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AMERICAN JOURNAL OF AGRICULTURAL SCIENCE, ENGINEERING, AND TECHNOLOGY (AJASET)

ISSN: 2158-8104 (ONLINE), 2164-0920 (PRINT)

VOLUME 7 ISSUE 2 (2023)

PUBLISHED BY: E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Agricultural Science, Engineering, and Technology (AJASET)

Volume 7 Issue 2, Year 2023
ISSN: 2158-8104 (Online), 2164-0920 (Print)
DOI: https://doi.org/10.54536/ajaset.v7i2.1383
https://journals.e-palli.com/home/index.php/ajaset

Problems Associated with the Implementation of Bioengineering in Hill Road Construction in Nepal

Prashant Shah[1*], Khetraj Dahal[2]

Article Information

Received: March 12, 2023
Accepted: April 13, 2023
Published: April 17, 2023

Keywords
Hill Road Construction, Bioengineering, Krishna Bhir, Jogi Mara, Banpea-Bardibas Highway, Landslide, Relative Importance Index

ABSTRACT

The landslide disaster, feeble geology, rapid deforestation, poor drainage system, and increase in mechanical strain have weakened the Krishna Bhir slope, Prithvi Highway, Dhading, Nepal. The objective of this article was to study the problems associated with bioengineering implementation in hill road construction with recommendations. For primary research, a map study, field observation, in-depth interview, focus group discussion, and questionnaire survey were used as an instrument for the field study. Published reports, papers, a thesis, database, manuals, and field observation were also reviewed. The landslide caused loss of property, ill effects on lifestyle, disturbance in the movement of goods and services, loss of availability of water due to damage to the water supply system, damage to the sewage disposal system, etc. During the construction period using the bioengineering technique, the major problem occurred during the installation of the bioengineered system (RII = 0.791), lack of training during construction (RII = 0.839), unavailability of space (RII = 0.817), inadequate supply of appropriate instruments (RII = 0.821) and improper selection of vegetation types (RII=0.839). The major problems were also seen during site monitoring and evaluation (RII= 0.853). Proper selection of plant species (RII=0.936) before implementation of the bioengineering technique is needed at hill roads, but the high installation costs (RII=0.841) could be the major limitation. Bioengineering application has a bright future if proper actions are taken in time. Solutions need to be formulated and implemented by understanding the major limitations of bioengineering techniques.

INTRODUCTION

Bioengineering is an alternative to the usual engineering techniques where vegetation is used as a primary tool. It uses green infrastructure to protect from natural calamities like a landslide, soil erosion, etc., in the form of soil stabilization and improved drainage function (Salter *et al.*, 2020). Civil engineering has been incorporating the concept of bioengineering to reduce the overall cost of the mitigation measures used for the landslide. The immediate protection in the form of the physical structure is provided by physical construction techniques, whereas vegetation techniques used in bioengineering need time to show its effect (Shrestha *et al.*, 2008). Nepalese geology has also been very favorable to bioengineering techniques in recent times due to its cost-effectiveness, low labor cost, and local availability of useful materials (Y. P. Dhital *et al.*, 2013).

Nepal is a mountainous country consisting of three major regions namely mountains, hills, and terai. Most hill districts of Nepal lack adequate rural transportation resulting in isolation, poor access to markets, high prices of commodities, irregular public services, and low economic opportunities (M. R. Dhital, 2015). To address the above-said social inequalities and physical, social, and economic hardship to the local people due to lack of access, the Government of Nepal has given high priority to constructing hill roads as prime infrastructure services to assist in realizing the goal of alleviation of poverty. The construction of the road in these regions has become a major challenge which has introduced the concept of Green Road and Bio-engineering techniques for solving these problems (Department of Roads, 2073). The concept of bioengineering in hill road construction was introduced in Nepal 40 years ago with roadside plantations in a US-assisted project on the Dhangadhi-Dadeldhura highway in western Nepal (Department of Roads, 2019). Nepal has been suffering from water-induced disaster problems, including soil erosion, debris flow, landslides, and flooding are common due to the unstable landscape. Soil erosion is the most important driving force for the degradation of upland and mountain ecosystems. The main soil bioengineering techniques used in Nepal are brush layering, palisades, live check dams, fascines, and vegetative stone pitching (Chalise & Kumar, 2019).

The Krishna Bhir is a cliff located in Dhading District by the side of the Prithivi highway, approximately 83 km from Kathmandu Valley. The landslide disaster at Krishna Bhir has become very infamous due to its serious and dreadful effects which have worsened the socio-economic and environmental condition of the region. The feeble geology, rapid deforestation, poor drainage system, and increase in mechanical activities have further weakened the Krishna Bhir slope leading to frequent landslides. Bioengineering was applied to this area by the Department of Road, Nepal in order to stop the mass movement of the hill slope and to strengthen it. Although it was an effective solution, the Krishna Bhir

[1] Department of Construction Engineering and Management (CEM), Nepal
[2] Lumbini International Academy of Science and Technology, Lalitpur, Nepal
[*] Corresponding author's email: prashantlife@gmail.com

slope has reverted back to its volatile state again (Maskey, 2016). Hence, this article evaluates the problems of hill road construction at Krishna Bhir using bioengineering techniques with future recommendations to prevent impending landslide problems.

METHODS

This study utilizes both primary as well as secondary research. A mixed method research is used in the study where the combination of both qualitative as well as quantitative data is used in order to answer the designated research question. Primary data was collected through a semi-structured questionnaire, focus group discussion, In-depth interviews (IDI) with key informants, and direct field observation. Secondary data regarding the research was collected from published and unpublished literature of the department of roads, Detailed project report (DPR) of Krishnabhir, different publication of Department of Road (DoR) books, newspapers, journals, research papers, and from different related concerned offices.

The study area for the study covered two selective sites which include Krishnabhir (Jogimara) and Banepa Bardibas Highway. A total of 240 respondents were selected for the survey which included 180 technical respondents (engineers and sub-engineers) and 60 non-technical respondents (community people, traffic police). For quantitative data, a set of multiple choice questionaries' was prepared for all the respondents where Likert's scale was used to get views of each respondent with a scale ranging from 1 to 5 Relative importance index (RII) was used to summarize the impact of each problem indicator (Azman *et al.*, 2019).

$RII = \Sigma W / (N * A)$

Where, W = Weighting as assigned on Likert's scale by each respondent in a range from 1 to 5, (1 = no impacts, 2 = negligible impact, 3 = marginal impact, 4 = moderate impact and 5 = major impact).

A = Highest weight (here it is 5)

N =Total number in the sample

For the qualitative data, field observation was carried out by personal visitation to the construction sites and collection of information. MAP surveys are derived from traditional private sector distribution surveys using Lot Quality Assurance Sampling (LQAS) (Duarte & Wong, 2019). The IDI was carried out among the six experts who were highly experienced and qualified in the field of road maintenance and construction works. Semi-structured interview questionaries' were prepared for the respondents and the response was recorded in the form of a video as well as a written text. Focus group discussions (FGD) were carried out between road construction experts, road users, road supervisors, and construction contractors. The qualitative data were analyzed using descriptive statistics and presented in the graphical form of charts, figures, and tables. Computer software and Microsoft Office Tools were used for the overall data analysis. Privacy, confidentiality, and anonymity were maintained throughout the research and written consent was taken from all the selected participants.

RESULTS

Socio-Demographic Data

The general socio-demographic information of the respondents revealed that most of them were from the age group of 40-49 (technical, 53%) and 18-29 (non-technical, 48%). Most of the technical as well as non-technical respondents were male (79% and 73% respectively). Most of the technical respondents were engineers (54%), employed (57%), had an experience of more than 5 years (65%) and were involved in non-governmental jobs (66%). The non-technical respondents were mostly farmers (34%) and local representatives (33%).

Problems Due to Landslide

According to the survey conducted among 240 respondents, Figure 1 shows that areas hit by the landslide that had fragile rocks mostly suffered problems of roads being washed away, road blockage, traffic problems, damage to a drainage system, loss of trees, loss of property, and increase of accidents. Most of the respondents agreed that all of the above were the major problems in the landslide-hit area. In addition, most of the respondents agreed that there was a loss of property and lifestyle (79%), disturbance in the maintenance of goods

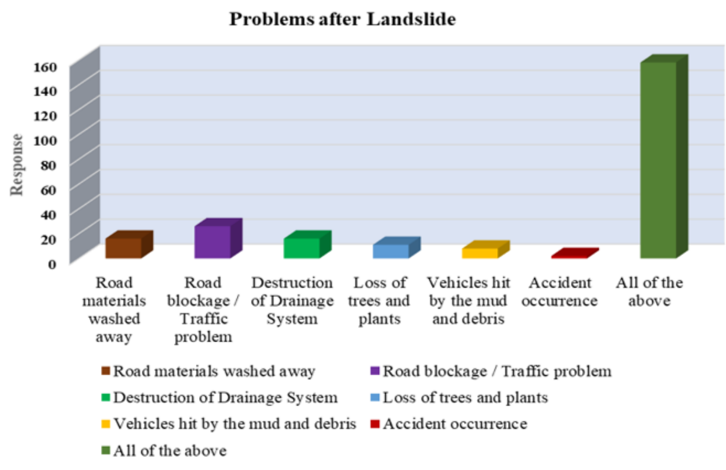

Figure 1: Major Problems after landslide

Table 1: Perception on problems after landslide

n = 240			
Items	**Yes**	**No**	**Maybe**
Loss of property and lifestyle	79%	7%	14%
Disturbance on movement of goods and services	57%	7%	36%
Loss of water availability, quantity and quality	79%	7%	14%
Damage water supply system.	60%	36%	4%
Damage sewage disposal system	58%	39%	3%

and services (57%), loss of water availability, quality, and quantity (79%), damage to water supply system (60%) and damage to sewage disposal system (58%) due to landslide.

Problems Before Construction Period

Table 2 shows that among 180 respondents, the majority of them agreed that the improper planning at the office before construction, inadequate priorities of office work before project execution, improper division of site segment, problems with access to site, lack of determining civil engineering works, improper selection of bioengineering technique, improper design of the civil engineering structure and bioengineering system, improper calculations of required quantities and rates, problems in budget finalization and improper preparation of documents for the project were major hurdles before the implementation of the construction work. The inadequate priorities of office work before project execution (RII= 0/954, Mean=4.772) was the major problem before construction work started using the bioengineering techniques.

Table 2: Problems Before Construction Work (n=180)

Item	Frequency of "5" responses	Frequency of "4" responses	Frequency of "3" responses	Frequency of "2" responses	Frequency of "1" responses	Weighted total	RII	Item Mean
Improper planning at office	118	25	14	12	11	767	0.852	4.261
Inadequate priorities of office work	165	3	4	2	6	859	0.954	4.772
Improper divisions of site segment	125	35	14	2	4	815	0.906	4.528
Assess to site	107	30	17	19	7	751	0.894	4.172
Lack of determining civil engineering works	116	48	10	2	4	810	0.826	4.500
Lack of selection of right bioengineering technique	147	21	6	2	4	845	0.939	4.694
Improper design of civil engineering structures and bioengineering system	157	11	6	2	4	855	0.950	4.750
Improper calculations of required quantities and rates	91	37	19	22	14	718	0.798	3.923
Budget finalization	85	47	19	11	18	710	0.789	3.944
Improper arrangements of implementation and preparation of the documents	104	37	12	19	8	750	0.833	4.167

Problems During Construction Period

According to Table 3, the improper installation of a bioengineered system (RII = 0.791, Mean = 3.956) was the main problem during the construction period using the bioengineering technique. In terms of the involvement of the local community during construction, lack of training (RII = 0.839, Mean = 4.194) was the major hurdle that caused the lack of involvement. In terms of transportation of the construction material, damaged road conditions (RII= 0.777, Mean= 3.883) were also another major hurdle that created problems in construction. The unavailability of space (RII=0.817, Mean=4.083) during the storage of construction material created another major problem during the construction works. There were no major disasters during the construction according to the respondents. The inappropriate supply of construction materials (RII= 0.821, Mean= 4.106) caused major problems in the mobilization of the construction equipment during the construction phase. In terms of mobilization of manpower, lack of training for the workers before and during the construction period (R= 0.839, Mean=4.194) posed a major construction problem.

The improper selection of the vegetation types (R=0.839, Mean= 4.194) during the construction phase also caused problems in the proper utilization of the available plant species. Bioengineering is only successful if there is the availability of a proper seed bed, but there was the unavailability of seedbed preparation at the site due to a lack of seedbed fertilization (R=0.829, Mean= 4.144). Political issues also caused problems during construction when the demand for a job for political workers increased (R=0.891, Mean= 4.456) at the construction site.

Table 3: Problems During Construction Work

Item	Frequency of "5" responses	Frequency of "4" responses	Frequency of "3" responses	Frequency of "2" responses	Frequency of "1" responses	Total respondents	Weighted total	RII	Item Mean
Site Clearance	14	49	36	37	44	180	492	0.547	2.733
Incorrect method of slope stabilization	86	20	22	32	20	180	660	0.733	3.667
Inaccurate selection of plant species	54	48	36	26	16	180	638	0.709	3.544
Installation of bioengineered system	95	36	15	14	20	180	712	0.791	3.956
Improper use of bioengineering materials	29	14	61	51	25	180	511	0.568	2.839
Problem due to inadequate involvement of local community									
Lack of awareness about Bioengineering Principle	57	29	33	17	44	180	578	0.642	3.211
Lack of training	121	15	12	22	10	180	755	0.839	4.194
Demand more salary	61	48	39	16	16	180	662	0.736	3.678
Threat from local community	13	36	20	24	87	180	404	0.449	2.244
Problems due to transportation of construction material at the site									
Lack of raw materials	57	29	33	17	44	180	578	0.642	3.211
Shortage of drivers	15	27	25	18	95	180	389	0.432	2.161
Damaged road conditions	85	38	24	17	16	180	699	0.777	3.883
Landslide and flood	19	34	17	23	87	180	415	0.461	2.306
Traffic issues	57	19	54	13	37	180	586	0.651	3.256
Problems due to storage of construction material at the site									
Lack of proper assessment	78	19	23	17	43	180	612	0.680	3.400
Unavailability of space	87	53	17	14	9	180	735	0.817	4.083
Local community issues in their private land	37	34	19	23	67	180	491	0.546	2.728
Problems associated with mobilization of manpower									
Lack of training before and after the construction period	113	27	13	16	11	180	755	0.839	4.194
Insufficient number of skilled manpower	66	62	27	9	16	180	693	0.770	3.850
Inadequate involvement of local community	41	35	14	23	67	180	500	0.556	2.778
Inadequate installer (un familiar with bioengineering principle)	9	34	17	43	77	180	395	0.439	2.194
Safety management	8	29	18	37	88	180	372	0.413	2.067
Problem associated with mobilization of plant and species at the site									
Improper covering of surface due to deep slope	20	27	43	59	31	180	486	0.540	2.700
Improper selection of vegetation types	109	32	17	9	13	180	755	0.839	4.194
Improper selection of plant propagation	53	55	14	23	35	180	608	0.676	3.378
Improper functioning of armour	15	34	21	43	67	180	427	0.474	2.372
Difficult to follow of contour walting	9	29	28	46	68	180	405	0.450	2.250
Problems associated with unavailability of seed bed preparation at the site									
Insufficient work space	43	37	33	38	29	180	567	0.630	3.150
Lack of irrigation system	44	32	17	22	65	180	508	0.564	2.822
Unavailability of locally adapted plants	56	55	14	23	32	180	620	0.689	3.444
Unavailability of seed bed fertilization	90	57	11	13	9	180	746	0.829	4.144
Problem associated with political issues during construction period									
Influence on tender award	14	37	33	38	58	180	451	0.501	2.506

Demand of job to political worker	131	25	8	7	9	180	802	0.891	4.456
Demand of commission	83	45	14	17	21	180	692	0.769	3.844
Delay due to strike and protest	26	47	21	41	45	180	508	0.564	2.822

Benefits After Bioengineering

Among the 180 technical respondents, the majority agreed that after the implementation of bioengineering construction works, the maintenance costs of the live plants around that area decreased after their establishment (RII= 0.972, Mean= 4.861). Other changes that were seen include slope stabilization, erosion control, low cost and long-term maintenance cost than traditional methods, groundwater control, environmental benefits of wildlife habitat, etc. (Table 4).

Table 4: Benefits after bioengineering (n=180)

Item	Frequency of "5" responses	Frequency of "4" responses	Frequency of "3" responses	Frequency of "2" responses	Frequency of "1" responses	Weighted total	RII	Item Mean
Slope stabilization	24	29	30	34	63	457	0.508	2.539
Erosion control	138	28	8	2	4	834	0.927	4.633
Low cost and long-term maintenance cost than traditional methods	124	27	12	9	8	790	0.878	4.389
Control ground water	22	11	45	53	49	444	0.493	2.467
Low maintenance of live plants after they established	166	7	4	2	1	875	0.972	4.861
Environmental benefits of wild life habitat	85	52	23	18	2	740	0.822	4.111
Improved water quality and quantity	45	78	18	14	25	644	0.716	3.578
Improved strength overtime as root system develop and increases structural stability	47	30	21	37	45	537	0.597	2.983
Promotion of aesthetic values	120	41	10	5	4	808	0.898	4.489
Engagement of local community staff	68	22	24	18	48	584	0.649	3.244
Reduce disaster	78	39	25	21	17	680	0.756	3.778
Development of agricultural land	35	26	29	35	55	491	0.546	2.728
Improve the life span of road pavement	128	32	11	6	3	816	0.907	4.533

Problems After Construction Work

According to the respondents, the major problem after the implementation of bioengineering during construction work was seen in site monitoring and evaluation (RII = 0.853, Mean = 4.267) (Table 5). The problems during the maintenance work were seen mainly in the mulching process (RII= 0.184, Mean= 4.072). During the maintenance, the workers were mostly using the improper method of mulching as well as weeding at the planted sites (Table 6).

Table 5: Problems after construction work (n=180)

Item	Frequency of "5" responses	Frequency of "4" responses	Frequency of "3" responses	Frequency of "2" responses	Frequency of "1" responses	Weighted total	RII	Item Mean
Site monitoring and evaluation	121	23	12	11	13	768	0.853	4.267
Removable of lateral support	22	11	45	53	49	444	0.493	2.467
Routine maintenance	69	47	28	22	14	675	0.750	3.750
Animal damage (protect live plant from animals)	87	38	18	22	15	700	0.778	3.889
Natural disaster	41	42	28	41	28	567	0.630	3.150
Human intervention	45	78	18	14	25	644	0.716	3.578
Deforestation	47	30	21	37	45	537	0.597	2.983

Table 6: Problems during site monitoring and evaluation (n=180)

Item	Frequency of "5" responses	Frequency of "4" responses	Frequency of "3" responses	Frequency of "2" responses	Frequency of "1" responses	Weighted total	RII	Item Mean
Protection of planted sites	91	19	41	15	14	698	0.776	3.878
Weeding	87	32	21	17	23	683	0.759	3.794
Mulching	92	46	18	11	13	733	0.814	4.072
Grass cutting	56	7	114	2	1	655	0.728	3.639
Watering	83	28	38	14	17	686	0.762	3.811
Apply for preventive maintenance	67	38	41	23	11	667	0.741	3.706

Purposed Solutions of Problems Before Implementation

Among the 180 technical respondents, most of them agreed to the fact that the proper selection of plants and species (RII= 0.936, Mean= 4.678) could be one of the major solutions to avoid the problems (Table 7). Other solutions include a focus on appropriate design and technology, consideration of plant propagation, proper mobilization of construction equipment and tools, training for the manpower, etc.

Table 7: Purposed solutions of the problems (n=180)

Item	Frequency of "5" responses	Frequency of "4" responses	Frequency of "3" responses	Frequency of "2" responses	Frequency of "1" responses	Weighted total	RII	Item Mean
Appropriate design, technology	134	19	11	9	7	804	0.893	4.467
Proper selection of plant and species	154	12	3	4	7	842	0.936	4.678
Consideration of plant propagation	149	14	8	5	4	839	0.932	4.661
Proper mobilization of construction equipment and tools	56	7	114	2	1	655	0.728	3.639
Provisions of proper training of manpower	138	28	8	2	4	834	0.927	4.633
Proper awareness of bioengineering principles to the local community	41	42	28	41	28	567	0.630	3.150
Proper monitoring and supervisions	129	29	7	9	6	806	0.896	4.478
Proper aware about limit, rules and regulations relating to the bioengineering technique	89	30	16	24	21	682	0.758	3.789
Proper arrangement of water drainage system	64	37	24	29	26	624	0.693	3.467
Proper waste water disposal system	54	47	34	18	27	623	0.692	3.461

Limitations of the Bioengineering Technique

In terms of the major limitations of the bioengineering technique (Table 8), the high construction and installation cost (RII= 0.841, Mean = 4.2056) and the limited amount of locally adapted plants around that area (RII= 0.814, Mean= 4.072) were the most relevant limitations. Other limitations include, taking long term for functioning, construction, and installation cost are high, difficulty to control human or animal traffic at the site, etc.

Table 8: Limitations of bioengineering technique (n=180)

Item	Frequency of "5" responses	Frequency of "4" responses	Frequency of "3" responses	Frequency of "2" responses	Frequency of "1" responses	Weighted total	RII	Item Mean
Installation season is often limited to plant dormant seasons	91	19	41	15	14	698	0.776	3.878

Site access limited	87	32	21	17	23	683	0.759	3.794
The availability of locally adapted plant may be limited	92	46	18	11	13	733	0.814	4.072
Labor needs are intensive and skilled, experienced labor may not be available	56	7	114	2	1	655	0.728	3.639
Installers may or may not be familiar with bioengineering principles and design	83	28	38	14	17	686	0.762	3.811
Alternative practices are aggressively marketed and often more widely accepted by the society and contractors	67	38	41	23	11	667	0.741	3.706
Plant successive rate is only 75 – 80%	45	54	34	25	22	615	0.683	3.4167
Takes long term for functioning	87	44	21	15	13	717	0.797	3.9833
Construction and installation cost are high	114	24	18	13	11	757	0.841	4.2056
Difficult to control human or animal traffic at the site	67	39	24	35	16	649	0.721	3.5856
Due to flood and drought condition, installation may be destroyed	89	31	15	29	16	688	0.764	3.8222
Supplemental planting may be needed after the completion of the project	83	48	12	18	19	698	0.776	3.8778

DISCUSSION

Bioengineering has been utilized in construction management for a very long time and is showing high relevance in recent times. Live vegetation has been in use for a very time in order to reduce soil erosion, for bed stabilization, and to protect seawalls and sand dunes from the force of water. Bioengineering provides long-term protection, which is capable of self-regeneration as well. (Evette *et al*., 2009). The increasing popularity of soil and water bioengineering constructions has paved the way for living plants and supplementary materials to be included in various construction projects. It has also improved the ecological values and the values of landscape aesthetics, together with the technical benefits of the bioengineering technique (Von der Thannen *et al*., 2021). Soil bioengineering has been present in Nepal for 30 years to deal with the problems of erosion on slopes, highway construction, and stabilization of the riverbank. Nepal's landscape has been quite familiar with bioengineering techniques as well and many construction activities have started using different bioengineering techniques. In terms of the projects in Nepal, the major bioengineering technique used are brush layering, palisades, live check dams, fascines, vegetative stone pitching, etc (Y. P. Dhital *et al*., 2013).

Additionally, the above study was conducted to evaluate the effectiveness of bioengineering techniques and the problems encountered while incorporating the bioengineering technique in the construction works at Krishna Bhir and Banepa Bardibas Highway. Both the responses of the technical personnel and the non-technical personnel in the study area were collected to know about the current situation of the construction site, the implementation of the bioengineering technique, its usefulness in the construction area, and its after effect. From the responses obtained, it was concluded that although the bioengineering technique had been beneficial to solve the problems related to landslide and soil erosion, the lack of preparation, design, proper implementation, maintenance, monitoring, evaluation, and other relevant factors had caused the slope and road to revert back to its deteriorating state. According to (Chandra Dahal & Raj Dahal, 2020), poor preparation and maintenance culture are the major problems that affect the projects like the one in this research. The problems in the proper implementation of the bioengineering technique, problems in the transportation of raw materials, problems in the storage of raw materials, lack of community participation, political issues, lack of mobilization of manpower, lack of proper selection of plant species for bioengineering and lack of seedbed for fertilization caused a ruckus during the construction activities. In addition, political influences during the construction phase also caused problems here and there. Projects in Nepal have a high political influence and change its picture according to the people in power which was also seen in this project (Rai, 2008). Not only during the construction period but the improper planning and design of the project before its implementation was also responsible for the future events that occurred in the area. Problems like improper planning at the office before construction, inadequate priorities of office work before project execution, improper division of site segment, problems with access to the site, lack of determining civil engineering works, improper selection of bioengineering technique, improper design of the civil engineering structure and bioengineering system, improper calculations of required quantities and rates, problems in budget finalization and improper preparation of documents for the project were some of the hurdles that created a negative impact on the project even before it started. After the construction was over, the lack of proper maintenance activities, monitoring and evaluation added up to already existing problems. After the evaluation of all the results, it can be clearly seen that the problems occurred due to the unfamiliarity, lack of awareness, lack of knowledge, lack of training and lack of skills among the people that were fully involved in the construction work using the bioengineering technique. Due to lack of proper information and knowledge about the bioengineering technique, the pre and post phase of the construction work suffered a lot. Lack of awareness among the community people also added up to the problems.

The participation of users in up-front decision-making (within the project design and planning phases, including the capacity to make meaningful choices among a series of options offered to them) leads to positive results in terms of any kind of construction project which was lacking in this project (Davidson *et al.*, 2007). People responsible for carrying out the construction design, choosing the bioengineering tools and system, budget finalization, preparation of initial documents, and fixing out priorities seemed to lack proper training and skills to perform their responsibility. The cracks in the initial phase caused the project to get affected in the later phase. Unfamiliarity with the seasonal plants, the importance of seedbeds, vegetation type, and plant selection in construction bioengineering caused many more hurdles leading to an unsatisfactory result.

Although benefits like slope stabilization, erosion control, groundwater control, protection of wildlife habitat, improved water quality and quantity, promotion of aesthetic values, reduction of disaster, development of agricultural land, and improvement in the life span of road pavement were seen (Rey *et al.*, 2019), these were not there to stay for a long term. The failure of the post-implementation maintenance phase created a big question mark on the effectiveness and long-term stability of the construction project. Problems in the protection of planted sites, weeding, mulching, grass cutting, watering, and lack of preventive maintenance caused the implemented construction work to suffer in long term.

So, the technical respondents emphasized that before starting any bioengineering construction works in the future special emphasis should be placed on appropriate design and technology, proper selection of plant and species, proper plant propagation, proper mobilization of construction equipment and tools, proper training of manpower, proper awareness of bioengineering principles to the local community, proper monitoring and supervisions, and proper aware about limit, rules, and regulations relating to the bioengineering technique. With an emphasis on these factors, the projects like these could lead to more successful results in a long term. But every process and procedure has its own limitations. Bioengineering also has its own limitations which need to be considered in the initial phases, so as to receive the least problems in the execution of any projects in the future (Fernandes & Guiomar, 2018). Lack of skilled bioengineering experts, expensive construction and installation costs, the unpredictability of plants, and unfamiliar installation techniques are the major limitations of bioengineering according to this study. Hence, in the future, the projects like the Krishna Bhir construction need to focus on initial phase preparation and post-implementation maintenance together with limitations of the bioengineering implementation for the success and effectiveness of the project.

CONCLUSION

The study focused on the application of bioengineering techniques during the construction of hill roads in Nepal, with specific reference to the Krishna Bhir and Banpea Bardibas highways. Bioengineering can be a very successful tool for any construction project like the one in Krishna Bhir and Banpea Bardibas highway if the focus is shifted to making people aware of bioengineering and providing required training and knowledge to respective personnel. The initial design and preparation phase should be given special consideration so that bioengineering techniques are executed efficiently. During the construction phases manpower utilization, raw material availability, skill development, etc. need to be given special focus for the proper execution of the project. Post-implementation maintenance also needs to go hand in hand with the project so that overall effective result is obtained. Although there were several problems during the hill road construction and post-maintenance, bioengineering application has a bright future if proper actions are taken in time. Solutions need to be formulated and implemented by understanding the major limitations of bioengineering techniques in the near future for the success of it in the hill road construction works.

Abbreviations

IDI - In- depth interviews
DoR - Department of road
DPR - Detailed project report
RII - Relative importance index
LQAS - Lot quality assurance sampling

Declarations

Availability of Data and Materials

All presented data are available under my request.

Author Contributions

All authors contributed to the study development and have read and approved the final version. Preparation of the original project, wrote the manuscript, Formal analysis and investigation, Methodology was written by Prashant Shah and Khet Raj Dahal.

Acknowledgements

The authors would like to thank the team members and supervisors who supported during the research work.

REFERENCES

Azman, N. S., Ramli, M. Z., Razman, R., Zawawi, M. H., Ismail, I. N., & Isa, M. R. (2019). Relative importance index (RII) in ranking of quality factors on industrialised building system (IBS) projects in Malaysia. *AIP Conference Proceedings, 2129*(1), 020029. https://doi.org/10.1063/1.5118037

Chalise, D., & Kumar, L. (2019). Land Degradation by Soil Erosion in Nepal : A Review. *Soil System, 3*(1), 12. https://doi.org/10.3390/soilsystems3010012

Chandra Dahal, R., & Raj Dahal, K. (2020). A Review on Problems of the Public Building Maintenance Works with Special Reference to Nepal. *American Journal of Construction and Building Materials, 4*(2), 39. https://doi.org/10.11648/j.ajcbm.20200402.12

Davidson, C. H., Johnson, C., Lizarralde, G., Dikmen, N., & Sliwinski, A. (2007). Truths and myths about community participation in post-disaster housing projects. *Habitat International, 31*(1), 100–115. https://doi.org/10.1016/j.habitatint.2006.08.003

Department of Roads. (2019). Roadside Bio-Engineering Site Handbook (O. Sattaur (ed.)). Spectrum Offset Press. https://dor.gov.np/home/publication/gesu-publication/roadside-bio-engineering-site-handbook-2-76-1-12

Dhital, M. R. (2015). Geology of the Nepal Himalaya: Regional perspective of the classic collided orogen. In Geology of the Nepal Himalaya: Regional Perspective of the Classic Collided Orogen. *Springer International Publishing.,* https://doi.org/10.1007/978-3-319-02496-7

Dhital, Y. P., Kayastha, R. B., & Shi, J. (2013). Soil bioengineering application and practices in Nepal. *Environmental Management, 51*(2), 354–364. https://doi.org/10.1007/s00267-012-0003-7

Duarte, B. P. M., & Wong, W. K. (2019). Optimal design of multiple-objective Lot Quality Assurance Sampling (LQAS) plans. *Biometrics, 75*(2), 572–581. https://doi.org/10.1111/biom.13008

Evette, A., Labonne, S., Rey, F., Liebault, F., Jancke, O., & Girel, J. (2009). History of bioengineering techniques for erosion control in rivers in western europe. *Environmental Management, 43*(6), 972–984. https://doi.org/10.1007/s00267-009-9275-y

Fernandes, J. P., & Guiomar, N. (2018). Nature-based solutions: The need to increase the knowledge on their potentialities and limits. *Land Degradation and Development, 29*(6), 1925–1939. https://doi.org/10.1002/ldr.2935

Maskey, S. (2016). A Case Study of the Krishna Bhir Slope Failure Disaster: Past and Present Scenario at a Glance. *International Journal of Geological and Geotechnical Engineering, 2*(1), 21-30. https://doi.org/10.37628/jgget.v2i1.78

Rai, K. (2008). The Dynamics of Social Inequality in the Kali Gandaki 'A' Dam Project in Nepal: The Politics of Patronage. Hydro Nepal: *Journal of Water, Energy and Environment, 1,* 22–28. https://doi.org/10.3126/hn.v1i0.881

Rey, F., Bifulco, C., Bischetti, G. B., Bourrier, F., De Cesare, G., Florineth, F., Graf, F., Marden, M., Mickovski, S. B., Phillips, C., Peklo, K., Poesen, J., Polster, D., Preti, F., Rauch, H. P., Raymond, P., Sangalli, P., Tardio, G., & Stokes, A. (2019). Soil and water bioengineering: Practice and research needs for reconciling natural hazard control and ecological restoration. *Science of the Total Environment, 648,* 1210–1218. https://doi.org/10.1016/j.scitotenv.2018.08.217

Salter, D., Howell, J., & Eagle, S. (2020). Bioengineering for Green Infrastructure. *In Asian Development Bank 20. Asian Development Bank*. http://hdl.handle.net/11540/11617

Shrestha, A. B., Karim, R., & Shah, S. H. (2008). Resource Manual on Flash Flood Risk Management Module 1: Community-based Management. International Centre for Integrated Mountain Development. https://www.researchgate.net/publication/237555620_Resource_Manual_on_Flash_Flood_Risk_Management_Module_1_Community-based_Management

Von der Thannen, M., Hoerbinger, S., Muellebner, C., Biber, H., & Rauch, H. P. (2021). Case study of a water bioengineering construction site in Austria. Ecological aspects and application of an environmental life cycle assessment model. *International Journal of Energy and Environmental Engineering, 12*(4), 599–609. https://doi.org/10.1007/s40095-021-00419-8