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ENVIRONMENTAL SUSTAINABILITY OF STRUCTURAL FLOOD MITIGATION MEASURES IN METRO MANILA, PHILIPPINES

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Introduction

Recent studies on climate change (Yusuf and Francisco, 2009) indicated that the Southeast Asian region will likely experience higher frequency of extreme floods in the coming years, thus creating higher demand for structural flood mitigation measures (SFMMs). SFMMs have become highly valuable in many urbanized flood prone areas; however, poor management decisions in the implementation of these infrastructures may lead to geomorphological, ecological and social ramifications. The process of environmental impact assessment (EIA) must then be taken as a necessary step in the planning of SFMMs to obtain a clear view of the costs and benefits, not only for social and economic development, but also to minimize the consequences on the ecological environment.

In principle, the assessment of environmental sustainability involves the estimation of how much the Earth's life support system can be maintained and improved by focusing on its biogeophysical aspects (Moldan et al., 2012). Such aspects can be evaluated through environmental impact assessment (EIA), where the resulting evaluation can represent the gains and losses a project or activity may incur on the general environment. EIA is a process undertaken to identify the beneficial and harmful impacts of projects, plans, programs or policies on the physical, biological and socio-economic components of the environment. The use of appropriate EIA techniques can aid planners and decision-makers in formulating appropriate actions based on informed decisions in light of project urgency and limited resources, which are common constraints in many developing countries, like the Philippines.

In the Philippines, particularly in Metro Manila, the use of EIA in the planning processes of SFMMs is predominant, however, certain aspects of the projects, such as environmental sustainability, are rarely investigated. Numerous methods are available to carry out EIA (e.g. Pastakia and Jensen, 1998; Tukker, 2000; etc.), however, to get an accurate estimate of environmental sustainability, it is important that the EIA method would provide the quantitative means to represent the qualitative environmental impacts of a project.

In this study, a modified rapid impact assessment matrix (RIAM) technique (Gilbuena et al., 2013), coupled with the evidential reasoning approach (Wang et al., 2006), was used to evaluate the environmental impacts of the planned SFMMs in Metro Manila. The planned SFMMs used in this study are composed of 2 river channel improvements and 2 new open channels as shown in Fig. 1.

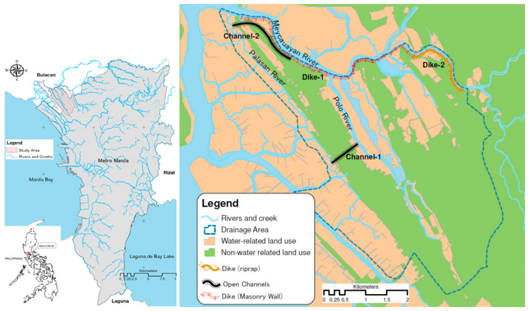

Fig. 1 Map of Metro Manila and the location of the study area

The result of the EIA is then used to calculate the environmental sustainability index using a geocybernetics model for estimating the level of sustainable development (Phillips, 2011). This study is intended to improve the EIA of SFMM in Metro Manila, but may also find application in other types of projects.

Study Area

The study area (approximately 20 km^2), as shown in Fig. 1, is located in the north-northwest part of Metro Manila, which is home to approximately 160,000 residents. Its topography is generally characterized by flat and low-lying coastal plains with ground elevation ranging from 0 to 1.5 m above mean sea level. It has a mixed land-use comprised of commercial, industrial and residential districts with fishponds. The river system has limited aquatic biota due to the poor water quality conditions. Migratory birds that feed on insects, fishes and invertebrates were observed wandering and nesting close to the river systems, while few patches of mangroves exist at the lower section of the main river. Most mangrove areas have been converted to fishponds and settlement areas. High volume of settlers is found on the left bank of the upper section of the main river and along narrow natural waterways. Due to the very poor discharge capacity of the study area, floods easily manifest during the rainy seasons, contributing to the slow economic growth of the affected municipalities. To improve the drainage conditions, 2 dikes and 2 open channels were proposed under the Metro Manila flagship program on flood mitigation (Department of Public Works and Highways, 2001). The river improvement works consist of masonry walls (Dike-1), riprap dikes (Dike-2), diversion canal (Channel-1), and a small open channel (Channel-2) within the study area.

Table 1 Environmental utilities and sustainability indices of the proposed 4 SFMM projects.

Structural flood mitigation measures	Environmental utilities per environmental category (Gilbuena, 2013)				Sustainability Index, S	Rank
	Physical/ Chemical	Biological/ Ecological	Social/ Cultural	Economics/ Operational		
Dike-1	0.0837	-0.1280	-0.0254	0.4000	0.0826	2
Dike-2	0.0837	-0.0770	-0.0383	0.4000	0.0921	1
Channel-1	-0.0622	-0.0763	-0.1253	0.4000	0.0341	3
Channel-2	0.0000	-0.1793	-0.1221	0.4000	0.0247	4

Methodology

The EIA of SFMM was carried-out using a modified RIAM technique (Gilbuena et al., 2013) extended with the evidential reasoning approach to assess the environmental utility of each environmental category. The range of utility values used for the utility-based information transformation of degrees of belief (Wang et al., 2006) is -1 to 1. The environmental sustainability index of each SFMM was estimated using a geocybernetics model that is slightly modified from Phillips (2011). In this study, to estimate the environmental sustainability index, the environmental utilities of the SFMM structures were used in lieu of the environmental scores since the environmental utility values represent the aggregated impacts of the SFMM with due consideration to the uncertainties in the decision-making process.

Results and discussion

Table 1 shows the estimated environmental utilities of each environmental category and sustainability indices of the proposed SFMM projects. The SFMM projects are ranked based on the sustainability index. Higher sustainability index means better sustainability. Based on the results, Dike-1 and Dike-2 have the highest environmental utility on the Physical/ Chemical category, while Channel-1 has the lowest with a value less than zero, which indicates potential "dis-utility". On the Biological/Ecological category, all the proposed SFMMs are expected to incur negative environmental utilities. Based on the assessment of the Social/Cultural category, the projects are generally not favourable as indicated by the negative environmental utilities, which perhaps is due to cumulative negative impacts during the construction period, particularly for Channel-1 and Channel-2. On the Economics/Operational category, all the projects are expected to generate a lot of positive impacts during the operation phase thus, may tip the point of the overall utilities of the proposed SFMMs towards positive environmental utility.

The sustainability index S was calculated using environmental utilities in Table 1. Based on the result, Dike-2 is the most environmentally sustainable, followed by Dike-1. The sustainability index of Channel-1 and Channel-2 are much less sustainable, but still greater than zero. In this study, it is defined that the project will most likely be sustainable if $S > 0$, generally deleterious to surrounding environment if $S < 0$, or the project is otherwise neither beneficial nor deleterious if $S = 0$. The results in Table 1 indicate that all the proposed structures are generally sustainable, which is important since these projects are expected to operate for an indeterminate period of time. Thus, aside from the expected economic and operational (protection against floods) benefits, the 4 planned SFMM projects are also sustainable.

Conclusion

The environmental sustainability of the 4 planned SFMM projects in Metro Manila was evaluated using the results of the environmental impact assessment (i.e. RIAM coupled with the evidential reasoning approach) and a geocybernetics model. The assessment by RIAM provided a quantitative representation of the qualitative assessment of the environmental impacts of the SFMMs, which allowed for the characterization of the aggregated impacts with uncertainties using the evidential reasoning approach. The concept of the geocybernetics model for sustainable development was used to estimate the environmental sustainability of each planned SFMM, which provided interesting insights on the nature of the environmental impacts, particularly the influence of each environmental category. The study thus provide an alternative approach in estimating the sustainability of SFMM projects, but may also be used for other types of projects.

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