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Original Article

Assessing the Impact of Miscanthus Sinensis on Soil Strength Parameters and its Role in Flood Erosion Control

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Abstract *- In this study, distinct types of ethnic plants of Arunachal Pradesh were examined for selection as a soil stabiliser. Considering the geographical factors and plant properties, the Miscanthus Sinensis plant was selected as a soil stabiliser. As an experimental study, 1 month old Miscanthus Sinensis plant was planted in a grid pattern on the bank of Pare River for an area of about 200 sqm. The plants were allowed to develop naturally for a year. Thereafter, the effect of the Miscanthus plant on the shear strength parameter of the soil was determined every month. It was determined using a triaxial test (UU condition) in the laboratory. Further, the important parameters such as Root Anchoring Index (IRA), Root Binding Index (IRB) and tensile strength of the root were determined to check the bonding strength between the root and the soil. It was observed that the presence of miscanthus improved the cohesion of soil up to 59 % to 90%. Miscanthus plants have remarkably high IRA and IRB values. Miscanthus plants restricted the flood velocity and soil movement during the flood.*

Keywords *- IRA/IRB, Miscanthus, Tensile strength, Stabilisation, Erosion.*

1. Introduction

Vegetation has long been recognized as a natural solution for enhancing slope stability, a concept deeply rooted in historical practices and increasingly valued in modern geotechnical engineering. Pioneering works by researchers such as Greenway (1987), Gray (1970), Gray and Leiser (1982), and Coppin and Richards (1990) have systematically explored the role of vegetation in mitigating slope failures. These studies collectively emphasize that vegetation affects slope stability through two principal mechanisms: increasing the load on the slope due to the weight of the plants and enhancing the resistance of the slope through the reinforcing effects of roots. The roots of vegetation penetrate the soil, creating a network that binds the soil particles together, thus improving shear strength and reducing the likelihood of erosion and landslides.

However, despite these foundational insights, much of the existing research has been either too general in its approach or limited in its applicability to specific regions or vegetation types. For instance, Greenway's (1987) broad review offers valuable generalizations about vegetation's role in slope stability but does not delve into the specific conditions or plant species that might be more effective in particular environmental contexts.

Similarly, case studies like those of O'Loughlin (1974), Riestenberg (1987), and Wu et al. (1979) have highlighted the consequences of vegetation loss on slope stability but have largely focused on specific types of vegetation, such as temperate forest species, leaving a gap in understanding the potential of other, less-studied plant species, especially in tropical and subtropical regions.

This study highlights a major lack of use of bioengineering measures customized for the peculiar climatic and geological conditions in the northeastern part, particularly Arunachal Pradesh. The hilly terrain, coupled with geologically fragile young mountains and high annual rainfall, predispose the region to increased soil erosion, landslides and gully formations. Some of the traditional methods in slope stabilization, like Vetiver grass, have been largely promoted due to their efficiency and efficacy in different regions. But, not every methodology is appropriate for all these environments. The introduction of non-native species such as Vetiver in the Northeastern region is alarming due to ecological compatibility and sustainability issues: despite being a tall grass with potential for environmental conservation, its local adaptability or long-term impact on tera-crust ecology remains unknown.

With a background of these challenges, the present experimental investigation aims to fill in this research gap by aiming to define miscanthus sinensis (a perennial tallgrass native to Asia) within vetiver grass and suggests it as an alternative solution for slope stabilization activity adapted for Arunachal Pradesh. However, unlike Vetiver, with numerous studies and implementations all over the world, Miscanthus sinensis has not been as largely researched for soil bioengineering purposes, especially in the Northeast region. Here, we attempt to bridge this gap by the evaluation of M. sinensis, including traits of root system architecture, erosion control capability and response in abiotic conditions with respect to change towards local climate conditions as well as its ecological footprint.

This research is novel in that its focus is on Miscanthus sinensis as a potentially more sustainable and environmentally friendly option for slope stabilization in an area of unique environmental challenges. In addition to providing an evaluation of the efficacy methods in preventing soil erosion and landslides compared with traditional approaches like the Vetiver system through a comparative analysis between Miscanthus sinensis, this study also examines its environmental impacts over time. This holistic assessment will pave the way for scientific yet site-specific bioengineering intervention that can assist in partial risk reduction from landslides and enhance the sustainability of slopes in Arunachal Pradesh.

This study's findings are expected to contribute significantly to the field of geotechnical engineering by introducing a new perspective on the use of vegetation for slope stabilization. The insights gained from this research could pave the way for more ecologically sensitive and region-specific approaches to soil stabilization, offering valuable lessons for other regions facing similar challenges.

The following factors need to be considered when choosing a method for stabilising soil:

- Culture
- Environment
- Cost

Many hard engineering techniques have been tried to resolve the issue in past years, but it has been ineffective while incurring large financial and environmental costs. With a low budget and environmental sustainability in the picture, it seems imperative to find a solution. But one such technique which shows a promising result is Bioengineering.

The most common and prominent technique in bioengineering is the Vetiver system. But, the Vetiver plant not being native to Arunachal Pradesh may cause harm to native flora and fauna. After researching and examining distinct types of plants in the state, it has been found that the Miscanthus Sinensis plant shows the same type of behaviour as the Vetiver plant.

In the grass family Poaceae, Miscanthus sinensis, shown in Figure 1, sometimes known as the eulalia or Chinese silver grass, is a species of flowering plant that is indigenous to eastern Asia and may be found in much of Arunachal Pradesh, China, Japan, Taiwan, and Korea. It is perennial grass, which can grow up to 0.8-2m tall while forming a dense root network and clump from an underground rhizome.

The flowers are purplish, white, and silver in colour. It is widely cultivated as an ornamental flower in most parts of the world. It has become an invasive species in most of the European and American countries, but it poses no threat in this part of the world since it is Aboriginal to Arunachal Pradesh.

The primary objective of this project is

- To study the effect of the Miscanthus Sinensis plant on the soil properties.
- To evaluate its effectiveness in preventing soil erosion and landslides.

2. Methodology

2.1. Selection of Plant

To meet the objective of the study, the diverse plants available in the adjoining areas of Papum Pare, Arunachal Pradesh, were explored, and finally, the Miscanthus plant was selected. While selecting the plant for this study, the following criteria have been considered:

1. It should have low shoot biomass
2. It should have large root biomass
3. It should be non-invasive to the local ecosystem
4. It should exhibit xerophytic and hydrophytic characteristics if it is to survive the forces of nature.

Table 1 shows the properties of different plants.

Fig. 1 Miscanthus plant

2.2. Selection of Site

Fig. 2 Location of the test site

Table 1. Criterion for selection of plant

Plant	Biomass Ratio	Nativity	Xerophytic	Hydrophytic
Amliso	Low	Native	Yes	Yes
Lemon Grass	Low	Native	No	Yes
Gooseneck	Low	Native	No	No
Rush	High	Native	No	Yes
Taro	Low	Native	No	Yes
Indian Goose Grass	Low	Native	Yes	Yes
Miscanthus	High	Native	Yes	Yes

Bank of Pare River was selected to conduct the experimental project work for the following reasons:

- It gets eroded every year during monsoon season.
- Accessible distance for better monitoring

The coordinates of the test site shown in Figure 2 are 27°14’53.0 “N 93°30’00.1 “E.

2.3. Method of Plantation

One-month-old Miscanthus plant saplings were planted on the site in December 2021. It was planted over an area of 20 m × 10 m sqm and 50 cm apart from each other.

2.4. Shear Strength Parameter Tests

The shear strength parameter of the soil was determined using a triaxial test (UU condition). For the undisturbed soil sample a custom-made mould of diameter 38mm was made.

The soil sample was collected from the site and brought to the laboratory under an airtight container carefully with great precaution so as not to disturb the soil sample. After the sample was brought to the laboratory, the soil was separated carefully from the mould and cut to a height of 76 mm. Then, it was tested for shear strength using a triaxial machine.

This process was repeated for March, April, May, and June. Where the age of the plant was 4,5, 6 and 7 months etc. A few of the soil samples served as a baseline (i.e., samples with no vegetation roots). Before the samples were analysed, the plants were allowed to develop for six to eight months.

2.5. Root Anchoring and Binding Index

Root Binding Index (IRB) and Root anchoring index (IRA)are important root parameters. By using the above indices, the binding strength of the root and soil can be determined.

If root IRA and IRB are greater than 1, then we can assume that the bond between soil and root is strong. And it may be able to withstand most of the overturning forces acting upon it.

2.6. Tensile Strength of Root

For the determination of the tensile strength of the root, a root specimen from the plants was taken, and testing was done under fresh conditions (within 24 hrs). 30 cm lengths of roots of various thicknesses were collected, and their diameter was measured. Then, a root was secured with a clamp at one end and connected to a polyethylene bag at the other end.

The polyethene bag was progressively filled with sand and continued until the roots failed. The bag and sand’s combined weight was measured to find the total load applied. This procedure was repeated for roots of diverse sizes.

2.7. Root Length Density and Root Density

The root length density (total length of roots per unit of soil volume; RLD) is an important indicator of the amount of soil that a root system has explored and, as a result, the amount of soil it has anchored.

Root density is another parameter which can be used to determine the effect of roots on the cohesion of soil.

To determine the values of RLD and RD, a whole plant was uprooted, thereby creating a hole. The hole’s volume was then calculated. The length of each root of the plant that was present within that hole was then measured.

RLD = Total length of roots in the volume/volume of pit
$= m^{-2}$

RD = mass of root/volume of root
$= mg/m^3$

$$C = 10.54+8.63\log RD \quad (1)$$

Where C is cohesion

3. Tests and Results

3.1. Sieve Analysis of the Soil

Sieve analysis of soil samples taken from the plantation site is shown in Table 2 and Figure 3.

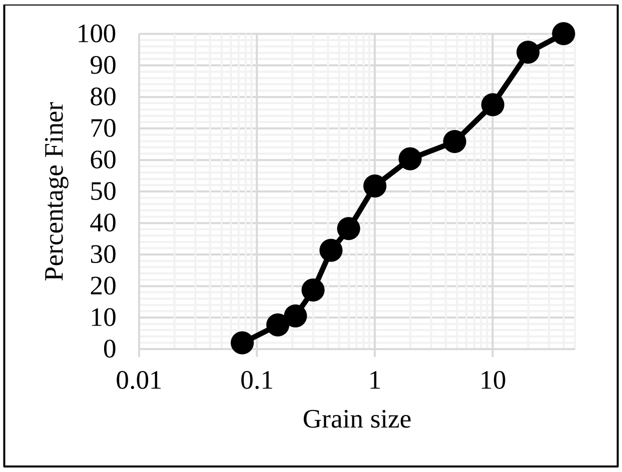

Fig. 3 Grain size distribution curve

From the particle size distribution curve, the following data are determined:

D_{10} = 0.2019mm, D_{60} = 1.963 mm, D_{30} = 0.4124 mm

Coefficient of curvature, Cc = $(D_{30})^2/D_{60}*D_{10}$ = $(0.4124)^2$/1.963*0.2019 = 0.429

Coefficient of uniformity, Cu = D_{60} / (D_{10}) = 1.963/0.2019 = 9.723

The soil is classified as SP, i.e., Poorly Graded Sandy Soil (as per IS: 1498 -1970)

Table 2. Sieve analysis of sample

Type	Size Distribution
Gravel (20 - 4.75mm)	28.324%
Coarse Sand (4.75-2.0mm)	5.456%
Medium sand (2.0 – 0.425 mm)	29.048%
Fine sand (0.425 – 0.075 mm)	29.358%
Total sand fraction	63.862%

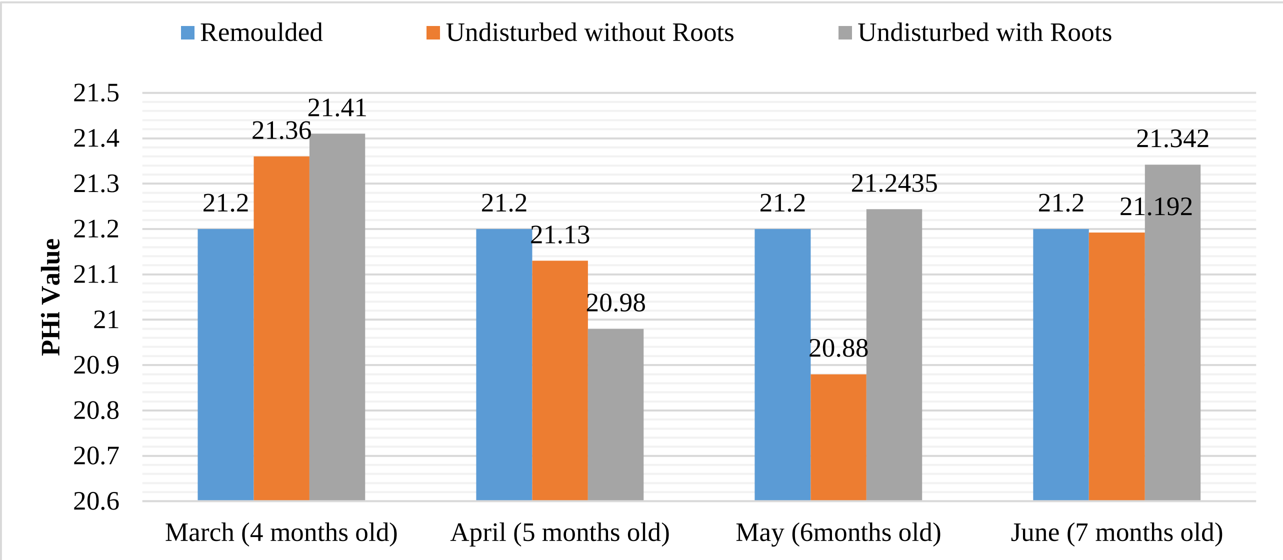

Fig. 4 Comparison of phi (ϕ) value

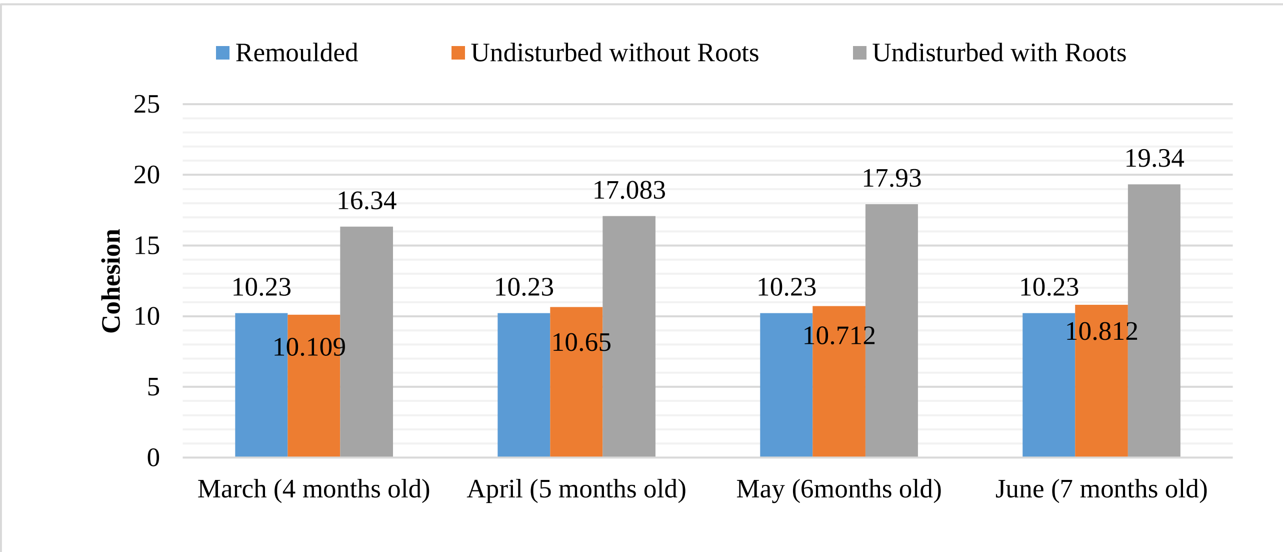

Fig. 5 Comparison of cohesion (C)

3.2. Shear Strength Parameters of the Soil

Comparison of shear strength parameters of soil under different conditions at different ages of plants are shown in Figures 4 and 5.

It has been observed that the roots have increased the shear strength of soil by 59.72% in March to 89.05 % in June.

But the phi (ϕ) value does not change much. Hence, it can be determined that the change in the shear strength of soil is mostly due to the increase of cohesion of soil because of plant roots.

3.3. Root Anchoring and Binding Index

The Index of Root Binding (IRB) and the Index of Root Anchoring (IRA) were calculated using a formula.

$$IRA= \sum D_v{}^2/dbh^2 \quad (2)$$

$$IRB =\sum D_h{}^2/dbh^2 \quad (3)$$

Where D_h and D_v are the diameters of horizontal (angle > 45°) and vertical (angle < 45°) proximal roots.

D_{v1}=981mm, D_{v2} = 678mm and D_{v3}= 781mm

D_{h1}= 872mm, Dh_2 =831mm and D_{h3}=712 mm

dbh = 383mm

Index of Root Binding, IRB = 39.759

Index of Root Anchoring, IRA = 40.5865

3.4. Tensile Strength of Root

A weight of 1.5 kg to 2.2 kg, approximately 477.9 kPa (kg/cm^2) or 0.479 MPa of root tensile strength, was discovered to cause tree roots up to 2 mm in diameter (first-rated roots) to fail.

It was also observed that the tensile strength of the root decreased as the diameter of the root increased, which concurs with Wang Chenglong et al. (2020).

3.5. Root Length Density and Root Density

The total length of the root under within the volume = 79.83 m

Volume of Pit = 0.029 m^3

RLD = 79.83/0.029

= 2752.756 m^{-2}

RD = 759 .78 kg/m^3

Now, C= 10.54+8.63 log RLD

C = 18.1364 kN/m^2

It has been observed that the RLD of the Miscanthus plant is higher compared to the plants available in our locality.

And the cohesion value we found using RD is almost equal to the cohesion value we found out using the triaxial test.

3.6. Site Result

Fig. 6 During the monsoon (site fully submerged under flood)

One-month-old Miscanthus plant saplings were planted on the site in December. It was planted over a 20 m × 10 m space, 25 cm apart from each other.

Even though some of the vegetation was nibbled by animals, many of the plants survived, allowing the study to go on.

After the monsoon season, the following was the situation of the site. It has been noted that during the monsoon season, the facility was entirely submerged beneath the water, as shown in Figure 6. However, because of its high root biomass and low shoot biomass, the plant was able to withstand the effects of the water current. However, some of the weaker plants were uprooted because of the influence of the water current, and Figure 7 shows the density of the roots of the miscanthus plant.

It was also observed that, within 8 months, new plants germinated around the old plants, which provided extra strength and support to the existing plants.

Fig. 7 Roots of matured miscanthus plant

4. Conclusion

This study investigated the effectiveness of using Miscanthus sinensis in stabilizing soil and preventing erosion and landslides, particularly in the context of the Northeastern region of India. The findings from the experimental work conducted at the selected site on the bank of the Pare River have demonstrated that Miscanthus sinensis can significantly enhance soil stability through its robust root system.

Key findings include:

1. Soil Reinforcement: The roots of Miscanthus sinensis were observed to create a strong binding network within the soil, which improved the soil's shear strength. The increase in shear strength was found to be directly related to the density and length of the roots.
2. Effectiveness in Erosion Control: The plant's ability to anchor the soil and reduce the movement of soil particles was evident in the reduction of soil erosion at the test site. The dense root network helped in retaining the soil, even during the monsoon season, which is typically associated with high rates of erosion.
3. Environmental Compatibility: Miscanthus sinensis is not of invasive species native to Arunachal Pradesh. It is non-invasive and resistant to pests and diseases in the region, which are good attributes of a bioengineering organism.
4. Sustainable Solution: A cost-effective and sustainable alternative to traditional hard engineering methods for soil stabilization with the use of Miscanthus Sinensis. Its perennial nature means longer-term gains without constant replanting.

In conclusion, Miscanthus sinensis has proven to be a viable alternative for soil stabilization in areas prone to erosion and landslides. Its use in bioengineering projects not only addresses the technical aspects of soil stabilization but also aligns with environmental sustainability goals. Further research could explore the long-term effects of Miscanthus sinensis on soil properties and its potential applications in other regions facing similar challenges.

The scope of this study was limited to determining how the Miscanthus plant improved the in-situ shear strength parameters. Further, the effectiveness of the work can be explored by considering the crucial characteristics and experiments as follows:

- To prevent the submergence of plants, the planting of more plants may be explored, and proper monitoring of the growth of plants may be maintained.
- Assess the effect of the plant on surface runoff.
- Proper records of the length of the root, shoot of the plant and planting methods may be examined.
- The period of study may be increased to observe the effectiveness of the plant on erosion control.
- Also, checking the cattle is necessary to prevent grazing of the plants.

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