Research Journal of
Environmental Sciences

ISSN 1819-3412

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Environmental Sciences 5 (8): 714-721, 2011
ISSN 1819-3412 / DOI: 10.3923/rjes.2011.714.721

Study on Using Riparian Buffer in Urbanizing Rural Floodplain

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ABSTRACT

Lowering the cost of flood damage in rural floodplain in comparison with urban floodplain and making more space to pass the flood into the river corridor are two main reasons of re-look on rural floodplain development strategy. Land-use changes due to urbanization increase flood hazard risk. This paper is a technical study on flood hazard assessment of developing rural floodplain by comparing three scenarios of agricultural floodplain, probable future semi-urban floodplain and using riparian buffer on floodplain with high risk. In this study for all the 3 scenarios, the flood damage cost is calculated based on the Annual Average Flood Damage (AAD) related to land-use and the values evaluated using Analytical Hierarchy Process (AHP) and Reasonable Goal Method (RGM). Results showed that under the normal pattern of development in study area, urbanization can increase AAD by more than 800 times. Also, comparison of value to cost ratio between three scenarios (rural area, urban area and riparian buffer) indicated that using riparian buffer is the best scenario in floodplain management strategies and rural area has better ranking than semi-urban area and this means that urbanization without building construction on floodplains is more suitable to flood management. Land-use changes during urbanization are unavoidable and coping with flood in the future needs to consider regulations for floodplains to decrease flood hazard.

Key words: Riparian buffer, flood risk assessment, flood risk management, flood hazard, land-use changes

INTRODUCTION

The main effective factors on flood hazard depend on new regulations, alleviation plans, changing land use configurations and susceptibility of flooded properties. For example in urban area the flood depth is the main effective factor on flood damage and for agriculture area, crop losses are substantially affected by the duration and occurrence time of the flood. There is horizontal development pattern in most of developing countries and this kind of development pattern will increase the flood risk. In addition, land-use and land management influence surface roughness either by land use type itself or vegetation structure.

Surface roughness controls overland flow velocity and floodplain flow rates (Downton *et al*., 2005). In fast growing suburban areas, the flood analysis based on a dynamic assessment of flood problems and urban growth models are essential to predict the evaluation of river basin changes and floodplain encroachments (Casale and Margottini, 1999). Even-though, there is an idea that a completely anti-encroachment policy approach would not be wise (Pottier *et al*., 2005) but former experiment shows that the stakeholders consider the regulations on environmental strategies and cooperate to riparian buffer development. Based on Gilard and Givone (1997) studies in basin development plans all the services, the decision makers and representatives of the inhabitants, must work together in the management of the land use. The catchment land-use drivers within strategies for flood risk management have a key role. The assessment of relationship between the catchment land-use and future flood risk under possible future scenarios shows that the importance of rural land-use management as a driver of flood risk is high for world markets and national enterprise due to a tendency towards intensive agriculture (Thorne *et al.*, 2007).

Balancing between the ecological integrity of the area and the needs of private and commercial landowners would be necessary to sustainable development in urbanizing rural floodplain. Riparian buffers can slow runoff, absorb excess water and decrease peak of flood flows during flood events. The riparian buffer zone represents a unique area of interaction between terrestrial and aquatic ecosystems and may improve water quality, reduce wind energy, modify microclimate, enhance habitat, reduce flood water levels and erosion and reduce hazards. Also, it can reduce public costs by serving as utility corridors and protecting high risk flood prone areas from development. Riparian buffers provide water quality protection and environmental benefit by filtering pollutants suspended in runoff and providing wildlife habitat. These buffers are also known as stream buffers and are vegetated areas next to water resources, such as streams, rivers and lakes. They may be forested or vegetated with native vegetation that is allowed to prosper. Depending on the needs of the individual land owner and flood management strategies, buffer zone may be designed. Buffer width should be corresponded to the width of the high risk floodplain. Downstream riparian buffers may be more effective in reducing flood than upstream buffers.

The Bernam River basin in west Malaysia is an area undergoing rapid land-use changes. Previous studies by Drainage and Irrigation Department of Malaysia predicted most of the agricultural lands in this river basin will change to urban area in 2020 which calls for more consideration on the role of agricultural and natural lands in floodplains to ensure sustainable development (Ranhill Brsekutu Sdn. Bhd. *et al.*, 2005). Land-use activities involve the clearance of forest and agricultural areas for housing, commercial or industrial purposes. The removal of vegetation reduces the infiltration and storage potential of soil and increase runoff and torrential condition. The proposed approach in this paper is analysis of urbanizing rural floodplain by comparison of flood damage between three scenarios of rural and semi-urban condition of floodplain using Annual Average Flood Damage and using riparian buffer on urbanizing rural floodplain.

MATERIALS AND METHODS

Flood damage assessment under present land-use: The first option is to keep the agricultural floodplain in its present state without building any structure. By overlaying two layers of flood zoning area and land-use map, one could define the flood risk and flood hazard for each land-use. (Fig. 1) shows the results of intersecting two layers of flood zoning and land-use map for 50 years ARI within the reach of Bernam River. The flood zoning shows that the agricultural lands are the most inundated area. The Annual Average Flood Damage (AAD) for agricultural floodplains was calculated based on the following formula (KTA *et al.*, 2003):

$$\text{AAD} = \text{SUM}[(D_{i-1} + Di) / 2 \times (P_{i-1} - P_i)] \tag{1}$$

where, D_i is Probable flood damage value of i-year return periods; Pi is Occurrence probability of i-year return periods.

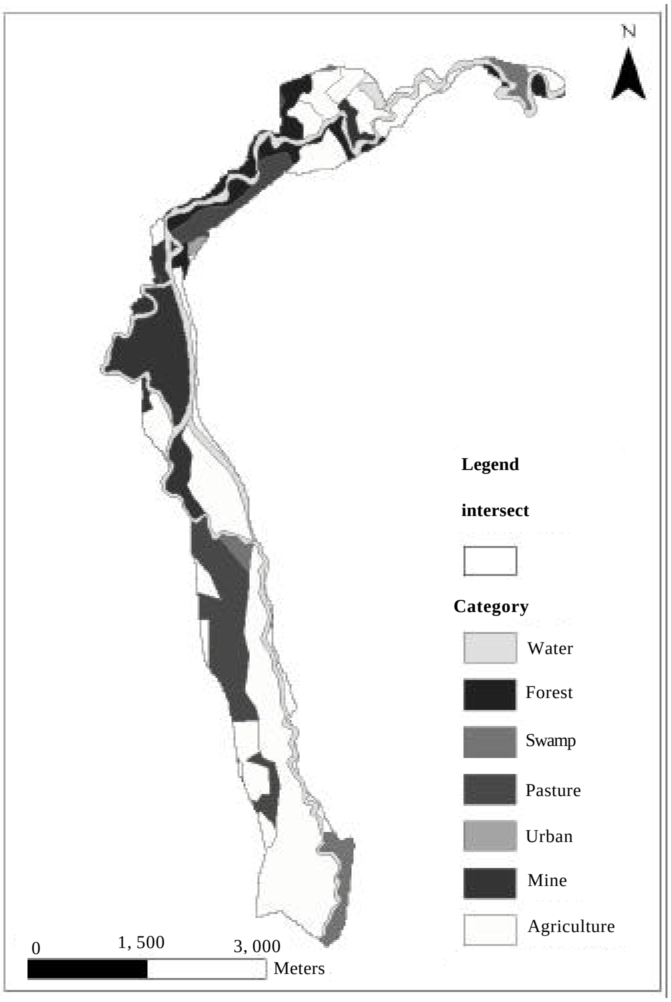

Fig. 1: Land-use of flooded area by overlaying land-use plan and ARI 50 years

Flood damage assessment under future land-use: The following calculation is based on work undertaken on urban area in Australia (KTA *et al.*, 2003) which assumes that in one hectare of floodplain, there are 12 flats located in 3 buildings. In evaluation of property damage for residential land-use types, the following equations are used:

For Depth of over floor flooding $H<1$ m

$$D = D2\ (0.06 + 1.42H - 0.61\ H2)\ R\ (1 + ID) + DCLEAN \qquad (2)$$

For Depth of over floor flooding $H>1$ m

$$D = D2\ (0.75 + 0.12H)\ R\ (1 + ID) + DCLEAN \qquad (3)$$

where, D is Value of damage to property (RM), D2 is Assessed value of residential property damage at 2m depth of flooding (H) or "size" (RM), H is Depth of over floor flooding (m), R is Reduction factor by virtue of a flood warning provision. (0.85 was adopted in this theorem), ID is Indirect damage factor (0.2 was adopted for this theorem), DCLEAN is Clean-up cost (RM).

And to make an allowance for the difference in comparable "size" between houses, flats and a unit, the following formulation was derived:

$$\mathrm{D2} = \mathrm{X}(\mathrm{I}(\mathrm{p}) + \mathrm{E}(\mathrm{p})) + (\mathrm{Y} \times \mathrm{St}(\mathrm{p})) \tag{4}$$

where, D2 is Annual assessed value of residential property at 2 m depth of flooding (RM), X is Total number of units/flats located on title block, Y is Total number of buildings which contain X, I (p) is Internal property value (RM), E (p) is External property value (RM), St (p) is Structural property value (RM).

To calculate the potential clean-up costs for residential properties:

$$\mathrm{DCLEAN} = \mathrm{Daily\ rate} \times \mathrm{Z} \times \mathrm{In}\,(\mathrm{H} / 0.023) \tag{5}$$

where, DCLEAN is Potential clean-up costs (RM); Daily rate is Earnings per day of one worker (RM/day); H is Depth of over floor flooding (m); Z is Factor accounting for sediment load and deposition.

Evaluation of using riparian buffer on floodplain: A buffer ordinance imposes costs on a local government in the form of staff time, staff training, public education efforts and technical assistance to landowners and developers. For landowners, the most significant cost of the ordinance is likely to be the loss of full use of the land covered by the riparian buffer. Theoretically this should have a negative impact on property values, although this is offset to some degree by the positive effects of improved aesthetics. Other costs include time spent delineating the riparian buffer and completing necessary documentation to submit to the local government authority. Protecting the riparian buffer during construction might also add slightly to construction costs. If the stream channel is degraded, the local government could require the landowner to take measures to stabilize the banks and restore vegetation.

Junk *et al.* (1989) notes that flooding is a natural feature of aquatic and riparian ecosystems. The frequency, duration and magnitude of floods help to determine both the physical and biological characteristics of the riparian zone. As discussed above, many riparian plants rely on cycles of flooding for seed dispersal and recruitment, while many fish species use riparian zones as nurseries, spawning grounds or feeding areas during high flows. A healthy riparian zone and a healthy stream system require the maintenance of the natural flow regime cited in Wenger (1999). Of course, while floods are good for the stream and the riparian zone, they can be very damaging to human structures and activities. Poff *et al.* (1997) offered that removal of riparian vegetation, drainage of wetlands and development of floodplains leads to larger magnitude floods that cause greater damage to property cited in Wenger (1999). To provide maximum protection from floods and maximum storage of flood waters, a buffer should include the entire floodplain. Short of this, the buffer should be as wide as possible and include all adjacent wetlands.

Nieswand *et al.* (1990) determined that slope and width were the main factors influencing the effectiveness of buffers in trapping sediment and associated pollutants. They developed a simple formula for determining width based on a modified Manning's equation:

$$W = k\,(s^{1/2}) \tag{6}$$

where, W is width of buffer in feet; k is width of buffer for flat floodplain (50 ft constant); s is percent slope expressed as a whole number (e.g., 5% slope = 5).

Establishment costs occur at the time of strip establishment while maintenance and opportunity costs occur on a recurring basis. To calculate an annual aggregate cost, establishment costs are annualized over the expected life of the buffer strip and added to annual maintenance and opportunity costs.

RESULTS AND DISCUSSION

After overlay the land-use map and the flood zoning map, the probable flood damage for different land-use was calculated and then using Equation 1, the amount of AAD for present and future condition of river was determined and indicated in Table 1.

By assuming that there are three buildings and 12 units in each hectare, the flood damage is equal to 282,050 Ringgit in each hectare using equations 2 to 5. By comparing Average Annual Flood Damage of Bernam River under present condition where land-use is mostly agriculture (0.0317 MRM) and in future condition where land-use will be mostly residential (26.7 MRM), the effect of land-use changes on flood damage is determined. Figure. 2 shows a comparison of flood damage in the study area under present and future land-use in different flow recurrence intervals. Based on Fig. 2, by increasing the recurrence interval of flow, the gap between flood hazard risk at present and future conditions will increase significantly. It is important to note that in this paper, the prediction of flood hazard is based on previous density pattern of urban development in this area. Comparison between agricultural floodplain in its present state without building any structures and future land-use in semi urban floodplain shows that by increasing urban area the probable flood damage increases about 800 times and by increasing the discharge the flood damage increases in a regular way. Even though the land-use change in developing rural floodplain area is inevitable but by making enough space to water conveyance in inundated area of river floodplain, the risk of flood hazard can be decreased acutely. Also, as shown in second option, because of circumstances of building construction effects on extension of floodplain area, building construction should be avoided as far as possible to keep open space on floodplains.

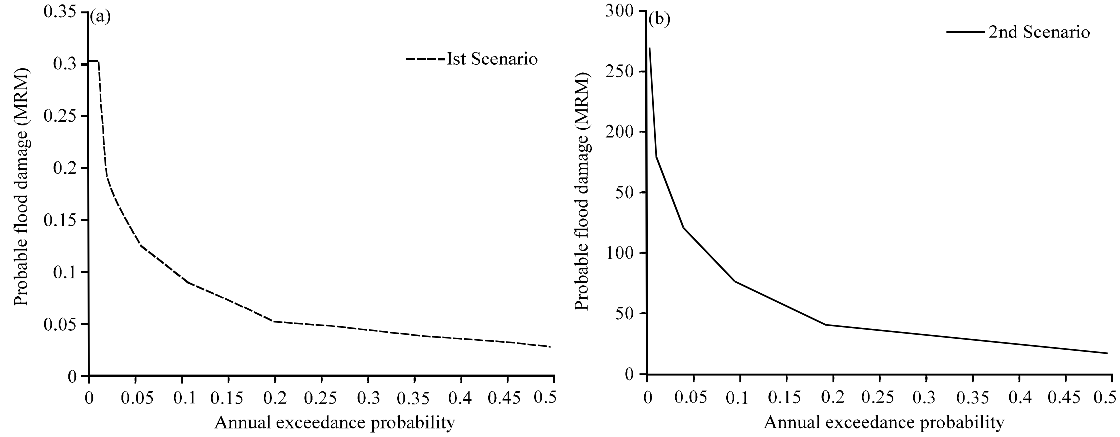

Fig. 2(a-b): Comparison of flood damage under present (a) and future (b) condition of Bernam River Basin

Table 1: Annual average flood damage of Bernam River (present and future land-use)

Return period (year)	Present AAD (RM)	Future AAD (MRM)
2		
5	0.0117	8.8
10	0.0189	14.8
20	0.0245	19.8
50	0.0293	24.4
100	0.0317	26.7
Total	0.0317	26.7

Table 2: The costs for 3 selected scenarios (50 years ARI) Million RM

Cost parameter	Scenario 1 (present)	Scenario 2 (future)	Scenario 3 (buffer)
Permanent measures cost	0	273.7	1.5
Damage reduction effectiveness (Permanent)	-0.19	-182.8	----
Emergency measures cost (Evacuation)	47.2	660.7	----
Damage reduction effectiveness (Emergency)	2.6	19.8	----
Flood insurance	5.19	42.5	----
Minimized cost	1.0	273.72	1.5

Table 2 shows the costs of present and future scenarios of study area (for 50 years ARI) which are related to cost of flood proofing for the first floor, reduced cost of flood hazard, the cost of evacuation, the blood cost by assuming 1% flood victims and the cost of flood hazard of 5 years RI as flood insurance. Minimized cost is equal to sum of permanent cost and probability of emergency cost minus permanent and emergency benefits and flood insurance cost.

By assuming s = 4 and k = 50 ft in equation (6), the buffer width W would be at least 100 ft and maximum width might be width of flood zone in 100 year return period. Also, if the annual average cost of tree planting (Oil palm) discounted at 0.04 have RM1186 ha^{-1} cost on buffer zone (Noormahayu *et al*., 2009) the total revenue for mentioned area would be about MR 1.5/year. This is considerable that oil palm trees have a good endurance in inundated area.

Different values have different importance; hence, there is a need to determine weights for each value separately. Pair-wise comparison technique in the context of Multi Attribute Decision Making (MADM) method called the Analytical Hierarchy Process (AHP) can compute weights representing the relative importance of the criteria. Assuming that C1 is public building, C2 is house value and C3 is income (land value in rural areas and household income in urban area). Based on the three pair-wise comparisons C2 vs. C1, C3 vs. C1 and C3 vs. C2 and using AHP method public building = 0.08, house value = 0.23 and income value = 0.69. Because individual judgments will never agree perfectly, using Consistency Ratio (CR) the degree of consistency achieved in the ratings is measured. The value of CR = 0.06 in this research falls below the threshold value of 0.1 and indicates a high level of consistency. Hence, we can accept the weights. Also, Reasonable Goals Method (RGM) was used to narrow the decision making process. RGM is based on the identification of goal in criterion space. Thus, the preferences are arrived at by examining trade-offs among criteria and expressed in terms of criterion value. The alternatives are then selected based on their proximity to goal. The RGM consists of rating and weighting. These rates (or scores) and weights are then applied to the results of the comparison of the evaluation sub-criteria that were generated.

Table 3: The corrected values and properties for the selected scenarios (50 years return period)

	Scenario 1 (present)				Scenario 2 (future)				
Parameters	Rate	Weight	Score	Value	Rate	Weight	Score	Value	Scenario 3 (buffer)
A) Household income		0.69		1.94		0.69		24.62	7134400
Employment	1	0.13	0.13	0.25	1	0.13	0.13	3.2	
Development	1	0.23	0.23	0.45	0	0.23	0	0	
Capitalization	1	0.33	0.33	0.64	0	0.33	0	0	
B) House value		0.23		8.78		0.23		1072	
Warning system	0	0.07	0	0	1	0.07	0.07	75.04	
Conveniences coverage	0	0.08	0	0	0	0.08	0	0	
Accessibility	1	0.08	0.08	0.7	1	0.08	0.08	85.8	
C) Public building		0.08		6.67		0.08		48.65	
Open space	0	0.03	0	0	0	0.03	0	0	
Proximity to roads	1	0.03	0.03	0.2	1	0.03	0.03	1.46	
Infrastructure cost	0	0.02	0	0	0	0.02	0	0	
Total value				2.24				165.5	7134400

Table 4: The value to cost ratio for present and future land-use and buffer scenarios

	Scenario 1	Scenario 2	Scenario 3
Value/Cost	2.24/1.0 = 2.24	165.5/273.72 = 0.6	7.13/1.5 = 4.8
Ranking	2	3	1

The alternative strategy rating is 1 (strong positive impact), 0 (slight positive impact) or -1 (does not impact). In this study, the sub-criteria supposed are shown in Table 3.

If the annual average revenue of tree planting (Oil palm) discounted at 0.04 have RM5600 ha^{-1} benefit on buffer zone (Noormahayu *et al.*, 2009), the total revenue for 1274 hectare (inundated area in 100 years recurrence interval of flow), would be about MR 7.13/year in selected reach of Bernam River.

Table 4 shows that using riparian buffer is the best scenario on floodplain management strategies and avoiding from building construction on floodplain will decrease flood hazard dramatically. This is considerable to simplify the analysis; there are many limitations in this study and improving the criteria and the evaluation methods could provide more accurate analysis. Land-use changes would change the related potential value in the future. Value changes can be economic, social or environmental and in this paper economic changes just studied.

CONCLUSIONS

Impermeable areas increase with land use changes due to urbanization. This phenomenon can increase runoff, flood risk and flood hazard. Evaluation of flood hazard risk is an important part of flood management system and awareness of all components of this system can change the decision making process for better productivity. The flood hazard risk under the current and future land-use of the study area in the Bernam River basin including rural and semi-urban area was analyzed. The Average Annual Flood Damage (AAD) related to land-use and the values evaluated using Analytical Hierarchy Process (AHP) and Reasonable Goal Method (RGM) shows that under a common pattern of urbanization development, the flood damage increases more than 800 times and by increasing the recurrence intervals of flow, flood damage will increase more seriously. Also, comparison of value to cost ratio between three scenarios (rural area, urban area and riparian buffer) shows that using riparian buffer is the best scenario on floodplain management strategies and rural area has better ranking than semi-urban. Land-use changes during urbanization are unavoidable and coping with flood in the future needs to consider regulations for floodplains to decrease flood hazard and increase values.

ACKNOWLEDGMENTS

The authors would like to acknowledge anonymous referees and Professor Lee Teang Shui and Professor Abdul Halim Ghazali for their valuable comments and suggestions. Also we thank DID staff on their kindly cooperation to prepare data and ITMA staff for assistance doing the field works.

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