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Civil Engineering structure and Bioengineering Technique for landslide reduction and there cost comparison; with reference to study in Kageshwori Manohara Municipality of Kathmandu, Nepal

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Abstract

Landslides pose a significant threat to communities in hilly and mountainous regions of Nepal where steep terrain and heavy monsoon rainfall contributes to their occurrence. This study focused on the study of four landslide sites for case analysis. Comprehensive data collection included Slope length, Slope width, Slope Angle, Material Drainage, Aspect, Site Moisture, Type of Soil, Type of Erosion/Mass Movement, past history of Landslide. Based on this data and suggestion from the expert, various bioengineering and civil engineering techniques were proposed for soil stabilization and erosion control. Bioengineering measures such as grass seeding, shrub and tree plantation, brush layering, jute netting, along with civil engineering methods like riprap, gabion work, soil nailing, shotcrete, chutes, and drains are suggested. The study also included a cost comparison between bioengineering and civil engineering measures. The cost analysis revealed that the expenditure for bioengineering measures amounted to NRs. 3,202,854.52, while civil engineering works incurred NRs. 6,199,496.55. Typically, the cost ratio between vi bioengineering and civil engineering is expected to be 1:3. However, due to the inclusion of water management components like stream chutes and riprap in bioengineering, the observed ratio is closer to 1:1.94.

In conclusion, this research highlights the significance of adopting bioengineering techniques as a sustainable, cost effective and community-centered approach to landslide risk reduction. The outcomes of this case study offers a holistic framework for mitigating landslide hazards in vulnerable areas like Adhikari Tole, ultimately contributing to the safety and well-being of its residents. The approach adopted in this study can serve as a model for similar landslide-prone regions in Nepal and other countries facing similar challenges.

Keywords: Civil Structure, Hill Slope, Landslides, Bio engineering., cost effective, sustainable approach

1. Introduction

Bioengineering is the use of living plants or plant components to manage soil erosion and land movement for engineering reasons. Bioengineering, a non-traditional engineering method, uses vegetation as a key tool. Green infrastructure can help protect against natural disasters like landslides and soil erosion [5]. Civil engineering has been embracing the concept of bioengineering to minimize the overall cost of landslide mitigation techniques. Physical construction techniques provide instant protection in the form of a physical structure, whereas bioengineering vegetation techniques take time to demonstrate their effectiveness [10].

The practice of bioengineering stretches back to the Fifth Century AD in ancient China and was used in Europe during the Dark Ages and Medieval times. Although it has been widely practiced in different areas of the world for many years, it was only in the last 25 years that it was introduced and modified to local conditions in Nepal. Bioengineering is especially beneficial in impoverished countries like Nepal, where implementation is relatively inexpensive. The materials are easily available and entail little costs, with labor being the key input - a cost effective asset in Nepal [8]. The concept of bioengineering in hill road construction was introduced in Nepal 40 years ago with roadside plants on the Dhangadhi-Dadeldhura highway in western Nepal in a US-assisted project [7]. In the modern sense, bioengineering was first introduced in Nepal on a massive scale with the involvement of the UK-based Transport Research Laboratory on the eastern Dharan Dhankuta highway, supported by the British government. They then facilitated the transfer of the technology to Nepali institutions and professionals [11].

"Disasters bring serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community to cope using its own resources" [13]. In terms of natural disasters in general, the number of occurrences has increased dramatically over the last 1 30 years (1991-2020). This rising trend may be seen both globally and in the Asian region. The overall number of disaster incidents in 2021 was 436, which was higher than the annual average of 376 during the previous 30 years [1].

Nepal is vulnerable to several recurring threats. The country is ranked 20th among the world's most vulnerable to many hazards [2]. In terms of climate change, earthquake, and flood risk, the country ranks fourth, eleventh, and thirty-first, respectively. Landslides, fires, droughts, epidemics, storms, hailstorms, avalanches, and GLOF are some notable calamities in Nepal. Nepal is very vulnerable to a variety of hazards, owing principally to its diversified topography and climatic conditions, geological position, rough mountains, and steep geography. Nepal not only has young mountains and geology, but it also contains almost one-third of the world's total 2,400 kilometers of Himalayas. Natural disasters have become more often as altitudes range from 59 meters to 8,848 meters in less than 200 kilometers [9]. Landslides are quick mass-wasting processes in which gravity causes variety of slope-forming material, from soils to rock to artificial fill, moves down the slopes.

According to [16], the term “landslide” is used to denote the “downward and outward movements of slope forming materials along surfaces of separation,” but it is probably the most overused and loosely-defined term used in slope studies. Several types of landslide exist and different nomenclature is used to classify them. A growing body of scientific opinion is in favors of limiting the use of the term landslide to describe situations in which masses of material move down a slope by sliding and to reserve related terms like “mass movements”, “mass wasting”, “slope movements,” and “slope failure” for other phenomena. Landslides may be triggered by natural or anthropogenic factors. Nepal is highly vulnerable to landslide because of its steep mountainous train, weak geographical formation along with steep topography in hilly region, over grazing of protective slope cover high intensity rainfalls during monsoon. As Nepal is tectonically active many mass movements. Such as landslide avalanches glacial Lake Outburst flood is triggered by earthquake. Due to unique geological structure like many places in Himalayan region the Himalayan nation have frequently witnessed the increasing impact of climate change resulting into different type of water-induced hazards including landslides [15], The rapidly increasing construction of infrastructures, such as roads, irrigation canals, and dams without due consideration given to natural hazards, is contributing considerably to triggering of landslides.

Nepal is a mountainous country divided into three major regions: mountains, hills, and terai. Most Nepalese hill areas lack effective rural transportation, resulting in isolation, inadequate market access, high commodity prices, irregular public services, and limited economic possibilities [4]. The Nepalese government has prioritized the construction of hill roads as a primary infrastructure service to address the social inequities and physical, social, and economic hardships encountered by the local population due to lack of access. Road construction in these areas has become a big concern. This challenge introduced the concept of Green Roads and Bio-engineering solutions for addressing these issues [6].

Bioengineering technology, which blends flora such as grass, bushes, and trees with tiny buildings such as small dams, walls, and drains, has helped Nepal resist landslides. In central Nepal, these facelifts have mostly happened along the 110-kilometer Naubise-Mungling portion of the Prithvi highway and the 36-kilometer Mungling-Narayanghat route. The bioengineering technique depends on Nepali farmers' centuries-old tradition of employing trees on terraced slopes of their crops and forests. Scientists have succeeded in decreasing expenses while maximizing the benefits of slope protection and stabilization by merging this indigenous technology with modern engineering structures [7]. In the past, road development in Nepal was done haphazardly, ignoring critical factors such as environmental preservation, advantages to the rural poor, and asset management. Following that, the German government funded the development of the green road concept (GRECO), which has been effectively utilized by numerous rural infrastructure projects in Nepal's hill districts for many years [17].

The main causes of landslides in Nepal are steep slopes, loose material, and significant rainfall during the monsoon season. Human construction activities, such as excessive cutting into slopes, disrupting natural drainage systems, and unsuitable land use, all contribute to landslide risk [12]. 3 Bioengineering increases the life of roads while decreasing maintenance costs [14]. The study investigates the viability and environmental friendliness of bioengineering techniques for minimizing landslide hazards in this location. The study looks on the effectiveness, practicality, and applicability of various bioengineering measures in Kageshwari Manohara Municipality to decrease landslide hazards, giving significant insights for policymakers, engineers, and stakeholders in Nepal and other landslide-prone areas.

2. Materials and Methods

The study area lies in ward no 1, Gagalfedi of Kageshwori Manohara Municipality of Kathmandu District at Pipaldanda-Adhikari Tole. KageshworiManahara municipality is divided into 1 to 9 administrative wards, covering a total land area of 27.38 km2. It is bordered by Sankarapur municipality of Kathmandu and Changunarayan Municipality of Bhaktapur district to the East, Ward number 32 of Kathmandu metropolitan city and Gokarneshwor municipality to the West, while Sankarapur and Gokarneshwor municipalities lie to the North, and Madhyapur Thimi of Bhaktapur district is located to the South. Geographically the area is bounded by latitudes 27°45'21.57"N and longitudes85°27'9.88"E. The Site is situated in an elevation of 1610m above Sea Level.

Following steps was followed to reach the expected output:

a) Problem identification: Soil erosion and landslide
b) Selection of site: Kageshwari Manohara Municipality-1, Pipaldanda-Adhikari Tole;
c) Objective: To compare the cost of bio-engineering technique with civil structural work in controlling soil erosion;
d) Literature review: study of available related documents, reports etc;
e) Data collection: Both the primary data and secondary data in the format of Qualitative data and Quantities data has been collected as:
    i) Primary data:
        - Field Observation and Measurement;
        - Questionnaire Survey;
        - Focus Group Discussion;
        - Key Informant Interview.
    ii) Secondary Data
        - Municipality Reports/Database;
        - Other study/Reports;
        - Research Articles, Journals
f) Calculation and design: on the basis of data, best fit bio-engineering solution has been provided in association with necessary civil structures.
g) Data Analysis/Comparison and validation: Cost of bio-engineering works has been calculated in the basis of thumb rule (based on literature) and is compared with the

probable cost (estimation) of civil works for mitigation of the landslide. The calculations were carried out as:

- Cost of bio-engineering was calculated as per proposed design. The rate analysis was used from relevant literature
- Cost for civil structures was estimated on the basis of unit rate captured fromliterature and was validated with municipal estimation;
- Cost of bio-engineering and cost for civil structures has been compared alongwith the social and environmental benefits.

3. Result and discussion

For the selection of appropriate bio-engineering technique, average length and average slope of the landslide are primary factors. Beside these, width of the landslide along with depth of the landslide, moisture content (including information about drainage system) are required. Four landslide sites in ward no1 of Kageshwara Manohara Municipality were selected for the study.

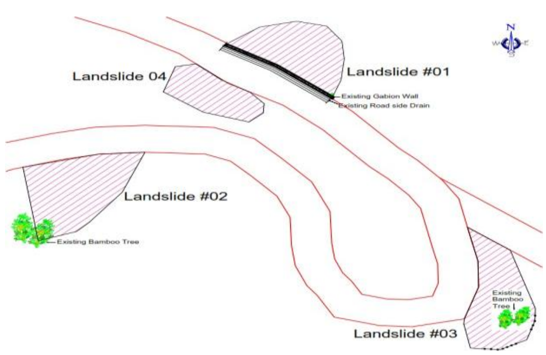


Fig1: Plan of Landslide (Field Survey, 2023) Fig2: Image of Landslide (Source: google map)

3.1 Description of Landslide of different zone

Landslide 1

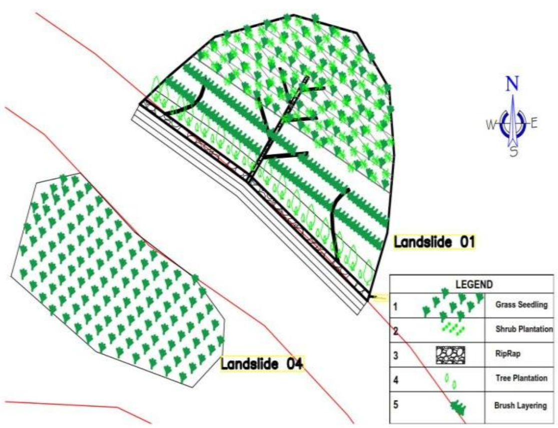
The landslide#1 measures 30m in both length and width, has a 45m slope angle, a depth less than 0.5m, and moderate material drainage. The aspect is south-facing, the site moisture is dry, and no gully erosion is noted. The measurement of the landslide 1 and other environmental factors are presented table 1

Table 1: Landslide Measurement

Description	Landslide #1
Average Length:	30m
Average Width:	30m
Average Slope Angle:	45m
Average Depth:	< 0.5
Material Drainage	Moderate
Aspect	South
Site Moisture	Dry
Gully erosion	no

Fig 3: Picture of Landslide 1

The potential solution for Landslide 1 is represented in Figure below:



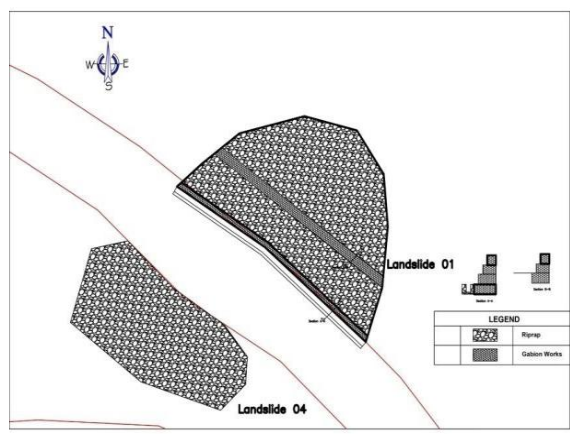


Figure 4: Proposed Bio-engineering solution for Landslide 1

Figure 5: Proposed Civil engineering solution for Landslide 1

In figure 4, bioengineering measures include planting trees at the base (Tree Plantation at Toe) to fortify the soil and prevent erosion, implementing a layer of brushwood on the slope (Brush Layering) for soil control and vegetation growth, introducing shrubs diagonally (Diagonal Shrub Plantation) to enhance soil structure and minimize runoff, establishing grass along contour lines (Contour Grass Plantation) to reduce water runoff and prevent erosion, and using stonesor hard materials (Rip-rap) as a protective layer to dissipate water energy and prevent further soil degradation. Together, these strategies aim to promote stability, control erosion, and restore the ecological balance of the affected area.

In figure 5, To prevent landslides, proposed civil engineering solutions include constructing gabion walls at the toe and middle of the slope. These structures, made of wire baskets filled with rocks, provide crucial support, contain soil, and minimize erosion. Rip-rap, involving the use of durable materials like stones, serves as a protective layer to dissipate water energy and prevent soil degradation. Additionally, implementing an effective drainage system is suggested to manage water flow and reduce the risk of landslides by alleviating excess water pressure in the soil. Collectively, these measures aim to enhance slope stability and prevent potential landslides.

Landslide 2

The landslide 2, measures 22m in length and 18m in width, has a 60 slope angle, a depth less than 0.5m, and moderate material drainage. The aspect is south facing, the site moisture is dry, and two number of gully erosion is noted. The measurement of the landslide 2 and other environmental factors are presented table below:

Table 2: Landslide Measurement

Description	Landslide #2
Average Length:	22m
Average Width:	18m
Average Slope Angle:	60
Average Depth:	<0.5
Material Drainage	Moderate
Aspect	South
Site Moisture	Dry
Gully erosion	Yes, 2 nos.

Figure 6: landslide at zone 2

The potential solution for Landslide 2 is represented in Figure below:

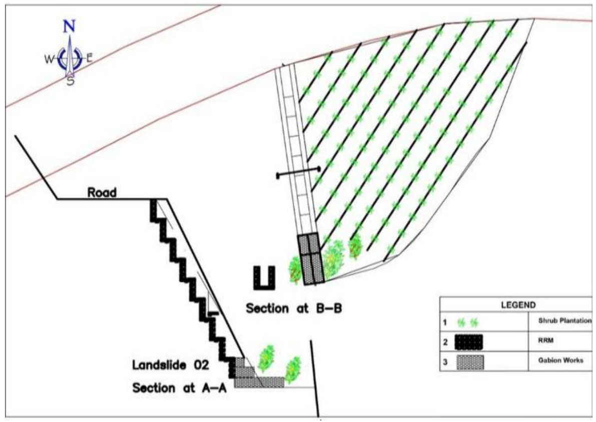


Figure 7: Proposed Bio-engineering solution for Landslide 2

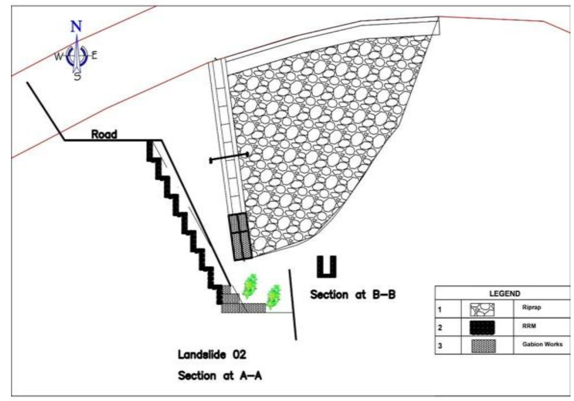


Figure 8: Proposed civil structure for Landslide2

In figure 7, A diagonal shrub plantation is employed to enhance soil stability and reduce surface water runoff.A chute is implemented to control the flow of debris and water, preventing excessive erosion. Additionally, a gabion wall with vegetation is constructed to provide structural support and ecological stability. Finally, a launching apron at the base of the slope absorbs the impact of falling debris, minimizing erosive forces and reinforcing overall slope resilience.

In figure 8, Solution including the implementation of a Chute (RRM) to control debris and water flow. A Gabion wall is constructed to provide structural support and contain soil movement. The introduction of a Launching Apron at the slope's base absorbs falling debris impact, reducing erosive forces. Additionally, Rip-rap is employed to create a protective layer, mitigating erosion and enhancing overall slope stability.

Landslide 3

The landslide 3, measures 15m in length and 25m in width, has a 50 slope angle, a depth less than 0.5m, and moderate material drainage. The aspect is South-East facing, the site moisture is dry, and three number of gully erosion is noted. The measurement of the landslide 3 and other environmental factors are presented table below

Table 3: Landslide measurement

Description	Landslide #3
Average Length:	15 m
Average Width:	25 m
Average Slope Angle:	50
Average Depth:	<0.5
Material Drainage	Moderate
Aspect	South-East
Site Moisture	Dry
Gully erosion	Yes, 3nos.

Figure 9: Landslide at zone 3

The potential solution for Landslide 3 is represented in Figure below:

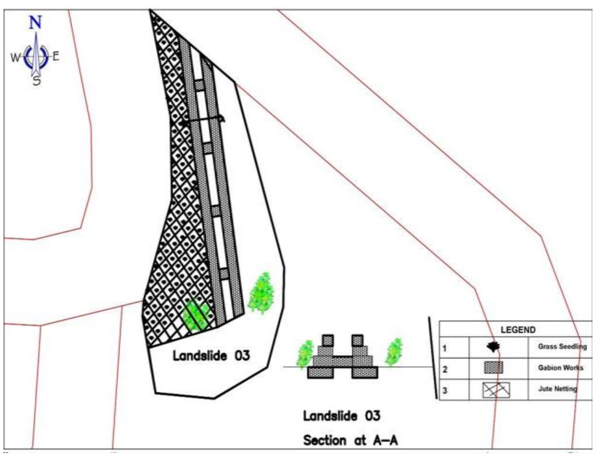


Figure 10: Proposed bioengineering solution

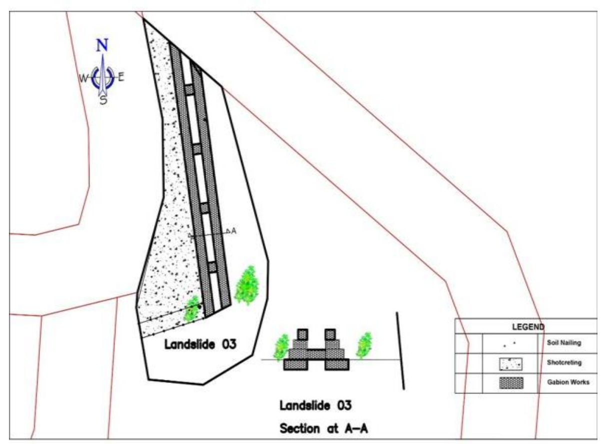


Figure 11: Proposed civil structure solution for landslide 3

Figure 10, shows the application of jute netting and grass seeding to promote vegetation growth, which aids in preventing soil erosion and enhancing the stability of the slope. Additionally, Gabion Retaining walls are being constructed on both side slopes, providing essential structural support to contain soil movement and prevent further destabilization. Another crucial measure involves the installation of a Check Dam using Gabion structures, acting as a barrier to slow down water flow, reduce erosion, and impede the transport of debris downslope.

Figure 11, shows the construction of gabion retaining walls on both side slopes to provide structural support and prevent further destabilization. A check dam, likely is recommended to slow water flow and minimize erosion. Additionally, shotcrete with soil nailing is suggested to reinforce and stabilize the slope.

Landslide 4

The landslide 4, measures 15m in length and 5m in width, has a 60 slope angle, a depth less than 0.5m, and moderate material drainage. The aspect is South-West facing, the site moisture is dry, no gully erosion is noted .environmental factors are presented table below:

Table 4: Landslide measurement

Description	Landslide #4
Average Length:	15 m
Average Width:	5 m
Average Slope Angle:	60
Average Depth:	<0.5
Material Drainage	Moderate
Aspect	South-West
Site Moisture	Dry
Gully erosion	No

Figure 12: Landslide Zone

The potential solution for Landslide 4 is represented in Figure below:

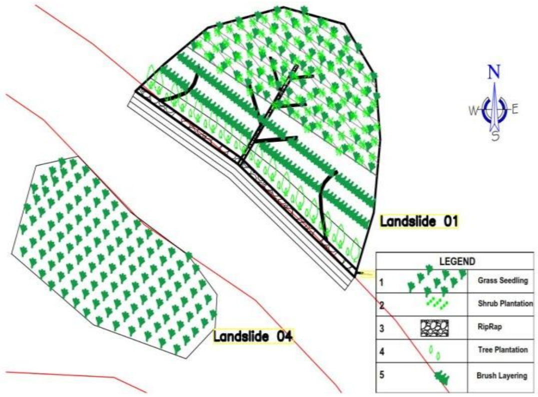


Figure 13: Proposed bioengineering solution for landslide 4

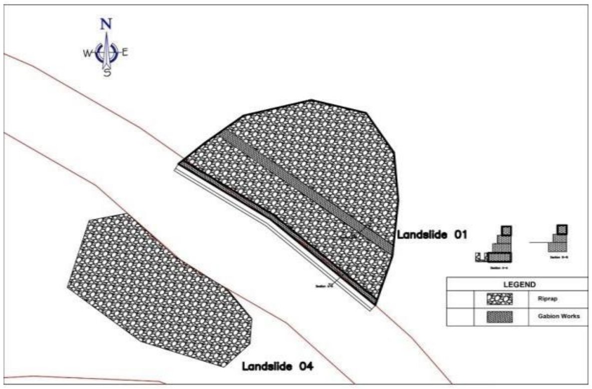


Figure 14: Proposed civil structure solution for landslide 4

Figure 13, shows implementation of diagonal/vertical plantation. This strategy entails planting vegetation in a diagonal or vertical pattern across the affected slope. The purpose of this plantation is to reinforce the soil structure and stabilize the landslide-prone area. Diagonal/Vertical Plantation serves multiple purposes. Firstly, the planted vegetation assists in reducing the velocity of surface water runoff, minimizing erosion and promoting soil retention. The roots of the plants play a crucial role in binding the soil particles, preventing them from being easily displaced.

Figure 14 shows specific Civil engineering solution, which involves the implementation of rip-rap. Rip-rap is a protective measure that utilizes durable materials such as stones to create a robust layer on the affected slope. This layer serves as a barrier against erosion,helping to dissipate the energy of flowing water and preventing further degradation of the soil. The use of rip-rap in Landslide #4 is intended to stabilize the slope, control erosion, andcontribute to the overall mitigation of the landslide risk in that particular area.

3.2 Abstract of Cost of Proposed Bioengineering and civil structure works

The quantity of various bioengineering works is determined by analyzing the drawings. This calculation involves employing established norms, specifically the Department of Roads (DOR) norms for bioengineering works, to facilitate a comprehensive Rate Analysis. The rates for labor,plants, and equipment are sourced from the District Rate of Kathmandu District.

Table 5: Estimated cost of bioengineering system

LANDSLIDE AT ADHIKARI TOLE, KAGESHWARI MANOHARA MUNICIPALITY-1,KATHMANDU, NEPAL					
Abstract of Cost					
Item No.	**Description**	**Unit**	**Quantity**	**Rate (NRs.)**	**Amount**
	Bio-engineering Work				
1	Tree Plantation	Nos.	10.00	250.00	2,500.00
2	Shrub Plantation	Nos.	533.00	250.00	133,250.00
3	Brush Layering	Rm	47.00	550.00	25,850.00
4	Grass Plantation	Sqm	446.00	200.00	89,200.00

5	Jute netting	Sqm	109.00	100.00	10,900.00
6	Earthwork excavation	Cum	174.95	350.00	61,232.50
7	Riprap	Cum	7.10	2,500.00	17,750.00
8	Dry stone soling	Cum	5.40	2,500.00	13,500.00
9	PCC (M20)	Cum	2.70	13,000.00	35,100.00
10	Rubble Random Masonry works	Cum	42.35	12,000.00	508,200.00
11	Gabion Works	Cum	368.00	5,000.00	1,840,000.00
	Total				**2,737,482.50**
				Total Cost of Part (1-11)	**2,737,482.50**
				VAT @13%	355,872.72
				Contingency @ 4%	109,499.30
				Grand Total	**3,202,854.52**

The estimated cost for the implementation of the proposed bioengineering system amounts to Rs. 32,02,854.52.

Table 6: Estimated cost of Civil Structure work

LANDSLIDE AT ADHIKARI TOLE, KAGESHWARI MANOHARA MUNICIPALITY-1,KATHMANDU, NEPAL

Abstract of Cost

Item No.	Description	Unit	Quantity	Rate (NRs.)	Amount
	Civil-engineering Work				
1	Earthwork excavation	Cum	712.90	350.00	249,515.00
2	Riprap	Cum	160.80	2,500.00	402,000.00
3	Dry stone soling	Cum	24.40	2,500.00	61,000.00
4	PCC (M20)	Cum	7.20	13,000.00	93,600.00
5	Rubble Random Masonry works	Cum	188.35	12,000.00	2,260,200.00
6	Gabion Works	Cum	368.00	5,000.00	1,840,000.00
7	Shortcrete	Cum	10.90	21,000.00	228,900.00
8	Soil Nailing	Rm	545.00	300.00	163,500.00
	Total				**5,298,715.00**
				Total Cost of Part (1-8)	**5,298,715.00**
				VAT @13%	688,832.95
				Contingency @ 4%	211,948.60
				Grand Total	**6,199,496.55**

The estimated cost for the implementation of the proposed Civil engineering system amounts to Rs. 61,99,496.55.

The cost analysis revealed that the expenditure for bioengineering measures amounted to NRs. 3,202,854.52, while civil engineering works incurred NRs. 6,199,496.55. Typically, the cost ratio between bioengineering and civil engineering is expected to be 1:3. However, due to the inclusion of water management components like stream chutes and riprap in bioengineering, the observed ratio is closer to 1:1.94.

Cost for Bio-engineering Works (NRs.)	**3,202,854.52**
Cost for Civil Engineering Works (NRs.)	**6,199,496.55**
Differential Amount (NRs.)	**2,99,6642.03**
Differential %	1.94
Ratio	**1:1.94**

4. Conclusion:

Appropriate bio-engineering technique, average length and average slope of the landslide are primary factors for selecting of appropriate bio-engineering technique. Beside these, width of the landslide along with depth of the landslide, moisture content (including information about drainage system) are required. Four landslide sites in ward no1 of Kageshwara Manohara Municipality were selected for the study.

Based on this data and suggestion from the expert, various bioengineering and civil engineering techniques were proposed for soil stabilization and erosion control. Bioengineering measures such as grass seeding, shrub and tree plantation, brush layering,jute netting, along with civil engineering methods like riprap, gabion work, soil nailing, shotcrete, chutes, and drains are suggested. Bio-engineering works holds significant advantages and importance when compares to traditional civil engineering solutions in the context of mitigating landslides. While civil engineering works have traditionally focused on rigid structures such as retaining walls and slope stabilization techniques, bio-engineering offers a more holistic and sustainable approach that leverages the natural processes of plant growth. The cost analysis revealed that the expenditure for bioengineering measures amounted to NRs. 3,202,854.52, while civil engineering works incurred NRs. 6,199,496.55. Typically,the cost ratio between bioengineering and civil engineering is expected to be 1:3. However, due to the inclusion of water management components like stream chutes and riprap in bioengineering, the observed ratio is closer to 1:1.94ecological systems to enhance the natural processes of plant growth and ecological systems to enhance slope stability and prevent landslides. - engineering works are less expenditure and environment friendly comparison to civil engineering works.

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