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Design Guidelines for Vegetative Approach Application to Mitigate Riverbank Landslides in Mangkang Wetan and Mangunharjo Villages, Semarang Coastal Area, Indonesia

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ABSTRACT

The Semarang coastal area is vulnerable to floods, land subsidence, and landslides, including Mangkang Wetan and Mangunharjo villages. The community villages struggle with flooding every year because of the riverbank landslides. The government's efforts to improve the critical embankments have not yet reached these villages. The community prevents landslides by a conventional method, such as using sacks filled with sand. However, this effort did not make it significantly effective. Therefore, this study proposes a vegetative approach as an alternative effort to reduce the landslide possibility and provide directions for riverbank management. This approach emphasizes soil conservation by applying a suitable plant type to reduce the landslides possibility. Determining the design guidelines for the vegetative approach starts by analyzing the physical condition of the village and the river to specify zone types; then continues by analysis of the appropriate vegetation types. Afterward, determine the design direction for each zone and recommend a suitable type of vegetation. The analysis results show two strategies related to the possible application of a vegetative approach. The do-nothing strategy is for locations that cannot physically intervene because there is no river border. In contrast, the do something strategy is applied to locations that physically allow for a vegetative approach at the river border. However, no single effort can prevent landslides, so it needs to combine mechanical and vegetative approaches that adjust to the physical characteristic of the river and the soil type.

Keywords: Design, landslide, riverbank, vegetative approach

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INTRODUCTION

The increasing population and their activities have led to escalated land conversion in urban areas, particularly from rice fields to build areas (Ducey et al., 2018; Oliver & Thomas, 2014), which further raises the risk of disasters, especially hydro-geomorphological disasters (Barros et al., 2021; Sidle & Onda, 2004; Su et al., 2021). Hydrological processes with natural landscapes and geomorphic processes with surface and subsurface waters in temporal and spatial aspects define hydro-geomorphology (Barros et al., 2021; Sidle & Onda, 2004). One of the hydro-geomorphological disasters is riverbank landslides caused by water erosion from upstream areas.

Riverbank landslides include shallow landslides that occur due to rainfall, where the duration of the rain is moderate to high, which is between 1–15 days with moderate to long rain intensity, as well as in an area with soil types that are difficult to hold water (Persichillo et al., 2017; Zêzere et al., 2005). Shallow landslides are difficult to detect early but can be mitigated through nature-based solutions, such as using the vegetation (de Jesús Arce-Mojica et al., 2019; Kalsnes & Capobianco, 2022; Persichillo et al., 2017). Shallow landslides are defined as landslides caused by the process of saturation of the soil layer due to heavy rains of short duration, involving the soil layer near the surface, move quickly, can flow, and usually occurs in flow landslides, slides, and collapses (the Indonesian Research Institute-LIPI). However, there are several efforts to overcome riverbank landslides, and the most common strategy is to develop an embankment made of a mixture of river stone, cement, and sand. These strategies are considered adequate for protecting and maintaining soil stability and preventing landslides, but it requires a high cost and does not have a minimal environmental impact (Bariteau et al., 2013).

Handling shallow landslides that have a significant long-term impact is applying suitable plants and involving the community in the process (Hostettler et al., 2019). Likewise, the President of the Republic of Indonesia, Joko Widodo, has encouraged and facilitated the local government and community to adopt the vegetative approach to mitigate. The vegetative approach has some benefits such as increasing water absorption using plant roots, maintaining soil stability, low cost in implementation, allowing the community to be involved in the process and sustaining to empower the community. In addition, this approach is in line with the recommendations of the Sendai Declaration related to Disaster Risk Reduction, which prioritizes ecosystem-based solutions. The Indonesian government introduced and promoted one type of plant to overcome shallow erosions: vetiver grass. This plant is one of the most widely developed plants, which can mitigate landslides by covering, protecting, and stabilizing the environment (Ghosh & Bhattacharya, 2018).

The Semarang City Government also obeyed the central government's instructions to use vetiver grass to reduce landslides. However, semarang is highly vulnerable to disasters (Li et al., 2016; Sherly et al., 2015), including a high potential danger of landslides (National

Disaster Management Agency of the Republic of Indonesia, 2015). Indeed, the most common disaster in Semarang City in 2020 was landslides in hilly and steeper slope areas (southern and left part of Semarang) and in the downstream area (coastal areas or north part of Semarang). This study focuses on shallow landslides in coastal areas, particularly in Mangkang Wetan and Mangunharjo villages, where the riverbank landslides were followed by flash floods that inundated community settlements. The existing disaster management strategies emphasize protecting coastal areas by developing mangrove conservation (Semarang City Government, 2016), whereas other efforts concerning shallow landslides handling have not been further exposed. Conventionally, the community independently makes deposits from sand-filled sacks as a prevention effort.

However, vetiver system implementation faces challenges such as lacking community support because they do not understand the vegetation's role in mitigating disaster risk. Likewise, the community comprehending the riverbank's role as river protection is lacking, so the river border is used as a garbage disposal, even as a place to live (permanent housing). Hence, it is essential to identify the possibility of a vegetative approach implementation to mitigate landslides in the coastal area of Semarang, especially in Mangkang Wetan and Mangunharjo Villages. Furthermore, the operationalization of the vegetative approach is also crucial; it discusses the plant types and riverbank arrangement, including the application of the vegetative approach and the appropriate design.

MATERIALS AND METHOD

Research Study Area

The research location is in the coastal landslides-prone villages, Mangkang Wetan and Mangunharjo Villages, Tugu District (Figure 1). Geographically, theMangunharjo Village is passed by the Beringin River, which reaches 0.03 km², whereas the Beringin River traverses the Mangkang Wetan Village, which reaches 0.26 km² (Semarang City Government, 2014). The width of the Beringin River in the upstream area is 20 meters, or more extensive than in the downstream area (Mangunharjo Village), and reaches 9.5 meters (Indrayati & Hikmah, 2018). Therefore, the Beringin River has a distinct classification; it is classified as a big river in the upstream area, while in the estuary area, it is classified as a small river (Maryono, 2009).

Every rainy season, the water of the Beringin River always overflows to inundate hundreds of houses of residents of these two villages. The flood triggered by high rainfall prevents the river from accommodating the water discharge and causes embankment landslides. The most significant impact of flooding occurs in the settlement located in the riverbank area or at 1.5–2 meters from the river. Moreover, the riverbank has no buffers that are left overgrown with weeds. Regarding the physical characteristics, this river has a flat slope and approaches sea level elevation, so it is difficult to drain water during high tide conditions (Figure 2).

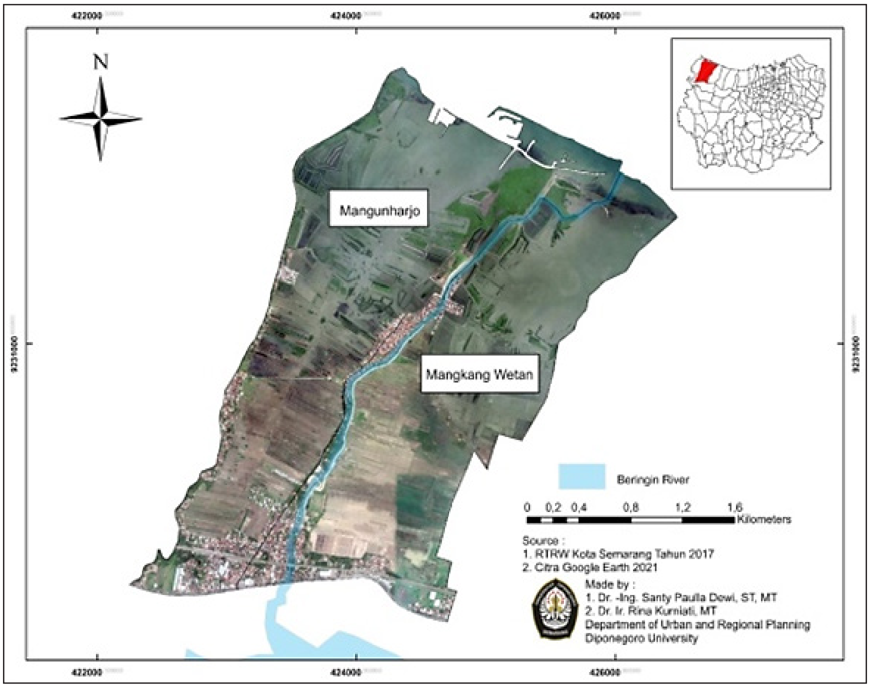

Figure 1. Research location
Source. Semarang City Drainage System Master Plan 2011-2031 (Semarang City Government, 2014)

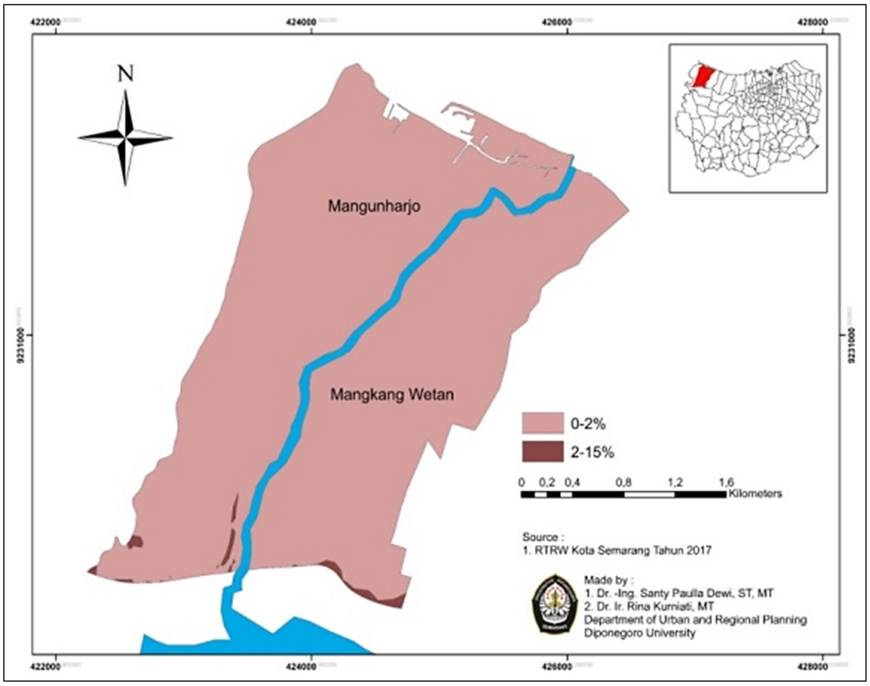

Figure 2. Slope of research location
Source. Spatial plan of Semarang City 2011-2031, (Semarang City Government, 2017)

Research Method

This study reveals vegetative approach implementation that appropriates the physical characteristic of the river to reduce the risk of riverbank landslides. The research method used is spatial by overlaying data related to the area's physical characteristics, such as soil type, slope, and land use, to determine land-use changes (size and the distribution). In addition, the vegetative approach design is formulated by comparing the government regulation on border and riverbank arrangement, green open space alignment, and river normalization.

The data used in this study are mainly collected from field observations, especially those related to the physical condition of the research area, and secondary data from government agencies such as data related to spatial planning and landslide management policies obtained from the Semarang Central Bureau of Statistics, Semarang Development Planning Agency, and Regional Disaster Management Agency (BPBD) of Semarang City. Following are the research process stages.

Identification of Physical Characteristics of the Research Area

The physical characteristics revealed from the land use, soil type, rainfall, slope, disaster mitigation reports, settlement, and dynamics data gained from government institution websites such as Semarang Central Bureau of Statistics reports or planning or development documents from Semarang Development Planning Agency and BPBD of Semarang City. The analysis technique is a spatial method that produces a map of the landslides-prone area and its level.

Analysis of Vegetative Approach

This analysis aims to determine the appropriate vegetation types for mitigating riverbank landslides. This stage was conducted by identifying various kinds of vegetation which can withstand landslides based on previous research (Adhitya et al., 2016; Herman et al., 2013; Izzul et al., 2020; Mentari et al., 2018; Risdiyanto, 2019). The vegetation analyzed is the type of vegetation that can grow in Indonesia, which means compatible to plant in the research area. Afterward, reviewing the kind of vegetation with the research area's soil type, slopes, and fertility. Besides, other economic considerations have also been considered, such as the vegetation price, maintenance aspect (whether the vegetation needs extra care), and availability (which relates to how the community gets plant seeds).

Analysis of Riverbank Design Guidelines

Determination of riverbank design guidelines is defined from the government regulations on riverbank arrangement and urban design standards, which are compared with the existing situation. The current condition of the research area showed that the riverbank was left with no specific vegetation. Meanwhile, the government's plan to normalize the river is still in progress due to land acquisition constraints; unclear the fixed realization of river normalization or to what extent the normalization is; whether all along the river or certain parts of the land that has been successfully acquired.

Therefore, according to public policy theory, there are two scenarios: do nothing and do something. The do-nothing scenario is also referred to as the status quo when the government has not yet successfully implemented the Beringin River normalization plan. Meanwhile, the do-something scenario represents that the design is adjusted to the government's plan combined with the study results of appropriate vegetation types.

RESULTS

Physical Characteristics

The Beringin River, which crosses Mangkang Wetan and Mangunharjo Villages, includes a river with an embankment in urban areas. Therefore, according to the Minister of Public Works and Public Housing Regulation, the border at the research location is at least three meters from the outer edge of the embankment border. However, there are some points in the Beringin watersheds where the width of the riverbank is less than three meters (Figure 3, the red number represents the area with a range of fewer than three meters). These locations are dangerous and experienced landslides because of the high-water runoff from upstream. The landslides include the type C zone, with the soil type being the Mediterranean and

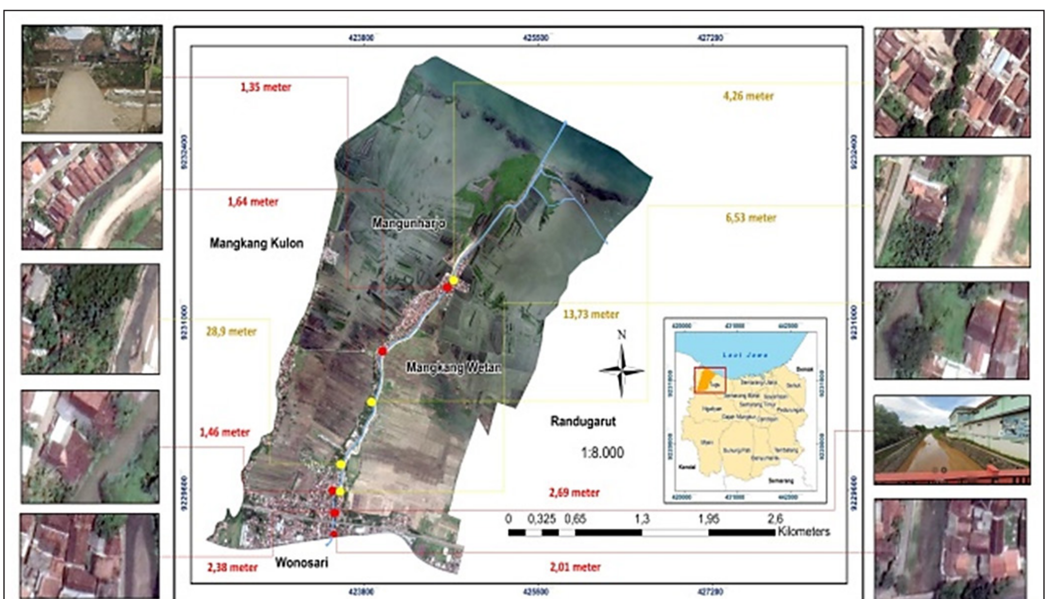

Figure 3. Riverbank existing situation (range between river and building or other functions)

residing on a low slope (0–20%). This soil is formed from sediment because surface runoff from upstream, composed of clay and sand, tends to be unstable, and suitable vegetation is needle-leaved and fibrous roots (Ministry of Public Works, 2007).

The area along the Beringin River is mostly occupied as housing. Housing in the river border zone (less than three meters from the river) always faces a flood that leads to riverbank landslides and then causes flash floods. Besides, land use in the downstream Beringin river basin consists of rice fields, industry, ponds, and mangroves (Figure 4). The land value in these two villages is relatively high because they are in the urban area of Semarang and close to the airport. Therefore, the demand for housing is relatively high, bringing considerable land conversion. The spatial analysis in 2017 and 2021 showed that land-use conversion occurred at several points on the left and right sides of the river; land conversion from the green open space to settlements on the left side and mangroves at the mouth of the river. The settlement that resided on riverbanks is not under government directives. In contrast, a downstream area should also need to accommodate a protection function that ensures no obstacles in flowing water to the sea.

However, the land conversion in the Beringin watershed, which was previously green open space to residential, is still following land use direction. Meanwhile, residential areas

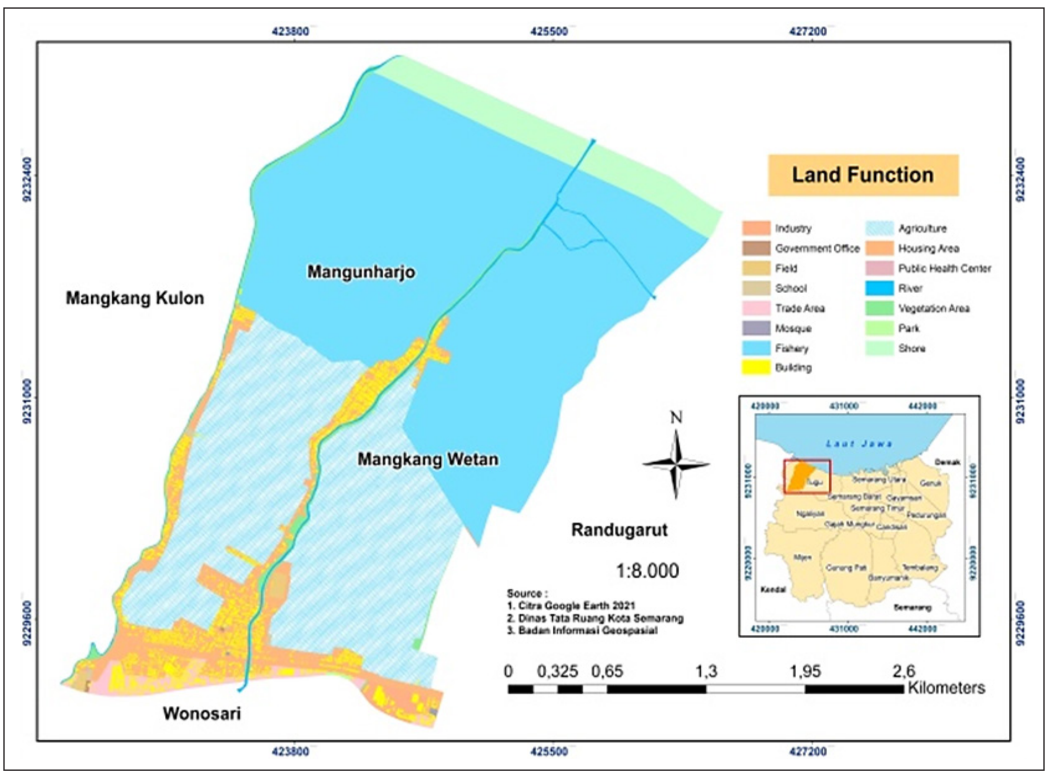

Figure 4. Land use of research area
Source. Spatial plan of Semarang City 2011-2031, (Semarang City Government, 2017)

that occupied the riverbanks are primarily located in central residential areas with a higher density than others. Indeed, one of the junior high school buildings is developed right by the river and has no border. The school manager developed a permanent cement barrier around the school buildings to mitigate riverbank landslides. Nevertheless, flooding still occurs yearly because the river capacity cannot accommodate the high water discharge.

Based on the Semarang City Drainage System Master Plan, Mangkang Wetan Village is included in the Beringin River drainage sub-system, while Mangunharjo Village is part of the Mangkang River drainage sub-system. Both villages have a dark brown Mediterranean soil type with a clay texture with low fertility and the ability to store and bind water, so it is categorized as prone to landslides. Furthermore, vulnerability to landslides is exacerbated by the lack of land cover on river borders, while some parts of riverbanks-built cement embankments that reduce vegetation. Consequently, the land conversion in the Beringin River basin declines river functions (Sutopo et al., 2019). In addition, the dark brown Mediterranean soil type has a high erodibility level, making the landslides risk high (Dariah et al., 2015). Therefore, based on the soil type, slope, and level of soil erodibility, the two drainage sub-systems are included in the category of moderate erosion hazard with erosion hazard of 17.50–46.25 tons/ha/year (Figure 5).

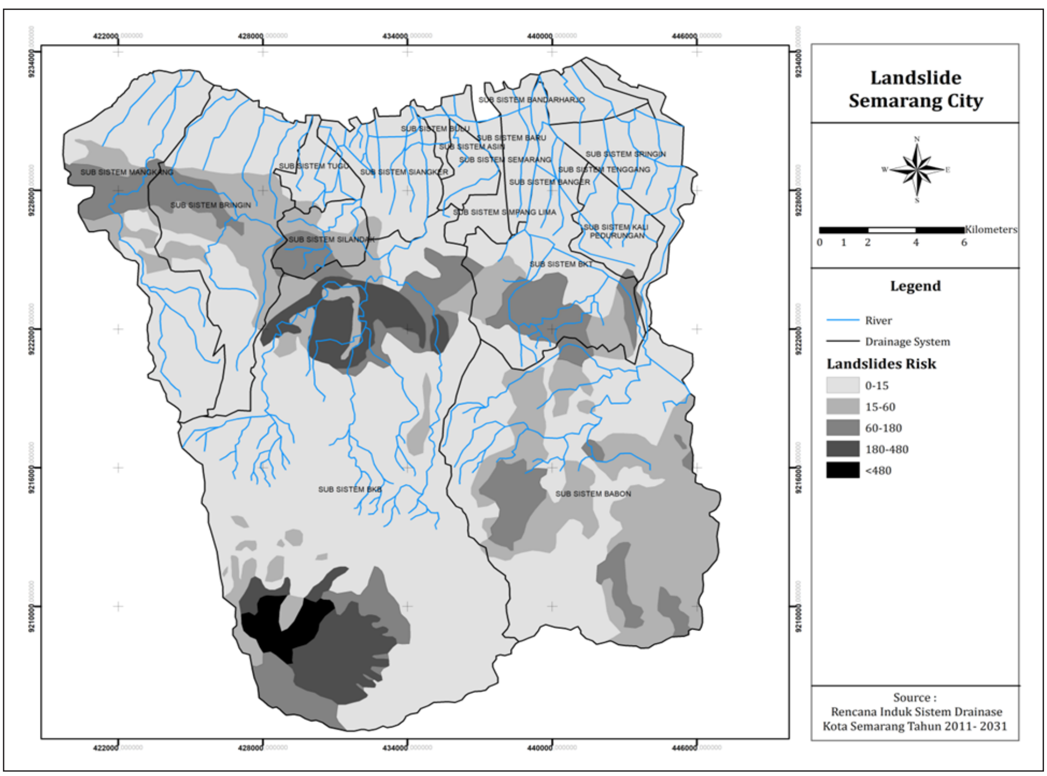

Figure 5. Landslides level map
Source. Spatial plan of Semarang City 2011-2031, (Semarang City Government, 2017)

Another problem in the Beringin watershed is sedimentation, where the total sediment deposition reaches more than 20,000 m^3/year, making the river shallow and narrow (Semarang City Government, 2014). Likewise, the growth of wild plants causes the river wide narrower. A high-intensity rain makes runoff that flows downstream cannot accommodate and leads to flooding and erosion. Based on the Semarang City BPBD report in 2020, the Beringin riverbank landslide was caused by the medium intensity of rainfall which reached 22.10 mm/month to 393.20 mm/month. It increased the volume of the Beringin River water, reaching 60 -70 cm, and caused the water to overflow into the settlements.

Vegetative Approach Application

The vegetative approach is one of the solutions to overcome riverbank landslides which is considered more accessible and economically than others, such as the concrete method (Leknoi & Likitlersuang, 2020). Likewise, this approach aims to reduce or delay water runoff and serve as a barrier to overcoming landslides. In addition, this method can also hold back sedimentation and reduce pollution carried by water to maintain water quality and the environment (Lobo & Bonilla, 2017). There are several techniques in the vegetation approach: reforestation, agroforestry consisting of alley cropping, strip cropping, grass strips, rows of crop residues, cover crops, and the application of cropping patterns, including crop rotation intercropping and relay cropping (Subagyono et al., 2003).

The Beringin riverbank was overgrown by wild plants that did not function optimally. There has been no reforestation effort on the river border, so it has not been planted with particular vegetation that can mitigate landslides. Only weeds, bushes, and banana trees are planted randomly by the community. Hence, vegetation on the riverbank in the coastal areas is vulnerable to contamination by mud and garbage carried by water runoff during floods. The selection of greenery in a vegetative approach may consider the plants' capacity to withstand the cliff structure from landslides, which refers to the following criteria:

- Vegetation that can protect embankments and riverbanks from cliff erosion and landslides
- Cover crops that can restrain the water runoff rate and can be a barrier
- Plants that have the robustness and produce leaf litter that easily falls off
- The selection of vegetation types considers the natural physical characteristics (soil type, water flow, microclimate temperature, and sunlight), economic aspects (affordable prices, easy to obtain, provide benefits), and social aspects (plants that are familiar to the community and easy to cultivate).

The following are vegetation that can protect the soil and mitigate landslides that differ from the characteristic (Table 1).

Table 1
Characteristics of vegetation

No	Vegetation	Strength	Weakness
1	Candlenut *(Aleurites moluccana)*	• Deeply penetrating taproot with multi-branched roots • Can thrive on Latosol, Podzolic, and Andosol soil types	• It needs three years to grow optimal • Not suitable for the type of soil in the study area (alluvial)
2	Vetiver grass (*Chrysopogon zizanioides)*	• It stabilizes the soil because the roots reach three m deep • Reducing pollution (chemical and medical waste, mercury) • Easy to maintain	• Short lifetime • Need to combine with other plants, mainly with land cover
3	Mindi (*Melia azedarach*)	• Deeply penetrating taproot with multi-branched roots	• Hard to obtain seeds, considering the wood has a high economic value, so that very demanding • Vulnerability to insects and plant pests
4	Yellow bamboo (*Bambusa vulgaris)*	• Its fibrous roots stabilize the soil • Easy to maintain • Can grow on all types of soil • Low-cost investment	• It needs five years of planting • It requires a large planting medium
5	Pandanus *(Pandanus amaryllifolius*)	• It has a large and long roots • The sea pandanus can break the waves and become a nesting place for turtles	• Suitable if applied to the beach or the sea
6	Banana tree (*Mussa sp*)	• Retain the soil moisture • Fibrous root system (rhizome roots)	• Requires care and fertilization to grow optimally • It is easy to collapse because the root does not penetrate the soil
7	Guava tree (*Psidium guajava l.)*	• It has a strong root system (taproot and fibrous) • It can grow in various soil types	• Requires a large planting medium

Determining vegetation characteristics needs to consider the plants growing irregularly along the riverbank. Therefore, it concludes that the vegetation types can be divided into conservation plants and riparian vegetation. Conservation plants play a role in revegetating river areas to be planted, especially in border areas. Meanwhile, riparian vegetation is the majority of plants that can survive in a water-submerged area. The following is an example of flexible riparian vegetation with a robust root system, such as vetiver grass, yellow bamboo, and guava. This vegetation can stabilize the soil and protect the riverbanks by reducing surface flow velocity when runoff and reducing pollution. In addition, the soil type has also determined the implementation of the vegetative approach, such as alluvial soil, which is included as a fertile soil with a flat slope of 0–2%.

The vegetative approach is addressed to give long-term protection for riverbanks against landslides and provide economic benefits for the community without damaging the environment. For instance, planting guava trees on riverbanks offers several advantages, such as being a conservation plant to revegetate borders and a commodity plant with an economic value to the community.

Based on the Drainage System Plan, one of the efforts to conserve soil in landslide-prone areas is the reforestation of river borders. However, the recommended plants are primarily trees that take a relatively long time to grow and impact. Therefore, the government currently encourages greening riverbanks by planting vetiver grass or *akar wangi* (the local name of vetiver grass), or *Chrysophogon zizaionide* to mitigate landslides. In Indonesia, the application of vetiver grass as a barrier to cliff landslides has only been introduced and encouraged by the government since 2007, although it was still on a small scale; even until 2010, initial studies or trials were still being conducted in several pilot locations (Kusnandar & Kusminingrum, 2011).

However, *akar wangi,* used as a craft material, has been around for a long time, especially in Bali and Garut. The root fibers are processed into bags, paintings, lampshades, prayer rugs, and others. The processing of vetiver into these crafts has been recognized and recorded as intangible cultural heritages in the domain of traditional crafts skills and proficiency by the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia in 2013.

Research from the Agency for the Assessment and Application of Technology showed that shoot and root growth and the ability to absorb pollution of vetiver grass were better when planted with river water media than groundwater media (Komarawidjaja & Garno, 2016). Therefore, the utilization of vetiver as an implementation of a vegetative approach to preventing cliff landslides is appropriate. In addition, with the government's support through various programs and assistance from the private sector in providing vetiver seeds, implementation in the research location is more likely. Therefore, ecological design is appropriate to mitigate the Beringin River's riverbank landslides (Sittadewi, 2016).

However, vetiver grass has a short lifetime (only reaches one year and needs to be planted the following year again); it requires a continuous and consistent commitment from the government and other parties to provide and facilitate the provision of vetiver seeds (Leknoi & Likitlersuang, 2020; Mondal & Patel, 2020). Furthermore, the growth pattern of vetiver grass tends to be vertical, so it needs to be combined (intercropped) with ground cover plants such as elephant grass and vegetables or bamboo and jute geogrids (Mondal & Patel, 2020). Hence, the local community's role is necessary to realize riverbank conservation. Meanwhile, the plants that economically have great value and can reduce landslide risks are more in the form of trees. However, it needs several years for the tree to absorb water and resist erosions. For instance, Candlenut, especially the sultan candlenut species, can produce oil as an alternative fuel, but it is not suitable for research areas with Mediterranean soil types. In addition, the vegetative approach cannot rely on a single vegetation type; it requires mixing with other plants or other methods.

Moreover, the vegetative approach in the research area is primarily realized in the form of mangrove conservation, whereas reforestation to prevent erosions is still focused on hilly steep slope areas. The vegetative approach is one of the soil conservation techniques besides mechanical and chemical techniques, by utilizing the root system of plants to absorb water, reduce runoff, and prevent soil structure damage. Hence, prevention of planting solid roots and growing fast in landslides is necessary, including in hilly steep slope areas and the lowland (Ministry of Public Works, 2007).

DISCUSSION

Realizing three meters of width for the Beringin riverbank is challenging; on the left side of the river or directly adjacent to the river embankment is a permanent building, whereas on the right side of the river is a rice field area (Figure 3). The landscape arrangement of the riverbank intends to maintain the river sustainability, both ecosystems, and prevent river damage caused by floods and riverbank erosions. The landscape arrangement of the riverbank intends to maintain the river sustainability, both ecosystems, and prevent river damage caused by floods and riverbank landslides.

Floods always occur in coastal areas, inundate settlements and paralyze accessibility to and from Semarang City. Therefore, the Semarang City Government seeks to overcome this by coordinating with other parties. One of them is the normalization of the Beringin River, which in its implementation is handled by the central government through the Pemali Juwana River Area Center for two years starting in 2020 along a length of 7.18 km. This river normalization plan has been around for a long time; starting in 2003, that emphasized land acquisition activities for settlements located in river border areas. The central government funds the river normalization, whereas the Semarang City government takes care of the land acquisition. Therefore, the land acquisition process started in 2003–2020, when 10 ha of land had been completed, and the remaining 8 ha were still being discussed with the community, especially in Mangkang Wetan and Mangunharjo Villages (Semarang City Government, 2021).

Therefore, the normalization of the Beringin River cannot be carried out in the two sub-districts before the land acquisition is finished. Hence, the vegetative approach implementation design at the research site refers to two strategies: do nothing and do something. The do-noting strategy is a situation where the existing alternative solutions have a detrimental impact (Patton et al., 2016). It means that the normalization of the Beringin River cause people will be evicted from their homes that have been occupied for years. In addition, there is a possibility that they will also lose their jobs or increase their expenses to pay for transportation costs from their new place to their workplace. On the other hand, if it remains today, the community will always experience flooding yearly. Meanwhile, the do something strategy refers to river normalization efforts as a solution to overcome flooding and improve environmental quality.

The guidelines for implementing vetiver as landslides barrier issued by the Ministry of Public Works are more intended for road slopes. Meanwhile, there is no guide to applying the vegetative approach on river slopes. Therefore, the formulation of these designs refers to the river's existing condition and the use of the surrounding land and government policies, especially the Law on Provision of Green Spatial Planning and the Semarang City Drainage System Master Plan.

Following are the explanation of do-nothing and do-something strategies:

1. A do-nothing strategy means that there is no intervention in the river. This strategy is applied when considering the land acquisition process, which takes a long time (17 years) but leaves 400 parcels of land unfinished. In this strategy, the design for the vegetative approach follows the existing condition where there are several points where the river border is free from buildings, but there are buildings in some places.

- Typology 1: the segment of the border area's left and right side of Beringin River in the garden, while the distance between the border and the building is equal to or more than three meters (Figure 6). It means that without a river normalization process, the width of the river border in this typology is in accordance with the standard for embankment rivers in urban areas. Although these areas have met

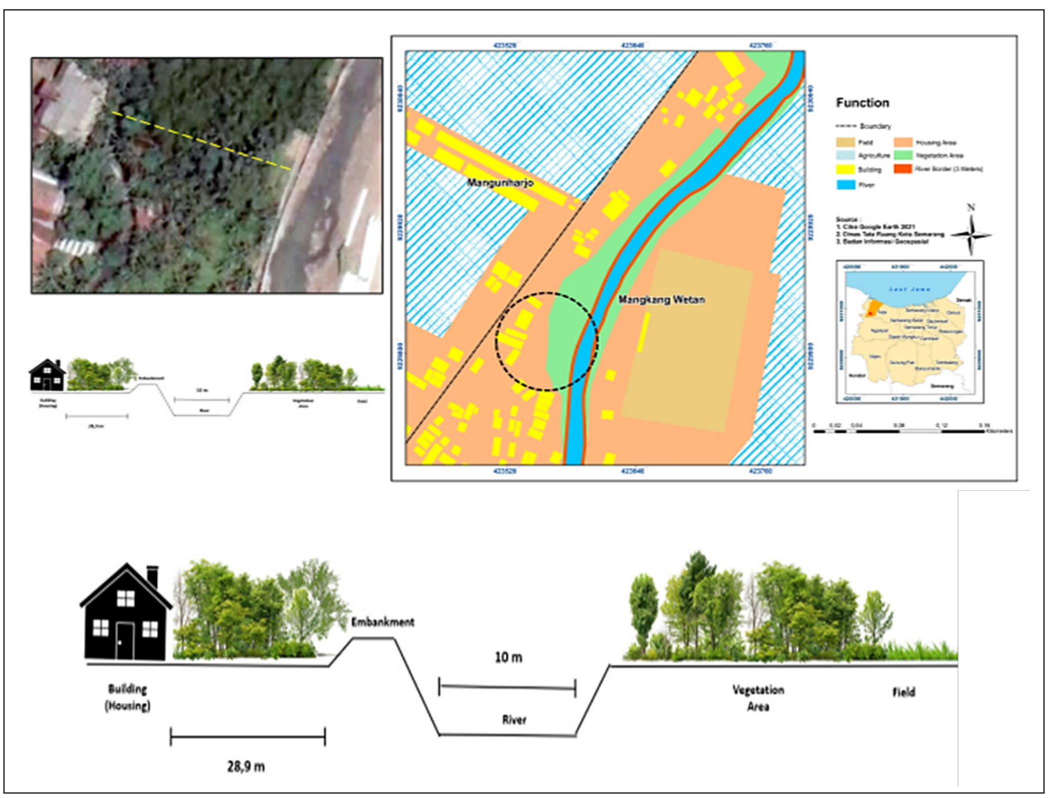

Figure 6. Design guideline for Typology 1

the requirements of the river border standard, it still faces flooding every year due to silting and narrowing of the river width and lack of vegetation buffer. The vegetative approach in this segment aims to mitigate flooding and conserve land, especially riverbanks. Based on the analysis of vegetative approach application, the plant that is possible to apply in this segment is the method of intercropping vetiver grass with elephant grass or bamboo (short term) or kinds of trees (long term). Another tree that can be combined with vetiver grass is the tamarind tree. Historically, this tree has been found in Semarang City, and even then, the toponym of the city's name is also taken from the tamarind tree (the local name is *pohon asem)*. In addition, the tamarind tree is one of the plants recommended by the Research and Development Center for Watershed Management Technology as vegetation that can prevent riverbank landslides.

- Typology 2: the left and right segments of the Beringin River border area are adjacent to the buildings (construction), with a distance between the borders of less than three meters (Figure 7). This area is the most affected by floods and landslides. Ideally, buildings on the riverbank need to be displaced, yet it is not easy to do because the community rejected the relocation scheme. Therefore, applying the vegetative approach in this segment adjusts to the existing conditions, where the design direction is combined with a technical method by hardening the embankment with cement. After the cement embankment, it plants vetiver grass and elephant grass as a cover crop. This pavement and composition are plotted in fewer than three meters border areas. However, the construction of river embankments with cement is quite expensive for local people with economic limitations (some are traditional fishers and industrial laborers), so it needs assistance from the government and other parties. If there are no supports, the minimal solution is combining vetiver grass with traditional embankment from sand sacks.

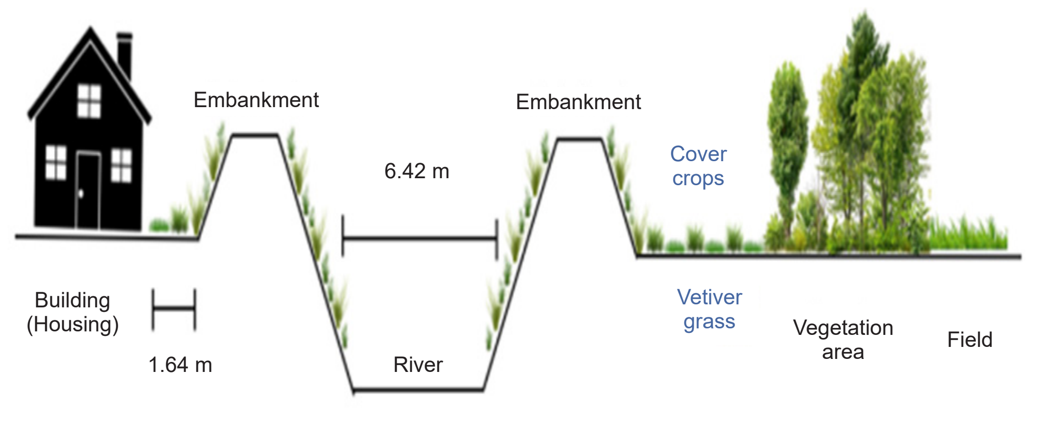

Figure 7. Design guideline for Typology 2

2. Do-something strategy

This strategy means that there is intervention from the government to overcome riverbank landslides by normalizing the river. Therefore, the design of the vegetative approach adjusts to the rules of normalization and reforestation of river borders.

- Typology 3: is a segment of the Beringin Riverbank normalized following government regulations. Riverbank rehabilitation, especially for the small rivers category with a watershed area that is less than or equal to 500 km^2, is carried out at least 50 meters from the left and right banks of the riverbed along the river channel (The Minister of Environment and Forestry Regulation No. 105 of 2018). The river normalization standard is ideal condition for rehabilitating riverbanks and mitigating landslides and floods. This normalization has been planned since 2020, yet due to the COVID-19 pandemic, this activity has not been carried out.

Hence, the design guideline in this segment considers an ideal pattern, particularly after the river normalization by building a barrier (Figure 8). The vegetative approach implementation utilizes vetiver grass planted after the barrier, intercropped with trees, such as guava and banana trees. Eventually, the community benefits economically from planting these trees by consuming or selling the fruits. River normalization means widening

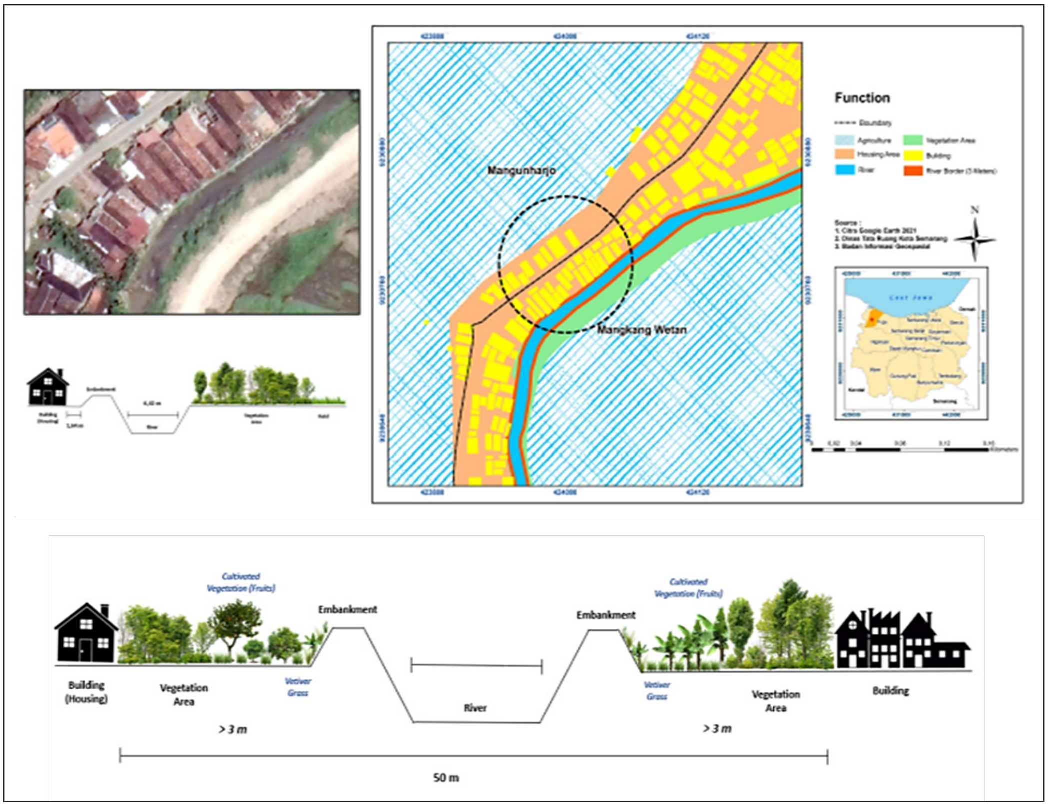

Figure 8. Design guideline for Typology 3

and restoring the cross-section of the river according to its class, improving the slope of the river channel, and strengthening the slope by making embankments, for example, with concrete blocks. The widening of the river is under government regulations that can accommodate the planned flood discharge for a ten-year return period of 180.59/second (Putra et al., 2014).

The essential point when implementing typologies 1–3 is that introducing vetiver grass to the community is challenging. For example, it can be seen from the previous study that the application of vetiver grass in Central Java Province was considered a failure due to: the lack of experts who understood the function of vetiver in preventing landslides, lack of community participation due to lack of understanding, and no economic benefits obtained by the community, making them less interested on vetiver development (Budi & Wariyanto, 2003). In contrast, the application of vetiver grass in Thailand, where there is good leadership in the community and a strong commitment from the government, the vetiver program has succeeded in improving the quality of the environment as well as the socio-economic status of the community (Leknoi & Likitlersuang, 2020).

CONCLUSION

The design guidelines for the application of the vegetative approach, both typologies 1, 2, and 3, can be applied in other locations, primarily on riverbanks that are prone to landslides, if they have the same characteristics, which are included in the category of dammed rivers in urban areas. Likewise, the selected vegetation types can adopt in other locations because the vegetation can be found and does not require specific maintenance. Hence, the community can participate in implementing this vegetative approach easily. In addition, if a do-something strategy has been implemented, the government not only focuses on this technical solution but also combines it with vegetative approaches such as tree planting so that the results are more optimal and benefit the community.

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