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Application of the Analytical Hierarchy Process in Selecting Natural Fibers for Limited-Life Geosynthetics

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Abstract: *This study uses the Analytical Hierarchy Process (AHP) to identify the most suitable natural fiber (coir, banana, and pineapple) for limited-life geosynthetics (LLGs) in slope stabilization projects in the Philippines. AHP is a widely used method that simplifies complex decisions by structuring criteria into a hierarchy and assigning weights based on expert judgment. These fibers were assessed using expert surveys, ranking their properties (tensile strength, tear strength, compression resistance) and geosynthetic functions (reinforcement, drainage, protection, filtration, separation). Current results point towards coir fiber as the most suitable due to its high tensile strength and reinforcing properties, with CR and CI values below 0.1. Pineapple fiber followed, with its balanced performance in hydraulic functions, while banana fiber showed strength in separation but underperformed in structural criteria in comparison. For more accuracy, future studies should conduct a larger-scale survey with more respondents and assess more locally-available fibers for different geosynthetic applications.*

Keywords: Soil stabilization; LLG; Natural fibers; MCDM; AHP

1. INTRODUCTION

Geotechnical engineering is a specialized branch of civil engineering focused on the study of earth's materials, their influence on soil behavior, and their impact on the infrastructure longevity [1]. Due to the erratic behavior of soil, structural instability has become a global concern—particularly in tropical countries, like the Philippines, which are susceptible to natural hazards, such as intense rainfall, flooding, and landslides [2]. In the construction industry, traditional methods of soil stabilization commonly use synthetic geosynthetics. While effective, these materials leave behind environmental waste, imposing negative environmental impacts as well as cost-related concerns [3]. In this context, natural fibers are available as an environmentally friendly alternative, with mechanical properties similar to conventional synthetic materials, as they show promising results in sustainability and waste utilization [4]. However, despite their potential, these fibers have not been extensively evaluated in the Philippines as geosynthetics in soil stabilization.

1.1 Research Objectives

This study aims to develop a systematic framework using the Analytical Hierarchy Process (AHP) to select natural fibers for limited-life geosynthetics in soil stabilization. Furthermore, the study focuses on assessing the feasibility and optimizing the application of these fibers in enhancing soil stability. Specifically, the study seeks to achieve the following objectives:

a) Establish and assess the availability and suitability of locally sourced natural fibers for limited-life geosynthetics;
b) Evaluate the key criteria of properties essential for evaluating soil stabilization projects;
c) Apply the AHP framework to select and rank limited-life geosynthetics, analyzing the most suitable fiber for slope stability.

1.2 Scope and Limitations

The study will focus on a range of available fruit-bearing fibers in the Philippines, which include coir, banana, and pineapple, while evaluating their properties that enhance soil stabilization. This aims to evaluate their practicality in slope stability applications within the Philippine construction industry. The exclusion of non-native plant fibers ensures that the findings of this study are directly applicable to local environmental conditions and soil stabilization practices. Additionally, the study will not consider chemical treatments, soil types, and geosynthetic types. Studies published from 2016-2024 will be referenced to formulate tables outlining the properties and functions to be assessed. These properties, shown in Table 1, serve as a guide for the analysis and findings of the study. Functions, on the other hand, will be based on their applicability in separation, drainage, reinforcement, protection, and filtration in infrastructure projects. This study will only consider the key criteria, mainly three mechanical strength properties, namely compression resistance, tear strength, and tensile strength, used to compare fibers based on suitability for soil stabilization, and will exclude advanced factors that are not relevant to the intended geosynthetic applications of the fibers.

Table 1. Properties essential for soil stabilization

	Property
	Weight

Physical Properties	Thickness
	Dimensions (width, length)
Mechanical Properties	Compression resistance
	Tear strength
	Tensile strength
	Puncture resistance
	Elongation
Hydraulic Properties	Permittivity
	Water flow
	Pore opening size

Note: Adapted from "Geotextiles: From design to applications," by R.M. Koerner, 2016.

To ensure that the natural fibers used for limited-life geosynthetics (LLGs) are the most appropriate for soil stabilization, the study will use the AHP selection method. This framework involves data collection and the conduct of a survey among 20 geotechnical experts, who were asked to rank the importance of each criterion, such as the material and strength parameters. The relation of each criterion will be compared and calculated in order to rank and ultimately determine the most suitable fiber for slope stability. Moreover, the effectiveness of the AHP framework is dependent on the accuracy of the criteria weighting process, which is affected by the stakeholders' interpretation of geosynthetic performance data.

1.3 Significance of the Study

The research study proposes the ideal LLGs for soil stabilization, which promotes biodegradable materials over synthetics and aligns with sustainable and cost-effective practices by minimizing waste. Since these materials are designed to last for a specific period, using LLGs does not require costly maintenance or disposal procedures after the project is finished. On the contrary, synthetic materials often need replacement or long-term maintenance, adding to their cost. In short-term infrastructure projects, LLGs offer optimal performance during the project timeline [5]. Given the abundance of natural fibers in the Philippines, many of which are underutilized and become waste. That said, this study aims to effectively use these fibers and address a gap in the current knowledge on the suitability and performance of natural fibers in slope stability. Moreover, the geotechnical engineering industry can optimize the use of natural and clean resources, adopting eco-friendly solutions that align with United Nations Sustainable Development Goal 9: Industry, Innovation, and Infrastructure. Ultimately, the findings of this study would benefit engineering practices by providing data-based insights into the most feasible natural fiber for limited-life geosynthetics.

2. REVIEW OF RELATED LITERATURE

In recent years, environmentally friendly methods have gradually been introduced in geotechnical engineering. With this, multiple studies have investigated the potential of natural fibers as geosynthetics, particularly their ability to enhance soil properties. However, selecting the ideal fiber for limited-life geosynthetics is a thorough process that requires the assessment of multiple variables, such as fiber properties and the overall performance of the geosynthetic. In order to carry out this multiple-criteria decision-making process, studies have proven that the Analytical Hierarchy Process is a reliable method for evaluating and ranking these factors.

2.1 Natural Fibers in Soil Stabilization

The potential of natural fibers for soil stabilization has been widely demonstrated across various studies, where fibers were incorporated to enhance soil properties. Coir fiber (Fig. 1), for instance, has been proven to enhance sub-grade soil strength. Kaushik and Singh [6] conducted California Bearing Ratio (CBR) testing and found that embedding coir at one-third depth (H/3) from the bottom increased CBR values. However, their study did not examine other key parameters such as shear strength or moisture absorption, emphasizing the need for AHP, a more comprehensive evaluation framework, that considers multiple performance indicators. In a separate study, banana leaf ash (Fig. 2) was used as a stabilizing agent. Rao et al. [7] observed that CBR and unconfined compressive strength values improved with 15% ash content. Thomas et al. [8] explored the use of pineapple fiber (Fig. 3) in sandy soil and found that shear strength was maximized at 0.75% fiber content. However, other mechanical and hydraulic properties were not evaluated, limiting the broader applicability of their findings. Collectively, these studies demonstrate the potential of natural fibers for soil reinforcement but also highlight gaps in comprehensive performance assessment and sustainability analysis. This study addresses those gaps by evaluating locally available natural fibers in the Philippines, including abaca, coir, banana, and pineapple, as alternatives to synthetic geosynthetics.

Figure 1. Coconut plant and fibers (coir)

Figure 2. Banana leaves and fibers

Figure 3. Pineapple leaves and fibers

The availability of fibers such as coir, banana, and pineapple is closely related to the production of their respective plants from which they are extracted. The Philippine coconut industry holds a large amount of importance for the agriculture sector as the second largest coconut-producing country in the ASEAN. In 2018, the country produced 14.7 million metric tons (MT) of coconuts, with top-producing regions including

Zamboanga [9], a notable site for extracting coir fibers derived from coconut husks. Since coir is recognized for its applications as a bioengineering material, like coconets [10], used for erosion control. Furthermore, Mindanao accounts for 85% of the national production of bananas, yielding 9.06 million MT in 2020 [11]. Despite fiber extraction not being very common on a commercial scale, recent efforts seek to enhance banana pseudostem fiber extraction through mechanical methods [12]. A significant producer of pineapples is Camarines Norte, which had 2.7 million MT of pineapples in 2020. In addition, pineapple and pineapple products are third as the country's largest export, after banana and coconut [13].

2.2 Limited Life Geosynthetics (LLGs)

LLGs have gained increasing attention in geotechnical engineering due to their ability to enhance soil performance for a specific duration while naturally degrading over time. This not only reduces long-term environmental impact but also aligns with sustainability goals. Recent studies have explored natural fibers as materials for LLGs, particularly in soil stabilization, erosion control, and reinforcement. Harinder and Shankar [14] investigated the use of coir geotextiles to improve sub-grade soils for pavement construction using CBR testing and Wheel Tracking Tests (WTT). Their results showed that incorporating 1% coir fiber significantly increased CBR values, and placing coir mats at one-quarter depth (H/4) minimized deformation. However, their study primarily focused on mechanical properties, emphasizing the need for an approach that includes physical and hydraulic parameters. Deugoué et al. [15] assessed banana-plantain fibers as geotextiles for erosion control, focusing on their tensile strength, elongation, and moisture absorption properties. Notably, the fibers exhibited high elongation and water absorption in wet conditions, which is critical for geotextile performance. Celis [16] explored pineapple leaves as a raw material for geotextiles, concluding that they had higher tensile strength and thinner thickness compared to abaca geotextiles. The tensile strength of pineapple leaf geotextiles (31.886 KN/m) was within the category of filtration geotextiles, demonstrating its potential in erosion control. By comparing the performance of pineapple leaves with other fibers, the overall viability and advantages in LLGs can be evaluated. The aforementioned studies all demonstrate the capability of several natural fibers as geosynthetics. They explore varying treatment methods and additives to the limited-life geotextiles, which improve the soil's tensile strength, mechanical behavior, physical properties, and thermal properties, proving that fibers are significant for enhancing soil properties. These findings are crucial for this study, which will focus on the physical, mechanical, and hydraulic properties of natural fiber geotextiles. From these findings, this study aims to extend current understanding by systematically assessing these properties to identify which fiber is best for each function of soil stabilization.

2.3 Analytical Hierarchy Process (AHP)

AHP is a critical decision-making method that encompasses all variables of complex structures, simplifying them into a hierarchy framework to make a correct assessment based on the relative importance of each factor. In order to ensure the accuracy of the findings, additional values, specifically the consistency ratio (CR) and consistency index (CI), must be below or equal to 0.1 or 10% for utmost accuracy and 0.2 or 20% for acceptable results.

Based on the related literature, there is potential to use the AHP through a questionnaire survey, with the respondents being geosynthetics experts, in assessing various soil properties for slope protection. Due to its simplicity and efficiency, it is widely used by studies from around the world to calculate the significance of uncertain factors. Numerous studies support AHP's effectiveness. Dano [17] used it to identify flood causes and solutions in Saudi Arabia, finding drainage management as the best option. Gonsalves et al. [18] found exoskeletons most useful for repetitive tasks with acceptable CR values (<0.2). Cauba et al. [19] used AHP-GIS to identify 14.5% of Agusan del Norte as suitable for bamboo plantations (CR = 0.05), while Felipe et al. [20] found only 26.47% of Luzon suitable for agrometeorological stations. Their findings are necessary for this research, which aims to utilize the AHP's structured approach to better understand how different natural fibers found in the Philippines contribute best to improving certain functions of soil.

3. METHODS

This study will utilize both qualitative and quantitative research methods. The use of the qualitative method includes the expert judgment gathered through a survey questionnaire to better evaluate the viability of fibers based on their properties for certain geosynthetic functions. The questionnaire, via Google Forms, will be sent to 20 geotechnical engineers with a background in geosynthetic application in civil engineering projects based in the Philippines. These engineers will be asked to rank and compare various fiber properties according to their relevance for limited-life geosynthetics in slope stabilization, as well as assess the performance of different fibers. On the other hand, the quantitative method will be applied to calculate the numerical and relative weights of each fiber to formulate a ranked list of fibers. Based on the related literature, the selected fibers are coir, banana, and pineapple, while key mechanical properties include tensile strength, tear strength, and compression resistance. The geosynthetic functions obtained were separation, drainage, reinforcement, protection, and filtration.

3.1 Data Collection Methods

Through the use of an AHP questionnaire, qualitative data will be obtained from expert judgment provided by geotechnical engineers, while quantitative data will consist of numerical values and weights assigned to the fiber properties and their relative importance based on Saaty's 1980 scale. The sample size will include 20 geotechnical engineers in the Philippines, selected based on the following criteria:

- A Bachelor's degree in Civil Engineering;
- Professional licensure (board passer);
- At least 1 year of experience in Geotechnical Engineering with additional experience in geosynthetics

These engineers will be asked to rank different fibers based on their suitability for each limited-life geosynthetics application. The data collected from the questionnaire will be used to assign weights of relative importance for each fiber to their respective function and application.

3.2 Data Collection Instruments

The study's methodology will utilize AHP, a multiple-criteria decision-making tool developed by Saaty (1980) and widely used in a variety of fields. Previous studies that used this process to evaluate numerous variables were reviewed to visualize the feasibility of AHP to determine the most optimal limited-life geosynthetic. All of the studies were able to ensure accurate and reliable results by calculating the CR and CI. The majority followed the percentage for the highest level of success, wherein the consistency values must be less than or equal to 0.1 (10%). Another study by Awad & Jung [21] relied on a CR and CI of less than or equal to 0.2 (20%) for tolerable but accurate results. This structured decision-making tool allows for a systematic comparison of factors by breaking down complex problems into a hierarchy of sub-criteria, which is particularly suitable for multi-criteria decision-making processes, such as the selection of fibers based on their geosynthetic properties. To ensure maximum accuracy in the calculated results, this study will use the general measure, maintaining the CR and CI at less than or equal to 0.1 (10%). This methodology includes five steps:

a) Define key criteria: The fibers under evaluation include coir, banana, and pineapple. These fibers will be assessed based on their mechanical strength properties, as well as their ability to perform essential functions such as separation, drainage, reinforcement, protection, and filtration in slope stabilization.

Fiber	Properties	Functions
Coir	Compression resistance	Separation
Banana	Tear strength	Drainage
Pineapple	Tensile strength	Reinforcement
		Protection
		Filtration

Table 2.2.1 A list of fibers, properties, and functions

b) Perform the AHP questionnaire: Experts will use Saaty's 1 to 9 scale to rank the relative importance of each fiber for its respective properties and functions. The scale is defined as follows:

Table 2.2.2. Saaty's 1980 scale of relative importance

Intensity of weight	Definition	Explanation
1	Equal importance	Two factors contribute strongly to the objective
3	Weak importance	Experience and judgment slightly favor one activity over the other
5	Essential or strong importance	Experience and judgment strongly favor one activity over the other
7	Very strong importance	Experience and judgment very strongly favor one over the other. Its dominance is demonstrated in practice
9	Absolute importance	The evidence favoring one over the other is of the highest possible validity
2, 4, 6, 8	Intermediate values between the two judgments	When compromise is needed

c) Check consistency: Assess the consistency of expert judgment and pairwise comparison by calculating the CR, which must be less than or equal to 0.1 or 10% to ensure accuracy using Equation 1.

$$CR = \frac{CI}{RCI} \qquad \text{Equation 1.}$$

where RCI is the random consistency index and CI is the consistency index, computed using Equation 2.

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \qquad \text{Equation 2.}$$

where λ_{max} represents the principal eigenvalue and n the number of compared variables.

d) Obtain the final weight of each fiber: Calculate the average of results gained from the questionnaire to derive the final weights for each criterion.

e) Formulate the ranking of fibers: Identify the most suitable fiber based on their final weights.

The following survey questionnaire is designed to gather expert judgments from geotechnical engineers regarding the suitability of different natural fibers for slope protection. The comparisons focus on specific soil properties and functions. The questionnaire is divided into three sections: Fiber Strength Properties, Fiber Functions, and Direct Comparison Between Fibers. Each section includes questions that ask the participants to evaluate the importance of a specific fiber in different aspects.

a) Fiber Strength Properties
   - For soil stabilization, how important is Compression Resistance compared to Tensile Strength in Banana?

- For soil stabilization, how important is Compression Resistance compared to Tear Strength in Banana?
- For soil stabilization, how important is Tear Strength compared to Tensile Strength in Banana?
- For soil stabilization, how important is Compression Resistance compared to Tensile Strength in Coir?
- For soil stabilization, how important is Compression Resistance compared to Tear Strength in Coir?
- For soil stabilization, how important is Tear Strength compared to Tensile Strength in Coir?
- For soil stabilization, how important is Compression Resistance compared to Tensile Strength in Pineapple?
- For soil stabilization, how important is Compression Resistance compared to Tear Strength in Pineapple?
- For soil stabilization, how important is Tear Strength compared to Tensile Strength in Pineapple?

b) Fiber Functions
- How suitable is Banana for Reinforcement compared to Filtration?
- How suitable is Banana for Reinforcement compared to Drainage?
- How suitable is Banana for Reinforcement compared to Protection?
- How suitable is Banana for Reinforcement compared to Separation?
- How suitable is Banana for Filtration compared to Drainage?
- How suitable is Banana for Filtration compared to Protection?
- How suitable is Banana for Filtration compared to Separation?
- How suitable is Banana for Drainage compared to Protection?
- How suitable is Banana for Drainage compared to Separation?
- How suitable is Banana for Separation compared to Protection?
- How suitable is Coir for Reinforcement compared to Filtration?
- How suitable is Coir for Reinforcement compared to Drainage?
- How suitable is Coir for Reinforcement compared to Protection?
- How suitable is Coir for Reinforcement compared to Separation?
- How suitable is Coir for Filtration compared to Drainage?
- How suitable is Coir for Filtration compared to Protection?
- How suitable is Coir for Filtration compared to Separation?
- How suitable is Coir for Drainage compared to Protection?
- How suitable is Coir for Drainage compared to Separation?
- How suitable is Coir for Separation compared to Protection
- How suitable is Pineapple for Reinforcement compared to Filtration?
- How suitable is Pineapple for Reinforcement compared to Drainage?
- How suitable is Pineapple for Reinforcement compared to Protection?
- How suitable is Pineapple for Reinforcement compared to Separation?
- How suitable is Pineapple for Filtration compared to Drainage?
- How suitable is Pineapple for Filtration compared to Protection?
- How suitable is Pineapple for Filtration compared to Separation?
- How suitable is Pineapple for Drainage compared to Protection?
- How suitable is Pineapple for Drainage compared to Separation?
- How suitable is Pineapple for Separation compared to Protection?

c) Direct Comparison Between Fibers
- Which fiber is more suitable for soil stabilization: Banana or Coir?
- Which fiber is more suitable for soil stabilization: Coir or Pineapple?
- Which fiber is more suitable for soil stabilization: Pineapple or Banana?

3.3 Ethical Considerations

All selected participants will be provided with an informed consent form on the first page of the questionnaire. The survey will include the purpose of the study, following the Data Privacy Act of 2012 (Republic Act 10173), and highlight voluntary participation. Furthermore, the consent form will state that all personal information and data collected remains confidential and solely for the study. In order to ensure transparency, the researchers will include a clear explanation of the AHP process and criteria used in the survey. This way, participants will be informed about how the pairwise comparison will be conducted to rank the list of natural fibers. This transparency aids participants in understanding the overall survey process and contributes to a fair and bias-free assessment. By implementing these measures, the study aims to protect the privacy and data integrity of participants while fostering trust and clarity throughout the research.

3.4 Data Analysis

Three types of analyses will be performed: assessment of fibers in different geosynthetic functions, evaluation of fiber properties, and the determination of overall fiber suitability for soil stabilization. Assessment of fibers in different geosynthetic functions focuses on assessing the suitability of each of the specific fiber for a geosynthetic function, (such as Reinforcement, Drainage) Expert judgments will be used to construct pairwise comparison matrices based on the Saaty 1–9 scale, with results normalized to calculate the priority weights of each function. The consistency of the judgments will be evaluated using Equation 2, where max is the largest eigenvalue of the pairwise comparison matrix. First, the matrix is normalized by dividing each element by the sum of its respective column. This way, the values in each column add up to 1,

$$A = \begin{bmatrix} 1 & a_{12} \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} \cdots & 1 \end{bmatrix}$$ Equation 3 [21]

and the comparisons are consistent and scalable. The priority vector is then determined by calculating the average of each row in the normalized matrix. This priority vector represents the relative weights or importance of each property.

$$\begin{bmatrix} 1 & a_{12} \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} \cdots & 1 \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \end{bmatrix} = \lambda_{max} \begin{bmatrix} w_1 \\ w_2 \end{bmatrix}$$ Equation 4 [21]

To confirm the validity of these comparisons, an eigenvalue is computed. This is achieved by multiplying the original pairwise comparison matrix by the priority vector.

$$AW = \lambda_{max} W$$ Equation 5 [21]

The result obtained will be a new vector. Dividing each element of this resulting vector by its value in the priority vector provides the approximations of the eigenvalues. The average of these approximations yields the largest eigenvalue of the matrix. The Consistency Ratio (CR) will then be calculated using Equation 1, and it should have a value of CR 0.1 to indicate acceptable consistency. This analysis will provide insights into the role of different fibers in achieving the desired performance outcomes and will guide the prioritization of fiber selection for specific functions and applications.

The evaluation of fiber properties aims to determine the relative importance of mechanical strength properties in contributing to soil stabilization. This phase focuses on the comparison of specific properties to evaluate their relative importance for a given fiber. Expert assessments will be used to develop two pairwise comparison matrices that systematically assess how one property compares to another in a similar context for the same fiber. This process will be repeated for all fibers to ensure that there is a comprehensive evaluation of property importance across all the options available. Findings from this analysis will be helpful in identifying which properties are most critical for slope applications and which are the most important attributes that contribute to effectiveness.

The determination of overall fiber suitability integrates the results from the previous analyses to calculate a composite score for each fiber. The weights of properties and functions will be aggregated using the formula

$$Score = \sum_{i=1}^{m} w_i \cdot s_i$$ Equation 3.

where w_i is the weight of each criterion, and s_i is the fiber's performance score for that criterion. This step will result in a ranked list of fibers, identifying the most suitable fibers for slope. Findings from this analysis will provide actionable insights into the optimal fiber choice and contribute to informed decision-making in engineering and construction projects.

4. RESULTS AND DISCUSSION

This study aimed to determine the most suitable natural fiber for slope stability applications using the Analytical Hierarchy Process (AHP). The hierarchy was structured across four levels as shown in Figure 4:

- Level I – Overall Goal (Identify the best fiber for slope stability)
- Level II – Criteria Groups (Fiber Strength Properties and Fiber Functional Suitability)
- Level III – Sub-criteria under each group
- Level IV – Alternatives (Banana, Coir, Pineapple)

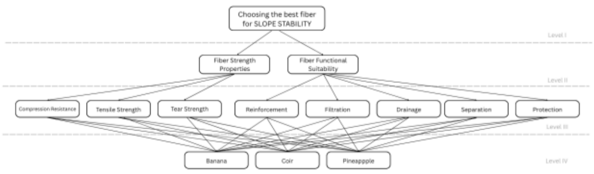

Figure 4. AHP Hierarchical Structure for Fiber Evaluation in Slope Stabilization

While the weighting for Level II (comparing Strength and Function) is still ongoing, this section presents preliminary results based on the full evaluation of Level III (sub-criteria) and Level IV (overall fiber comparison).

4.1 Fiber Strength Properties

Three sub-criteria were used to evaluate the mechanical performance of each fiber: Tensile Strength, Tear Strength, and Compression Resistance. These are key considerations in slope stability, where fibers must resist pulling, tearing, and crushing forces.

Table 4.1. Fiber Strength Properties

	Coir	Banana	Pineapple
Compression Resistance	0.2068	0.1625	0.1747
Tear Strength	0.2063	0.339	0.2365
Tensile Strength	0.5869	0.4985	0.5889

All matrices had CR<0.10, indicating consistent and valid judgments. From the results, tensile strength was the most heavily weighted factor for all factors, which means it is important in slope reinforcement where the material must resist tension forces from shifting soil. Coir and pineapple both performed well, but coir had the highest average across the strength properties. Banana fiber, however, while strong in tear strength, scored the lowest in both tensile and compression strength, suggesting more limited structural stability under load.

4.2 Fiber Functional Suitability

Five functional roles were assessed to determine how well each fiber could perform in the field: Reinforcement, Filtration, Drainage, Protection, and Separation.

Table 4.2. Fiber Functions

	Coir	Banana	Pineapple
Reinforcement	0.5501	0.3343	0.3395
Filtration	0.1188	0.1795	0.1805

Drainage	0.0817	0.0956	0.0993
Protection	0.1237	0.1896	0.1925
Separation	0.1257	0.201	0.1882

All matrices again met the consistency requirement (CR < 0.10). Coir fiber ranked highest in reinforcement, the most critical functional criterion for stabilizing slopes, making it structurally advantageous. Banana fiber leads in separation, indicating it may be helpful in preventing the mixing of soil layers, but lacks overall strength and versatility compared to the other fibers. Pineapple fiber demonstrated the most balanced functional performance, consistently ranking second or highest in filtration, drainage, and protection, which are essential in preventing slope saturation and erosion.

4.3 Fiber vs. Fiber

A direct pairwise comparison of the three alternatives was also conducted to assess overall expert preferences, considering both strength and functional suitability:

Table 4.3. Fiber Weights

Coir	0.6550
Banana	0.1313
Pineapple	0.2137

The Consistency Ratio (CR) for this matrix was 0.0652, which falls well below the 0.10 threshold. This indicates that expert judgments in ranking the three fibers overall were consistent and reliable. Although pineapple fiber performed consistently well in multiple functional criteria, coir fiber was rated as the most suitable overall. This is largely due to its superior performance in tensile strength and reinforcement, two of the most structurally significant attributes in slope stabilization. Pineapple fiber, while weaker in reinforcement, showed strong hydraulic performance (filtration and drainage), making it ideal for erosion-prone slopes with high water exposure. Banana fiber, though scoring well in separation, did not perform strongly in any other key criteria, limiting its suitability to surface-level or supportive roles in multi-layered slope systems.

5. CONCLUSION

This study applied the Analytical Hierarchy Process (AHP) to evaluate banana, coir, and pineapple fibers for slope stabilization based on current data from Level III sub-criteria. The current results show that coir fiber is the most appropriate because of its higher tensile strength and reinforcing ability, while pineapple fiber came in second due to its balanced hydraulic performance. Despite being the least effective overall, banana fiber demonstrated promise in terms of separation and tear resistance, suggesting its value in layered systems. Furthermore, these rankings are validated by the calculated CR and CI values being below 0.1. Future research should include more participants in order to increase the accuracy of the analysis. To support wider and more sustainable use in real-world settings, it is also advised to expand the analysis to include additional natural fibers, such as bamboo and abaca fibers, and assess their potential use in various geotechnical applications.

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