NATURE BASED LANDSLIDE RISK MANAGEMENT PROJECT IN SRI LANKA

Final Report

June 2019

Implemented by:
National Building Research Organization

Technical Assistance by:
Asian Disaster Preparedness Center

Financially Supported by:
The World Bank

THE WORLD BANK

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Executive Summary

In the past, when implementing structural mitigation interventions for landslide risk management, country has largely relied on engineering solutions and the application of nature-based and hybrid (engineering and nature based) approaches was limited. It has been demonstrated in many countries in Asia that the risk-informed nature based solutions can be also effective in reducing the occurrence and impact of such landslides. Therefore, World Bank has launched an Analytics and Advisory Services Project on "Nature Based Landslide Risk Management" in April 2018. This project, which is implemented by the National Building Research Organization (NBRO), aims to raise awareness and deepen the knowledge on the role of nature based and hybrid solutions for landslide risk management within the country. The Asian Disaster Preparedness Center (ADPC) has been assigned to provide implementation support and technical guidance in executing the project activities. The objective of this assignment is to carry out activities to raise awareness and deepen the knowledge within the Government of Sri Lanka on the role of nature-based[1] solutions for landslide risk management and to apply this knowledge in a number of pilot demonstration sites under the ongoing Climate Resilience Improvement Project (CRIP). The project period is around 14 months and expected to end in June 2019.

The project is designed around 05 task areas and this final project completion report summarises the achievements under each task area. Chapter 1 of the report provides the back ground to the project, project objectives and description of main task areas of the project. Chapter 2 highlights the activities carried out under project Task A: "Implementing a Capacity Building Programme for NBRO". The activities under this task commenced with the conduct of training needs and gap assessment survey and the project initiated training programs have been designed incorporating recommended subject areas by the respondents of the survey. In addition, the project has organized events to disseminate the project outcome through events organized at national and international levels.

The activities carried out under Task B of the project on "Assessment of Relevant Legal, Regulatory and Institutional Framework" is summarized under Chapter 3. A full report on the study outcome of relevant legal, regulatory and institutional framework as well as the recommendations are some of the highlights provided in the Chapter.

Task C was devoted to "Preparation of a Comprehensive Landslide Risk Management Plan for selected Pilot Sites". The activities under this task was carried out based on two pilot sites in Badulusirigama in Badulla District and Galaboda in Rathnapura District. Chapter 4 provides an overview of the planning process, design of mitigation plans utilizing bio-engineering and hybrid solutions as well as the implementation aspects and the budget.

Chapter 5 provides an overview of the activities under Task D: "Preparation of a Guidance Document on Nature Based Landslide Risk Management Approaches". This guidance manual has been developed with the purpose of providing guidance to those who are involved in

[1] Not only planting trees but include landscape-level planning of land use, good land management practices in cropping, grazing and forestry, careful road construction, terracing and other contour-aligned practices in fields and plantations.

landslide risk management works (NBRO, relevant local authorities, other practitioners) to help in designing, implementation and monitoring the nature-based risk management solutions for landslide and erosion risk reduction applied under a range of physical conditions. The manual consists of 10 chapters covering practical as well as theoretical aspects of bio-engineering measures that can be applied for managing the landslide risk. It is developed for introducing basic concepts and creating general understanding of various aspects of nature based solutions and not intended to provide a comprehensive theoretical understanding on the subject.

The objective of Task E is the organization of a "Dissemination /Validation Workshop" and submission of the Final Report incorporating the suggestions made during the stakeholder workshop. The said workshop was organized as the last activity of the project, considering the importance of disseminating the outputs to a wider audience and for obtaining technical resource inputs on the completed project activities, deliverables etc. The Stakeholder Meeting was organized on June 3, 2019 at Hotel Taj Samudra, Colombo with the participation of representatives from eighteen organizations including the project implementing agency National Building Research Organization (NBRO), World Bank (WB) and technical partner of the project Asian Disaster Preparedness Center (ADPC), Thailand.

The following important lessons could be drawn from the activities undertaken under the project:

- Developing a process for application of nature based solutions (NBSs) for landslide risk mitigation from scratch is difficult but achievable. Availability of data plays a significant role in selecting candidate sites. When data is limited reasonable assumptions can be made but better if data can be made available through additional investigations and other efforts;
- Advance work carried out for literature survey has given lot of inputs for designing the project activities and lining up them in a systematic order;
- Limited awareness on the subject increased the interest for learning as well helped in developing a better understanding of the subject and for creating appropriate knowledge base within the implementing agency - NBRO.
- Creating an interest group consists of a young and enthusiastic set of scientists representing multiple disciplines was a good indicator for success. Linking project staff with national and international level subject experts selected to provide resource inputs under different tasks could help in achieving the sustainability. They can continue extending help in enhancing the capacity and knowledge of the group beyond the existence of the project;
- Training will not provide assurance for capacity building but NBRO through demonstration of its capacity at the end of phase I indicated that project initiated capacity building was effective.

There is a bigger scope for promoting nature based solutions in future as an effective instrument for disaster risk mitigation. It will be easy to promote nature based solutions in Sri Lanka because several government institutions are working with similar or parallel objectives and mandates. This helps in creating an enabling environment for promoting application of nature-based solutions for protection and conservation of natural environmental resources.

Acronyms

ADB	: Asian Development Bank
AD	: Agriculture Department
ADPC	: Asian Disaster Preparedness Center
CRIP	: Climate Resilience Improvement Project
DCS	: Department of Census and Statistics
DoM	: Department of Meteorology
DMC	: Disaster Management Center
DRM	: Disaster Risk Management
DRR	: Disaster Risk Reduction
DS	: District Secretary
DSD	: Divisional Secretariat Division
FD	: Forest Department
GoSL	: Government of Sri Lanka
GND	: Grama Niladhari Division
GN	: Grama Niladhari
ID	: Irrigation Department
IUCN	: International Union for Conservation of Nature
JICA	: Japan International Cooperation Agency
LHMP	: Landslide Hazard Mapping Program
MOH	: Ministry of Health
MoDM	: Ministry of Disaster Management
PG	: Provincial Government
NBRO	: National Building Research Organization
RDA	: Road Development Authority
SD	: Survey Department
UDA	: Urban Development Authority
UNDP	: United Nations Development Program
UNCHS	: United Nations Center for Human Settlements (UNHABITAT)
TNGA	: Training Needs and Gap Assessment
WB	: World Bank

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Chapter 1: Project Background and Objectives

1.1 Introduction

In the recent past landslides have become the most widespread and frequent disaster events in hill country districts of Sri Lanka. Most of them appear to have occurred within the Central, Uva, Sabaragamuwa and Sothern provinces and in areas bordering the Western, Southern and Central Provinces. Due to such landslide events, considerable extent of impacts in terms of deaths, injuries, socio-economic impacts relating to destructions to property and infrastructure are reported annually. The current trends in landslide disaster events and resultant impacts are likely to get increased due to the impacts of climate change, climate variability and consequent extreme weather conditions, to a considerable magnitude in the near future.

Considering the above, the Government of Sri Lanka (GoSL) has designated the National Building Research Organization (NBRO) to be the focal agency mandated with the responsibilities of landslide risk management services and studies. Currently NBRO provides such services to the Government and private sectors as well as to the general public. Currently NBRO operates under the purview of the Ministry of Public Administration and Disaster Management. Actions undertaken by NBRO are directly linked to the operational framework under the National Disaster Management Plan (NDMP) of Sri Lanka. NBRO works in close partnership with Disaster Management Center (DMC) and other agencies within the Ministry and all other related stakeholders to full fill the tasks under NDMP covering all aspects of landslide risk management.

NBRO has implemented the Landslide Hazard Mapping program (LHMP) covering major landslide prone areas since the unfortunate devastating landslide events in late eighties. NBRO has produced maps covering high landslide prone areas in 1:50,000 scale for all above districts and at 1:10,000 scale for certain districts. Currently such maps are available for selected areas in districts such as Kalutara, Galle, Hambantota, Nuwara Eliya, Matale, Kandy, Kegalle, Ratnapura, Matara and Badulla. The current progress of the mapping program and the locations where mapping has been carried out is shown in figure 1.1 below. The mapping carried out by NBRO so far has led to the revelation that around 5200 families (around 25,000 people) live in landslides high risk areas and another 5700 families (around 26,000 people) live in settlements with moderate landslide risk.

In addition in line with its mandate, the NBRO carries out detail studies of potential landslide hazard-prone areas, risk evaluation and provides recommendations for minimizing any landslide risk. The Government of Sri Lanka (GoSL) intends to take actions to mitigate and manage landslide risks as a major intervention of its future disaster risk management strategy. Major elements of this strategy would include: a) systematic resettlement of the communities now living in high landslide risk areas in safe locations; b) promote public investments on civil works to mitigate risk in both high and medium risk areas; and c) establish a systematic program for monitoring of landslide risk at other critical locations. In addition, landslide risk mitigation of critical infrastructure including public schools, hospitals and road connections etc. has also become a government priority. The World Bank and several donor agencies have fledged support to the GoSL for implementation of this strategy by providing technical and financial assistance. The donor community including the World Bank, through different programs implemented in the recent past, extended help to GoSL to develop a detail, clear and implementable action plan to mitigate landslides risk in vulnerable communities as well as on critical infrastructure and to undertake risk mitigation interventions.

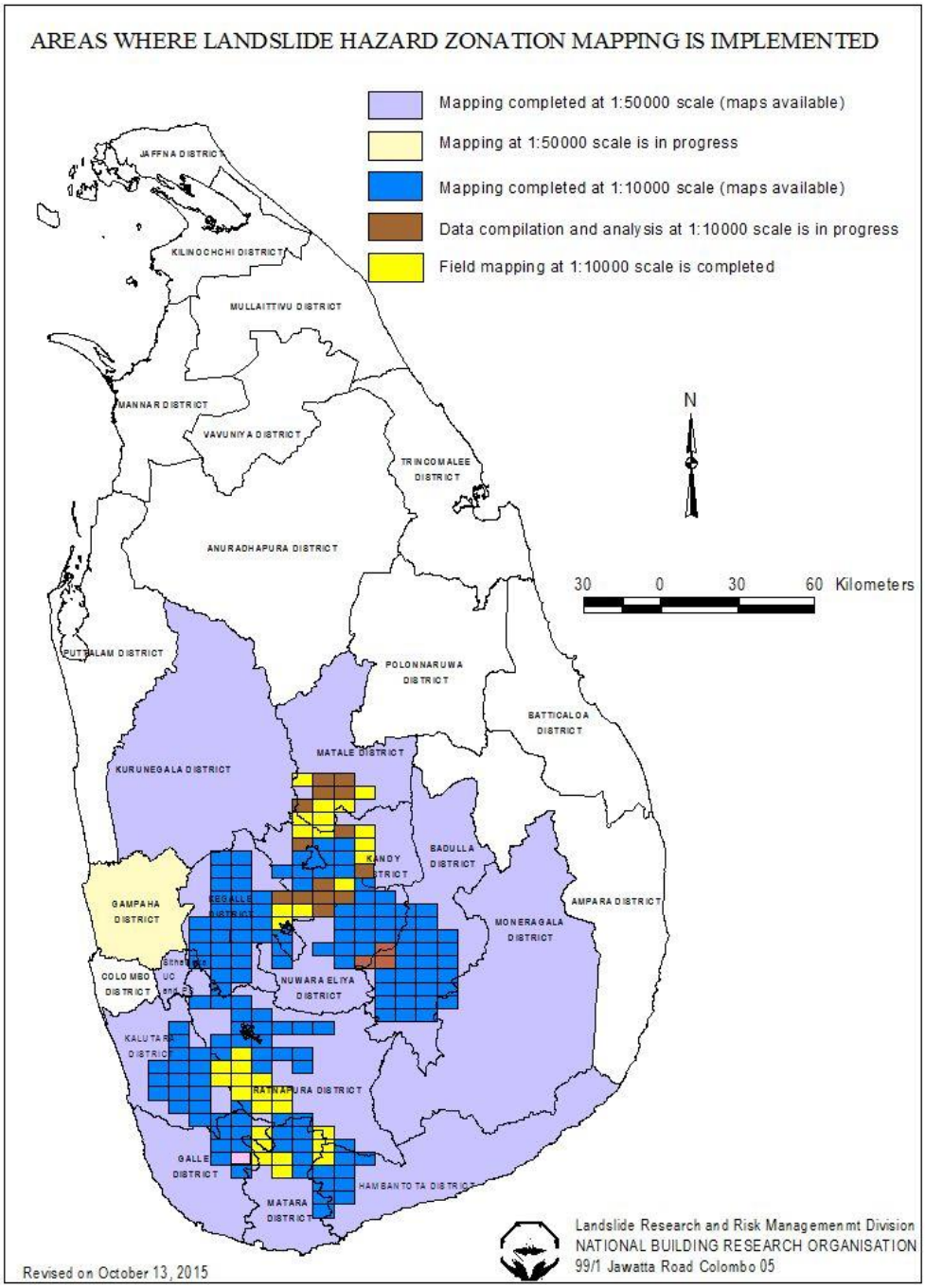


Figure 1.1: NBRO Landslide Hazard Zonation Mapping Locations

The Climate Resilience Improvement Project (CRIP) is one of such programs financed by the World Bank and implemented by the Ministry of Irrigation & Water Resources Management. CRIP aims to reduce the immediate physical risks and improve the understanding of disaster risks so that future investments are targeted to their best use. Through the same, National Building Research Organization (NBRO) receives financial and technical assistance from WB for execution of selected landslide risk management interventions such as assessment of landslide hazard, vulnerability and exposure, the study of the potential for structural landslide risk mitigation measures, execution of structural mitigation work in selected critical locations etc. The selected structural mitigation interventions implemented under the program includes physical landslide mitigation works, including the stabilization of hillsides with retaining structures, surface and sub-surface drainage networks.

In the past, when implementing structural mitigation interventions for landslide risk management, country has largely relied on engineering solutions and the application of nature based and hybrid (engineering and nature based) approaches were limited. It has been demonstrated in many countries in Asia that the risk-informed nature based solutions can be also effective in reducing the occurrence and impact of such landslides. Therefore World Bank has launched an Analytics and Advisory Services project on Nature Based Landslide Risk Management in April 2018. This project aims to raise awareness and deepen the knowledge on the role of nature based and hybrid solutions for landslide risk management within the Government of Sri Lanka. The Asian Disaster Preparedness Center (ADPC) has been assigned to provide implementation support and technical guidance in executing the project activities.

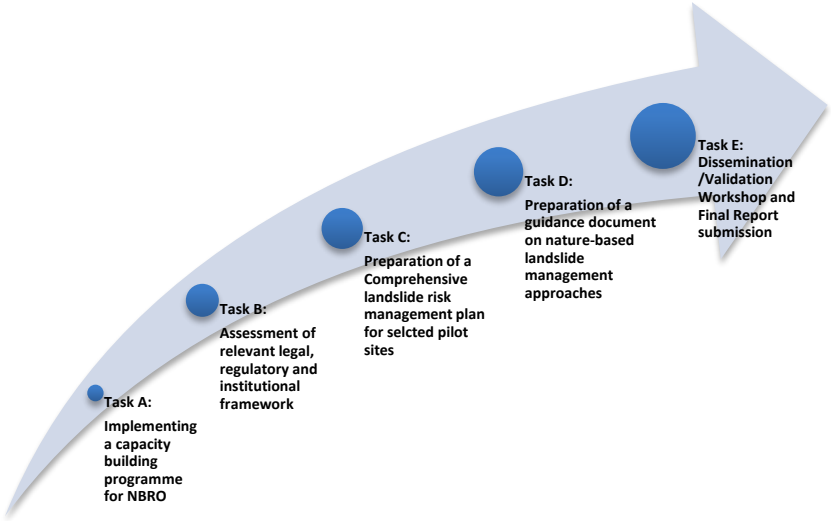
1.2 Objective of the assignment

The objective of this assignment is to carry out activities to raise awareness and deepen the knowledge within the Government of Sri Lanka on the role of nature based[2] solutions for landslide risk management and to apply this knowledge in a number of pilot demonstration sites under the ongoing Climate Resilience Improvement Project (CRIP).

The activities implemented under the project expect to support the GoSL in piloting and potentially scaling up the use of nature based and especially hybrid (i.e. the combination of structural and green) solutions for landslide risk management, and leverage the lessons learned in Sri Lanka to support the future application of similar solutions in the wider South Asia region.

1.3 Project Tasks

In accordance with the ToR document the project consists of following tasks:



[2] Not only planting trees but include landscape-level planning of land use, good land management practices in cropping, grazing and forestry, careful road construction, terracing and other contour-aligned practices in fields and plantations.

Chapter 2: Task A: Implementing a Capacity Building Program for NBRO

2.1 Training Needs and Gap Assessment (TNGA) Survey

The project team initiated a Training Needs and Gaps Assessment survey at the beginning of the project in order to ascertain the information related to;

- existing approaches for landslide disaster risk management;
- the level of application of nature based landslide risk management activities in Sri Lanka;
- Identify competencies, knowledge and skill gaps, and organizational expectations for capacity development;
- Obtain stakeholder expectations in relation to project initiated training.

The consultative process undertaken through the TNGA survey has uncovered several key gaps and challenges, which stakeholders consider as main apprehensions. Some of them are common to landslide risk management capacity development and some are particularly important in creating an enabling environment for application of the nature based solutions. According to the survey, in recent years, while there has been a notable progress in the development of general capacities to manage disasters within the country, the gains have lagged in relation to specific technical areas such as management of landslide disaster risk. As well, it has become a concern that the landslide disaster risk management related capacity development has not been carried out as a regular endeavour, covering the capacity development needs of all the stakeholders.

The full report on the Training needs and the Gap assessment survey is provided as Annex A1- "Training Needs and Gap Assessment Survey Report"

2.2 Project initiated Training.

The above mentioned TNGA survey has helped in identifying expectations of the stakeholders for capacity building. Some of the important and essential subject areas have been included in the 03 project based training courses conducted during the project period. The training curriculum and agenda of the selected thematic areas have been prepared in consultation with the NBRO and WB task team and expected to improve the theoretical understanding on the subject, meet knowledge gaps and to create competencies needed for promoting nature based solutions for landslide risk management.

The full report on Project Initiated training is provided as Annex A2 – "Report on Project Initiated Training"

2.2.1. Project Based Training 1 - Training on "Application of Google Earth Engine (GEE) Platform for Land Cover Monitoring and Satellite-Based Rainfall Estimation"

ADPC conducted a training workshop on "Application of Google Earth Engine (GEE) Platform for Land Cover Monitoring and Satellite-Based Rainfall Estimation" during 1-4 October 2018 in Sri Lanka Institute of Development Administration (SLIDA) auditorium, Colombo to support effective implementation of landslide risk management interventions. The purpose was to build the capacity of technical officials of NBRO and other stakeholder agencies for better

utilization of state-of-the-art technology of remote sensing to analyse land use, land cover and satellite estimated rainfall (Global Precipitation Measurement (GPM)) for reducing landslide risks. Land cover change is important for decision making process of landslide risk management as it can be measured on a regular basis using satellite technology and applying remote sensing (RS) technology. Usually in-situ rainfall data are being used for estimation of rainfall thresholds, as the point of trigger of landslides. Since in-situ observation station networks are not much dense in hilly areas or in complex terrains, estimation of rainfall thresholds has been a challenging task. Therefore, rainfall estimates from satellite-based Global Precipitation Measurement (GPM) mission, which has a horizontal resolution of (10 km x10 km) can be considered to be a good supplement dataset for calculating rainfall thresholds to strengthen landslide early warnings systems in countries.

Dr. Ate Poortinga, and Mr.Susantha Jayasinghe from ADPC, Thailand provided resource inputs for conducting this training and 31 participants from 8 agencies attended the four-day training session. Participants were introduced to Earth Engine Code Editor Platform, basic programming concepts and Earth Engine data structures, methods, functions, and algorithms. Furthermore, the participants were provided with training on utilization of innovative Google Earth Engine (GEE) platform, which could use for other applications as well. The GEE platform is widely used for writing and executing scripts to share and repeat geospatial analysis and processing workflows, such as land cover mapping.

Few photos of the 4 day training event

2.2.2 Project Based Training 2 – "Nature Based Landslide Disaster Risk Management – Part 1"

In view of building capacity and improving the knowledge on the subject of Nature Based Landslide Risk Management, ADPC team organized a training workshop on "Nature Based Landslide Disaster Risk Management – Part 1", during 12 – 13 November 2018 at the

Movenpick Hotel, Colombo. Around 27 participants from 9 agencies attended the two-day training session. The purpose of the training was to build the capacity of technical officials of NBRO and other stakeholders for better utilization of state-of-the-art technology on the subject for effective implementation of landslide risk management interventions.

The nature based solutions for landslide risk management is known as a cost effective and environmentally friendly landslide risk management practice, which can be successfully applied with other engineering measures as well as an alternative to such measures in selected locations, where vegetation can be used to improve the slope stability.

The participants were exposed to the following subject areas during the training workshop:

- Bio-engineering methods for mitigation of landslide risk;
- Matric suction as an important soil parameter which influences the behaviour of unsaturated soils;
- Ways of improving the mechanical and hydrological properties of soil through vegetation;
- Methodology applied in developing a comprehensive model to compute plant root based suction and the root reinforcement effect;
- Approach for site selection and implementing nature based landslide risk management activities;
- Modelling root reinforcement in unstable slopes;
- Application aspects of software "KU Slope" for root zone modelling;
- Limitations and challenges through study of selected case studies from the region.

Few photos of the 2 day training event

Prof. Athula Kulathilaka, Dr.Udeni Nawagamuwa from University of Moratuwa. Dr.Anurudda Karunarathna from University of Peradeniys, Dr. Muditha Pallewattha from Irrigation Department and ADPC consultant Dr. Suttisak Soralump from Kasetsart University, Bangkok have provided resource inputs during the training in making presentations and providing facilitation support during the discussion sessions held.

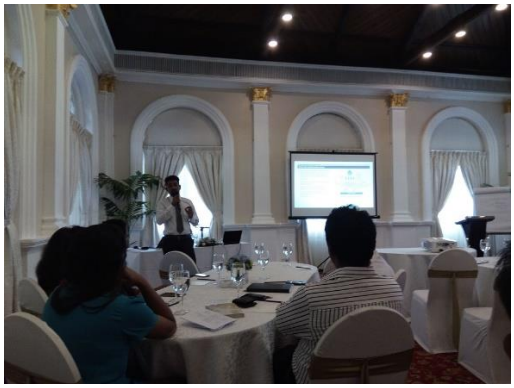
2.2.3 Project Based Training 3 – "Nature Based Landslide Disaster Risk Management – Part 2"

The Training workshop on "Nature Based Landslide Disaster Risk Management – Part 2", was held during 30-31 May 2019 at Hotel Taj Samudra, Colombo. The training was attended by 28 participants from 9 different institutes.

Having covered the theoretical aspects of the subjects during the previously held training on Nature Based Landslide Risk Management part 1, the 2nd training elaborated more on practical aspects as well as presented the outcome of the activities carried out under the project.
The participants were exposed to following thematic areas:

- Application aspects of Geo-engineering and Bio-engineering methods (and hybrid methods) for mitigation of landslide risk;
- Different methods of improving mechanical and hydrological properties of soil through vegetation;
- Quantitative assessment of impact of bio-engineering applications using a computer model employing limit equilibrium and finite element analysis;
- Practical aspects of analysis of the impact and contributions of vegetation in slope stabilization in a given vulnerable slope;
- Understanding on the approach for site selection, planning and implementation of hybrid (geo-engineering and nature based) solutions for landslide risk management;
- Mechanical consideration of tree root in a slope;
- Contribution of tree root in different compositions of a hill-slope and some idea on modelling root reinforcement in unstable slopes;
- Limitations and challenges in landslide risk management activities including nature based solutions through case studies from Taiwan.

Among the resource persons were two invited professors from Taiwan. They are, Professor Ko-Fei from National Taiwan University and Professor Tien-Chien Chen from National Pingtung University of Science and Technology. In addition, local experts, Dr. Udeni Nawagamuwa from University of Moratuwa and Dr. Anurudda Karunarathna from University of Peradeniya conducted presentation sessions and provided their resource inputs for the benefit of the participants of the workshop.

Few photos of the 2 day training event

2.3 Organization of special panel discussion at 9th Annual NBRO symposium to share project experience widely

In order to provide an understanding on the purpose and objectives of the project on Nature Based Landslide Risk Management and to present the theoretical and practical implementation aspects of the project, a Panel Discussion was organized at the annual NBRO symposium and was held on 18th December 2018, at the Gallface hotel, Colombo.

The following panel members participated in the discussion:

Panel Moderator:
Mr. N M S I Arambepola, Team Leader, Nature Based Landslide Risk Management Project

Panel Members:
Dr. U. P. Nawagamuwa, Senior Lecturer, Dept. of Civil Engineering, University of Moratuwa
Dr. Pathmakumara Jayasinghe, Senior Scientist, National Building Research Organization
Mr. H.M.U.Chularathna, Director, Sevanatha Resource Center & Consultant, ADPC
Ms. Priyanka Dissanayake, Disaster Risk Management Specialist, World Bank

Photos of the panel discussion held at NBRO symposium on 18th December 2018

2.3 Organization of a study tour to Thailand.

One of the key tasks of the project was to develop the capacity of NBRO scientists and engineers on the implementation of environmentally friendly nature based solutions. A study tour was arranged to have an exposure on ongoing landslide risk management activities in Thailand.

Further, the participants attended the Inception Seminar under "ASEAN project on Disaster Risk Reduction" in order to share their knowledge and Sri Lankan experience on landslide risk management with fellow colleagues from ASEAN countries.

A detail report on the study tour outcome is provided as Annex A3- "Report on the organization of a study tour to Thailand"

Participants

The names and affiliations of the participants are given below.

1. Dr. Udeni P. Nawagamuwa
   Senior Lecturer, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa

2. Dr. Pathmakumara Jayasinghe
   Senior Scientist, Landslide Research & Risk Management Division, National Building Research Organization

3. Mr. Lilanka Kankanamge
   Engineer, Geotechnical Engineering Division, National Building Research Organization

4. Mr. Chinthaka Ganepola
   Geotechnical Engineer, Asian Disaster Preparedness Center, Sri Lanka Country Office.

Organizers / Facilitators

1. Dr. Senaka Basnayake, Director, Climate Resilience Department, Asian Disaster Preparedness Center, Bangkok, Thailand.

2. Dr. Suttisak Soralump, Associate Professor, Department of Civil Engineering, Kasetsart University, Thailand.

3. Ms. Katevilai Nil-on, Administrative Coordinator, Climate Resilience Department, Asian Disaster Preparedness Center, Bangkok, Thailand.

Few photos of the sites visited by the participants where nature based solutions were applied are listed below.

Overall view of the site

Participants inspecting the mitigation completed by "TOR" blocks

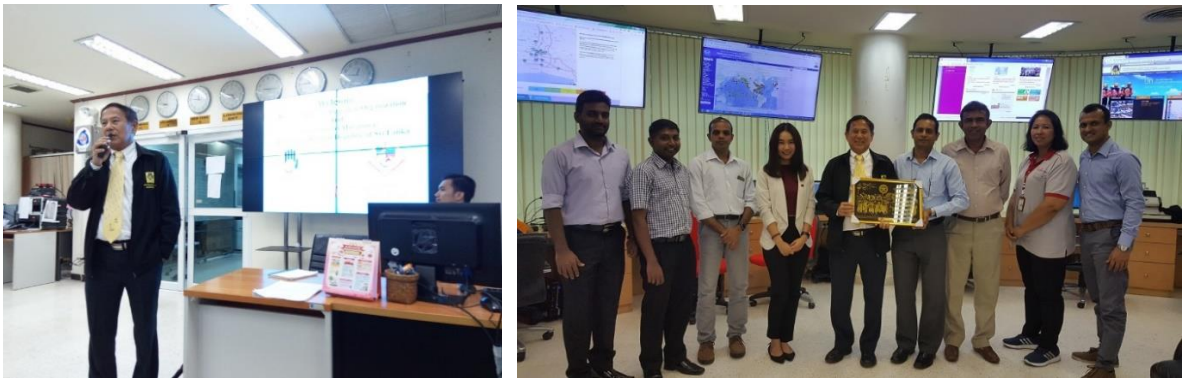
"Vetiver" Plant Nursery

In addition, the participants got the opportunity to visit Kasetsart University and National Disaster Warning Center in Bankok.

Participants visited Geotechnical Research and Development Center (GERD) of Kasetsart University to have a discussion on mathematical modelling of vegetation effect on slope stability.

Participants attending a training session at Kasetsart University

The participants also visited the Operational Room of National Disaster Warning Center and attended a Presentation session conducted by the Center.



Participants at National Disaster Warning Center in Bankok

Chapter 3: Task B: Assessment of Relevant Legal, Regulatory and Institutional Framework

3.1 Preparation of an Assessment Report on Relevant legal, Regulatory and Institutional framework to provide appropriate recommendations

ADPC team in association with NBRO has carried out a study on available policies, approaches/solutions in terms of legal, regulatory and institutional arrangements in order to find out the level of existing policy environment and institutional set up, which could contribute in creating an enabling environment for application of nature-based landslide risk management solutions in Sri Lanka.

The purpose of this task is to review the existing legal, regulatory and institutional frameworks for landslides risk mitigation and to provide recommendations necessary for revision of legal, regulatory frameworks and intuitional level changes for integration of nature based landslide risk management solutions suitable for Sri Lanka as a part of long term landslide risk management strategy.

The study has covered following policy areas:

- Conservation of forest and protection of upper watershed areas;
- Land use planning and land management;
- Protection of environment and natural resources;
- Soil conservation, prevention of soil erosion and land degradation;
- Water resources management and conservation of water sources;
- Disaster Risk Management.

There are landslide vulnerable areas, where undertaking engineering solutions for landslide risk management is not possible on the technical grounds or not feasible due to cost effectiveness or other reasons of socio-economic nature. Nature based solutions might offer a possible alternative solution in such cases and therefore it is essential to carry out necessary research, pilot studies and demonstration projects etc. to build the confidence on application aspects of the same.

One of the key findings of this study is the availability of laws, regulations and policies related to protection and conservation of natural environmental resources in Sri Lanka. It is also revealed that most of these laws, regulations and policies are connected with overlapping responsibilities and approaches to address the issues of environmental protection and conservation. These policies also have a main focus on ensuring sustainability of the natural environmental resources through application of nature based solutions to address the concern issues.

Some of the prominent policies in this regard are National Policy on Watershed Management, National Land Use Policy, National Forest Policy and National Environment Policy. Policy overlaps related to the above areas cannot be avoided as the objectives of each are quite similar and cover specific tasks and disciplines. However, the positive aspects of such policies is that, it helps to create an enabling environment for promoting application of nature based solutions to protect and conserve natural environmental resources. It will be easy to promote nature based solutions through number of government institutions working with similar or parallel objectives and compatible interests. Establishment of a high level multi-agency or multi-

ministerial committee with necessary authority and capacity aimed at coordination, addressing multiple problems in integrating programs and promoting nature based solutions for various sectors including hazard risk reduction will be appropriate in order to unify the government efforts and optimization of resources and investment.

At the end of the study, a comprehensive report was prepared, providing recommendations for revision of existing as well as introducing new policies, organizational strengthening, capacity building, improving inter-agency coordination at national and sub-national levels etc. This will help in future action for addressing the gaps as well as in strengthening the policy, regulations, procedures, institutional and legal set up for landslide risk management.

Report on Assessment of Relevant Legal, Regulatory and Institutional Framework and Recommendations is provided as Annex B1

3.2 National Workshop to validate findings and recommendations

ADPC team organized a National Level Validation Workshop with the participation of senior executive staff of stakeholder institutions to present the findings and recommendations. This workshop was also used as a platform to validate findings, get comments and suggestions from stakeholders on the proposed recommendations. The workshop was organized on 28th September, 2018 at Waters Edge Hotel, Battaramulla and 40 participants attended the meeting. This workshop was organized in partnership with National Building Research Organization (NBRO) and World Bank, Colombo office.

Few photos of the proceedings of the National Workshop

As mentioned above, the study has uncovered certain gaps in policies, approaches and in terms of legal, regulatory and institutional arrangements. The participants have provided useful technical inputs to above study findings and recommendations included therein. Necessary amendments have been introduced accordingly to the final task report on Assessment of Relevant Legal, Regulatory and Institutional Framework and recommendations.

The study findings, presented and discussed at the workshop, are expected to help in future in creating an enabling environment for application of nature based landslide risk management solutions suitable for Sri Lanka.

Few photos of the proceedings of the National Workshop

The proceedings of National Stakeholder Workshop to validate the findings and recommendations are provided as Annex B2.

Chapter 4: Task C: Preparation of a Comprehensive Landslide Risk Management Plan for selected Pilot Sites

4.1 Development of selection criteria for selecting candidate sites for application of nature based landslide mitigation solutions.

Nature based solutions cannot be applied in all the cases of landslides for mitigating the risk. Some may become technically not suitable and there are limitations in obtaining expected results. Where as in some other cases it is essential to consider other aspects such as cost effectiveness, socio-economic conditions in selecting nature based applications as the most appropriate mitigation option. Therefore, specific situations must take into account in selecting the most appropriate candidate sites for application of Bio-engineering measures for mitigation of landslide risk. Proposed site selection criteria for short listing of candidate sites for application of Nature Based Solutions and/or hybrid solutions will need to fulfil the following criteria. The proposed site selection criteria and the weightage allocated for the respective factor is given below in Table 4.1.

Table 4.1: Weightage factors assigned to each criteria

Name of criteria	Weightage Factor
Depth to failure plane	5
Rate of potential movement	5
Slope range & category (in degrees)	5
Suitability for creating a vegetation cover	5
Sustainability/maintenance challenges	3
Geotechnical data availability	3
Probable loss considering the exposure elements at risk within impact zone	5

More details related to the above listed criteria for selection of sites for application of Nature Based Solutions in landslide risk management is provided in Annex C1 – "Report on Landslide Risk Management plan for two sites"

4.2 Selection of pilot sites for implementation of activities of the project.

The project team visited several sites recommended by NBRO with the NBRO team led by the Director of Landslide Services & Studies Division Mr. R. M. S. Bandara. Finally, project team in consultation with NBRO selected two sites for pilot studies and for developing a comprehensive landslide risk management plan using the above given selection criteria.

The two selected sites had more positive and favourable factors for application of nature based solutions and therefore the project studies and comprehensive landslide risk management plans were prepared under this task for the following two sites:

1. Landslide site at Badulusirigama, Badulla.
2. Landslide site at Galabada Rathnapura.

4.3 Overview of selected pilot sites

4.3.1 Site at Badulusirigama in Badulla District.

The landslide at Badulusirigama is located within the premises of Uva Wellassa University in Badulla District. With respect to administrative boundaries, the area belongs to Badulla Divisional Secretariat and lies within Rambukpotha and Hindagoda Grama Niladhari Divisions.

Coordinates

Latitude N	Longitude E	X (m)	Y (m)	Z (m)
6.980315	81.075787	233,374.1543	197,744.052	790

Figure 4.1 Aerial view of upslope of the landslide and Uva Wellassa University Premises

Few photos of Project team carrying out field investigations at site

The site had been one of the pilot sites under the program named “Technical Corporation for Landslide Mitigation Project (TCLMP)” which was implemented by NBRO with assistance from JICA. All the works relevant to the TCLMP project had been completed by now and the maintenance and monitoring activities of the site at present is being carried out by NBRO.

A network of surface and subsurface drains was constructed in order to improve surface drainage of water, minimize infiltration of storm water and lower the ground water level in order to arrest any further ground movements. NBRO has been performing continuous monitoring of the activity of the landslide using extensometers, inclinometers, strain gauges and ground water level monitoring gauges.

4.3.2 The site at Galabada, Rathnapura District.

The site belongs to Galabada Grama Niladhari Division of Rathnapura District. The land forms a part of Galabada Estate and is owned by Hapugasthenna Plantation Company of Finlay Group.

Coordinates

Latitude N	Longitude E	X (m)	Y (m)	Z (m)
6.707467	80.466949	166,084.1696	167,572.147	220

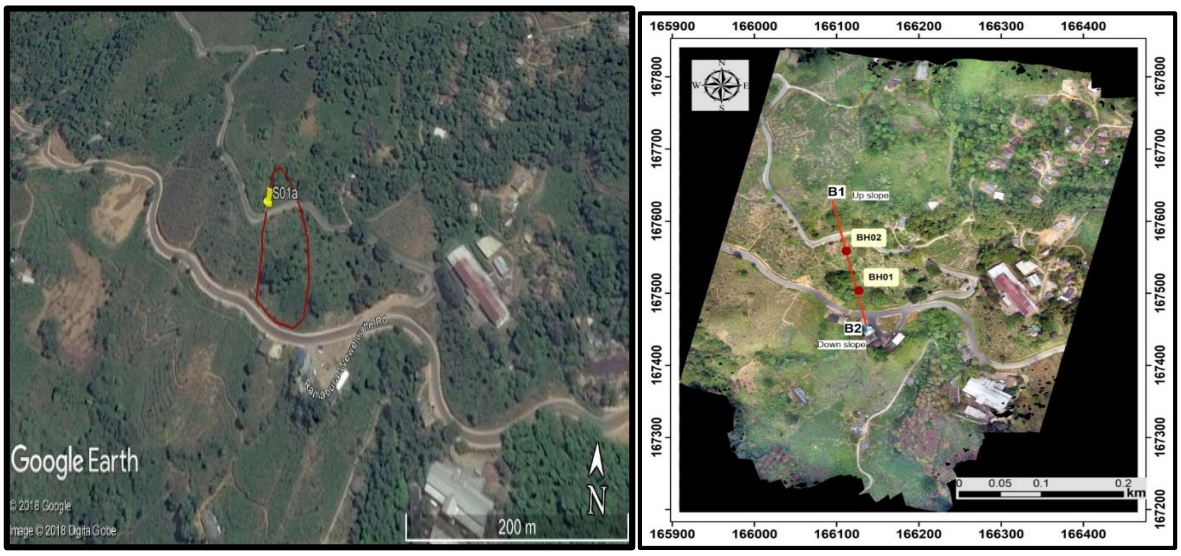


Figure 4.2 Aerial images showing the affected location marked with a red polygon

According to information gathered from NBRO scientists at Ratnapura district office, the site has shown ground movements since 30 years back. A JICA funded project had been initiated at the location and several types of instrumentation such as piezometers & extensometers had been installed during the period 2011 – 2012 for the purpose of monitoring the movements. Large movements were recorded in the year 2014 and 2016. Most probable reason for such movements had been the excavation activities near the toe area of the slope for construction & renovation activities of Rathnapura - Rathganga road. However, the aforementioned project had come to a standstill and the installed instrumentation had been removed subsequently.

At present, A Japanese firm has taken initiative to install a different set of instruments and the observations are being done by NBRO in partnership with JICA project team. Data obtained from the site using the instruments installed at site are available on the on-line portal "Landslide Remote Monitoring System" maintained by NBRO.

Few photos of Project team carrying out field investigations at site

4.3 Socio-economic survey and Geo-technical assessment carried out for the 02 pilot sites.

A socio-economic survey was carried out in both selected sites (Annex C1) to see the actual risk due to initiation of the respective landslides. In addition, preliminary geotechnical assessments (Annex C1) have been carried out in both sites to determine site conditions in terms of stability of the slope and material properties. Further, a drone survey was carried out at both sites to obtain a detail Digital Surface Model (DSM) and cross-sections necessary for undertaking slope stability assessments.

4.3.1 Highlights of the Socio-economic survey carried out at Badulusirigama site

Table 4.2 - Summary of elements at risk

Elements at Risk	**Quantity**
Total Number of buildings	95
Number of residents/occupants	355
Road length (minor and major roads) (km)	1
Power supply facilities (No. of High tension line towers)	4
Water supply facilities (Transmission pipe length in m)	400
Vulnerable land extent (total area in sq. km)	0.08

Main Findings of the building survey

1. Majority of head of households (56%) are male headed. About 73% of the heads are 50 years and older.
2. Major portion of the heads are engaged in Government sector employment.

3. 68% of the housing units are residential while 24% are Line Houses
4. Majority of them have been constructed during the period 1980-1990 where government organizations have acted as designer of the house.
5. Majority of the structures consist of Load Bearing Walls and Small Bricks were the major material of construction.
6. Major portion of the housing units consist of;
    - cement floors
    - foundations mainly of rubble works
    - Wood roof structures with asbestos as the roofing material
    - Have a systematic drainage system
7. 69% of the units are located on a terrain with gentle slope while 31% of the units are located on steep slopes.
8. No landslide signs were observed in 58% of housing units, however cracks on buildings, stagnation of water and subsidence were observed in some units.
9. 71% of the respondents reported that they had not received any instruction on disaster preparedness.
10. Most families prefer to relocate within the current GN division.

4.3.2 Highlights of the Socio-economic survey carried out at Galaboda site

Table 4.3: Elements at risk

Elements at Risk	**Quantity**
Total number of building units	73
Number of residential buildings	33
Number of residents/ occupants	117
Number of commercial building units	25
Number of industrial building units	13
Number of building units which house institutions	2
Road length (km) Major Roads Minor Roads	 0.51 2.22
Number of Power supply facilities (High Tension line length in m)	403
Vulnerable land extent (total area in sq. km)	 0.15

Main Findings of the building survey

1. Majority of head of households (75%) are male headed. About 46% of the heads are of 40-50 age group while 39% are 50 years and older.
2. Major portion of the heads are engaged in Private sector employment.
3. 54% of the housing units are Line Houses while 35% are Residential Units.
4. Majority of them have been constructed before year 1990 where mainly masons have acted as the designer of the house.
5. Majority of the structures consist of Load Bearing Walls and Cement Blocks was the major material that had been used in construction.
6. Major portion of the housing units consist of
    - cement floors
    - foundations mainly of rubble works
    - Wood roof structures with asbestos as the roofing material
    - Do not have a systematic drainage system
7. 75% of the units are located on a rolling terrain while the rest on steep slopes.
8. No landslide signs were observed in 68% of housing units, however cracks on buildings were observed in some units.
9. 56% of the respondents reported that they had not received any instruction on disaster preparedness.
10. Most families prefer to relocate within the current GN division

4.5 Community consultations

In addition, during the process of mitigation planning design preparation the project team had discussions with the University of Uva -Wellassa and members of the community living below the landslide area. The idea was to explain the planned activities, reasons for mitigation interventions and to obtain views of the university and the members of the community.

4.6 Preparation of Mitigation plans incorporating bio-engineering measures.

Nature-based solutions or bio-engineering solutions are defined as techniques that use live plants or plant parts to fulfil engineering functions. Bio-engineering mitigation measures are proven to be an appropriate, cost effective and nature friendly practice which is appropriate for stabilization of slopes. It can be applied as a standalone practice as well as a practice in combination with other Geo-engineering measures.

One of the main tasks of "Nature Based Landslide Risk Management Project" is to prepare a comprehensive landslide risk management plans for selected pilot sites. The purpose of the task is to demonstrate the methodology for preparation of a comprehensive landslide risk

management plan for two vulnerable pilot sites described above so that NBRO and stakeholders will be able to get a good idea about design aspects, planning, monitoring and budgeting for application of nature based solutions for mitigating landslide prone areas.

The selection of two sites mentioned above was done after visiting five candidate sites and using the site selection criteria mentioned above. Both sites have already installed set of monitoring equipment and are subjected to rigorous monitoring process for some times. In Uva-Wellassa site already NBRO has undertaken some mitigation measures with JICA assistance and a series of directional drilling has been executed for lowering the water table. The directional pipes are connected to surface drainage system and water discharge is regularly being monitored by NBRO.

As mentioned above a detail exposure survey of elements at risk and a socio-economic assessment was carried out in both sites. Subsequently a geo-technical assessment was carried out at both sites using the parameters obtained through the investigations previously conducted by NBRO.

The results are summarized below. More details are provided in the Annex C 1 – "Report on Landslide Risk Management plan for two sites".

4.6.1 Stability assessment conducted at Badulusirigama site

The conditions of the slope was simulated in Geo Studio modules considering both Finite Element and Limit Equilibrium approaches to check possible shallow failures. Spencer method was adopted to calculate the factor of safety. The shallow slip surface was assumed to be varied between 2.5 – 3.0 m which is typical for shallow landslides in Sri Lanka. This depth was selected based on previous experiences of NBRO and as well as considering the values reported in the literature.

The conditions of the slope was simulated in Geo Studio modules considering both Finite Element and Limit Equilibrium approaches. The analysis was conducted under three cases;

1. Slope without any mitigation measures,
2. Modified slope with subsurface drains and
3. Modified slope with application of a hybrid system (Sub-surface drains + vegetation).

Information on the sub surface profile were extracted from the investigations done by JICA team of investigation and the test results available at NBRO. Different strength properties assigned for each subsurface layer is summarized in table 4.4.

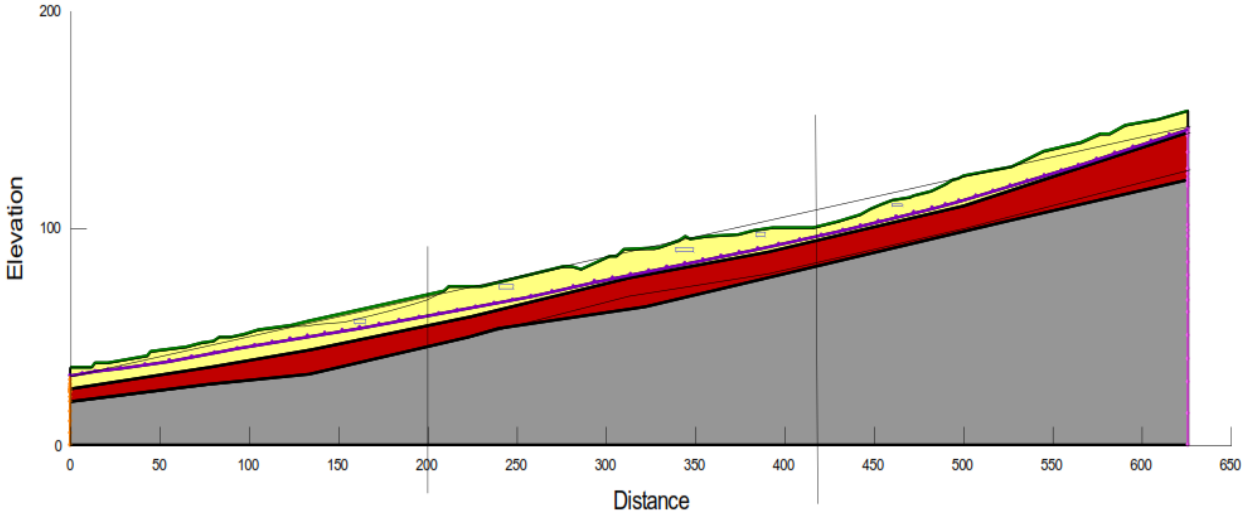


Figure 4.5: Idealized subsurface profile

Table 4.4: Geotechnical parameters assigned for each subsurface layer

Layer	Colour code	Cohesion (kPa)*	Phi (deg)*	Phi b (deg)**	Unit weight (kN/m^2)
Colluvium		7	12	10	15
Completely weathered rock (soil)		7	14	-	16
Mod. Weathered Rock		20	40	-	19

*Monitoring Report No. 08 Published by JICA and NBRO Studies
**Kankanamge et.al (2018)

The subsurface profile shown in figure 4.5 was divided into three zones after studying the results of the geophysical investigations carried out by JICA team of experts. Figure 4.6 shows the division of zones. In the stability analysis, each zone was modelled separately.

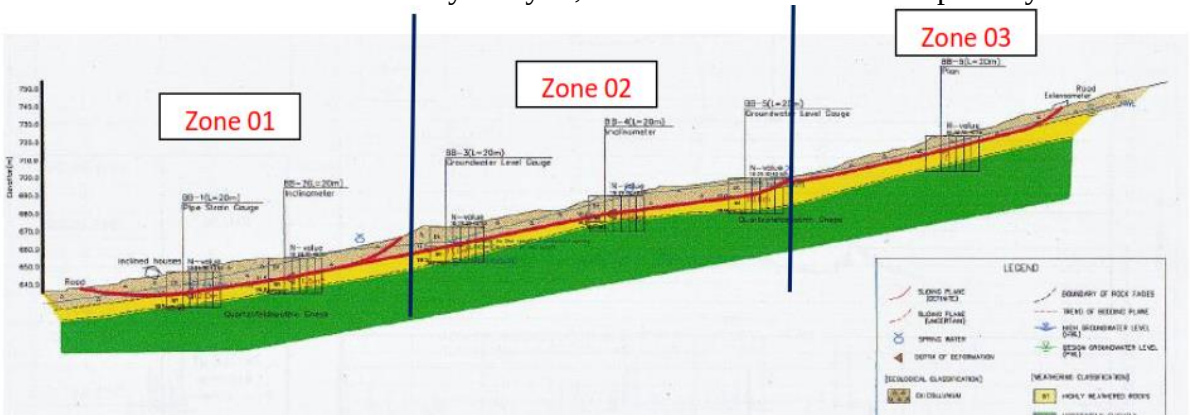


Figure 4.6: Division of three zones for stability analysis

Results and Discussion

Case 1: Slope without any mitigation measures

Table 4.4: Factor of safety of different zones when there are no mitigation measures

Zone	FoS under existing conditions
01	1.001
02	0.959
03	0.913

From the stability analysis conducted, it is evident that the Zone 03 has the lowest safety margin indicated by a factor of safety value of less than one. The safety criteria of the other two zones are also not satisfactory as the FoS value is slightly greater than one which is not acceptable. Therefore, appropriate mitigation measures need to be applied in order to improve the safety margins of the entire slope.

Case 2: Modified slope with subsurface drains

Under this case, the slope was analyzed by introducing subsurface drains drilled at different levels and having length of approximately between 30- 40 m. The angle of inclination of these drains are maintained between 6 degrees and 9 degrees with respect to the horizontal.

The new safety margins of the slope and the percentage increase of the FoS are summarized in the Table 4.5.

Table 4.5: Factor of safety improvement after drainage improvement

Zone	FoS before drainage improvement	FoS after drainage improvement
01	1.001	1.281
02	0.959	1.256
03	0.913	1.218

Table 4.6 indicates that stability has increased upon the introduction of subsurface drainages. The highest increase of factor of safety is on zone 3.

Case 3: Modified slope with hybrid solutions (Subsurface drainage + vegetation)

The effect of vegetation was incorporated to slope stability by calculating soil cohesion due to presence of roots which is defined as root cohesion. This value was treated as an additional cohesion provided to the soil layers.

Calculation of root cohesion and its variation due to different spacing patterns

Step 1:
The following formula was used to calculate the tensile strength:

$$T_r = \frac{F_{max}}{\pi\left(\frac{D^2}{4}\right)}$$

where F_{max} is the maximum force (N) needed to break the root and D is the mean root diameter (mm) before the break.

Step 2:
Root cohesion which is needed for design and analysis of the stability of slopes was obtained from the formula given. It was obtained from the study carried out by Schwarz et al. (2010);

$$Cr = 0.48 * Tr * (RAR)$$

$$\mathrm{RAR} = \frac{A_r}{A} = \frac{\sum_{i=1}^{n} \pi d_i^2/4}{A}$$

d – diameter of the root
A – effective soil cross section area
This increment in cohesion value is used in stability assessments to evaluate the vegetation effect and was applied in function of the plants' root zone.

Step 3:
As the next step, an average value of root cohesion for the entire slope, $\bar{c}_r$ was calculated considering the spacing between each plant row as suggested by Mahannopkul & Jotisankasa (2019). They have applied the formula for testing vetiver plants:

$$\bar{c}_r = \frac{c_r l_r}{l_r + l_s}$$

l_r – width of the plant row
l_s – spacing between each plant row (width of the non-reinforced zone)

For the pilot analysis, Eugenia caryophyllus species which is commonly known as Clove was used. Its properties were given in the table below.

Table 4.6: Properties of the Clove root

Crop name	Scientific name	Age (yrs)	Average root cohesion (MPa) for different spacing (m)			
			2.0	1.5	1.0	0.5
Clove	Eugenia caryophyllus	20	0.038	0.048	0.064	0.096

The shear strength parameters of Colluvium soil layer was adjusted accordingly due to presence of Clove roots. The amended values are given in table 4.7.

Table 4.7: Revised geotechnical parameters upon application of vegetation (Clove)

Layer	Colour code	Cohesion (kPa)	Phi (deg)	Phi b (deg)*	Unit weight (kN/m^2)
Colluvium after Vegetation		22	12	10	15
Colluvium		7	12	10	15
Completely weathered rock (soil)		7	14	-	16
Mod. Weathered Rock		20	40	-	19

The soil layer "Colluvium after vegetation" by considering the average root depth zone of Cloves which is around 2m to 3m.

Afterwards, variation of factor of safety was analysed for shallow slip surfaces upon introduction of subsurface drainages and vegetation (hybrid solution). The results are given in table 4.8.

Table 4.8: Variation of factor of safety after applying subsurface drainages with vegetation (Hybrid solution)

Zone	FoS before drainage improvement	FoS after drainage improvement	FoS after drainage improvement and applying vegetation for shallow slip surfaces
01	1.001	1.281	1.464
02	0.959	1.256	1.261
03	0.913	1.218	1.232

This analysis shows that the factor of safety values could be increased further by introducing vegetation. However, it is to be noted that more no. of results of root cohesion data are needed for different plant species in order to quantify the degree in increase of safety factor accurately.

4.6.2 Stability assessment conducted at Galabada Site

A stability analysis was carried out using Spencer method and assuming the sub surface profile indicated in figure 4.8.

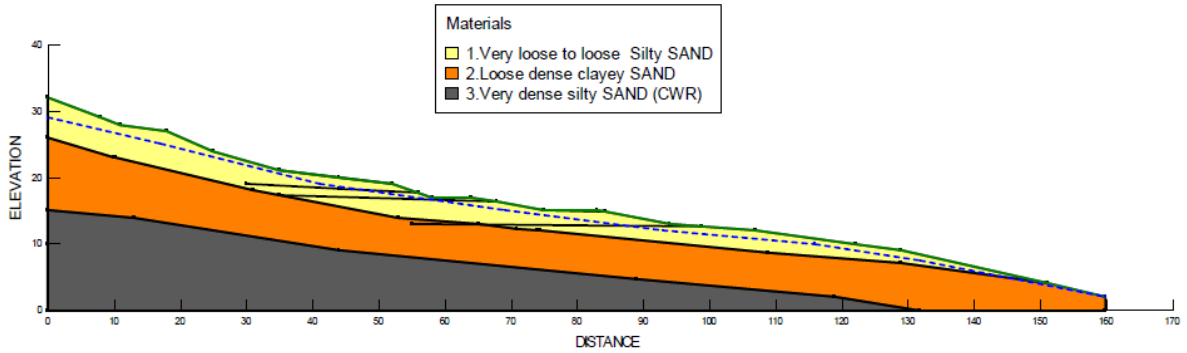


Figure 4.8: Subsurface profile of the slope. Galabada in Ratnapura

The slope was analysed by assuming the presence of three layers as indicated in Table 4.9.

Table 4.9: Geotechnical parameters of different layers

Layer	**Cohesion (kPa)**	**Friction angle (°)**
1. Very loose to loose silty SAND	1	20
2. Medium dense clayey SAND	2	21
3. Very dense silty SAND (CWR)	10	35

The stability margin of the slope, under existing conditions and without any mitigation measures is indicated in Figure 4.8.

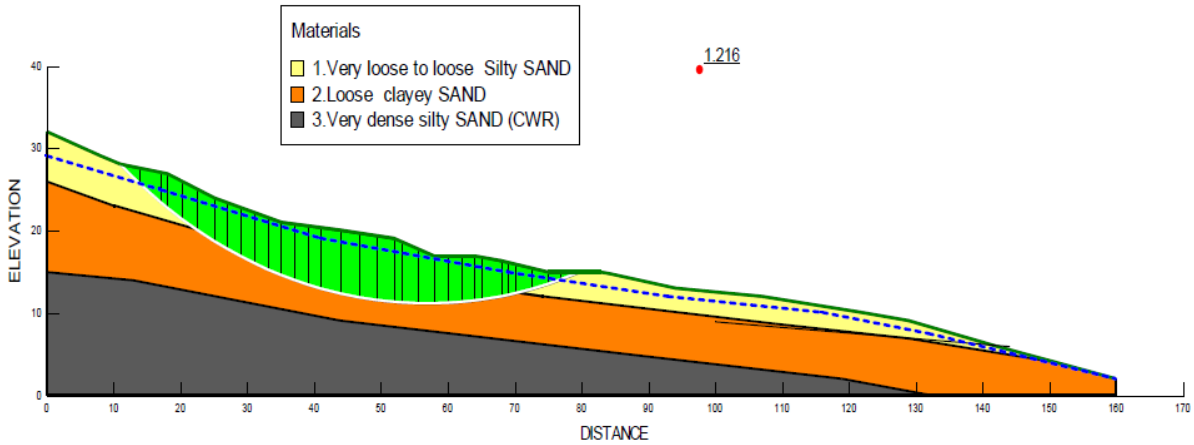


Figure 4.9: Stability condition of the existing slope

The failure plane is at a depth of around 9 – 10.0 m, which indicates the failure is of deep seated type. The current computed factor of safety is around 1.2. This analysis more or less simulate the existing slope conditions, as per the monitoring data and general observations made during site inspections.

Introduction of subsurface drainage *(Engineering measure to increase the current factor of safety)*

A subsurface drain was introduced to lower the water table. The location and the length of the drain was selected based on information on seepage conditions of the site. The stability conditions after the introduction of the subsurface drain is presented in figure 4.9.

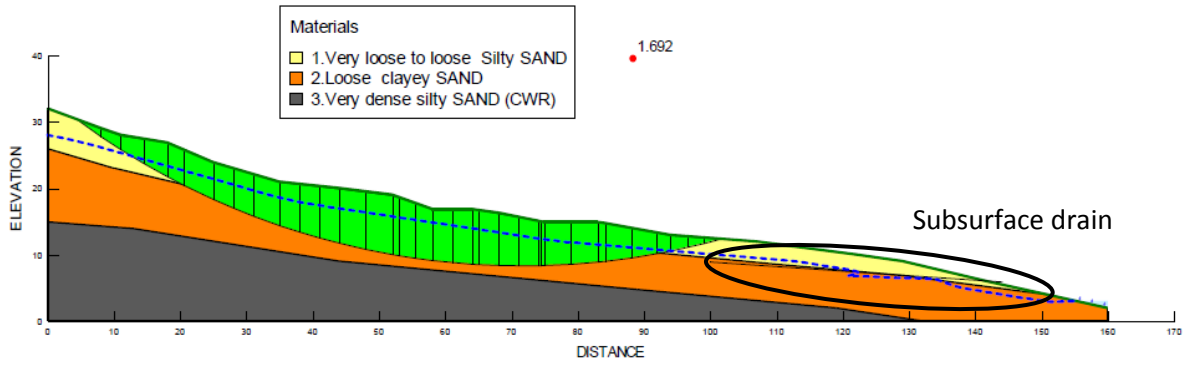


Figure 4.10: Stability conditions after the introduction of the subsurface drain

The factor of safety has been increased to a value of 1.692 which was around 1.216 previously. But still the critical failure surface is deep seated. However, it can be decided that subsurface and surface drainage improvement will be a good measure to rectify this deep seated slide.

4.6.3 Bio-engineering mitigation measures at Badulusirigama site

As mentioned above at the Badulusirigama site some mitigation work has been already applied and as per the monitoring data the stability has been improved after said applications of directional drilling at the site. However there is a need for application of further measures to improve the safety factor where there was a marginal increase after lowering the water table. In the mitigation design through application of additional bio-engineering measures an attempt has been made to increase the safety factor in location where it was found to be marginal. In addition a SWOT analysis has been done for the area to be stabilized in order to come up with appropriate bio-engineering solutions.

The full description of the methodology used and the mitigation plan design, budget, work plan is provided in the Annex C1 – "Report on Landslide Risk Management plan for two sites".

4.6.4 Bio–engineering mitigation measures at Galabada site

During site inspections, it was observed that the landslide area is prone to water logging. In addition, surface erosion was a critical concern that must be addressed in terms of proper means. Washing out of surface soil in fallow areas of the body of the landslide was observed. Accumulation of water at relatively low level areas of the soil mass also leads to slope instabilities by increasing the weight of the sliding mass, as well as increasing the pore water pressures through infiltration.

In this context, plant species which have higher rates of evapotranspiration capacities have been suggested to be introduced in water logging areas as they can remove water from soil at comparatively higher rates. Grasses or small shrubs like species can be planted to control the surface erosion. This type of vegetation would help to keep the soil particles intact.

The full description of the methodology and the mitigation plan design, budget, work plan are provided in the Annex C1 – "Report on Landslide Risk Management plan for two sites".

Chapter 5: Task D: Preparation of a Guidance Document on Nature Based Landslide Risk Management Approaches

Guidance manual on nature based landslide risk management approaches has been developed with the purpose of providing guidance to those who are involved in landslide mitigation work (NBRO, relevant local authorities and other practitioners) to help in designing, implementation and monitoring the nature based mitigation solutions applied for landslide and erosion risk reduction under a range of physical conditions. The manual consists of 10 chapters covering practical as well as theoretical aspects of bio-engineering measures that can be applied for mitigating the landslide risk. It is developed for introducing basic concepts and creating general understanding of various aspects of nature based solutions and not intended to provide a comprehensive theoretical understanding on the subject.

The nature based and hybrid solutions presented in this guidance document on nature based landslide risk management approaches are chosen specifically to suit for meeting Sri Lanka's needs for landslide risk mitigation. Some of the good practices of bio-engineering for stabilization of vulnerable slopes and reducing the erosion potential, applied elsewhere also have been included in the document.

The full document on Guidance manual on nature-based landslide management approaches is provided as Annex D1 – "Guidance Manual", Annex D2 – "Plant Manual", Annex D3- "Summary of bioengineering characteristics of plants in wet and intermediate zones of Sri Lanka" Annex D4 – "Field guide to plant identification".

5.1 Summary on the Content of "Guidance Manual"

CHAPTER 1- Introduction

- General overview
- Types of slope failures and landslides
- Types of movement observed in landslides
- Common types of landslides and slope failures observed in Sri Lanka
- Factors that contribute to triggering of landslides in Sri Lanka
- Landslide Hazard Zonation Maps prepared by NBRO

CHAPTER 2 – Mitigation of Landslides

- **Framework for landslide risk management**
- **General approach for mitigation of landslides**
    - Surface protection/ control of surface erosion
    - Modifying geometry and/or mass distribution
    - Modifying surface water regime – surface drainage
    - Modifying groundwater regime – subsurface drainage
    - Modifying mechanical characteristics of the unstable mass
    - Transfer of loads to more competent strata
- **Criteria for Selection of mitigation options**
    - Factors which determine the hazard
    - Factors which affect the nature and quantification of risk

    - Factors which affect the actual feasibility of specific mitigation measures,
    - Morphology of the area in relation to accessibility and safety of workers and the public;
    - Environmental considerations, such as the impact on the archeological, historical and visual/landscape value ;
    - Preexisting structures and infrastructure that may be affected, directly or indirectly;
    - Capital and operating cost, including maintenance
- **Examples of mitigation measures at landscape level**

CHAPTER 3: Services that vegetation can provide in improving the stability of slopes and in preventing surface erosion.

- Purpose and importance of a nature based landslide risk management
- Bioengineering and biotechnical stabilization techniques
- The explanation on root traits
- Comparison between Geo-engineering slope protection measures with some of Bio - engineering functions of vegetation.

CHAPTER 4: Selection of candidate sites Assessments of potential for applying NBSs and hybrid solutions

- Principals in application of nature based solutions or bio-engineering solutions in landslide risk mitigation
- Proposed site selection criteria for short listing of candidate sites for application of Nature Based Solutions and/or hybrid solutions
- Results of the socio-economic study and geo-technical assessment at pilot sites of Badulusirigama and Galaboda.

CHAPTER 5- Plant selection and planning process

- Rationale and Scientific approach
- Natural vegetation types in landslide-prone areas of Sri Lanka
- Root-soil matrix
- Laboratory testing program for obtaining strength of plant roots in landslide prone areas
- Planning process
    - Assess project site
    - Establish objectives
    - Collect site specific data
    - Assess bio-engineering potential
    - Evaluate alternatives and select best management practice
    - Select suitable plants

- Aspects of concern (plant community succession, short-term re-vegetation , Controlling weeds
- Types of plants (Herbaceous species, Woody tree species etc.)
- Ecological, management, and economic criteria
- A simplified plant species selection framework
- Five main criteria used for providing the appropriate information for plant selection and their descriptions:
    - Plant type and structural characteristics
    - Hydrological significance
    - Root strength characteristics
    - Ecological significance
    - Economic value

CHAPTER 6: Planting Techniques and selecting an appropriate configuration in utilization of appropriate services of vegetation in stabilization of slopes

- Plant materials and planting techniques
    - Seeds
    - Cuttings
    - Plants
- Selection of Planting configuration
    - Root mats
    - Horizontal or contour lines
    - Downslope or drainage course planting
    - Diagonal lines
    - Combinations of vegetation species
- Vegetative techniques
- Comparative assessment of different Vegetative techniques.
- Slope stabilization techniques used at different scales of seriousness

CHAPTER 7 – Evaluating the enhancement effects of vegetation on slope stability through modeling related factors

- Modeling factors that help in mechanical strengthening of subsoil formations through vegetation
- Root reinforcement effect
- Development of simple root model - mathematical model**.**
- Modeling factors that help in improving the hydrological regime of the slope through vegetation
- Experience of the WB funded Nature Based Landslide Risk Management project in Sri Lanka.
- Example of numerical analysis of the slope for both pilot sites

CHAPTER 8 - Establishment of Plant Nurseries

- Establishment process
- Other factors that will be useful to consider during establishment of Plant Nursery.
- Construction of different kinds of beds
- Providing bed shades and fencing
- Water supply
- Compost production and supply
- Nursery management

CHAPTER 9 – Work plan preparation and budgeting

- Major tasks and sub-tasks that will be included in the work plan.
    - Site preparations
    - Civil engineering work
    - Bio-engineering work
    - Plant nursery development and maintenance
    - Post execution inspection and maintenance
    - Remuneration
- Sample work plan
- Sample budget
- Sample scheme for instrumentation and monitoring
- Sample monitoring and evaluation plan to assess the performance of nature based solutions in-situ.

CHAPTER 10- Case studies from South Asia, East Asia & the Pacific & lessons learnt

ANNEXES

Annex 1: Plant Manual

Annex 2: Summary of bio-engineering characteristics of plants in wet and intermediate zones (120 Nos)

Annex 3: Detail description of recommended plants

Chapter 6: Proceedings of the Stakeholder workshop to present outcome of the project organized under Task E.

The Nature Based Landslide Risk Management Project, implemented by NBRO has completed its project activities as per the work plan. Considering the importance of obtaining technical inputs on the completed project activities, deliverables and the final outcome, a Stakeholder Meeting was organized on June 3, 2019 at Hotel Taj Samudra, Colombo. Representatives from eighteen organizations including the project implementing agency National Building Research Organization (NBRO), World Bank (WB) and technical partner of the project Asian Disaster Preparedness Center (ADPC), Thailand attended the event.

Figure 6.1: Few photos of the stakeholder workshop and its audience

Director General of NBRO (DG-NBRO), Eng. (Dr.) Asiri Karunawardena, welcoming the participants of the final stakeholder workshop, stated that due to escalation of landslide events and associated impacts in terms of number of deaths & socio-economic status, the government of Sri Lanka has taken various initiatives to reduce such negative impacts. Among them are;
1. Landslide Hazard Zonation Mapping program to identify the most hazard prone areas;
2. Resettlement of most vulnerable people in to safer areas,
3. Structural and non-structural mitigation interventions to reduce the potential impacts due to landslide events.

However, in the past Sri Lanka has largely relied on engineering solutions for landslide risk mitigation and the application of nature based and hybrid (engineering in combination with nature based) approaches were limited due to various reasons including lack of experience and confidence. It has been demonstrated in many countries in Asia, that the risk-informed nature

based solutions can be effective in reducing the occurrence and impact of landslides. DG-NBRO further stated that recognizing the importance of application of nature based solutions for landslide risk management in mitigating the landslide risk in Sri Lanka, NBRO has taken the initiative to implement this project on "Nature Based Landslide Risk Management", to gain more experience. He has thanked the World Bank for providing financial assistance for implementation of the project and the Asian Disaster Preparedness Center (ADPC), Thailand for providing technical assistance in project implementation.

Mr. Suranga Kahandawa delivering a short message from World Bank (WB) stated that the World Bank has decided to fund the this Analytics and Advisory Services project with the aim of raising the awareness on the subject and deepening the knowledge within country on the role of nature based solutions for landslide risk management. WB would like to see that NBRO considers this type of mitigation measures in future because such green initiatives are becoming more popular worldwide due to the fact that such initiatives promote more conservation practices and sustainability of environment and natural resources. On the other hand, it is more cost effective and can be used for achieving multi-tasks in creating not only safer but also more visually acceptable and ecologically sustainable slopes. Mr. Suranga Kahandawa also stated that it is also expected to apply this knowledge in a number of pilot demonstrations under different projects including under the ongoing Climate Resilience Improvement Project (CRIP) funded by the World Bank. He thanked NBRO for taking the initiative to implement the project and also thanked ADPC team for their technical assistance for implementation of the project.

Dr. S. Amalanadan, Additional Secretary, Ministry of Public Administration and Disaster Management, delivering a message from the ministry, congratulated DG-NBRO and staff for successfully completing an important set of pilot initiatives utilizing nature based solutions for mitigating landslide risk. He stated that the ministry has a great confidence on the capacity and competence of NBRO in landslide risk management and in various other areas of geo-hazard risk management. Up to date, ministry has obtained technical assistance from NBRO for various problems arising in the recent past and every time NBRO has provided the best possible as well as cost effective technical solutions. Nature based solutions are getting popular in many countries in the region and it is nice to see that NBRO also is going with the latest trends and trying to adapt environmentally friendly solutions for managing landslide risk in the country. Dr. Amalanadan has further stated that the ministry has a belief that the pilot initiatives undertaken by NBRO for application of nature based solutions to mitigate landslide risk can be scaled up and applied under various climatic and physical conditions prevailing in landslide prone districts in Sri Lanka. Hence, there is a need for NBRO to take this initiative forward and make arrangements to sustain the capacity build under WB funded initiative.

Dr. Senaka Basnayake, Director, Climate Resilience of Asian Disaster Preparedness Center (ADPC), provided a brief introduction to the project, project tasks and progress of the activities made under the project. He thanked NBRO for the assistance provided to the project team and cooperation extended. He also thanked World Bank for providing an opportunity to work with NBRO for undertaking this important project not only beneficial for Sri Lanka but also for the region.

After the introductory presentation, Dr. Senaka Basnayake officially presented the "Guidance Document on the use of Nature Based Solutions for Landslide Risk Reduction" which was compiled under the current project to World Bank, National Building Research Organization and Ministry of Public Administration and Disaster Management.

Figure 6.2: Presentation of "Guidance Document" by Asian Disaster Preparedness Centre to World Bank, National Building Research Organization and Ministry of Public Administration and Disaster Management
From left to right: Mr. Suranga Kahandawa (World Bank), Eng. (Dr.) Asiri Karunawardena (NBRO), Dr. S Amalanadan (Ministry of Public Administration and Disaster Management), Dr. Senaka Basnayake (ADPC)

Subsequently, following technical presentations were made by the project team members to share the knowledge and experience on implementation of nature based and hybrid (engineering and nature based) approaches for landslide risk management in two selected pilot sites in Badulla and Ratnapura districts.

- Importance of Nature Based Approaches for Landslide Risk Reduction in Sri Lanka – Mr. R. M. S. Bandara, Project Director, RLVMMP, NBRO
- Developing a comprehensive model to compute root reinforcement effect for mechanical strengthening of sub-soil formations and mitigation plan development using Nature Based and Hybrid Solutions - Eng. (Dr.) Udeni Nawagamuwa, Consultant (ADPC)
- Case studies on model simulations carried out through application of Nature Based and Hybrid Solutions for mitigating the landslide risk in two selected pilot sites - Eng. Lilanka Kankanamge – Geotechnical Engineering Division (NBRO)
- NBRO approach in plant identification in nature-based landslide risk management – Dr. Pathmakumara Jayasinghe - Landslide Research & Risk Management Division, (NBRO)
- Landscape planning approach for Landslide Risk Reduction in two pilot demonstration sites – Ms. Deemathi Perera, Human Settlements, Planning and Training Division (NBRO)
- Developing a Manual on application of Nature Based Solutions in Landslide Risk Mitigation – Mr. N. M. S. I. Arambepola (ADPC)

During the discussion time, following comments and suggestions were made by the participants.

- It is better to explore the possibility of replacing tree species used in the mid-zone area of the Uva- wellassa site such as Kenda, Geduma with more valuable, medicinal tree plant varieties such as Kohomba, Bulu, Nelli etc. which are also appropriate for the area;
- Root ball method is usually good for getting the rapid growth of plant species where and when necessary. But in the case of Galaboda site if this method is used for Kumbuk type tree species, in the lower region in Galaboda site, it might not give the expected results as usually during root ball process the tap root will be cut while preparing the root ball plants;
- It is a good way to use commercially important plant species in between Vetiver plant lines in the case of head region of the Uva-welllsa site;
- In the Plant Manual, introduction of index properties of different plants is a commendable intervention. It is good if root structure/architecture also could be considered as an important index property among others provided. It is good, if steps can be taken to add the same in to the available index properties;
- When modelling, the qualitative impact due to integration of plant species in soil formations, it is better to take both root tensile strength as well as the weight of the tree plants in to consideration. Usually in areas where further loading is questionable due to potential loss of stability, weight will have a greater contribution if the area is packed with tree species with considerable weight;
- When planning for utilizing plant species from nurseries, native plants such as Geduma, Kenda etc. has a lower success rate while preparing potted plants or plants in polyphone bags. It is usually a naturally grown plant and introducing the same in to a new area is difficult;
- Before planting the recommended plant species obtaining soil nutrition levels of the available formations at site, should be considered as a major requirement. Since the soil formations are the main source of nutrients needed by plants for growth, it is necessary to see the levels. If the nutrition level is found not adequate, measure should be taken to supplement through addition of compost or any other chemical fertilizer;

During the answer session, the presenters have provided explanations to the comments made by the participants. Whereas, the positive suggestions made by the participants were well accepted and necessary actions will be taken to integrate them in future work.

Under the agenda item of way forward, Dr. Senaka Basnayake, Director, Asian Disaster Preparedness Center (ADPC), has informed the audience that the World Bank has extended the project in to phase II, which will be effective until end June 2020. He has presented the tasks and activities planned for the second phase which will cover the landslide prone districts of Nuwara Eliya, Ratnapura, Galle and Matale. He added that a detail discussion would take place on 4th June 2019, at NBRO on the tasks and planned activities under phase II and suggestions of NBRO will be considered during project implementation in future.

At the end, while delivering concluding remarks, Dr. Pathmakumara Jayasinghe, Senior Scientist, NBRO thanked all the representatives of the stakeholder agencies present and requested their cooperation in implementing the phase II of the project.

Annexures

Annex A1 - Training needs and gap assessment survey report

Annex A2 - Report on project initiated training

Annex A3 - Report on the organization of a study tour to Thailand

Annex B1 - Report on assessment of relevant legal, regulatory and institutional framework

Annex B2 - Proceedings of the national workshop to validate the findings and recommendations.

Annex C1 - Report on landslide risk management plan for two sites

Annex D1 - Guidance Document on nature-based landslide risk management

Annex D2 - Plant Manual

Annex D3 - Summary of bioengineering characteristics of plants

Annex D4 - Field guide to plant identification