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Extraction of Enset Pseudostem Fiber and Manufacturing of Erosion Control Mats

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KEYWORDS

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water permeability
soil retention
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ABSTRACT

This study reports the development of biodegradable soil erosion-control mats using Enset pseudostem fibers reinforced with plant-derived polymers and natural tackifying agents. The fibers were sustainably extracted, spun into threads, and woven into durable mats, followed by a plant-based polymer coating to enhance structural integrity and environmental resistance. Experimental results demonstrated that mat performance is highly sensitive to formulation parameters, including thickness, polymer concentration, and tackifying agent levels. Tensile strength peaked at 498 N for a 10 mm thick mat with 5% polymer and 2% tackifier, whereas a 15 mm mat with 30% polymer and 0.1% tackifier exhibited lower tensile strength (170 N), indicating that lower polymer concentrations combined with higher tackifier levels enhance mechanical durability. Water permeability was higher in mats with lower polymer content (5%), while denser formulations with higher polymer concentrations reduced flow, and soil retention ranged from 86–98%, with optimal retention achieved at moderate thickness, high polymer, and tackifier levels. Comparisons with conventional natural-fiber mats (coir, jute, banana) indicate that Enset fiber mats provide a competitive balance of mechanical strength, water permeability, and soil retention while offering advantages of local availability and sustainability. Overall, the results highlight the potential of Enset pseudostem fibers as eco-friendly alternatives to synthetic erosion-control materials and provide a framework for optimizing mat formulations for application-specific performance.

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1. Introduction

Soil erosion is a major environmental issue that has a significant impact on ecosystem stability, water quality, and agricultural productivity. Erosion control mats are a vital component of the many approaches developed in response to global efforts to reduce erosion. Erosion control mats, also known as erosion control blankets or mats, are widely used in land rehabilitation, agriculture, and building projects in order to stabilize soil surfaces and stop erosion. These mats are often composed of synthetic or biodegradable materials and provide either short-term or long-term protection against soil loss due to wind, water runoff, or other environmental factors [1-3]. However, the widespread use of traditional erosion control materials, such as synthetic polymers or non-biodegradable fabrics, raises concerns about their environmental impact and long-term sustainability. In response to these challenges, there is a growing interest inexploring alternative materials that offer comparable or superior erosion control propertieswhile minimizing environmental harm [1-3].

Annually, Ethiopia losses approximately 1.5 billion tons of topsoil from the highlands to erosion which might have added over 1.5 million tons of grain to the country's crop. This suggests soil disintegration represents a huge danger to rural efficiency, food security, and natural manageability in Ethiopia. With its rough territory and weakness to disintegration because of elements like deforestation, overgrazing, the nation faces a squeezing need for powerful disintegration control measures. Customary techniques, for example, terracing and afforestation, have been utilized, yet their viability is restricted, and they frequently require critical work and assets. So to reduce those effects and replace old, costly and time taking techniques for farmers, this paper focuses on the application of widely available local material instead of synthetic one. Conventional erosion control materials have long-term effects and environmental sustainability problem because they are frequently made of synthetic polymers or non-renewable resources. Substitute materials that provide good erosion control qualities with the least amount of negative environmental effects in response to these worries are needed [4-6].

Enset pseudostem fiber emerges as a promising candidate for eco-friendly erosion control mats. Enset (Ensete ventricosum), also known as the "false banana" or "Abyssinian banana," is a versatile plant native to Ethiopia and other parts of East Africa. Enset has long been cultivated for its starchy pseudo-stem, whichserves as a staple food source in many communities. Since Enset (Ensete ventricosum) harvest in many pieces of Ethiopia, especially in the Southern and Western districts, it is very much adjusted to different environmental zones and is famous for its strength to dry season and unfortunate soil conditions and offers extra advantages, including soil preservation through its broad root foundation and the potential for fiber extraction. Also provide inherent strength, endurance, and biodegradability make it a viable environmentally harmless option for erosion control mats. Mostly offer cost savings in terms of reduced maintenance needs for our low income farmers. However, beyond its culinary uses, Enset offers additional benefits in the areas of technical textile such as rope, agrotextile and geotextile materials due to its fibrous materials obtained from their mid ribs and pseudo-stem of Enset plant [7-11].

The study aims to extract enset pseudostem fibers and manufacture erosion control mats using selected processing methods, including fiber extraction, preparation, and mat fabrication with plant-based binding materials. It involves characterizing both the fibers and the mats by evaluating key properties such as fiber morphology and tensile strength, as well as mat performance through tests on durability, water permeability, and soil retention. Overall, the research seeks to determine how factors such as mat thickness and binding agents influence the mechanical and functional properties of the mats, establishing agro-waste Enset fiber as a sustainable material for erosion control applications.

2. Literature Review

2.1. Soil erosion, Environmental Effect and Controlling Mechanism

Soil erosion may be characterized as the process whereby soil particles are detached and subsequently removed off the land surface by various drivers, including water, wind and anthropogenic activity [12]. The excessive loss of soil through erosion is detrimental to soil fertility because nutrient-rich top soil is removed, and it ultimately impacts agricultural production [13]. When soil particles are washed into nearby water bodies sedimentation occurs, which can impact water quality and disturb aquatic systems [14]. Soil erosion also leads to increased flooding because eroded land can no longer absorb and retain as much water [15]. Loss of vegetative cover due to deforestation, overgrazing, and land development, increases the likelihood of soil erosion [16]. Climate change has the potential to exacerbate soil erosion by increasing the frequency of extreme rainfall events and/or altering precipitation patterns [17]. A viable method for stabilizing soils against erosion is through the application of erosion control mats that protect the soil surface and can also facilitate improved vegetative growth [18]. Erosion control mats manufactured from natural fibers (i.e. coir, jute, or other agricultural residues) are increasingly being used for environmental sustainability [19]. Erosion control mats function as physical barriers to the direct impact of raindrops by improving water infiltration and stabilizing soil structure [20]. Studies show that erosion control mats combined with revegetation significantly reduce soil loss compared to bare soil, making them an environmentally effective erosion management technique [21].

2.2. Overview of Enset Plant (Ensete Ventricosum) and Its Importance

Amharic language names as "Enset" or "false banana," Ensete ventricosum is a perennial herbaceous plant indigenous to the Ethiopian Highlands and other parts of East Africa. As member of the Musaceae family, it is related to the actual banana plant, Musa spp. Millions of people in Ethiopia depend on enset, a key food crop, for their livelihoods, cultures, and food security. Thanks to its adaptability to a variety of agro-ecological circumstances, including locations with low soils and irregular rainfall, enset is commonly described to as the "tree against hunger". Anatomically, the plant is tightly packed leaf sheaths that emerge from a subterranean corm or rhizome make up the enset pseudo stem and resemble to banana fibers as shown in Figure 1. In contrast to actual banana plants, enset creates a pseudostem made upof overlapping layers of leaf sheaths rather than a genuine stem. These leaf sheaths act as a storehouse for nutrients and water, as well as giving the plant structural support [22-25].

The main components of enset pseudostem fibers are cellulose, hemicellulose, and lignin,with trace amounts of pectin, extractives, and ash as shown in Tabel1. The mechanical qualities, longevity, and environmental compatibility of enset fibers are all influenced by their chemical makeup [26].

Table 1. Chemical composition of banana fiber [26]

S. No	Content	Banana fiber (%)
1	Cellulose	69.5
2	Hemicellulose	15
3	Lignin	5.45
4	pectin	0.5
5	Fat and wax	1.5

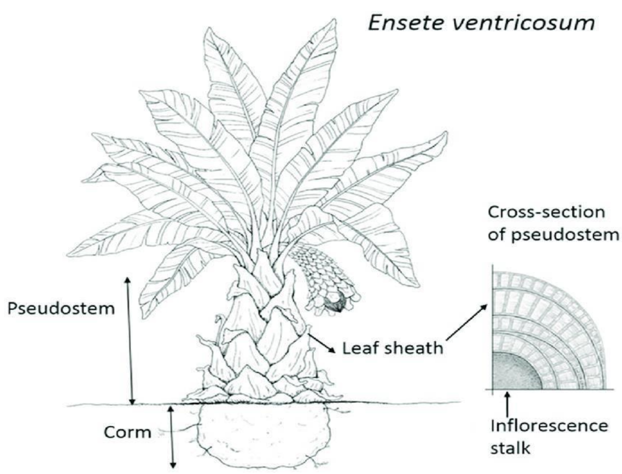

Figure 1. Anatomy of Enset Plant

2.3. Types of Mat and Application of Mat as Erosion Control

Conventional natural fibers used in erosion-control products exhibit distinct physical and mechanical characteristics that influence their performance. Coir fiber is relatively lightweight with a density of about 1.15–1.45 g/cm³ and shows a broad tensile-strength range of 54–250 MPa due to natural variability, along with a moderate Young's modulus of 4–7 GPa and highly variable elongation at break (3–40%). Jute fiber is denser, typically ranging from 1.3 to 1.46 g/cm³, and demonstrates much higher tensile strength (393–800 MPa) and stiffness, with a Young's modulus commonly between 10 and 30 GA [27-41]. Banana fiber is comparatively light, with reported densities around 0.75–0.95 g/cm³, yet it offers exceptionally high tensile strength in the range of 529–914 MPa and a Young's modulus of about 27–32 GPa, making it one of the strongest natural fibers used in erosion-control applications. These fibers also differ in chemical composition, with coir exhibiting high lignin content that slows biodegradation, jute showing moderate cellulose and lignin levels that balance strength and degradability, and banana fiber containing very high cellulose content that contributes to its superior mechanical properties. Overall, the physical and mechanical variation among coir, jute, and banana fibers highlights the importance of selecting fiber types that match the specific functional requirements of erosion-control systems [27-41].

Table 2. Comparative Table of Conventional Natural Fibers Used in Erosion Control [27-41].

Property	Coir Fiber	Jute Fiber	Banana Fiber
Density (g/cm³)	1.15–1.45 [35]	1.30–1.46 [38]	0.75–0.95 (up to ~1.02 reported) [41]
Diameter (µm)	100–450 [36]	20–200 [39]	~167 [41]
Tensile Strength (MPa)	54–250 [35]	393–800 [7]	529–914 [41]
Young's Modulus (GPa)	4–7 [35]	10–30 (range up to 55 reported) [40]	27–32 [41]
Elongation at Break (%)	3–40 [35]	1.16–1.8 [40]	1–3 [41]
Lignin Content (%)	~40–45% [37]	~12–14% [39]	~15% [41]
Cellulose Content (%)	27–45% [37]	58–63% [39]	~82% [41]
Moisture Behavior	High water uptake [36]	Moderate moisture absorption [40]	Good moisture regain [41]

There are several types and combinations of erosion control mats available. Types of erosion control mats include biodegradable options like straw, jute, and coconut fiber (coir), as well as synthetic mats made from materials like polypropylene or nylon [42-44]. Most commonly mats used for erosion protection obtained as:

Rolled mats: These are pre-made mats that have been conveniently rolled up for installation and transit. They come in a variety of materials, including jute, straw, coconut fiber (coir), and synthetic geotextiles.

Woven Mats: These mats provide a flexible and long-lasting erosion control solution. They can be made from natural or synthetic fibers. They are frequently utilized in channels and steep slopes where more fortification is required.

Blanket Mats: Made of either biodegradable or photodegradable netting, a layer of fibersor mulch is layered between the mats. In environmentally sensitive locations, they are frequently utilized for vegetation establishment and slope stability.

Hydroseeded Mats: These mats offer a complete solution for slope stabilization by combining erosion control elements with mulch, seed, and fertilizer [42-44].

In order to prevent soil erosion and stabilize slopes, embankments, and other susceptible areas, specialized materials called erosion control mats also referred to as erosion control blankets or geotextiles are applied to the soil's surface and used to offer temporary or long-term protection against erosion brought on by precipitation, wind, or water flow. Erosion control mats stabilize the soil by holding soil particles firmly in place so that water or rain cannot wash them away as shown in Figure 2 [45].

Establishment of Vegetation: A lot of erosion control mats are made to encourage the growth of vegetation. The mats protect and maintain recently planted vegetation until it gets established by fostering a microenvironment that is favorable to seed germination and root growth [46].

Water Management: By reducing the speed at which water moves across the soil's surface, erosion control mats assist in the management of water runoff. This lowers the possibility of surface erosion and encourages groundwater recharge by facilitating more efficient water infiltration into the soil.

Sediment Control: Erosion control mats reduce sedimentation in neighboring lakes, rivers, and streams by stopping soil erosion. By doing this, you can preserve the quality ofthe water and shield aquatic environments from the damaging effects of sedimentation.

Figure 2. Biodegradable Soil Erosion Control Mat [45]

Erosion Control: By serving as a physical barrier, erosion control mats stop erosive pressures from causing soil particles to separate and move. This reduces the risk of erosion harming sensitive locations including building sites, revegetation initiatives, and roadsideembankments [45,46].

3. Material and Methodology

3.1. Materials

The materials and equipment for this study were: Enset pseudostem fiber, the main natural reinforcement because of its strength and biodegradability; bio-based polymers from corn or soybeans, acting as natural binders to help fiber stick together; and a manual spinning wheel to twist fibers into continuous yarn. We used weaving equipment, a handloom, to make the final woven structures. Simple tools like scissors were used to cut the fibers and woven samples. Water was used to activate the polymer coating, and natural soil tackifying agents were added to help the soil stick and control erosion. The woven samples were checked using a water permeability tester to measure water flow resistance, and abrasion testers to check for wear under conditions that imitate a field. A mill pin was used to hold the erosion control mats to the soil. A strainer was used to filter fiber slurry when treating it with polymer, and a stove was used to cure the biopolymer on the fiber structure. Lemon juice was used as a natural preservative to prevent microbes from degrading and discoloring the materials during processing.

3.2. Methodology

3.2.1. Extraction of Enset Pseudostem Fibers

After harvesting mature Enset pseudostems, the outer leaf sheaths were removed to access the inner layers, which contain abundant fibers, as shown in Figure 3. The fibers were manually extracted using a blade to crush the material, scraping off the soft tissue to separate the long fibers. Once extracted, the fibers were carefully washed with water to remove any remaining debris. After washing, the fibers were air-dried to reduce moisture content, facilitating proper handling and subsequent processing [47,48].

Figure 3. Extracted Enset Fiber (Image Camera resolution, 100MP)

3.2.2. Design and Fabrication of Erosion Control Mats from Extracted Enset Fiber

The cleaned and dried Enset fibers were manually spun into yarn using a wheel-spinning device to achieve uniform thickness and facilitate handling. The spun fibers were then woven into mats using a traditional handloom in the laboratory, following a grid-like pattern to ensure structural integrity and allow water infiltration, as illustrated in Figure 4. During weaving, a bio-based polymer binder was applied to enhance bonding between fibers and improve durability under wet conditions. The fabricated mats were trimmed to the required dimensions and conditioned at room temperature prior to further testing.

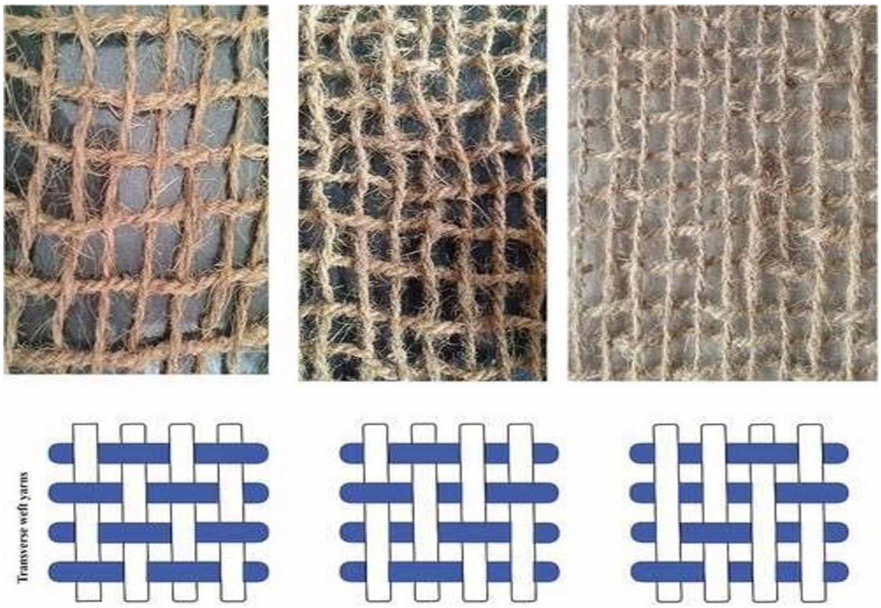

Figure 4. Woven Structure and Hand woven Mat (Image Camera resolution, 100MP)

3.2.3. Preparation of Corn-Based Tackifying Agent (Corn Dextrin Solution)

Corn dextrin was produced by heating cornstarch through a controlled roasting process. First, the oven was preheated to 200 °C (392 °F), and one cup of cornstarch was evenly spread on a lined baking tray. The cornstarch was baked for approximately two hours, with intermittent stirring, until it gradually turned light brown, indicating dextrin formation. The roasted material was then removed from the oven and allowed to cool to room temperature. A tackifying solution was prepared by dissolving ¼ cup of the resulting dextrin powder in ½ cup of warm water and stirring thoroughly until a homogeneous mixture was obtained. If required, a small amount of baking soda was added to adjust the viscosity and stickiness of the final solution.

3.2.4. Incorporate Polymer Materials (Corn powder) Into Mats

Using a spray method apply biodegradable polymers (corn bead) that are in line with environmental sustainability objectives along with strength-enhancing polymer ingredients to the woven enset pseudostem fiber mat to increase its stability and durability. These polymers can make the mat stronger and more resilient while maintaining its biodegradability [34].

3.2.5. Tests of Enset Fiber woven Mats

Measurement of the mats' tensile strength, water permeability and soil retention under various test scenarios.

3.2.5.1. Durability (Tensile Strength Test, ASTM D4595)

Test Methods: To evaluate the robustness and structural integrity of the erosion-control mats, mechanical testing was performed as shown in Figure 5. Multiple representative samples of the mats, each measuring 10 × 15 cm^2, were prepared. One end of each sample was secured to a stationary clamp on a tensile testing apparatus, while the other end was attached to a moveable clamp. The force applied by the moveable clamp was gradually increased until the sample failed, and the maximum force sustained by the sample (measured in Newtons or pounds-force) was recorded.

Figure 5. Tensile Strength testing of Enset Fiber Mats

3.2.5.2. Soil Retention (ASTM D6460)

Test Method : To simulate rainfall or water flow over the erosion-control mats, a controlled field setup was used, as shown in Figure 6. Prior to water application, the mass of dry soil to be placed on the mat was measured. A predetermined amount of soil was then evenly spread onto the mat, after which water was applied at a regulated rate to replicate runoff or rainfall. The amount of soil retained by the mat was subsequently measured to evaluate its effectiveness.

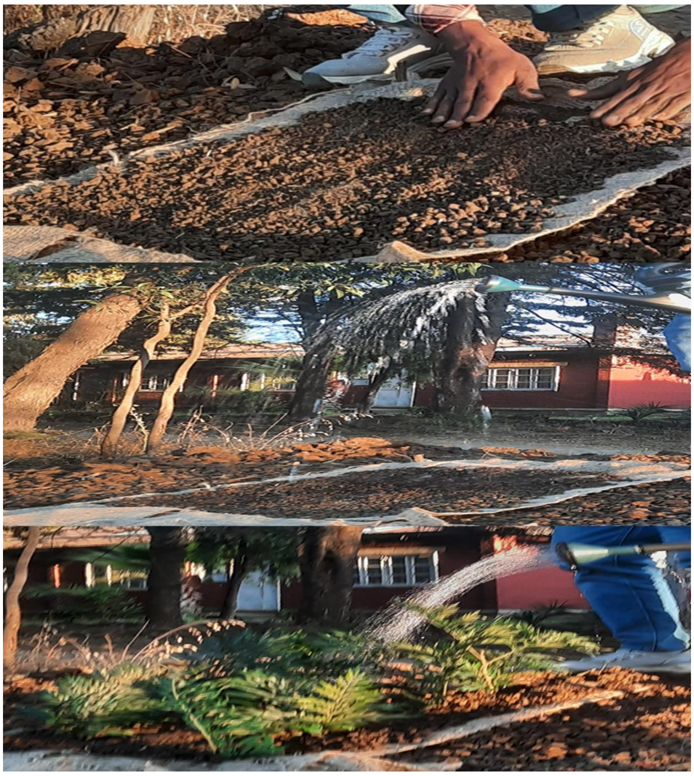

Figure 6. Mat Soil Retention Field Test

3.2.5.3. Water Permeability (ASTM D4491) Test

- ✓ To determine how durable and resistance to water damage as well as how breathable a mat is.
- ✓ To improve product quality
- ✓ To ensure compliance with industry standards

Test method:

- A permeability testing apparatus with a timer, a graduated cylinder and a water reservoir assembled as illustrated in Figure 7.
- The erosion control mat placed within on a permeable surface to replicate field conditions.
- A known quantity of water applied onto the erosion control mat’s surface evenly and consistently over the mat's surface.
- The time taken for water to pass through the mat recorded
- Finally the mat's water permeability (permittivity) determined, using the formula given in ASTM D4491, expressed in L/m^2/s.

Figure 7. Mat Water Permeability Test

4. Result and Discussion

4.1. Results Analysis

The experimental findings show how the concentration of plant-based polymers (Factor B), natural tackifying agent (Factor C), and material thickness (Factor A) affect the tested materials' tensile strength (durability), water permeability, and soil retention qualities. Significant differences in performance between the various experimental scenarios are shown by the data.

4.1.1. Tensile Strength (Durability in N)

Tensile strength of enset fiber woven mats as illustrated in Figure 8, a measure of the material's durability, varied significantly between the experiments. Experiment 2 had the highest tensile strength (498 N), with Factor A being 10 mm, Factor B being 5%, and Factor C being 2%. This suggests that a lower concentration of plant-based polymers combined with a higher concentration of natural tackifying agents improves material durability when the thickness is moderate (10 mm). In contrast, Experiment 7 had the lowest tensile strength (170 N), with Factor A being 15 mm, Factor B being 30%, and Factor C being 0.1%. This suggests that increasing material thickness and plant-based polymer concentrations while lowering the tackifying agent concentration has negative effects on durability.

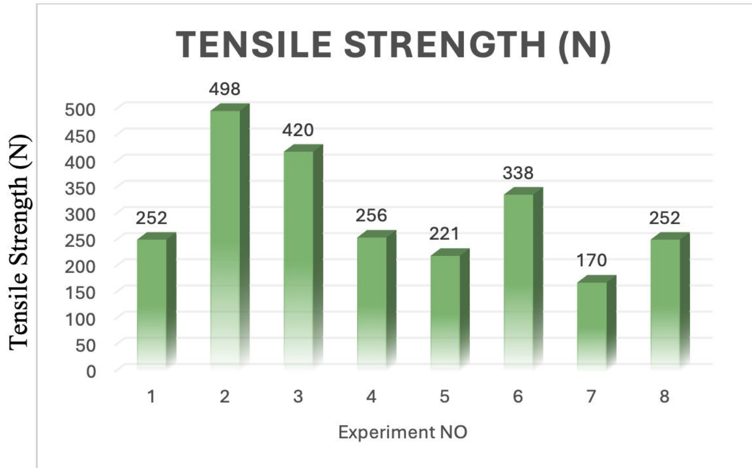

Figure 8. Mat Tensile Strength under Different Factors

Findings:

- Experiment 2 exhibits the highest tensile strength (498 N), whereas
- Experiment 7 exhibits the lowest tensile strength (170 N).

Analysis: Higher concentrations (2%) consistently improved durability across experiments, indicating that Factor C (the concentration of the natural tackifying agent) is crucial in increasing tensile strength. However, the interaction between Factors A and B also seems to be important, as thicker materials (15 mm) with higher polymer concentrations (30%) generally showed lower tensile strength.

4.1.2. Water Permeability (L/m²/s)

The ability of a material to permit water to pass through is measured by its water permeability as illustrated in Figure 9. Water permeability was generally higher in experiments with lower plant-based polymer concentrations (5%) as seen in Experiments 1 (32 L/m²/s) and 2 (24 L/m²/s). Conversely, Experiments 3 (24 L/m²/s) and 4 (34 L/m²/s) showed that water permeability decreased with increasing polymer concentrations (30%). This suggests that water permeability tends to decrease with increasing polymer concentration, most likely as a result of the denser material structure that is created at greater concentrations.

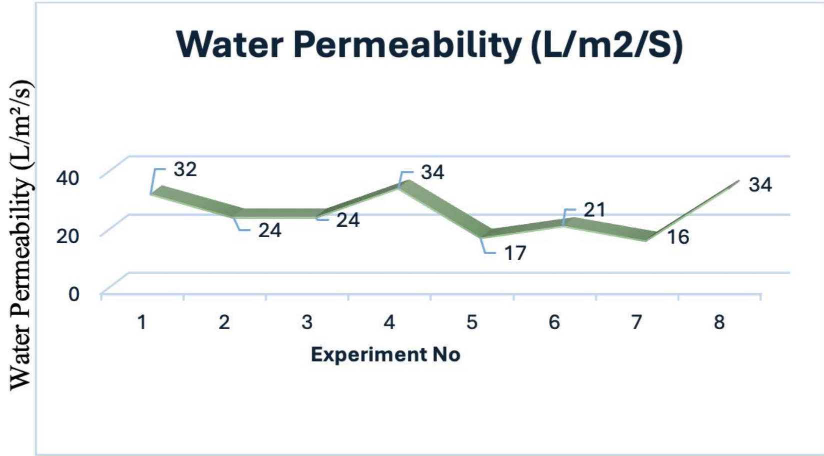

Figure 9. Mat Water Permeability under Different Factors

Findings:

- Experiments 1 and 4 had the largest water permeability (32 and 34 L/m²/s, respectively).
- Experiment 7 has the lowest water permeability (16 L/m²/s).

Analysis: It's interesting to note that the concentration of the natural tackifying agent (Factor C) had a less noticeable impact on water permeability than Factor B. But as demonstrated in Experiments 5 (17 L/m²/s) and 7 (16 L/m²/s), thicker materials (15 mm) consistently showed decreased water permeability, indicating that material thickness also affects water flow regulation.

4.1.3. Soil Retention (%)

In every testing, the material's capacity to hold soil, or soil retention, was consistently high, ranging from 86% to 98%. Experiment 4 had the highest soil retention (98%) with Factor A of 10 mm, Factor B of 30%, and Factor C of 2%. This implies that the best soil retention is achieved by combining moderate thickness, high concentrations of plant-based polymers, and high concentrations of tackifying agents. In contrast, Experiments 1 and 6 showed the lowest soil retention (86%) while having lower amounts of polymers (5%), as well as lower concentrations of tackifying agents (0.1% and 2%, respectively).

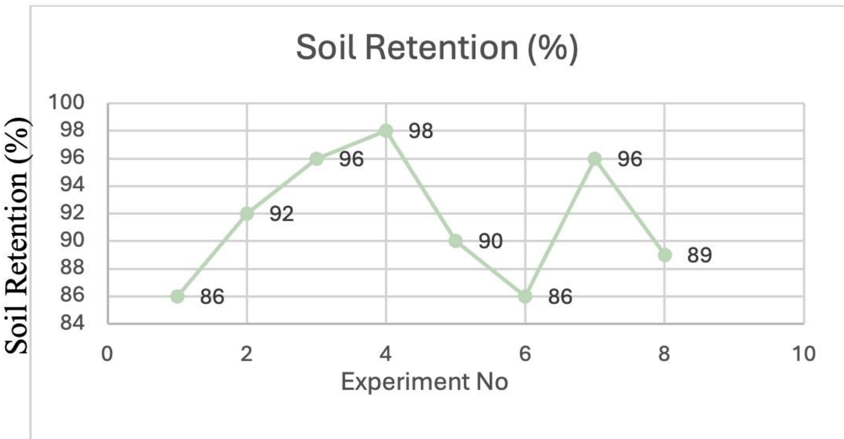

Figure 10. Mat Soil retention under different factors

Findings:

•Experiment 4 had the highest soil retention rate (98%).
• Experiments 1 and 6 have the lowest soil retention rates (86%).

Soil retention calculation

$$\text{Soil Retention Percentage} = \left(\frac{\text{Initial soil mass} - \text{Eroded soil mass}}{\text{Initial soil mass}}\right) \text{x}100$$

Sample number One:

Initial dried soil mass = 100gm

Initial mass of mat = Area * GSM = $2m^2$ *$300g/m^2$ = 600g

Mass of mat after eroded = 698g

Calculate the retained soil mass:

Final soil mass retained = mass of mat after erosion – initial mass of mat

= 698g – 600g = 98g

Soil retention percentage = (final mass of soil/initial mass)*100

= (Mf/Mi)*100

= (98/100)*100=98%

Analysis: The results indicate that Factor B (plant-based polymer concentration) and Factor C (natural tackifying agent's concentration) are critical for maximizing soil retention. Higher concentrations of both factors generally improved soil retention, while material thickness (Factor A) had a less significant impact on this property.

5. Discussion

The observed variation in tensile strength, peaking at 498 N for the 10 mm, 5% polymer, 2% tackifier formulation, indicates that a lower concentration of biopolymer, combined with a higher tackifier, maximizes durability, a trend that echoes findings in natural- fiber geotextiles where minimizing polymer saturation allows the fiber network to better carry load [49-52]. In contrast, the dramatic strength reduction in the 15 mm, 30% polymer, 0.1% tackifier sample (170 N) likely arises from overfilling of the fiber structure, reducing the fiber–fiber interactions, a mechanism similarly documented in hybrid composites reinforced with coir and other fibrous reinforcements [53-55]. Our permeability results also align with literature: mats with lower polymer concentrations (5%) showed higher water flow rates (e.g., 32 $L/m^2/s$), while increased polymer content reduced permeability, suggesting denser internal microstructure, as previously seen in natural fiber composites [54-56]. The consistently high soil retention (86–98%) across experiments, especially the 98% retention in the mat with 10 mm thickness, 30% polymer, and 2% tackifier, demonstrates effective binding of soil particles, which supports conclusions from geotechnical studies showing that cohesive natural-fiber geotextiles significantly enhance soil particle entrapment [52, 54,56]. In lower polymer/tackifier combinations (Experiments 1 and 6), retention dropped to 86%, reinforcing the role of binding agents in ensuring mechanical cohesion, consistent with reports that weaker binding reduces soil capture capacity [54-56]. Together, our findings suggest that by fine-tuning polymer and tackifier concentrations, Enset fiber mats can achieve performance comparable to conventional natural- fiber erosion- control products (such as coir and jute), but with the benefit of being locally sourced and potentially less costly. Previous studies emphasize coir's high lignin content (~35–45%) that confers long-term durability (slow biodegradation) in geotechnical applications [50,52,54-56], while jute fibers offer high tensile strength (up to ~860 MPa) and stiffness (modulus of ~10–30 GPa) [52,53,54-56]. Banana fibers, meanwhile, have been shown to deliver very high strength in composites (~500 MPa) with moderate density and elongation characteristics [54-56]. When compared side- by- side, our Enset fiber mats show a favorable trade-off between mechanical integrity, permeability, and soil retention that is competitive with these established fibers, highlighting their potential as sustainable erosion- control solutions. The present study thus demonstrates not only the viability of Enset pseudostem fibers in erosion control but also a method to optimize their formulation for application-specific performance. The results of the experiment show that enset pseudostem fiber mats' mechanical durability and soil retention properties are much improved by increasing polymer concentrations. This enhancement is ascribed to the polymer's facilitation of denser matrix formation and enhanced inter-fiber bonding, which strengthens the mats' structural integrity under shear and tensile stresses. Higher polymer concentrations do, however, come with a trade-off: less water permeability, which is crucial for erosion control applications. The mats' reduced hydraulic conductivity would make them less appropriate for locations that need a lot of drainage capacity, including steep slopes or areas that receive a lot of rainfall. In order to balance durability and hydraulic performance, the polymer-to-fiber ratio must be carefully considered during mat production.

The outcomes also demonstrate how well enset pseudostem fiber mats work as a sustainable substitute for artificial erosion control materials. Unlike synthetic geotextiles that contribute to microplastic pollution, the mats have exceptional biodegradability, meaning that at the end of their existence, they will have no environmental impact. Additionally, by repurposing waste materials and lowering reliance on non-renewable resources, the utilization of enset pseudostem fibers, a plentiful agricultural byproduct, is consistent with the concepts of the circular economy. These mats' affordability further increases their allure for widespread use in developing nations where financial limitations frequently prevent the adoption of cutting-edge erosion control methods.

The novelty of this work lies in introducing Enset pseudostem fiber, an agricultural resource that has received minimal scientific attention, into the development of erosion-control mats, in contrast to well-studied natural fibers such as coir, jute, and banana. This study provides the first systematic extraction and characterization of Enset fiber specifically for erosion-control applications, addressing gaps left by previous research focused on traditional fibers. The unique microstructural features of Enset fiber, including its high cellulose content and naturally intertwined bundle morphology, offer performance characteristics not typically observed in jute or banana fibers. Furthermore, the work establishes a sustainable valorization route for Enset waste, which remains largely underutilized compared to the commercially established coir industry. The simplified, low-energy extraction process demonstrated here also contrasts with the more industrialized processing requirements of coir and jute. In addition, the resulting Enset-fiber mats exhibit distinctive biodegradation behavior linked to their chemical composition, offering an alternative ecological profile. This study also documents for the first time the water-absorption and soil-retention capabilities of Enset-fiber mats, revealing functional differences relative to existing natural-fiber products. By focusing on a regionally abundant yet neglected fiber source, the research promotes local material production and reduces reliance on imported fibers. Mechanical performance comparisons further show that Enset fiber can meet or exceed certain functional requirements of established erosion-control mats, positioning it as a competitive new material. Collectively, these contributions provide new scientific evidence and practical manufacturing insights that clearly distinguish Enset pseudostem fiber from commonly used natural fibers in erosion-control applications. The comparison of most commonly used natural fibers for erosion-control applications were summarized in Table 3.

Parameter	Enset Pseudostem Fiber	Coir Fiber	Jute Fiber	Banana Fiber
Cellulose Content (%)	High (≈ 60–70%)	Moderate (≈ 45–55%)	High (≈ 60–65%)	High (≈ 55–65%)
Lignin Content (%)	Moderate	High	Low–moderate	Low–moderate
Fiber Tensile Strength (MPa)	Moderate–high (dependent on extraction)	Moderate	Moderate–high	High
Fiber Diameter (μm)	Finer and more uniform	Coarse	Fine	Medium
Water Absorption Capacity	High (beneficial for soil moisture retention)	Moderate	Low–moderate	High
Biodegradation Rate	Faster (due to lower lignin than coir)	Slow (high lignin)	Moderate	Moderate
Processing Complexity	Low (simple extraction)	Moderate–high	Moderate	Moderate
Availability/Utilization	Underutilized (novel material)	Widely	Widely used	Limited regional

		commercialized		use
Cost of Raw Material	Low	Moderate	Moderate	Low–moderate
Suitability for Erosion-Control Mats	High (good moisture retention + biodegradability balance)	High durability	Good soil contact properties	Good mechanical properties

Table 3. Comparison of Common Natural Fibers for Erosion-Control Applications

6. Conclusion

The experimental results demonstrate that achieving an optimal balance among tensile strength, water permeability, and soil retention in Enset fiber mats requires careful adjustment of material thickness, polymer concentration, and tackifying agent levels. For instance, a 10 mm thick mat with 5% plant-based polymer and 2% tackifying agent (Experiment 2) exhibited excellent tensile strength and soil retention while maintaining moderate water permeability. In contrast, a thicker mat (15 mm) with higher polymer content (30%) and minimal tackifying agent (0.1%) (Experiment 7) retained soil effectively but displayed reduced permeability and mechanical strength. These findings indicate that formulation strategies should be tailored to specific application requirements: thinner mats with lower polymer concentrations enhance permeability, whereas moderate thickness combined with low-to-moderate polymer content and higher tackifying agent concentrations optimize durability and soil retention. Overall, the Enset fiber mats consistently demonstrated strong mechanical performance, effective water passage, and high soil retention, highlighting their potential as sustainable, biodegradable alternatives to conventional synthetic erosion-control materials. Their adoption offers significant prospects for improving soil conservation and environmental sustainability, particularly in erosion-prone regions such as Ethiopia. The results of this study provide a practical framework for designing natural-fiber mats that meet both functional and ecological objectives.

Author Contribution

Adane Workneh and Alhayat Getu Temesgen participated in the conception of the study, participated in the manuscript preparation and presented results.

Declaration of Competing Interest

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Consent to Publish Declaration

Not applicable

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