope. Further studies will be necessary to broaden the variation of the planting methods.

**Acknowledgements** In this project, we would like to thank the following engineers for everything from seed selection to construction. Thanks to Mr. Yuji Nakano (Nakano Research Institute of Greening Technology), who taught us many things such as how to select seeds, cut slopes, install drainage channels, and types of fertilizers. Thanks to Mr. Gyeltshen Wangdi as a chief engineer of the Lobeyasa Regional Office for providing us with a germination test yard and supporting site management. Thanks to Mr. Tshering as a Project Manager of Floriculture and Amenity Landscaping Center (FALC), for giving us information about suitable seeds and fertilizer on the site in Lobeyasa. Thanks to Dr. Atsuko SATO of Civil Engineering Research Institute for Cold Region, for teaching how to transplant grass-growing areas. Thanks to Mr. Chimi Rinzin of the Department of Livestock, Animal Nutrition Division for giving us various seeds for vegetation works in Lobeyasa, so we could try germination tests with pots and in the yard of Lobeyasa R.O. and selected suitable seeds in Lobeyasa smoothly. We would also like to thank the staff involved in the JICA Bhutan Office and Headquarters for their tremendous support for the project.

## Reference

World Food Programme (2017) Bhutan road network. <https://dlca.logcluster.org/display/public/DLCA/2.3+Bhutan+Road+Network>. (browsed on 31 May 2019). Available maps can be obtained from logistics capacity assessments (LCAs)

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