Palmyra Palm and the Protection of Landslide along the Canal

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Abstract

Sugar palm tree has been considered as a valuable multipurpose tree for several centuries for the production of food and construction materials that will produce income for rural communities. Sugar palm, also known as Palmyra palms, are economically useful and widely cultivated, especially in South -East Asia. The Palmyra palm tree has long been one of the most important trees of Cambodia and India. In Thailand, the sugar palm tree (*Borassus flabellifer*) plays an important role. It provides different products such as juice, sugar, leaves, timber, fruits, underground seedlings, and roots. As the sugar palm tree has a deep root system (up to 15 m), it can be used to control landslides or soil erosion on the river edge, if it is planted along the roadside or canal as Thailand has numerous canals, both natural and man-made, used for irrigation of agricultural cultivation and boat transportation, which was a major travel method in the past. Additionally, landslide along canals is a common problem in all regions of the country, a problem which the government needs to address with a huge budget for the construction of concrete fences to prevent that erosion. Therefore, this review aimed at describing the benefits of the root system of sugar palm tree, that can also be applied for the protection of landslide along the canals to promote the utilization of sugar palm root, as an economic and environmentally friendly methodology for slope protection and erosion control along the canal. Since Natural calamities as tsunamis, cyclones, floods, etc. cause landslides and soil erosion with loss of lives, damages of crops and trees quite often, affecting the economy on a large scale, heightened due to human activities in the coastal area of rivers, oceans, canals, mountains, destroying forests, cutting trees and other landscapes, there should be the adoption of traditional landslide protection mechanisms including wide-scale tree plantations as Palmyra palm along the canal and other coastal areas as the roots can tightly hold the soil and such measures can reduce landslides due to heavy rainfall and other natural calamities. However, only Palmyra palm plantation or vegetation defense mechanisms cannot stop the natural disaster. So, these tree plantation factors require optimal planning, maintenance, and support of communities which have to be carefully studied by management team and policymakers to take appropriate steps and measures for achieving a sustainable and long-lasting green defense shield.

Keywords: Sugar palm, Root system, Landslide protection

Introduction

Sugar palm tree (*Borassus flabellifer* L.) is one of the oldest trees in the history of tree families in Asia. These trees have an important role in Southern and South-eastern Asia, including Phetchaburi province of Thailand. They are one of the sources of income for agriculturists in Phetchaburi, especially in rural areas, and they are commonly called Tantanot (Nujnetra, 2017) and is also considered to be a multi-purpose tree as it can be used in many ways for both human and animal consumption, such as juice, sugar, leaves, timber, fruits, underground seedlings and roots as traditional medicines (Borin, 1996a).

According to Sukamaluddin, Mulyadi, Dirawan, Amir, and Pertiwi (2016), Palmyra palm trees are a symbol of the Jeneponto city, in Indonesia. This native sugar palm tree has large long hairy roots, the trunk is tall and straight, about 25 to 30 meters in height, the diameter of the trunk is between 40 and 50 cm, has a deep root system (up to 15 m), which can be used to control soil erosion (Borin, 1996a).

Landslides in the hilly territories are very common, especially in the rainy season due to heavy rainfall leading weak rocks and unconsolidated surficial deposits to convert to a water-saturated surface. Such types of high-intensity rain events, snowmelt can increase the pore pressures of soil and accelerate new landslides. If the soil has pore spaces filled with water, pressures within the pores will raise and these pressures can only be retained by plants. So, it is advisable to grow more trees along the hill slopes to strengthen the forest soils and discharge water through evapotranspiration. Trees and other vegetation not only exclude water from the soil via transpiration but also intercept some water and snow on branches and eventually evaporates. Therefore, plantation like sugar palm tree plays a significant role in maintaining slope stability, eliminating water, and decreasing pore pressures that could trigger landslide due to soil erosion (El Dorado Irrigation District, 2002). This paper aims to present the importance of sugar palm tree plantation along the canals for the protection of landslide to solve canal erosion problems, which Thailand has been facing in all regions and also targeted at a local level using minimal resources and appropriate agricultural technology.

The benefit of the different parts of sugar palm tree

Palmyra palms are economically useful and widely cultivated in South -East Asia and has long been one of the most important trees of Cambodia and India (Jana & Jana, 2017). It is a multipurpose tree because it has an extensive benefit to mankind, no part of the tree can be considered as a waste (Ramachandran, Swarupanandan, & Renuka, 2004). So, this tree has been considered as an economic asset. Among its different parts, the juice is considered as the main provider of the primary source of income. Its leaves, fruits, fiber, and trunk also provide food, animal feed, and materials for construction along with other domestic uses. The following headlines give a brief explanation.

Juice (Jaggery/Sap)

Sugary sap, called toddy, can be obtained from the young inflorescence of both male and female plants and it is usually fermented to make a beverage, or concentrated to produce crude sugar or jaggery (Jana & Jana, 2017). Borin (1996a) informed that for the male tree, the sugar palm liquid can be collected only for 3 months of the year, while the female tree can serve 5-6 months a year. The average yield of juice was 5 kg/day/tree, with an average13.5% (sugar content), and is commonly collected once a day. However, there are highly productive trees, which can be collected up to 20-25 kg of juice per day. It is more profitable to tap the older trees (over 30) because their sap contains more sugar and the yield is steadier. The naturally fermented palm juice is also a common alcoholic beverage in the countryside, and vinegar is also made from fermented juice. When the juice is allowed to ferment through the action of airborne microorganisms, the alcohol content of 5 to 6% may be reached (Borin, 1996b). Apart from this, sugar palm juice contains highly digestible carbohydrates (sugars). It is an alternative energy source for animal feeding in rural areas in Cambodia. Sometimes, juice and scums from sugar palm are poured on the rice straw and fed immediately to cattle. Moreover, the fresh sugar palm drink has no side effects that can impact personal health (Savji, Gunalan, & Solanki, 2011).

Leaves

Sugar palm leaves can be harvested two to three times a year, except for the trees from which juice is being collected. The leaves are mostly used for thatch, but also used for making baskets, hats, rice storage boxes, fans, and fancy boxes and so on. Approximately 80-90% of rural houses in Cambodia are constructed with leaves and trunks from palm trees. The leaves of the sugar palm tree can also be used as a nest for bats that provide manure, which is a good source of fertilizer. The bats can provide 0.5 to 1 kg of manure per day which could be sold to

the city for flower gardens (Borin, 1996a; 1996b). Morton (1988) reported that a well-thatched roof will last for 2-3 years. Sugar pam tree is also used in India for making thatch roof, mats, baskets, fans, hats, umbrellas, etc. These are mostly used in Assam and West Bengal (Jana & Jana, 2017). There are many traditional manuscripts in Hindu culture, which were written on sugar palm leaves (Kumar, Sreekumar, & Athvankar, 2009). Similarly, it is used as a paper in Indonesia (Jana & Jana, 2017) and Cambodia (Borin, 1996b). So, both Hindus and Buddhists venerate the paper made from this tree for writing sacred inscriptions in olden times (Sandhya, Sudhakar, David, & Rao, 2010).

Trunk/Stem

In India, it is planted to provide windbreaks on the plains (Sukamaluddin et al., 2016). The palm trees are cut for timber when they are over 10 m high and are about 70-100 years old. House fences can be made from the sugar palm stalks, including a strong and wiry fiber suitable for cordage and brushes. The black timber from sugar palm is hard, thick, and strong, that can become highly valued for construction purpose, especially in structures exposed to water, such as wharves, fences, and boats. For example, in Cambodia, palm trunks are commonly used to build canoes, the same as in India. Dried and holed trunk of the sugar palm tree is also used for making boats and can carry at least 3 persons for fishing or transportation on the lakes or canals (Renuka, Bhat, & Basha, 1996; Borin, 1996b).

Fruits

Sugar palm fruits are edible in all the stages. The upper part of the fruit must be cut off to reveal the sweet jelly seed sockets to eat. The soft-shell at the top of each fruit is chopped in slices to be used in soups with fish or meat and other vegetables (Borin, 1996b). The kernel is eaten fresh or prepared as a sweet with some sticky rice which is commonly sold along the roadside, and tender fruits that fall prematurely, are chopped for cattle feeding. The ripened fruit of the outer layer also can eaten be raw, boiled, or roasted (Jana & Jana, 2017).

Fibers

The fibers from fresh leaf stalk can be produced as rope and threads. It is separated from the palm leaf stalk by hand beating or crushing and then removing the pith by hands or tools (Velmurugan & Manikandan, 2005). Painting brush and brooms are also made from leaf stalk.

Roots

In the study of Gummadi, Battu, Keerthana Diyya, and Manda (2016), a thin transverse section of the fresh root of sugar palm was taken using a microtome and studied. 28 chemical constituents have been identified from ethanol root extract by Gas Chromatogram-Mass spectrometry (GCMS) analysis and the root of *B. flabelifera* was investigated for antioxidant activity.

Figure 1 Sugar palm tree (*Borassus flabellifer*) planted in Thailand

Root system

Apart from the benefit of the sugar palm tree for pharmacological aspects, some literature reviews reveal that their root system has long hairy roots and side roots based on the trunk (Sukamaluddin et al., 2016). And as the sugar palm tree has a deep root system (up to 15 m), it can be used also to control erosion (Borin, 1996a). Furthermore, Jana & Jana (2017) reported that sugar palm trees, when grown on banks of water bodies, can prevent soil erosion and help to recharge the water table.

In the Tamil culture of India, sugar palm trees played an important role in water management in ancient times. The ancestors had a planned vision for the future water needs of the generations that followed, but most importantly, a well-balanced ecosystem was maintained. Unlike, other trees, Palmyra palm's roots go vertically into the ground, which in turn brought the groundwater to various levels along the path. It irrigated the land, played a significant role in the circulation of water in the aquifers, river beds, and rivers. It is normal to find palmyra palms growing around traditional ponds or lakes like a fence.

Figure 2 Sugar palm root system

The protection of landslide along the canals

Landslide is a natural process in which soil and rock materials are detached or loosened from their original location and deposited elsewhere. The process predominantly occurs due to runoff from rainfall. The removal of vegetation leaves soil to be more susceptible to erosion. The primary factors that influence the rate of landslide are climate, land use, and geology. In general, areas with high-intensity precipitation and frequent rainfall experience higher rates of erosion. When the sloped areas become entirely saturated, and the infiltration recharges the water table on the slopes, most of the time, landslides can occur (Carlos, Reyes, Cerrud, Cortizo, & Maximiliano, 2018).

Lawrence (2017) has discussed that canal erosion/landslide is caused principally by two factors namely; (a) factors that dispose of water to high-speed flow (b) soil characteristics of the area involved.

(a) Mostly high or steep slope, unprotected or unvegetated soil are all factors that dispose of water to high-speed flow. High slopes enhance the movement of water and persuade kinetic energy and momentum to the molecules of water. Vegetation hinders the flow of water and therefore serves as a barrier to water flow. Hence, vegetation can reduce the velocity of water flow and momentum.

(b) Another factor that can stimulate or discourage erosion is soil characteristics. In the rocky based zone, erosion appearance is rarely unlike in other areas where the soils are simply lumped together. Apart from that, natural factors like tectonics and uplift, climatic factors, geotechnical properties of soil can cause canal erosion too.

Researches related to landslides along the canals

El Dorado Irrigation District (2002) reveal the report about landslide potential along the El Dorado canal. The purpose of this memorandum is to identify landslides that have impacted the El Dorado Canal, determine the probability of landslides occurrence, and identify the potential for landslides to affect the canal in the future. In January of 1997, significant destruction to the canal has happened resulting in many landslides, triggered by the high-intensity rainfalls during1996-1997. Their study report that seven landslides have caused canal failures every 10 years on average. It means that one landslide occurs due to a canal failure every 1.4 years. Environmental damage occasionally causes canal failures. The water in the canal is spilled onto the soil when the canal breaks, which erodes the hill slope. To mitigate these problems, the canal El Dorado has replaced with tunnels in the areas that have the highest potential of landslides. Historically landslides that have impacted the canal or have a high potential to affect the canal have been mitigated with the construction of the El Dorado Tunnels.

Carlos et al. (2018) presents the importance of the Landslide Control Program and describes the methodology used to identify instabilities using data from the different types of instruments installed along the waterway. The primary purposes of the instruments are to locate the slide surfaces and to monitor the rate of movement and the variation of water pore pressures which could affect slopes stability. These measurements are used for detecting and forecasting landslide events and for issuing alerts.

Malawai (2011) study the cause of failure and remedy approaches of the riverbank, Hui Kaen River, Nonsila sub-district, Nonsila district, Khon Kaen province in Thailand. Two remedy approaches were proposed. The first one was the concrete pavement on both sides of the riverbank, which is a popular approach for the irrigation canal. The second one was the sand filled mattress pavement on both sides of the riverbank, to prevent soil erosion. From the cost analysis, the second approach was considered as suitable with the cost estimate of 3,603 baht/meter length.

Canal Landslide Control Practice

Autoridad del Canal de Panamá (2012) made a research for evaluation of the erosion control methods implemented by the Panama Canal Expansion Program and the result stated that canal erosion control has 2 types: the structural controls include gabions, riprap, culverts, silt fences, and sedimentation basins. Non-structural controls include hydroseeding, geotextiles, and mulch and netting.

1) Hydroseeding or hydro mulching involves applying a combination of grass seed, fertilizer, hydromulch and water in one liquified state to the soil surface. It is proposed to be the most efficient and cost-effective permanent due to its one-time application and low maintenance. The germination of the seeds depends on the weather, time of year, amount of water, and other factors, but generally, the grass grows in 5-7 days. Hydroseeding works well because the seed is suspended in a nutrient-rich slurry that promotes faster germination than ordinary seeding.

2) Another permanent erosion control method is the use of riprap, which consists of heavy stones placed at the inlets and outlets of pipes or paved channels to protect against soil erosion. Materials other than rock are also used as riprap, including rubble, broken concrete slabs, and preformed concrete shapes (slabs, blocks, rectangular prisms). Its effectiveness depends on the mass and size of the materials that are used and the gaps between the rocks trap to decrease the flow of water, reducing its ability to cause erosion (Colorado Department of Transportation, 2004).

According to The New York Standards and Specifications for Erosion and Sediment Control (Department of Environmental Conservation, New York, 2005), riprap should be a well-graded mixture with 50% by weight larger than the specified design size. The minimum layer thickness should be 1.5 times the maximum stone

diameter but in no case less than 6 inches. Stone for riprap should be hard, durable field or quarry materials. They should be angular and not subject to breaking down when exposed to water or weathering.

3) Gabions are rectangular baskets fabricated from a hexagonal mesh of heavily galvanized steel wire. The baskets are filled with rock and stacked atop one another to form a wall. They are a porous type of structure that can sometimes be vegetated. Gabions are used to reduce the velocity of concentrated runoff or to stabilize slopes with non-cohesive soils. Gabions can be used on steeper slopes than riprap and are sometimes the only feasible option for stabilizing an area where there is not enough room to accommodate a vegetated solution. Rodriguez (2018) explained the landslide control measures as given under:

4) Articulated Concrete Blocks form a grid of interconnected units that can be used for erosion control on embankments of waterways and manmade drainage channels.

5) Mechanically stabilized earth (MSE) walls have replaced many traditional concrete retaining walls in recent decades because they offer several advantages over conventional reinforced concrete walls, including ease and speed of installation, and also are adaptable to a variety of sites.

6) Geotextiles are commonly used to control erosion and improve soils over which roads, embankments, pipelines, and earth-retaining structures are built. Depending on the application, geotextiles may have an open mesh weave, a warp-knitted structure, or a closed fabric or nonwoven surface. The specific type of geotextile used is based on several criteria, including separation, filtration, drainage, reinforcement, sealing, and protection. Synthetic geotextile filters have been found to have considerable use as alternatives to granular filters. Since the original geotextile erosion control application in 1957, thousands of successful projects have been completed (Colorado Department of Transportation, 2004).

Moreover, sugar palm trees planted on banks of canal and river can also prevent soil erosion because sugar palm root systems can hold the soil in place to protect the soil from raindrop splash impact and overland flow as shown in Figure 3.

Figure 3 Sugar palm tree planted along the canal in Pathum Thani, Thailand

Related researches of soil erosion prevention

Satriawan, Fuady, and Mayani (2017) planted a 1-2-year-old palm tree on a 15-40% slope that was arranged on erosion plots 10mx5m. The results showed that palm tree cultivation could reduce the rate of surface runoff, soil erosion, and also nutrient loss

Alaguraj (2017) reported that the palmyra palm tree not only maintain water resources, but also be a friend of bird and animals, and can bear a severe drought. The palmyra palm tree planted on the banks of water bodies will help to reduce soil erosion. Similarly, Barfod, Balhara, Dransfield, and Balslev (2015) described that the fibrous root system of palms is very efficient in preventing soil erosion.

Liang, Knappett, Bengough, and Ke (2017) reported that vegetation can substantially reduce earthquake-induced slope deformation in the soil conditions

Plant cover protects the soil against erosion by reducing water runoff and by increasing water infiltration into the soil matrix. Plants shelter and fix the soil with their roots reduce the energy of raindrops with their canopy. Also, vegetation can act as a physical barrier, altering sediment flow at the soil surface (Zuazo & Pleguezuelo, 2009)

Root mechanical strength reflects their anatomical structure, especially the percentage of phloem and xylem cells, and the degree and speed of periderm lignifications. The cohesion force of root-soil composite systems is notably higher than that of soil without roots (Hu et al., 2013).

Construction of concrete fence for landslide protection

There is a wide variety of concrete based systems for control of landslide. It can protect the canal against high- velocity flows. Cast in place systems such as concrete retaining walls and concrete channels are used in urban areas where absolute control of erosion is required as it can protect against erosion for many decades (Polster Environmental Services, 2003).

Concrete revetment walls/ fence are permanent structures located along the canal frontage of land to protect it from erosion, caused by the canal system's tidal waters and boat wash and these walls need an engineered long-life design along with regular inspection and proper maintenance for long time use.

Concrete walls may also include integral step iron-type ladders for access, vertical joints at regular intervals, and weep holes (a weep hole is a small opening that allows water to drain from within an assembly).

Concrete pavement revetments are cast in place on a prepared slope to provide canal bank protection and it is a type of rigid revetment that does not conform to changes in bank geometry due to removal of foundation support, or outward displacement by hydrostatic pressure, slide action, or erosion of the supporting embankment at its ends. Concrete pavement revetments are also among the most expensive stream bank protection designs. In the past, the concrete pavement has been best utilized as a subaqueous revetment (on the bank below the water surface) with vegetation or some other less expensive upper-bank treatment (Colorado Department of Transportation, 2004). Figure 4 shows the construction of a concrete fence along the canals in Thailand to prevent landslide and soil erosion.

Figure 4 Concrete fence for canal landslide protection in Thailand

Cost of concrete construction

Since a lot of canal and river of Thailand has many landslide problems, it needs construction of the concrete fence for protecting the erosion. Some studies of the concrete construction project are conducted to prevent the landslide along the canal in Chumphon province that has the length 220 meters of wall, which requires a budget for construction as 12,470,000 Baht as given in Figure 5 (Ministry of Agriculture and Cooperatives, 2014). So, the construction of concrete walls to prevent erosion on the canal banks, although popular, is very expensive in construction cost. Therefore, it should be replaced with another cheaper and natural solution with less cost through adoption of vegetative measures like sugar palm cultivation, replacing the concrete fence to save the construction costs and at the same time lower maintenance requirements in the long term.

Figure 4 Construction of concrete fence for canal landslide protection

Also, the involvement of local communities by adopting a self-help approach, using their skills and expertise to carry out their protection projects in the propagation, planting, and maintenance of the canal by plantation of sugar palm plantation is very important in the future to save major inputs from governmental agencies. This has been supported by Thuy, Sobey, Truong, Director, and Asia (2006) who clearly showed that the use of vegetative control for protecting landslide along the canal (vetiver glass) was an economic and environmentally friendly treatment that would give an equivalent degree of protection for significantly less capital expenditure.

Conclusion and Suggestions

All the sugar palm tree parts are dominantly used for many purposes such as timber, fuelwood, beverages, roofs, edible, building materials, handcrafts, and medicine. Through the cultivation of the palm, people will be economically, culturally, socially, religiously, and environmentally benefitted. Less water requirement for cultivation, the capacity of the plant to withdraw water from underground, the longevity of the plant (nearly 100 years), low space utilizing capacity, soil erosion preventing capacity, the capacity to recharge the water table, an excellent plant as a windbreak, provides natural shelter to birds, bats, and wild animals.

Apart from the benefits of sugar palm tree that are mentioned above, literature reviews reveal that their root system, being long, large, and deep-rooted can be used also to control erosion in landslide-prone area due to heavy rainfall or other weather conditions such as on the banks of the rivers or canals. Thailand, which has many canal banks suffer from landslide problems. As a remedy, concrete fences are usually constructed for protecting that erosion, but the construction cost is very high. Therefore, it is highly recommended to switch from the concrete fence to another natural method of protection with less cost. The sugar palm cultivation is the alternative fence and

solution, with a considerable saving in construction costs and the lower maintenance requirements in the longer term. Some of the recommendations obtained from literature reviews are given below:

- To protect from the impact of natural disasters, there should be the integration of traditional defense mechanisms including wide-scale tree plantations as Palmyra palm along the coastal area as the roots can tightly hold the soil along with the modern method of construction of the embankment. A combination of traditional mechanisms with modern scientific approaches will help more to reduce the effects of natural and other climate changed impacts on human ecology to make a region to be more productive and sustainable (Rahman & Rahman, 2015).

- Only natural tree plantation or vegetation defense mechanisms cannot stop the natural disaster. Its effectiveness depends on the intensity of the flood, tsunamis, or cyclone along with the structure of plantation. So, these factors of tree plantation require optimal planning, maintenance which have to be carefully studied by the management team to take appropriate steps and measures and proper maintenance aided by participation and support from local authorities and communities to make the planting projects successful and to have awareness of its importance (Tanaka, 2009).

- Tree and vegetable plantations along the coastal area for preventing landslides, soil erosion under the impact of natural disaster as floods and cyclones require studies to know plants and trees root traits, strength and structure as root traits including length, diameter, and distribution of the root are influencing factors of soil fixation. This information, obtained through research studies are essential to a landslide engineer while considering management strategies (Stokes, Atger, Bengough, Fourcaud, & Sidle, 2009).

- The potential loss of life and assets due to the impact of natural disasters as floods causing landslides on the coastal and hilly areas of Asia is increasing. This is due to increasing human activities for residential and infrastructure development, aided by poorly constructed roads and the loss of soil reinforcement and increase in water extraction by tree roots along the coastal area of rivers, canals, mountains, etc. during heavy rainfall or earthquakes. It is important to understand the roles that trees and forests can play in preventing landslides as scientific studies have already confirmed their roles in obstructing smaller landslides and rockfalls. Due to this, planners and policymakers need to have more attention, by encouraging land uses with more tree and vegetable plantation on the coastal area to reduce soil disturbance as a remedy for climate change adaptation in a region (Forbes & Broadhead, 2011).

Thus, there are many opportunities to utilize the sugar palm tree as an alternative to structural engineering measures for canal bank protection. So, there should be steps for the promotion and utilization of sugar palm trees as an economic and environmentally friendly methodology for slope protection and canal landslide control.

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