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APPLICATION OF COCONUT COIR MATTING AND VEGETATION FOR RIVERBANK EROSION PROTECTION

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Abstract

In this paper, a sustainable and non-structural solution is identified to solve the problem of riverbank erosion by using the case study of Pusu River in the district of Gombak, Selangor, Malaysia. Several types of non-structural and sustainable materials were used as riverbank protection in the study area with the application of coconut coir mat and vetiver grass and their effectiveness were evaluated. The coconut coir was fabricated in the laboratory as per ASTM D6525 and it was applied in four plots at the riverbank that consist of different configurations namely bare soil, coconut coir mat with natural vegetation, coconut coir mat with vetiver grass, and vetiver grass on its own. To analyse the effectiveness of the configurations, two tests such as visual inspection test and riverbank erosion assessment using erosion pins were conducted. This study concludes that coconut coir helps vetiver grass roots to grow more expansively as compared to the growth of the vetiver grass without coconut coir. The application of vetiver grass is proven to be 90.5 % effective which is higher than other types of configurations with a 0.05 cm/day mean erosion rate observed.

Keywords: coconut coir, erosion pin, riverbank erosion, vetiver grass

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INTRODUCTION

River rehabilitation and restoration is not entirely new, as it has been practiced since a century ago (Bischetti et al., 2012). A great variety of strategies have been made across the world to restore the natural watercourse in their places, particularly which have been damaged due to natural disasters such as floods as well as anthropogenic intervention. Anthropogenic activities are still polluting the rivers in many countries, including Malaysia (Firdaus, Rasidi and Said, 2021). Since water is considered as one of life source, a serious attention on the activities that lead towards damaging this natural watercourse should be controlled to a minimum level (Tun Ismail et al., 2023). Nevertheless, a sustainable strategy towards the restoration of the riverbank is of great interest nowadays. There are numerous methods of riverbank protection designed throughout the years. Most of the river protection designs invented are conventional methods applying structural components such as reinforced concrete and steel structures.

At this present moment, it is crucial to produce a more sustainable design as it is more environmentally friendly and cost-effective in comparison to conventional designs. Nevertheless, in order to solve the problem, a sustainable solution is important where there must be a balance in environmental, social and financial aspects (Mickovski, 2016). It is proven that the soil bioengineering approach is an option that meets the requirements of technical and environmental concerns as there is a significant number of technical literatures on the subject produced in the preceding decades (Bischetti et al.,2012).

Despite the various methods of implementing riverbank protection available, it is important to make a proper selection of methods that can be implemented to avoid consequences such as excessive protection and redundant structures (Islam, 2008). The author also stated that riverbank protection built to protect a single point can also have an impact on the others points downstream.

The proposed method adopted in this study covers a series of sustainable strategies and designs from past researchers in producing a design that will help to solve the riverbank erosion in the study area. Types of materials and riverbank protection designs are produced by considering the cost, effectiveness, and sustainability features. Other than that, a physical scale model that is used for a procession of test runs is constructed in order to justify the effectiveness and the efficiency of the proposed design.

LITERATURE REVIEW

Riverbank Erosion

It is important to acknowledge the definition of riverbank erosion based on the types, characteristics and morphology of the riverbank before looking into possible methods to be implemented as riverbank protection measures (Islam, 2008). Collell et al. (2017) highlighted that engineering approaches are important to be implemented, as natural processes alone such as riparian vegetation are unable to withstand the present soil erosion problem. The authors also categorized the methods of protection into three categories which are conventional engineering, bio-engineering and compound solution that include structural and non-structural methods.

Riverbank erosion can be defined as the motion of the soil and sediment at the bank or bed of a river due to various causes, which may be due to the flow of the water, land use or weathering. Islam (2008) claims that the bank erosion phenomenon is a process that is repeated in sequences and that there are four sub-processes involved, which are abruption of riverbank slopes, slipping of the unstable slope, discharging of the failed soil of the slipping slope to the riverbed and lower part of the slope and the riverbank becoming unstable. This cyclic process is influenced by two main factors, which are hydraulic instability and geotechnical instability.

Soil erosion can be classified into two categories which are geological erosion and accelerated erosion (Abidin et al., 2017). Geological erosion is a natural phenomenon as the earth basically moves but the movement is not significant and the process requires a long period of time. This movement is actually a process to stimulate the formation of soil to be in an equilibrium state (Abidin et al., 2017). The authors also explained accelerated erosion which is a phenomenon where the soil moves because of the removal of vegetation that support the soil formation. Therefore, it is important to adopt appropriate riverbank protection measures in solving the issue of riverbank erosion.

Bio-Technical Riverbank Protection

Bio-technical engineering is a combination of geotechnical and bio-engineering disciplines that include vegetative and non-vegetative structural components (Morgan & Rickson, 1995). Similarly, Collell et al. (2017) states that artificial or natural material can be applied to bio-engineering measures in order to provide more structural stability.

On top of advantages of vegetation methods, especially its self-regeneration and soil stabilization improvement capability, bio-technical engineering also provides many equal opportunities to the economy, society, and nature aspects (Mickovski, 2016; Mickovski & Thomson, 2017). This type of approach is aligned with as sustainable development in which nature is not left behind while constructing a reliable, stable and durable structure with many precautions related to the sustainability of the environment, such as preserving natural life, minimizing waste and utilizing resources to the fullest (Mickovski, 2016).

Coconut Coir Matting

The scientific name of coconut is *Cocos Nucifera*. It is a fruit that has the thickest fiber strain among all types of natural fibers (Thyavihalli Girijappa et al., 2019).

The coconut coir is suitable to be a coir mat because of its properties of being a renewable resource, cost-efficient, highly water absorbent and full of nutrients that can support vegetation growth (Verma & Gope, 2015).

Jaafar et al. (2020) stated that erosion control matting can provide many significant advantages as the mat not only help to protect the surface runoff due to rainfall at the riverbank but also helps to cover the vegetation which increases the stability of the riverbank. The authors also stated that the mats can be made of natural materials such as fibers, wood or straw. On top of that, Jaafar et al. (2020) also conducted a case study in which coconut coir was utilised as a protective measure on the slope to minimize the effect of water erosion. It was proven that coconut coir matting helps vegetation development and provides extra reinforcement on the soil as the shear strength of the soil is increased. A case study by Jaafar et al. (2020) has proven that planting vegetation with matting shortens the length of the vegetation root while simultaneously increasing the concentration of the said root. This phenomenon also improves the stability of the riverbank soil.

Application of Vetiver Grass

Vetiveria Zizanioides or more commonly known as vetiver grass was promoted in 1980 by the World Bank as a land conservation measure in India (Leknoi & Likitlersuang, 2020). The authors also further discussed that Vetiver grass is highly functional where it is beneficial in various applications such as agriculture, slope stabilization, land mining, wastewater treatment and contaminated land rehabilitation. Moreover, the authors also described a few special characteristics to vetiver grass that are not exhibited by other vegetation, namely strong and fibrous roots that can penetrate soil approximately 2 or 3 meters per year, high tolerance to the extreme weather conditions such as flood and drought due to its survivability.

A slope profile simulation with and without vetiver grass were done in Malaysia to compare the slope factor of safety concluded that the application of vetiver grass is highly effective in order to provide protection to the slope without considering the its angle as shown in Figure 1 (Mohd Taib et al., 2020). Moreover, vetiver grass is proven to be more affordable and cheaper (Mondal & Patel, 2020). In addition, the authors state that the combination of vetiver grass with other protection measures has the potential to produce long-term riverbank conservation.

Selection of Riverbank Erosion Protection Strategies

Riverbank protection measures can be divided into three categories which are conventional hard structural, non-structural, and mixed methods (Collell et al., 2017). This study focuses on the non-structural method with the addition of sustainable features, which is a method that is more considerate to the environment with the use of organic materials and involving minimum alteration to the natural structure of the riverbank. In addition to that, two types of techniques have been shortlisted as the potential sustainable protection measures, which are bamboo planting and application of coconut coir mat.

It can be concluded that the application of coconut coir mat is more feasible than planting bamboo for a few reasons, chief of which it takes a lot of time for the growth of the bamboo plant. Based on research by Pertiwi et al. (2021), the result of bamboo planting can only be obtained after three to five years after planting. On the other hand, the application of coconut coir mat only takes less than a month just to observe the growth rates of the vegetation in the model (Jaafar et al., 2020).

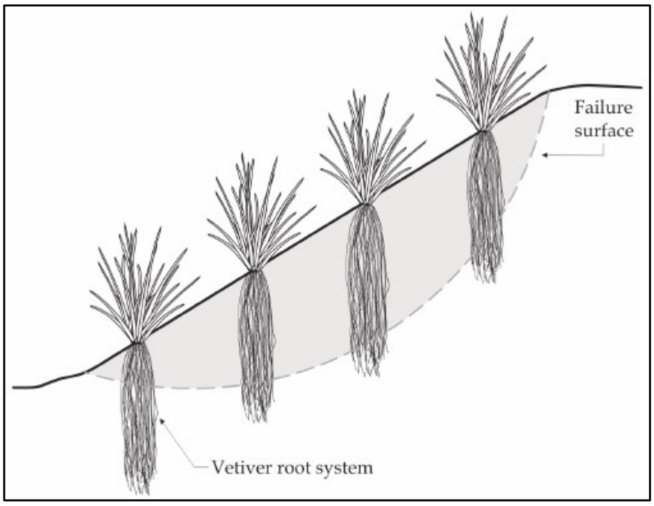

Figure 1: Application of vetiver grass as slope protection.
(Mohd Taib et al., 2020).

RESEARCH METHODOLOGY

Initially, a site investigation was carried out in order to attain associated data and parameters regarding the main problem occurring in the study area. The design of the riverbank protection for this study involves the application of coconut coir mat. On top of that, fabrication of coir mat and samples preparation were done. There were four types of configurations namely bare soil, coconut coir mat with natural vegetation, coconut coir mat with vetiver grass, and vetiver grass on its own. Testing of application and fieldwork data collection includes visual inspection test, riverbank erosion assessment using erosion pin and soil test. Based on the qualitative and quantitative data obtained, further analysis and discussion were done to justify the objective of this study.

Site Investigation and Materials Selection

One of the earliest stages of this study consists of conducting several site visits to assess the location of the study area and to collect data. The location of the study area is the downstream part of Pusu River as illustrated in Figure 2. Additionally, the Pusu River is one of the tributaries of Gombak River and it is the biggest watercourse in Gombak District. However, upstream of the Pusu River, many activities take place that have a negative impact on the Pusu River ecosystem including illegal construction, illegal logging and illegal farming.

Figure 2: The aerial view of Pusu River

Based on the visual inspection conducted, it can be concluded that Pusu River is facing sedimentation problems and riverbank erosion. The riverbank erosion is majorly due to hydraulic instability as the flow of the river and the volume of water are decreasing gradually due to the high sedimentation concentration in the river.

A site visit was also conducted to assess the river geomorphological condition to identify the location of the riverbank erosion. The types of riparian vegetation which naturally exist on the riverbank at Pusu River are *Ludwigia Alternifolia* and common natural grass. Some other parts of the riverbank were observed to be without vegetation (Hambal, 2021).

The selection of vetiver grass with coconut coir matting is due to other factors, as well such as the cost of the material. Vetiver grass is commercially used in many industries in Malaysia, and the cost is considered affordable, at around RM 4.80 per polybag. Not only that, the coconut coir is made of coconut husk, which is considered to be an abundant waste product of the agriculture industries in Malaysia. Due to this fact, it is cheap to acquire the coconut coir. In addition, the selection of material is also influenced by the serviceability of the protection measure. In this case, both of the materials did not require much maintenance as the coconut coir and vetiver grass are considered strong in other to withstand extreme conditions such as drought and flood. Thus, due to the short study period of this project, setting up a test model for a coconut coir mat with the planting of vetiver grass is the best method that is sustainable and not involving artificial structural components.

Fabrication of Coconut Coir

Coconut coir mat can be easily obtained as it is commercially available. In this study, coconut coir mats were fabricated in Kulliyyah of Engineering laboratory using Compression Testing Machine, as shown in Figure 3, with reference to ASTM D6525: Standard Test Method for Measuring Nominal Thickness of Rolled Erosion Control Products.

Procedure of Fabricating Coconut Coir Mat

The first step of fabrication is to extract the coconut husk to turn it into the coconut coir. This process was done by splitting and peeling the coconut husk from the pith in order to get a fibrous state of coconut coir which is easier to mould and shape. The coconut coir obtained from the previous process is heated in the drying oven at a temperature of 160°C for 5 minutes to complete the process of the extraction as shown in Figure 4.

Figure 3: Compression Testing Machine

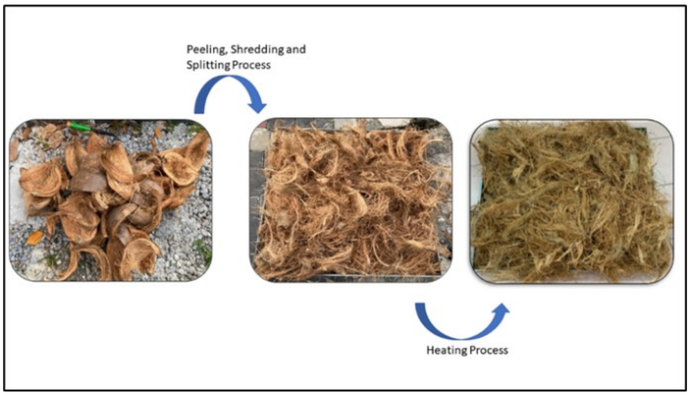

Figure 4: Extraction process of coconut coir

The process continues to the fabrication of coconut coir mat by pressing the coconut coir using Compression Testing Machine for 10 minutes with 6 kN pressure in order to fabricate with a thickness of 6 mm as per ASTM D6525: Standard Test Method for Measuring Nominal Thickness of Rolled Erosion Control Products. The coconut coir is fabricated using Aggregates Crushing Value Mould and prepared using a special method in order to produce the coconut mat in the most efficient manner and applicable to the Compression Testing Machine as shown in Figure 5.

Sample Preparation
The test model was conducted in the study area and will be categorized into four configurations which are:

1. Bare soil.
2. Soil with natural vegetation on the riverbank with coconut coir matting.
3. Soil with the addition of vetiver grass with coconut coir matting.
4. Soil with the addition of vetiver grass planted independently.

The vetiver grass was selected due to its characteristic of having a long root system that can be a structural component of the soil. In this study, the planting techniques do not involve hydroseeding as it may cause many uncertain scenarios, such as the availability of the seeds and the failure of the seedling stages. Hence, vetiver saplings were used at this stage. The test model also involved natural vegetation that already exists in the riverbank area. The grass in the surrounding area underwent replanting when the coconut coir mat was installed. Finally, in order to prepare soil without vegetation, a section of the test site needs to be cleared of any vegetation prior to coconut coir mat installation.

Figure 5: Fabrication of coconut coir

Testing
Visual Inspection Test
The visual inspection test was performed in order to observe the effects of installing coconut coir mats on the vegetation in the four conditions. The characteristics of the vegetation roots were observed once weekly for three months. This procedure is important in order to justify whether combining coconut coir mats with vegetation helps to improve the growth rate of the vegetation. Photographic images were taken as an observation to compare each

different condition which also includes the growth of vegetation roots and the overall condition of the test.

Riverbank Erosion Assessment Using Erosion Pin

Erosion rates were observed by using erosion pins installed at all four plots. This assessment method will give a more precise detail of whether the coconut coir mat can provide additional support to the soil of the riverbank or otherwise. 28 pins were inserted in a horizontal alignment approximately 30.4 cm deep in the soil sample. Measurements from the tip of the pins to the riverbank surface were taken at regular intervals from April to June 2022.

ANALYSIS AND DISCUSSION

Visual Inspection Analysis

Figure 6 shows the visual comparison of the vetiver grass root observation at initial condition taken on 19 April 2022 and its final condition taken on 2 June 2022. From the observation, it can be seen that vetiver grass roots with coconut coir grew more expansively compared to those without coconut coir. This finding could be attributed to the application of coconut coir seemingly being beneficial to the growth of vetiver grass roots. This is in agreement with Jaafar et al. (2020) where coconut coir matting helps vegetation development and provides extra reinforcement on the soil.

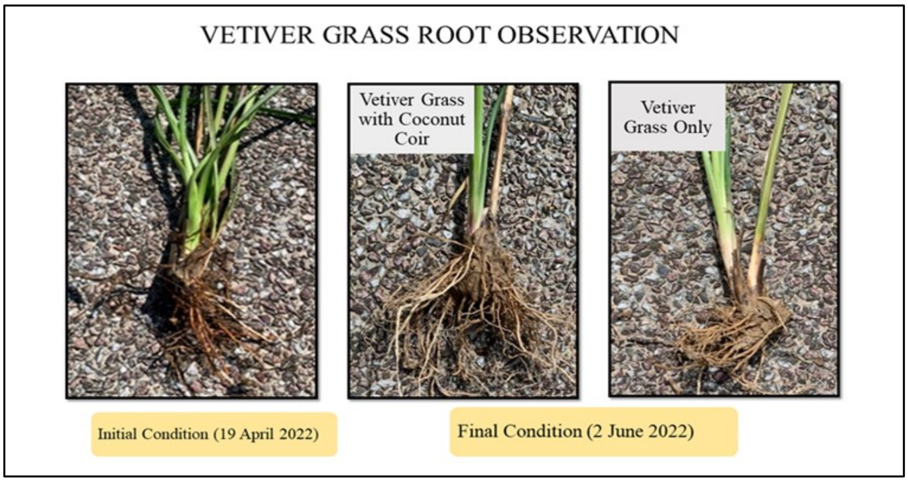

Figure 6: Vetiver grass root visual observation

Erosion Pin Assessment

In this erosion pin data assessment, the mean of the erosion rates for every plot, the percentages difference of the effectiveness of each method with respect to the average of the mean erosion rates, and the spatial variation of each pin will be discussed. All of these results are pertinent in terms of justifying the effectiveness of the suggested sustainable solution for riverbank erosion.

Mean Value for Erosion Rates

The mean value of the erosion rates for every plot is calculated to exhibit the riverbank erosion that has occurred. The mean value for erosion rates of each plot is calculated by averaging the exposed length for each pin divided by the number of data collection days. The mean value of erosion rates for every plot is shown in Figure 7. The highest mean of erosion rates was exhibited by the bare soil plot, which is 0.0818 cm/day, and the lowest is in vetiver grass with coconut coir plot which is 0.0360 cm/day. Therefore, it is proven that vetiver grass with coconut coir is the most effective in protecting the riverbank from erosion, followed by the natural vegetation with coconut coir (0.0461 cm/day) and vetiver grass installed independently (0.0502 cm/day).

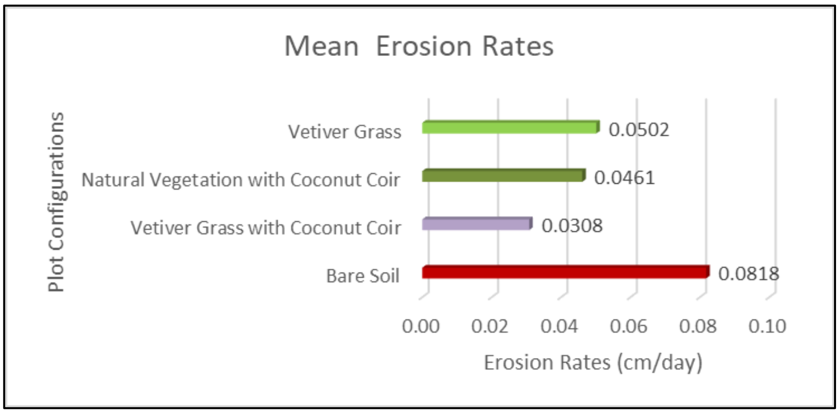

Figure 7: Tabulation of erosion rates mean value

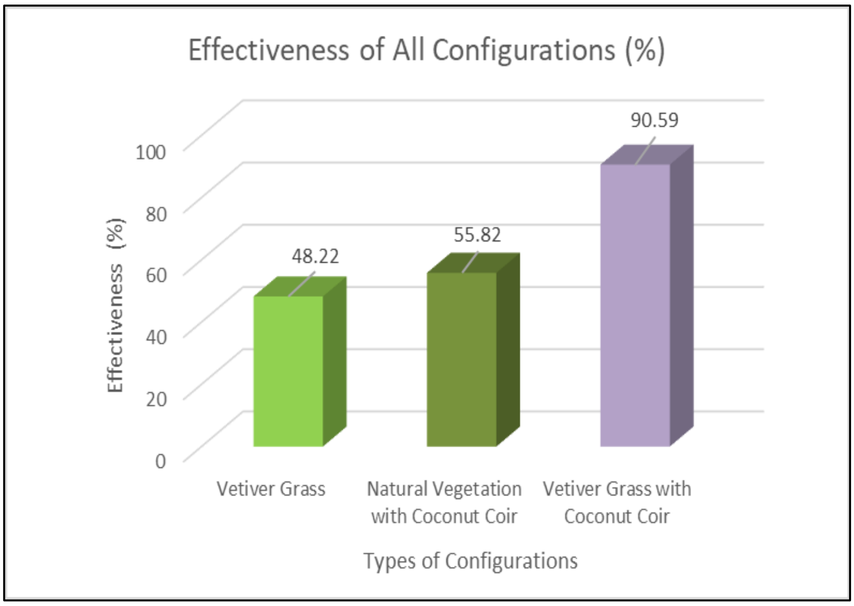

Figure 8: Effectiveness of all condition types to reduce erosion rates

The output of the mean values for erosions of each plot could also be represented in terms of effectiveness expressed as percentage difference of the mean erosion rates of the various configurations against that of bare soil.

Results show the highest percentage of effectiveness was obtained for the configuration of vetiver grass with coconut coir at 90.59% as compared to its counterparts shown in Figure 8. Ultimately, this indicates the application of vetiver grass with coconut coir matting is proven to be the most effective solution to treat the riverbank erosion at the Pusu River.

Spatial Variation of Erosion Value

In order to provide a different perspective of the erosion that occurred at the riverbank, spatial variation of erosion values at each pin was introduced. This erosion value denotes the change of the exposed length of the pin from the beginning to the end of the observation period. In Figure 9, the magnitude of this change is represented by the size of the circle.

The bare soil plot demonstrated the biggest change of erosion value compared to other types of configurations, which exceeds 10 cm at the toe of the plot. Conversely, the lowest change of erosion value was exhibited by the vetiver grass with the coconut coir configuration followed by natural vegetation with coconut coir, vetiver grass only and lastly the natural grass on its own.

Figure 9 also demonstrated that the erosion majorly happened at the toe of each plot. However, the proposed method, which is the application of the vetiver grass with coconut coir, still provides good protection as it lessens the change in measurement at the toe of the riverbank.

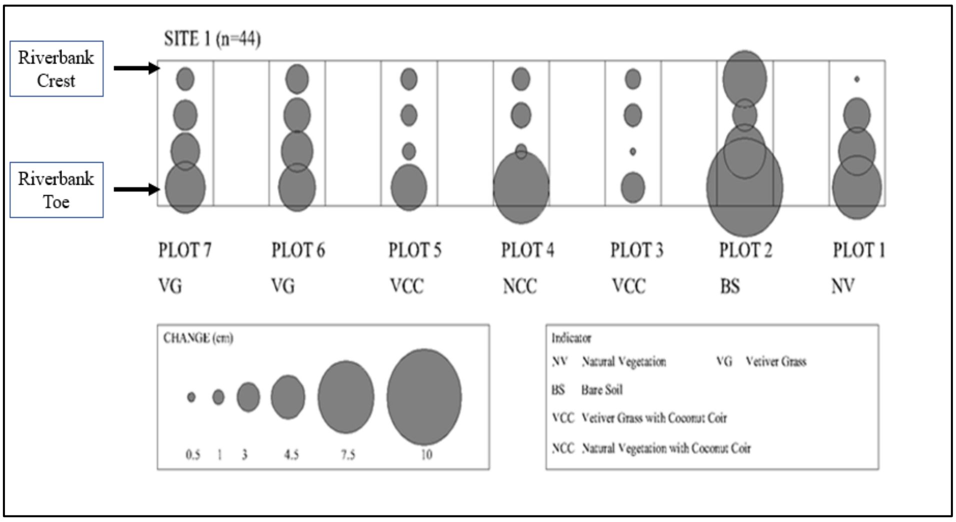

Figure 9: Spatial variation of all configuration

CONCLUSION

This research has succeeded in applying and evaluating the efficiency of various configurations of sustainable materials and vegetation for the purpose of riverbank protection measures in Pusu River. Coconut coir and vetiver grass were selected specifically for this study considering the cost, effectiveness, and sustainability features. Field observation and measurements were successfully conducted for four different plots consisting of bare soil and the other configurations which are coconut coir mat with natural vegetation, coconut coir mat with vetiver grass, and vetiver grass alone.

The configuration of coconut coir mat and vetiver grass is proven to provide the best result in terms of providing effective protection toward the riverbank as evidenced by 0.308 cm/day erosion rate, 90.59% efficiency and lowest magnitude of change in erosion value. Furthermore, with regards to root morphology, results show that the configuration of vetiver grass and coconut coir achieved the best outcome in which the vetiver grass roots have grown more expansively compared to other configurations. These findings suggest that this configuration enhances the soil strength therefore leading to better riverbank stability. Future study can be undertaken on other parameters that includes hydraulic, geotechnical and bio-engineering aspects to further enhance the efficiency of non-structural and sustainable riverbank protection measure.

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