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Research paper

Case study of exploited riparian corridors: rapid assessment of ecological health for riparian buffer width

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ABSTRACT

Riparian corridors are areas immediately adjacent to flowing waters. They are significant in ecological terms as a transitional zone between aquatic and terrestrial ecosystems. Therefore, conservation of riparian corridors has been gaining significance in river basin management. In this regard, this study has investigated the riparian buffers that fringed the Riveria residential estate in the city of Kuching, Sarawak, examining its structures and health indices in response to the development gradient. The riparian health assessment presented here specifically considers its associated buffer widths, plus the exploration of three attributes, namely human activities, vegetation cover, and groundwater table. The results show that the most appropriate range of buffer width is between 40 and 100 m. Results also suggest that riparian buffer width is a key factor influencing riparian health and functionality.

Keywords: Field investigation; Kuap River; nipah swamp; proper functioning condition; rapid assessment; riparian buffer; watercourse management; wetlands

1 Background

Naturally vegetated riparian corridors are among the most productive and diverse plant communities. This vegetation has adapted to wide fluctuations in water levels and regular flooded conditions (Klapproth and Johnson 2009). In Southeast Asia, the nipah swamp is common. However, Singapore has declared the nipah palm an endangered and protected species due to excessive land clearings (Liow 2000, Udofia and Udo 2005). The species (*Nypa fruticans*) lines the banks of the Kuap River in Kuching, Sarawak, and used to stretch for miles (Figure 1(a)). The lushness of the vegetation has been gradually displaced by buildings, bridges, and roads, as riparian wetlands are cleared too close to river banks (Figure 1(b) and 1(c)).

The nipah palm grows in soft mud, usually where water is calmer with regular inflow of freshwater and nutritious silt. It can tolerate infrequent inundation, as long as the soil does not dry out for too long. Though its trunk lies horizontal and underground, nipah leaves grow straight from the ground. The trunk branches and each branch ends in a bunch of fronds. This habit of growing from underground stems results in almost pure stands of nipah palm. This stem stabilizes river banks, preventing soil erosion. New fronds emerge quickly after damage, protecting the land after storms while continuously producing useful products for the locals (Tan 1996).

Figure 2 depicts a typical cross section of a riparian corridor in the Kuap River. The floodplain comprises deposits of alluvium, with sandy and greyish coarse texture. The outer edge of the nipah swamp passes sharply into the kerangas forest (heath forest), in which the upland feature is insignificant due to the flatness of the alluvial plain. Parts of the kerangas forest are frequently inundated by the Kuap River, which supports the vegetation. The sandy soil is often lacking in nutrients. Because of these conditions, the trees and other plants in the kerangas forest have adapted by being smaller. Generally the forest has a low, uniform canopy, with thick underbrush and rich growth of mosses and epiphytes (Newbery *et al.* 1986, Proctor 1999).

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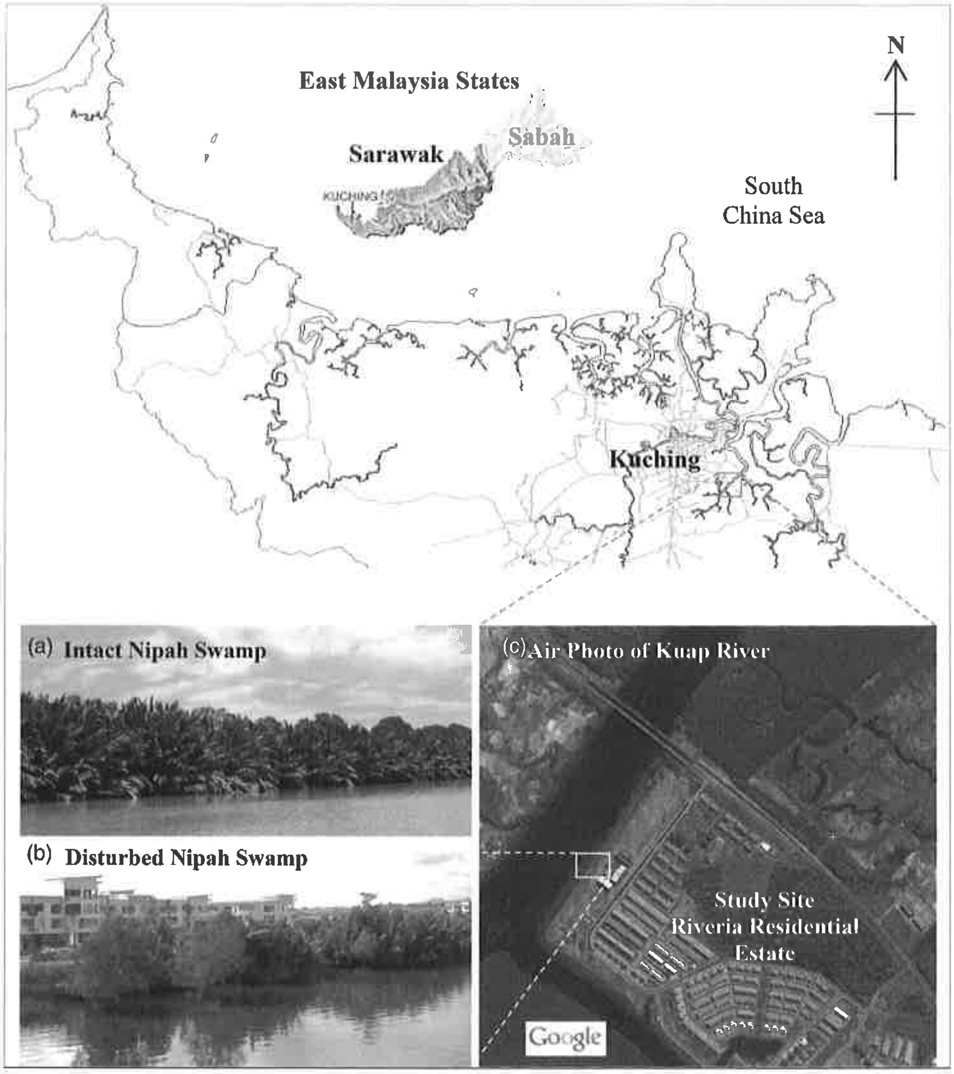

Figure 1 Exploitation of riparian zones along the Kuap River.
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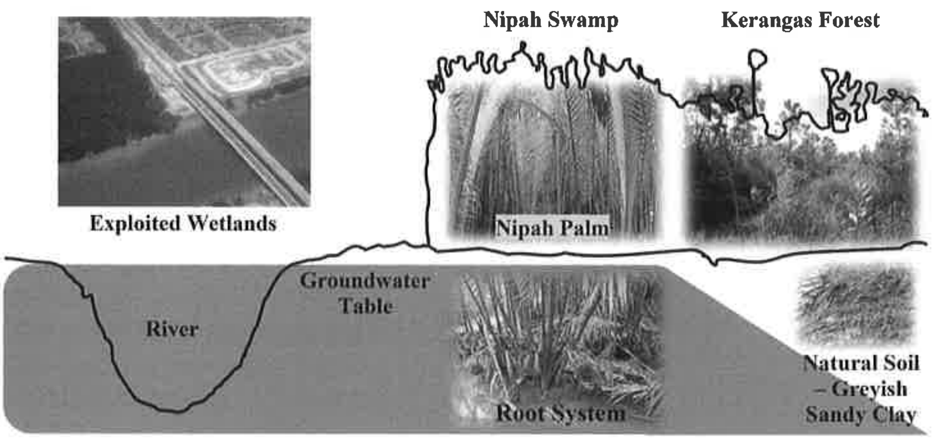

Figure 2 Typical cross section of a riparian corridor.

2 Motivation

Riparian corridors are recognized as an important part of stormwater management, for surface runoffs are eventually drained to streams or rivers. Preserving riparian corridors allows for a stable watercourse as the downstream receiver of runoff. The Urban Storm Water Management Manual for Malaysia, locally known as MSMA 1st Edition (DID 2000), outlines the topic of riparian management in Chapter 43 and MSMA 2nd Edition (DID 2012) re-iterates its necessity in Chapter 17. Both manuals maintain that riparian corridors should be managed by retention of existing plants or replanting if disturbed with appropriate native species. When riparian corridors are properly managed, they make substantial and positive contributions to clean water, as well as to ecosystems and human health (Mah and Bustami 2012).

Continuous riparian buffers are found to correlate with higher overall watershed water quality and aquatic diversity (Schlosser and Karr 1981, Weller *et al.* 1998, Kennedy *et al.* 2003). Riparian buffers also play an important role in managing nitrogen uptake in watersheds (Mayer *et al.* 2007). The following studies have examined the appropriateness of riparian buffer widths to gain services desired by humanity. Castelle *et al.* (1994) reported that riparian buffers of less than 5–10 m provide little protection for aquatic resources under most conditions. Stewart *et al.* (2001) reported that riparian buffers of 30 m support healthy fish communities, and that fish density grows with increases in buffer widths beyond 30 m. The United States Department of Agriculture guidelines (Bentrup 2009) recommend a buffer width of at least 30 m (100 ft) to cater for biodiversity. A renowned Lake Erie guide (Davis 2004) has called for at least 45 m (150 ft).

In Malaysia, a desk study (NAHRIM 2010) has revealed a range of widths from as little as 15 m to as wide as 100 m or more depending on the intended function. Researchers also applied the findings from the desk study to Skudai and Labis Rivers in Southern Peninsular Malaysia. The former is a lowland river (average slope 2.4%) and the latter a highland river (average slope 15%). This study specifically pointed out that buffer width should proceed from the associated stream order as the higher stream order is connected to a higher percentage of catchment coverage; hence, a wider width is required, and vice versa.

What about the well-being of the riparian corridors itself? The natural riparian wetlands of the Kuap River were bulldozed to a remnant strip of 30 m thick, shown in Figure 1(c), a practice considered correct according to the available guidelines. However, nipah palms on the effected stretches were found dwindling at a rapid pace and other plants (*Sonneratia* sp.) were growing excessively in the disturbed stretches (Mah 2014) in Figure 1(b). Researchers find that this is unlikely to be due to sea level rise, as the nipah swamp in the vicinity of the study site was found to be intact and flourishing. Increasing salinity would affect the entire ecosystem.

There remains a paucity of research in the area particularly with respect to the ability of the riparian corridors to continue their ecological functions amid disturbances of human activities. Thus, it is essential that relevant scientific data are acquired to defend and validate minimum riparian buffers and at the same time maintaining the health of the riparian buffers involved. Towards this end, efforts have been made to include riparian health in the management of natural riparian wetlands. Riparian corridors along the Kuap River and its tributaries Merdang River that fringe the Riveria residential estate (01°29′28.4″N, 110°23′46″E) have been taken as the study site. The residential estate began construction in 2004, and is still expanding at the time of writing (Figure 1(c)).

3 Rapid assessment

A rapid assessment on riparian health has provided some structure to the observations and evaluates the nipah swamps. The tool used is properly functioning condition. This assessment method is common to North America, with which the protocol developed by British Columbia's Forest and Range Evaluation Program (FREP) in Canada is adopted. The fieldwork team refers to FREP evaluation form on lakes, ponds, and wetlands (FREP 2008a, 2008b).

Assessment is done by observations and interpretations based on one's background, experiences, and perceptions (Mah 2011). The study site has been organized into 20 sampling plots (Rozainah and Aslezaeim 2010, Mohd Faiz *et al.* 2012), a method common among biologists for biota sampling. Field enumerators pay several visits to the site areas and photographs are taken for comparison and discussion among the team members. Riparian health statuses are categorized as functioning, intermediate, and non-functioning (Prichard and Clemmer 1996). Findings from the rapid assessment are tabulated in Table 1.

Riparian attributes, namely human activities, vegetation, and moist soil, are tagged along according to their plots. The authors have anticipated in a previous study that the three are interacting and inter-dependent attributes in wetland ecosystems (Mah and

Table 1 Riparian health assessment

Plot	Health status of the nipah swamp[a]	High human activities[b]	Abundant vegetation[c]	Moist soil[d]
1	Non-functioning	√		
2	Intermediate	√		
3	Non-functioning	√		
4	Non-functioning	√		
5	Non-functioning	√		
6	Intermediate	√		
7	Intermediate	√		√
8	Functioning		√	√
9	Intermediate	√		√
10	Intermediate	√		√
11	Intermediate	√		√
12	Intermediate	√		√
13	Functioning	√		√
14	Intermediate	√		
15	Functioning		√	√
16	Intermediate	√		
17	Functioning		√	
18	Functioning		√	√
19	Functioning		√	√
20	Functioning		√	

[a]PFC rapid assessment of the nipah swamp.
[b]>60% of human activities.
[c]>40% of vegetation cover.
[d]high groundwater levels.

Kuok 2013). Therefore, they are selected as indicators to relate the health of the nipah swamp along the Kuap River. By choice, these three attributes are valued because they are easier to access (Carlsson *et al.* 2003).

We adopt 100 m × 100 m plots as this size covers adequately the riparian and human activities to identify locations that have been interrupted and are considered as a source area. These plots start at the water edge and extend 100 m towards inland perpendicular to the river. Per Plot 1, it does not appear so. Precautions have been taken by the field enumerators regarding such discrepancies, and what appear in Figures 3 and 4 are the canopies of mangroves. Such observations do not apply to the nipah palms, as their leaves extrude vertically.

It can be seen from the figures that the selected width was able to cover the activities along the river corridor. It is also clear that the main activities within each plot can be significantly reflected as human activities and vegetation cover. Based on this, the two attributes are the most convenient yet simple tools available for this study. Another attribute, the survival of wetlands dependent on watery habitats, has been identified and discussed at the end of this section.

The use of air photo is to determine and document boundaries of 20 plots in total. Coupled with global positioning system devices, in-field conditions are recorded and verified in order to rectify any peculiarity comparing land and photographed objects. Quantitative analysis and data gathering are done through a series of air inspections via Geographical Information System (GIS). GIS is utilized in identifying the coverage of human activities, vegetation cover, and its width (Tables 2 and 3).

Figure 4 Human activities in the study area.
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Figure 3 Vegetation cover in the study area.
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Vegetation reflects and interacts with the effects of soils and hydrology that form and operate in the riparian corridors. Vegetation are seen and interpreted more easily, providing an early indication of riparian health and helping to understand the successional trend at the site. Apart from that, pristine riparian wetlands in the opposite river bank are available to allow comprehensible comparisons among the plots.

The GIS model indicates that vegetation cover on average makes up only 39%, which is much lower compared to 61% of human activities. There are few plots that still maintain a high composition of vegetation cover, such as plots 15, 18, and 19. In stark contrast, plots 1 and 3 have less than 10% of vegetation cover due to human activities that include site clearing and soil compaction. These have caused major alterations to the riparian corridors.

The vegetation here refers to wetland species that are hydrophilic in nature. They thrive in water-soaked soils owing to high groundwater supplied by the river waters. Therefore, groundwater level within the 20 plots is qualitatively observed (Table 4). Visual assessment is accepted as an integral component of efforts to assess the health of stream and riparian areas (Ward *et al.* 2003). Wet and dry soils are visibly discernible, and therefore are categorized as 'high' and 'low' groundwater levels, respectively. Those in between are categorized as 'medium' in terms of groundwater level.

Table 2 Area, percentage, and width of vegetation cover for each plot

Plot	Vegetation area (m^2)	Vegetation area (%)	Vegetation width (m)
1	331	3.3	29.5–33.9
2	1188	11.9	15.8–24.3
3	712	7.1	8.5–18.3
4	1644	16.4	21.3–32.4
5	2700	27.0	26.5–39.5
6	2941	29.4	30.0–31.1
7	3851	38.5	36.2–42.7
8	4074	40.7	39.3–45.5
9	3684	36.8	38.2–48.3
10	3423	34.2	34.0–89.3
11	2777	27.8	28.6–38.2
12	2804	28.0	41.1–44.3
13	3319	33.2	34.2–67.6
14	2805	28.1	29.2–76.9
15	8606	86.1	40.7–114.6
16	2659	26.6	31.8–40.2
17	5986	59.9	25.9–46.7
18	9668	96.7	63.4–104.1
19	8113	81.1	35.4–94.3
20	6722	67.2	46.8–94.5

Table 3 Area and percentage of human activities for each plot

Plot	Human activities area (m^2)	Human activities area (%)
1	9669	96.7
2	8812	88.1
3	9288	92.9
4	8356	83.6
5	7300	73.0
6	7059	70.6
7	6149	61.5
8	5926	59.3
9	6316	63.2
10	6577	65.8
11	7223	72.2
12	7196	72.0
13	6681	66.8
14	7195	71.9
15	1394	13.9
16	7341	73.4
17	4014	40.1
18	332	3.3
19	1887	18.9
20	3278	32.8

Table 4 Groundwater condition for moist soil

Plot	Groundwater level	Remarks
1, 3, 14, 16	Low	The soil is dry 
2 4–6	Medium	The soil surface is wet 
17, 20		
7–13 15	High	The water is visible on top of the soil 
18–19		

Average coverage for human activities and vegetation is about 61% and 39%, respectively. Therefore, the average line is taken as a benchmark here. Those plots with human activities more than 60% are given a √ (tick) in Table 1. Similarly, those plots with vegetation cover more than 40% are also treated the same. For moist soil, only those labelled high groundwater level have been marked with a tick. Those labelled medium are not, because this broad category may include borderline cases.

The above demonstrates that the higher the gradient of human activities, the more the riparian corridor degrades to non-functioning as showcased in plots 1–6. Because of the removal of vegetation cover, the soil cannot facilitate the capturing of water, resulting in a low groundwater table. This proves to be a disaster to hydrophilic nipah palms in general and other attaching wetland species (Figures 5 and 6). On the other hand, the higher the composition of vegetation, the more the plots remain as a functioning riparian corridor as in plots 17–20. The remaining plots of 7–16 have high groundwater levels, and yet high levels of human activities put the nipah swamp to intermediate; or in another words, at risk.

Figure 5 Condition of the nipah swamp at plot 5.

Figure 6 Condition of the nipah swamp at plot 11.

4 Implication analysis

Nipah swamps along the Kuap River serve as riparian buffers and are the predominant control of landscape connectivity between the Riveria residential estate and the river system. The consequences of interactions among the tell-tale attributes on the nipah swamps are notably in need of research, especially with respect to determination of appropriate riparian width.

From the data obtained in Table 2, we have plotted a graph of riparian widths according to plots in Figure 7. The findings from rapid assessment (Table 1) indicate that plots 1, 3, 4, and 5 have been found to be malfunctioning, thus providing a context for using the maximum value among these plots as a reference. This allows the boundary of healthy and dysfunctional nipah swamps to be introduced on the same graph. By doing so, it has successfully demonstrated the presence of a relationship between riparian width and the health of the study site. Half of the riparian corridors are still healthy and functioning.

The results show that the most appropriate range of riparian width is 40–100 m for a nipah swamp. Most of the functioning plots have buffer widths ranging between 41.99 and 95.03 m, which complies more with the guidelines recommended by Davis (2004), rather than those of Bentrup (2009). Those between 30 and 40 m of width are observed to be unable to

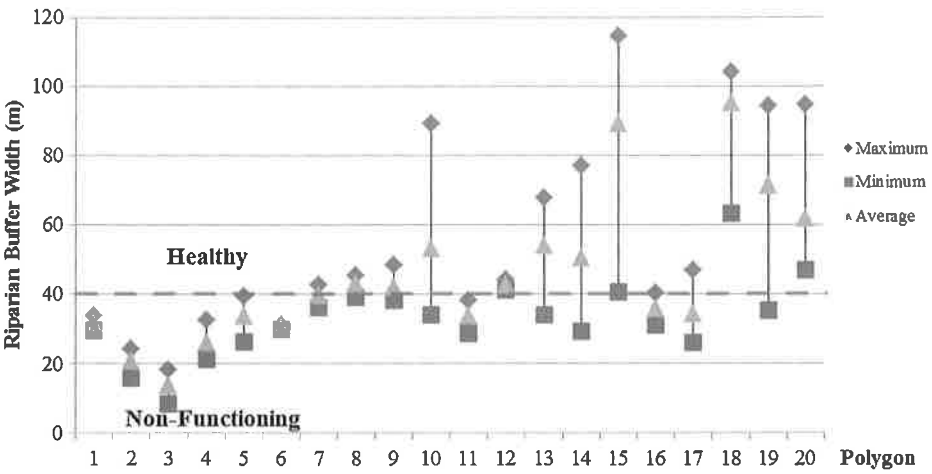

Figure 7 Riparian width plot.

recover their natural complexity and processes of dynamic equilibrium and critical characteristics of riparian ecology.

Observations of a healthy natural nipah swamp in the field are encouraging to portrait a positive coexistence trend. This case study has been able to demonstrate how such a framework can be established. Coexistence of a nipah swamp and human activities is suggested with the maintenance of a minimum riparian buffer width of 40 m. The concept is simple, yet provides a framework to place other species a place in our circle of concern and value.

5 Conclusion and recommendations

Realistically, there is no ideal riparian width applicable to all circumstances. The necessary width varies considerably based on the specific management goal. In this study, three approaches to GIS and rapid assessments have been applied to assess ecological health of nipah swamps hand-in-hand with their associated range of riparian widths. Field investigations have successfully been carried out in stretches of the Kuap River bordered by the Riveria residential estate. The outcomes from the investigation and analyses have revealed that half of the riparian corridors under study are still under healthy and functioning conditions, suggesting an appropriate riparian width range from 40 to 100 m specific to nipah swamps. It is recommended that effective management for conserving riparian corridors should be given priority by connecting people to the environment by upholding positive coexistence, instead of dominating natural resources.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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