UNIVERSITI PUTRA MALAYSIA

IDENTIFYING POTENTIAL DAM SITE USING THE FOREST DIVERSITY ASSESSMENT IN BENGOH CATCHMENT, SARAWAK, MALAYSIA

LES ANAK MET

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IDENTIFYING POTENTIAL DAM SITE USING THE FOREST DIVERSITY ASSESSMENT IN BENGOH CATCHMENT, SARAWAK, MALAYSIA

By

LES ANAK MET

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Abstract of thesis presented to the senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

IDENTIFYING POTENTIAL DAM SITE USING THE FOREST DIVERSITY ASSESSMENT IN BENGOH CATCHMENT, SARAWAK, MALAYSIA

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November 2016

Chairman : Associate Professor Latifah Abd Manaf, PhD
Faculty : Environmental Studies

Dams are built to provide water for irrigated agriculture, domestic or industrial use, flood control, irrigation, navigation, sedimentation control, hydropower and to support economic development. Despite the benefits provided by the dams to humankind, dam developments leads to the irreversible loss of species populations and ecosystem. As forest diversity assessment constitutes the major component in the ecological evaluation, it is paramount for the ecological evaluation of dam projects to be strengthened and emphasized so as to provide criteria and information that can be used to support decision-making by the relevance authorities with regard to natural conservation. The study focuses on four specific objectives, that is, measuring the species diversity of plants vegetation, developing the land-cover map and ecosystem map of Bengoh Catchment, determining the rarity and viability value of plants vegetation in four different types of forest vegetation and assessing the ecosystem-loss impact score and ecosystem fragmentation impact score using the rarity and viability value based on fragmentation impact map for the ranking of potential dam site. The approach begins with the mapping of the land cover and ecosystem of Bengoh Catchment where the dam projects have been proposed. The classification of forest was performed using the information generated from the data collected during the field work and also from the digitise topographic maps. The species diversity of the forest ecosystem were calculated using the diversity index expression. The identification of the potential dam site was done by accessing ecosystem loss impact score and ecosystem fragmentation impact score using the rarity and viability value. A total of 148 species and 72 families were recorded within the four different types of forest ecosystem. Out of 148 species, 22 trees species were recorded at primary forests, 72 species were recorded at the old secondary forest, 37 species were recorded at young secondary forest and 17 were recorded at agroforestry. The diversity index indicates the species richness, species diversity and evenness in all four major forest ecosystems were relatively high. The rarity value of all the four types of ecosystem was relatively high; indicating that the species in the ecosystem were distributed equitably and reflecting the commonness of the species. The viability value of the entire

four ecosystems is relatively low indicating that the species are prone to extinction. The impact analysis carried out in this study which generates the ecosystem-loss impact scores and ecosystem-fragmentation impact scores of the proposed dam site and gives a clear picture on which alternative to be considered as one of the most appropriate site for the proposed dam project. Based on the analysis of the impact score of the five alternatives, alternative 4 is the best-performing with the overall impact score 0.663 with respect to the ecosystem-loss and the ecosystem-fragmentation impact. Thus, Alternative 4 appears to be the most appropriate site for the dam project. The approach to this work paths the way to alleviate the impact of dam development on the displacement of ecosystem and to develop methods of evaluating the long-term impact, as well as the viability of populations and ecosystems.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

MENGENAL PASTI KAWASAN BERPOTENSI BAGI EMPANGAN DI TADAHAN BENGOH SARAWAK, MALAYSIA, MENGGUNAKAN PENILAIAN KEPELBAGAIAN HUTAN

Oleh

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Pembinaan empangan bertujuan membekalkan air untuk saliran pertanian, penggunaan domestik atau industri, membantu mengawal banjir, pelayaran, kawalan pemendapan, menjana kuasa hidro dan menyumbang kepada pembangunan ekonomi. Walaupun pembinaan projek empangan memberi manfaat kepada manusia sejagat namun ia turut menyebabkan kemusnahan terhadap populasi spesies dan ekosistem. Memandangkan penilaian kepelbagaian hutan menyumbang kapada komponen utama dalam penilaian ekologi maka ianya amat penting bagi penilaian kepelbagaian hutan bagi projek pembinaan empangan diupayakan dan diberi keutamaan bagi menyediakan kriteria dan maklumat yang boleh digunakan oleh pihak berwajib dalam membuat keputusan yang berkaitan dengan pemeliharaan alam semula jadi. Kajian ini berfokus kepada empat objektif khusus, iaitu, mengukur kepelbagaian spesis tumbuhan bagi tadahan Bengoh, menghasilkan peta tutupan bumi dan peta ekosistem bagi tadahan Bengoh, menentukan penilaian jarangan(rarity) spesies dan nilai daya maju (viability) spesis tumbuhan di empat tempat kawasan hutan yang berbeza bagi tadahan Bengoh, dan menilai skor kesan kehilangan ekosistem dan skor kesan pemecahan ekosistem dengan menggunakan nilai penilaian jarangan(rarity) serta nilai daya maju (viability) berdasarkan peta impak bagi menentukan kedudukan potensi lokasi empangan. Pendekatan ini bermula dengan melibatkan pemetaan tutupan bumi (land cover) dan ekosistem tadahan Bengoh di mana projek empangan telah dicadangkan. Pengkelasan hutan dibuat menggunakan maklumat yang diperolehi daripada pengumpulan data semasa kerja lapangan dan juga daripada peta topografik digital. Kepelbagaian spesies bagi ekosistem hutan dikira berdasarkan fungsi kepelbagian index. Sejumlah 148 spesies, 22 spesies tumbuhan telah direkodkan di hutan primer, 72 spesies direkodkan di hutan sekunder tua, 37 spesies direkodkan di hutan sekunder muda dan 17 spesies direkodkan di hutan agro. Keputusan menunjukkan bahawa nilai kejarangan untuk keempat-empat ekosistem iaitu hutan primer, hutan sekunder tua, hutan primer muda dan hutan agro adalah secara relatifnya tinggi menunjukkan bahawa taburan spesies dalam sesuatu ekosistem adalah seragam dan

mempamerkan ciri-siri sepunya spesies. Nilai daya maju (viability) spesies untuk keseluruhan empat ekosistem secara relatifnya rendah menunjukkan bahawa spesies tersebut terdedah kepada kepupusan. Analisis impak yang dijalankan dalam kajian ini menghasilkan skor impak kepupusan ekosistem dan skor impak fragmentasi ekosistem bagi kawasan cadangan pembinaan empangan yang mana skor impak tersebut memberikan gambaran yang jelas tentang pemilihan kawasan cadangan yang paling sesuai sebagai tapak projek pembinaan empangan. Daripada lima pilihan cadangan tapak pembinaan empangan, pilihan ke-4 merupakan pilihan yang paling sesuai dengan impak skor keseluruhan 0.663 berasaskan skor impak kepupusan dan skor impak fragmentasi ekosistem. Oleh yang demikian pilihan ke-4 merupakan tapak yang paling sesuai untuk pembinaan empangan di kawasan tadahan Bengoh. Dapatan daripada kajian ini membuka ruang untuk mengurangkan kesan pembangunan empangan ke atas ekosistem dan untuk mewujudkan pendekatan penilaian kesan jangka panjang termasuk daya nilai maju (viability) populasi dan ekosistem.

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I certify that a Thesis Examination Committee has met on 16 November 2016 to conduct the final examination of Les Ak Met on his thesis entitled "Identifying Potential Dam Site using the Forest Diversity Assessment in Bengoh Catchment, Sarawak, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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LIST OF ABBREVIATIONS

AF	Agroforestry
Alt	Alternative
ASEAN	
Asl	Above sea level
BIA	Biodiversity Impact Assessment
CEIA	Canadian Environmental Impact Agencies
CORINE	Coordination of Information on the Environment, European Union
CBD	Convention on Biological Diversity
D’	Simpson Index of diversity
Dhb	Diameter at breast height
Dist	Distance
Dmg	Margalef’s index of richness
DV	Disturbance value
DWS	Department of Water Supply
E	Species Evenness
EF	Ecosystem fragmentation impact score
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
El	Ecosystem-loss impact score
F	Flood control
Frag	Fragmentation
GIS	Geographical Information System
H	Shannon Weiner index
HD	Highest disturbance value
HIV	Highest isolation value
HP	Hydropower
Hv	Highest value core area
I	Irrigation
ICM	Integrated Catchment Management
ITTO	International Tropical Timber Organization

Iso	Isolation
Iv	Isolation value
IVI	Important Value Index
IVI	Important Value Index
JUPEM	Department of Survey and Mapping Malaysia
Km	kilometre
km^2	kilometrer square
LnS	Natural logarithm of the total number of species
m	meter
NRE	Ministry of Natural Resources and Environment
OSF	Old Secondary Forest
Peri	Perimeter
PF	Primary Forest
RC	Recreational
Rd	Relative density
Rd	Relative density
RD	Relative Dominance
RD	Relative dominance
RE	Rarity value of species
Rf	Relative frequency
Rf	Relative frequency
RR	Regulating Reservoir
Sc	Core area
SESCO	Sarawak Electrical Supply Cooperation
SF	Secondary forest
Sr	Silt retention
UNESCO	United Nations Educational, Scientific and Cultural Organization
Vc	Core value
VL	Viability score
W	Water supply
YSF	Young secondary forest

CHAPTER 1

INTRODUCTION

1.1 Background of study

Dams are built for multiple purposes which include providing water for irrigated agriculture, domestic and industrial consumption as well as providing alternative for meeting energy needs and supporting economic development. According to World Commission on Dams (2000) about one fifth of the world's agricultural land is irrigated, 12 % of large dams are designated as water supply dams, hydropower provides 19% of world's total electricity supply and 13 % of all large dams in the world have a flood management function. Statistic from the Department of Water Supply Malaysia (2012) shows that 80 dams being built throughout Malaysia and majority of the hydropower dams are located in State of Sarawak.

Despite the importance of dams in promoting the betterment of humankind the existing of dams posed adverse impact to terrestrial ecosystems and biodiversity. The inundated of the reservoir cause direct impact in terms of ecosystem loss, ecosystem fragmentation and land degradation. However, the ecosystem loss and the ecosystem fragmentation can be reduced if the appropriate site is being identified prior to the construction of dams based on the ecological evaluation approach.

Ecological evaluation presumably seeks to provide a quantitative statement of the worth which a competent ecologist attributes to a particular biological system. In the light of this definition, two types of ecological evaluation can be discerned. First, ecological evaluation as an assessment of ecosystem qualities per se, based on the thought that some ecosystem attributes are more important or interesting than the others, regardless of their social interest. Second, ecological evaluation as a socio-economical procedure to estimate the function of the natural environment for human society (Van Der Ploeg and Wlijm 1978; O'Connor 1974; Geneletti 2006).

The ecological evaluation is considered one of the most important components in producing Environmental Impact Assessment (EIA) of any land used projects such as dams which pose adverse impact on areas with considerable nature conservation interest. The ecological evaluation results are to be used in determining the ecological significance of the study area and also for the selection of indicators (core are, isolation and disturbance) used to express changes in such an ecological significance. The results also help to estimate the ecological significance of the study area in the post-project conditions.

Despite the significant role played by the ecological evaluation within the EIA, it is still lacking of common frame work which is used to support the impact assessment on the ecological components. Thompson et al. (1997) and Geneletti (2002) ascertain that, there

is no common type of data, no common way of processing and organising the information, no common way of selecting the evaluation criteria and no common way of expressing the impacts compared to other disciplinary studies which tend to follow more structured procedures that guide the entire assessment, from the data collection to the discussion of the relevance of the impacts. Husnain (2012) highlights the incomplete ecological evaluation as part of the root cause of poor performance of EIA in dam development projects, where unwise decision making leads to the destruction of habitats, biological diversity, ecological services, agricultural lands and livelihood resources. According to Byron (2000) and Geneleti (2002), the assessment of ecological components tends to be flawed and the weakness of the analysis of ecological impacts, such as the loss and the fragmentation of ecosystem limits the influence of ecological components in the decision-making process of a development due to the fact that their relevance are not sufficiently stressed and justified in Environmental Impact Statement (EIS).

The conservation of the biological diversity or biodiversity is the most significant objective of the ecological evaluation. Biodiversity has emerged as a key environmental issue and a major driving force behind efforts to reform land management and development practices worldwide and also to establish a more harmonious relationship between people and nature (Noss and Cooperrider 1994, Geneletti 2002). Among the anthropogenic activities that pose the highest threat to conservation of biodiversity is the construction of dams. Such development projects interfere with the natural habitat conditions and consequently influence the abundance and distribution of plant and animal species.

1.2 Problem statement

Dams are promoted as an important way to meet water and energy needs and to support economic development, not only in Malaysia but throughout the globe. In Malaysia, 80 dams have been built (Department of Water Supply,2012) and 12 hydropower dams project have been planned for implementation for the period of 2008 until 2012 (Sarawak Electrical supply Cooperation, 2008). However, dam developments leads to the irreversible loss of species populations and ecosystem due to the fact that the impacts are many and complex and it is hard to establish a common and standardised ecological evaluation framework. As forest diversity assessment constitutes the major component in the ecological evaluation, it is paramount for the ecological evaluation of dam projects to be strengthened and emphasized so as to provide criteria and information that can be used to support decision-making by the relevance authorities with regard to natural conservation.

Despite the importance of ecological component, the standard methodology for forming the ecological evaluation particularly the forest diversity assessment is still lacking (Roome, 1984). Asian countries provided the poorest information on forest diversity assessment, with 71 percent of the forest assessed through expert estimates or general mapping. Field surveys have often focused on timber volume and tree species composition and to a lesser extent on biomass and other forest and tree attributes (FAO,

2001). These weaknesses of the forest diversity assessment lay on the weaknesses of ecological evaluation which formed the most significant component of the EIA.

The shortcoming of the forest diversity assessment refers to the study area in which the impact analysis normally considers the designated area and the analysis of the biodiversity features focus on the designed conservation sites or protected species only. Furthermore the biodiversity is not addressed in its complexity but the analysis is typically limited to one level only without providing a scientifically justification for doing so. Another shortcoming of the forest diversity assessment refers to the lack of quantitative prediction of ecosystem-loss. This is due to the omissions of those technical parameters that are fundamental to estimate the space occupation of the dam projects. On the other hand, the ecosystem-fragmentation is not quantified in an objective way and often just mentioned or described in general term. Operational guidance on how to perform a prediction of the impacts caused by the projects in terms of fragmentation is lacking due to insufficient use of specific indicator to predict the habitat fragmentation (Geneletti 2006). Furthermore the assessments are poorly structured and its transparency is ambiguous. One of the reasons behind this shortcoming is that, the assessing implies subjective judgments and this may appear inappropriate with the scientific validity of the work. Didham and Raphael (2010) point out that habitat fragmentation is a landscape-level phenomenon, and patch-level processes (patch area, edge effects and patch shape complexity) can only be understood within a landscape context (isolation and matrix structure). Consequently, it is difficult to find actual fragmentation assessments. If less effort is being taken to address these issues, more and more ecosystem could be severely threatened due to degradation brought about by the dam projects.

1.3 Research Objectives

The main objective of this research is to identify the potential site for the dam project in Bengoh Catchment area using ecological evaluation approach. This objective will lead to various objectives as follows:

1 to determine the species diversity indices of plants vegetation of Bengoh Catchment
2 to produce the land-cover map and ecosystem map of Bengoh Catchment
3 to determine the rarity and viability value of plants in four different types of vegetation in Bengoh Catchment
4 to assess the ecosystem-loss impact score and ecosystem fragmentation impact score using the rarity and viability value based on fragmentation impact map for the ranking of potential dam site.

1.4 Significances of the study

This study focuses on the assessment process which explores the interaction between the dam development and biodiversity. Thus, the Biodiversity Impact Assessment (BIA) has been considered to estimate the loss and fragmentation ecosystem posed by Bengoh Dam project. The impact analysis carried out in this study which generates the ecosystem loss impact scores and ecosystem fragmentation impact scores of the proposed dam project mark a significant discovery in producing a sound Environmental Impact Statement particularly the dam project. The outcome of the analysis gives a clear picture on which alternative is to be considered as one of the most appropriate site for the proposed dam project. This will help to provide criteria and information that can be used to support decision-making by the relevant authorities with regard to natural conservation.

The result of this study provides a significance contribution to the improvement of environmental related policies particularly in minimizing the impacts of dam development on biodiversity. It paths the way to alleviate the impact of dam development on the displacement of ecosystem and to develop methods of evaluating the long-term impact, as well as the viability of populations and ecosystems. Furthermore, it gives the opportunity to identify areas where new legislation or major enhancements to existing legislation are needed for management of threatened or endangered species and ecosystem. A review on Environmental Impact Assessment (EIA) and other related legislation need to be done to strengthen requirements for assessing direct or indirect biological diversity loss and fragmentation.

The result of this study also revealed that BIA could make the application of ecological assessment easier and more effective. Moreover the method applied for analysing the impact is more structured and transparent based on the use of indicators such as rarity, core, isolation, disturbance and viability. Nevertheless the outcome of the analysis based on the impact scores may constitute only potion of the entirely environmental discipline that forms the Environmental Impact Assessment. Other factors such as economic, social and political scenario may be at odd with the results of the environmental assessment.

1.5 Scope of the study

The geographical boundary of the study is dictated by the expected spatial spread of the impact, or at least of the main impacts that can be predicted. This leads to an effort toward defining the boundary of the study area on an ecological basis. The study area is extended to the whole landscape(s) of Bengoh Catchment where the project is to be sited. This is to ensure a comprehensive spatial assessment of the impacts (ecosystem loss and ecosystem fragmentation) on biodiversity.

This research focuses on the ecosystem level. This is due to the fact that ecosystem level is usually the most relevant and consequently the one that needs to be fully investigated when dealing with dam projects. Moreover, conservation is in many cases most efficient when focused directly on the ecosystem (Noss and Cooperrider 1994; Geneletti 2002).

This research proposes to address all the ecosystems living within the boundary of the study area. Four types of forest ecosystem are considered in this study. These include the primary forest, old secondary forest, young secondary and agroforestry. Geneletti (2002) states that the most common method for mapping ecosystems consist of mapping the vegetation types. This indicates that vegetation communities are considered a representative for delimiting the boundaries of ecosystem units. This assumption is justified by the fact that vegetation communities typically show a strong relationship with both their physical environment and the organisms they act upon. Moreover, vegetation mapping represents a feasible alternative to carry out a truly complete biodiversity survey. As a result, it is widely held that vegetation cover types can be used as surrogate for the ecosystems in which they participate and represent typical stating point of ecological evaluation.

Dam projects have caused severe habitat reduction which occurs when a natural ecosystem is converted to an artificial system. For this reason, dams projects have been selected as the target of this research. The impact considered in this study encompasses the direct loss of ecosystem and the fragmentation of ecosystem.

The following research questions have been established after considering the paramount aims of this research.

1 Is there any significant correlation of forest diversity index between different types of forest ecosystem?
2 How can GIS facilitate in generating land cover map and ecosystem map as well as fragmentation map for assessing ecosystem loss and ecosystem fragmentation?
3 Does relationship exist between forest diversity and rarity value as well as viability value of the forest ecosystem?
4 How can forest diversity assessment help to generate ecosystem loss impact score and ecosystem fragmentation score for identification of the most appropriate dam site?

1.6 Thesis organisation

Chapter 1 sets the basic of the research by introducing the scope and the outline of the study. Chapter 2 deals with the literature review which scans through both the scientific publications and practical application of various studies on the application of ecological evaluation methods in regards to the EIA for the land-use development projects, particularly the dam projects. The chapter also details the limitation and challenges faced by the ecological evaluation. Alternative approaches are considered and elucidated as the way forward to enhance the ecological evaluation framework. Towards this end, an ecological evaluation method for the EIA of dams based on ecosystem rarity is proposed to address research in this field. This method allows the loss and fragmentation of the ecosystem of the alternative dam site to be determined in an objective and replicable way.

Chapter 3 proposes a methodological approach for performing the ecological evaluation of dam developments. In particular, the approach focuses on two types of impact, the ecosystem loss and ecosystem fragmentation. The approach begins with the first step that involves the mapping of the land cover and ecosystem of Bengoh Catchment where the dam projects have been proposed. The second step is to determine the plant species diversity, richness, evenness and dominance and also the important value index of plant species in different forest ecosystem; primary forest, secondary forest and agroforestry of tropical rain forest of Bengoh Catchment. The third step focuses on assessing the rarity and viability values of plants species in the four major forest ecosystems of Bengoh Catchment. The final step focuses on identification of the potential dam site of Bengoh Catchment by assessing ecosystem loss impact score and ecosystem fragmentation impact score using the rarity and viability value.

Chapter 4 deals with the results and discussions of the study based on the proposed methodology. The chapter describes the floristic characteristics of the different forest ecosystem and the different alternatives, as well as the main features of the area to be affected by the dam project. This chapter also deals with the alternative evaluation based on the ecosystem-loss impact score and fragmentation impact score and final recommendations for the most appropriate dam site.

The study concludes with Chapter 5, which summarises the work done and offers some concluding remarks, as well as thoughts for future development of this research. The chapters summarize the approach applied in this study and highlight the significances of this research with regards to the conservation of biodiversity and to ensure sustainable environmental and development. Recommendations on further research and improvement on policies related to biodiversity are also highlighted.

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