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IDENTIFICATION OF THE POTENTIAL DAM SITE OF BUNGOH CATCHMENT BY ACCESSING ECOSYSTEM LOSS IMPACTSCORE AND ECOSYSTEM FRAGMENTATION IMPACTSCORE USING THE RARITY AND VIABILITY VALUE

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ABSTRACT

Bungoh catchment which is a segment of Sarawak Kiri River catchment areas is located in latitude between 1.184° to 1.296° N and in longitude between 110.106° to 110.242° E and 60 km from Kuching, the capital of Sarawak, Malaysia. The catchment covers an area of approximately 127 square kilometres. The altitude ranges from 20m to 1300 m a.s.l. The construction of dams at the catchment area leads to the ecosystem loss and ecosystem fragmentation. In this study, the overall impact caused by ecosystem loss is quantified by estimating the rarity of the ecosystem types based on the species of vegetation and multiplying the value of the of each ecosystem type for each predicted area loss for all the alternatives. The use of rarity criterion for the ecological evaluation resides in the fact that the rarer is a feature, the higher is its probability of disappearance. Three patch indicators encompass the core area; isolation and disturbance reused to measure ecosystem viability which is used to determine the ecosystem fragmentation impact score. 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.

INTRODUCTION

Lately, ample attention has been paid to various environmental degradation in Malaysia, however the ecological studies are still scanty. One of the most significant anthropogenic activities which pose adverse impact on terrestrial habitats is the construction of dam in an ecological rich area (Nauman, 2003). The construction of dams at the catchment area leads to the fragmentation of ecosystem. The dam projects and the local disturbances such as sifting cultivation and selective logging alter the ecological processes operating in the fragments and have additive or interactive effects with fragmentation on forest communities structure and function (Cochrance *et al.*199; Nepstad *et al.*1999; Gascon, Williamson and Fonseca 2000; Laurance and Cochrane 2001; Cayuela *et al*. 2006). The construction of dam projects in Malaysia forces adverse impacts on environment particularly the biodiversity.

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The sites and watersheds are within the core area for strict biodiversity conservation, and the dams and related facilities are close and within eco-regions, key biodiversity areas, and conservation corridors in one of the world's centre of plant diversity. The two significant impacts considered in this article are the habitats loss and habitat fragmentation. The direct loss of habitat caused by the dam projects is relatively straight forward to predict. However the fragmentation of habitat patches into smaller and more isolated units is a more complex issue and its estimation necessarily involves a higher degree of uncertainty (Genelletti, 2006).The direct loss of habitat refers to the land conversion from the original lower to an artificial cover. The total amount of land that is to be occupied by the completed infrastructure scheme is defined as "land-take" (Treweeh, 1993; and Byron, 2000). In the light of the most prominent type of impact caused by the dam projects, the habitat loss is being predicted based on the documentation and guidelines prepared and adopted by various development agencies at the federal and state levels such as the Environmental Impact Assessment Guideline for Dam and/ or Reservoir Guidelines for Dam and/ or Reservoir Projects

(1995). In addition, the international laws or guidelines as well as the scientific literature are being incorporated in the prediction of the impacts. Despite the availability of those documentations and guidelines for the impacts prediction, the computation of the actual amount of land that is to be occupied by the completed dam projects or reservoirs is less simple that it may appear. The size of the dams is normally known after the project blueprints, the total area that is to lose its original vegetation cover is likely to be broader. This is due to the alteration of the surrounding area during the construction and the activities of other related infrastructure. Furthermore, the actual inundated zone and the new lake edge would be known after the impoundment process is completed.

Based on the analysis of EIA of dam projects in Sarawak, the author highlighted that the technical parameters of the dams are normally clearly indicated, but the expected amount of land that is to be occupied by the completed dams project including the inundated zone are not quantified during the impact prediction. As a result, the data of the impact is vague and difficult to be justified. There will always be a flood larger than the designed flood that can occur within the river system, even though statistically the chances are very small. These failures do not pose a threat to life, but can create extensive property and ecological damage (Lemperiene, 1993). Another impact of dam projects which poses the greatest threat to biodiversity is the fragmentation of ecosystem. The fragmentation of ecosystem may have implications for biodiversity conservation and can affect a variety of population and community processes over a range of temporal and spatial scales (Saunders, Hobbs and Margules 1991; Debinski and Holt 2000; Fahrig 2003; Cayuela *et al*. 2006). Habitat fragmentation refers to the break-up of habitat expanses into smaller and more isolated units. The term “fragmentation” is used widely to describe human alterations of natural landscapes (Knight *et al*., in press). Lord and Norton (1990) define this process as the disruption of continuity, especially as it relates to ecosystem processes. Forman (1995) discusses how fragmentation affects the area, size, shape, and configuration of landscape elements, in an overall process of land transformation that has major implications for conservation (Lord and Norton 1990; Wilcove *et al*. 1986).

Fragmentation has been variously defined to describe a reduction of total area, an increase isolation of patches, and a reduced connectedness among patches of natural vegetation (Rolstad 1991). Fragmentation tends to reduce habitat area and to isolate patches of native vegetation (especially in late serial stages) from each other, both of which can lead to local species extirpations (Wilcox 1980; Wilcox and Murphy 1985). Moreover, the loss of some species in this way can lead to multiple extinctions through community-level secondary effects (Wilcox and Murphy 1985). Fragmentation determines a wide range of threats to biodiversity, such as invasion of exotic species, reduction of organism movement, reduction of genetic diversity and population viability, alteration of ecological flow paths (Saunders and Hobbs 1991, Harris 1984, Noss and Cooperider 1994, Soule and Wilcox 1980). There is a vast ecological literature demonstrating the ecological importance of habitat integrity and infrastructures and the impact of fragmentation on biodiversity. In general, the greater the patch size, the higher its functionality (Willies et. al., 2011). In the light of the significant effect of fragmentation towards biodiversity, manuals of good practices and guidelines explicitly encouraged to consider those impact have been established in the Environmental Impact Assessment Guidelines for Dams and/ or Reservoir Guidelines for Dam and/ or Reservoir Project DOE 1995. Unfortunately, operational guidance on how to perform a prediction of the fragmentation impacts caused by the dam project is still lacking. This is because fragmentation itself represents a very complex effect, whose modelling can be still considered in an experimental phase (Bogaert *et al*., 2000). A number of scientific journal and publication have discussed the impact caused by the fragmentation of the natural ecosystem (Gonzales *et al*., 2002; Augett, 2005; Gasto *et al*., 2006; Willis *et al*., 2011). However, those contributions tend to focus on modelling the response to fragmentation of individual species or communities, being mostly oriented to site-related conservation plans (Geneletti, 2006). Citing the study done by Didham and Ewers (2012) on using the Laurance and Yensen’s(1991) core area model to predict its impacts edge effects in fragmented habitats, they highlight the inability of the model to consider the shape variation in large fragmentation with very high shape complexity.

The impact prediction in EISs is still generally prior in particular the measurement of spatial indicators, such as habitat connectivity, size and shape, to quantify the effects of fragmentation is uncommon (Byron, 1999, Byron *et al*., 2000 and Geneletti 2006). The EIA of dam project in Malaysia cited fragmentation but unfortunately, no indicators were used to measure it. A similar conclusion was drawn by Geneletti(2002),and Melloni 2004 which stated that in the Italian EISs review, indicators for fragmentation were computed only in one case and about 75% of the EISs of infrastructure development did not even mention fragmentation as a possible effect where else the remaining 25% did mention fragmentation but no measurement were done to justify its impact. Gelenetti (2000a) states that the most common method for mapping ecosystems consists of mapping the vegetation types due to the fact that vegetation communities are considered as representative for delimiting the boundaries of ecosystem units. Moreover, the vegetation communities typically show a strong relationship with both their physical environment such as soil and rock type, climate and topography, and the organisms they host.

Furthermore, vegetation mapping represents a feasible alternative to carrying out a truly complete biological survey. Due to these reasons, it is widely held that vegetation-cover types can be used as surrogates for the ecosystems in which they participate (Custri and Kiester 1996, Noss and Cooperrider 1994, Spellemberg 1994, Austin and Margules 1986). As a result, vegetation cover or in general the land cover represents the typical starting point of ecological evaluations. In this study, the overall impact caused by ecosystem loss is quantified by multiplying the value of each ecosystem type for its predicted area loss and by summing-up the result whereasthree patch indicators have been selected to predict the effects of fragmentation. The indicators are the core area, isolation and disturbance. Those indicators are used to measure ecosystem viability. Treweek and Veitch(1996) indicate that fragmentation reduces ecosystem viability.

MATERIALS AND METHODS

Study area

The study was carried out at the Bungoh catchment which is a segment of Sarawak Kiri River catchment areas and upstream of Bungoh Dam. It is located in latitude between 1.184° to 1.296° N and in longitude between 110.106° to 110.242° E and 60 km from Kuching, the capital of Sarawak. The catchment covers an area of approximately 127 square kilometres. The altitude ranges from 20m to 1300 m a.s.l. The forest ecosystem constitutes of primary forest, secondary forest and agro-forest. The climate is equatorial type with warm and humid weather throughout the year; and annual rainforest of the area is approximately 3.990 mm/year with a high proportion falling during the North West monsoon season from November to February. The driest period occurs from June to August. The mean temperature is approximately 26.6°C and means relative humidity is around 85.3%. The wind pattern in this area generally shows relatively calm condition with 33.9% of the time with wind blowing and light breezes recorded for 42% of the time. The catchment is an area of complex geology involving a whole range of sedimentary rocks, igneous intrusive and extrusive rocks with associated metamorphism.

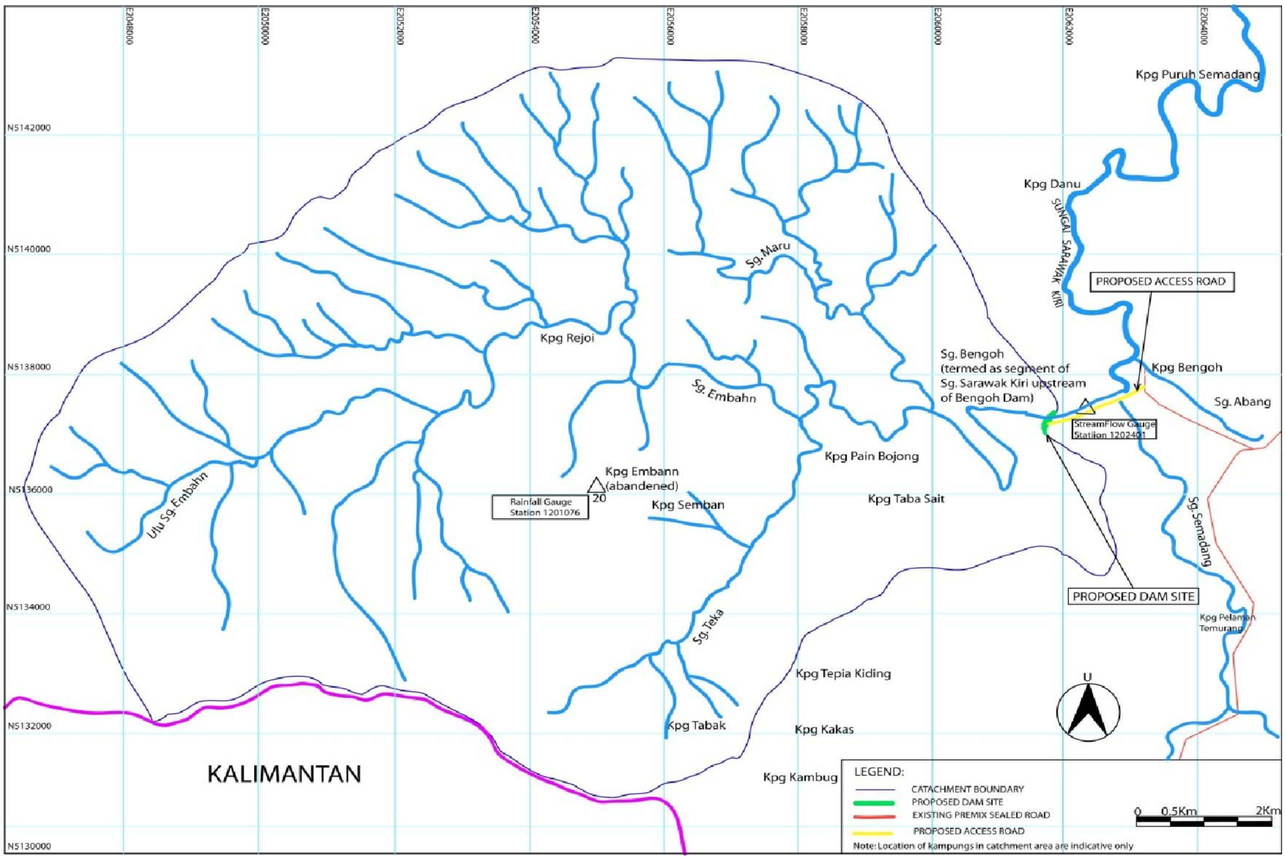


Figure 1. Locality of Bungoh Catchment area

Since this study focuses on the ecosystem level of biodiversity, the first step is to generate the ecosystem map which has a suitable spatial resolution. The primary objective is to establish a method like BIA so as to provide a sound justification on the ecological aspects for the decision makers, with regard to the site of the dam projects. Considering the ecosystem as the best level to state the condition of biodiversity, therefore the most common method to mapping ecosystem consists of mapping the vegetation types (Monavari and MomenBellah Fard,2010; Geneletti,2003). The data required for this study lays on the map of the five ecosystem types namely the primary forest, old secondary forest, young secondary forest and agroforestry along with a map of the proposed alternative dam site.

Assessing ecosystem loss impact score

The selected criteria (rarity) can be measured for an ecosystem type in an objective and replicable way (Geneletti 2006). Furthermore, the use of rarity criterion for the ecological evaluation resides in the fact that the rarer is a feature, the higher is its probability of disappearance. Smith and Theberge (1986), Margules and Usher (1981), and Geneletti(2006) have pointed out that rarity is the most commonly used criteria when assessing the relevance of an ecosystem for biodiversity conservation.First, the rarity of the ecosystem types based on the species of vegetation is estimated. Later, an ecosystem loss impact score can be quantified by multiplying the value of the of each ecosystem type for each predicted area loss for all the alternatives. Therefore, the ecosystem loss impact score would be calculated as follows:

$$ELi = \sum_{j=1}^{n}(Aj * Rj)$$

where:

Eli = ecosystem-loss impact score of alternative i;
Aj = predicted area loss for ecosystem or species type j;

Rj = assessed rarity value of ecosystem or species type j;
N = number of ecosystem or species types.

Assessing ecosystem fragmentation

The extent of habitat fragmentation is an important indicator of habitat quality due to the fact that the dam development projects may result in the reduction of habitat into smaller and more scattered patches.Three patch indicators have been selected to predict the effects of fragmentation. The indicators are the core area, isolation and disturbance. Those indicators are used to measure ecosystem viability. Treweek and Veitch(1996) have indicated that fragmentation reduces ecosystem viability.

(a) Core Area

This indicator can be calculated as follows:

$$Core\ Area\ \ = Actual\ area - fragment\ area$$
$$Core\ value = \frac{core\ are}{The\ heighest\ value\ core\ area}(0 \leq \text{core value} \leq 1)$$

(b) Isolation

This indicator can be generated based on edge-to-edge distance between a patch and its surrounding patches and calculated as follows:

$$Isolation = \frac{Fragment\ area)}{Total\ area\ remaining} x\ Total\ isolation$$
$$\text{Isolation value} = -(\frac{isolation}{The\ heighest\ isolation\ value}) + 1(0 \leq \text{isolation value} \leq 1\ )$$

(c) Disturbance

This indicator can be generated by measuring the average distance between the edges of an ecosystem patch and the surrounding sources of disturbance, i.e., anthropogenic activities such as shifting cultivation and resettlement (villages).

$$\text{Disturbance} = \frac{fragment\ perimeter)}{Perimeter\ remaining}\ x\ Total\ disturbance$$
$$disturbance\ value = \frac{Disturbance}{The\ heighest\ disturbance\ value}$$

(d) Viability

Ecosystem viability can be calculated using the following expression:

$$\text{Viability} = (0.42 * Cove\ value + 0.36 * isolation\ value + 0.22 * diturbance\ value)$$

(e) Ecosystem fragmentation impact score

Ecosystem fragmentation impact score can be generated by multiplying the losses in viability by the value of the affected ecosystem and then by their remaining area, based on the following expression:

$$EFi = \sum_{j=1}^{n}(VLj * Sj * Rj)$$

Where:

EFi = ecosystem fragmentation impact score of alternative i;
VLj = assessed loss in viability of ecosystem patch j;
Sj = area of ecosystem patch j;
Rj = rarity value of ecosystem patch j;
n = number of ecosystem patches affected by the project.

RESULTS AND DISCUSSION

Many planning decision carried out in infrastructure and other development issues cause the fragmentation of natural habitats which result in both habitat loss and isolation, as well as habitat degradation (Opdam and Wein, 2002; Gontier *et al*., 2006; Monavari *et al*., 2010). The report of the World Commission on Dams (2000) have stated that to date, over 400,000 km^2 of the earth have been flooded due to damming and the direct impacts include habitat loss, elimination of flora and fauna and, in many cases land degradation. It also states that an estimated 60% of the world's large river basins are highly or moderately fragmented by dams. In this study, the impact of the dam projects toward the natural ecosystem was first analysed by generating the ecosystem maps at baseline stage as shown in Figure 2.

A comprehensive spatial impacts assessment on biodiversity can be achieved by taking into consideration the whole landscapes that cover the entire catchment where a dam project is located. Different types of forest ecosystems of the study area is illustrated in Figure 2. The comparison between the baseline ecosystem map and the other alternatives allow the computation of the expected loss for each ecosystem type.The rarity is selected as a criterion to assess the relevance of the ecosystem with respect to the conservation of biodiversity. This is due to the fact that the rarer the species and ecosystems, the more they are prone to extinction and therefore their conservation become a priority. The computation of rarity value of an ecosystem is based on the expression given in 3.4(e). Table 1 illustrates the rarity value of different ecosystem types which are computed in different phasesthat include the baseline and the alternatives. The ecosystem loss impact score is calculated and illustrated in Table 2which defines as "weighted kilometres" due to the fact that they represent the losses in kilometres weighted by the assessed rarity of each ecosystem type. Figure3 shows the comparison between the five alternatives of the proposed dam site.

The fragmentation impact caused by the five alternatives dam project is determined based on the reduction of viability of the ecosystem that remains after the commissioning of the project. The ecosystem viability is used to generate the ecosystem fragmentation caused by the dam project. As a result, it is necessary to quantify viability values as shown in Table 3 and it can be computed by using the expression given in 3.6(d). The value for all the indicators involved (core, isolation and disturbance) are calculated based on the expression given in 3.6(a),(b),and (c). The weights assigned to each indicator is based on the relative importance of one indicator with respect to another in determining ecosystem viability as stated by Geneletti (2000). The fragmentation impact maps are shown in Figure 4. The maps highlight the spatial spread of the fragmentation impact of each project alternative. To allow a numerical comparison of the alternatives, each fragmentation-

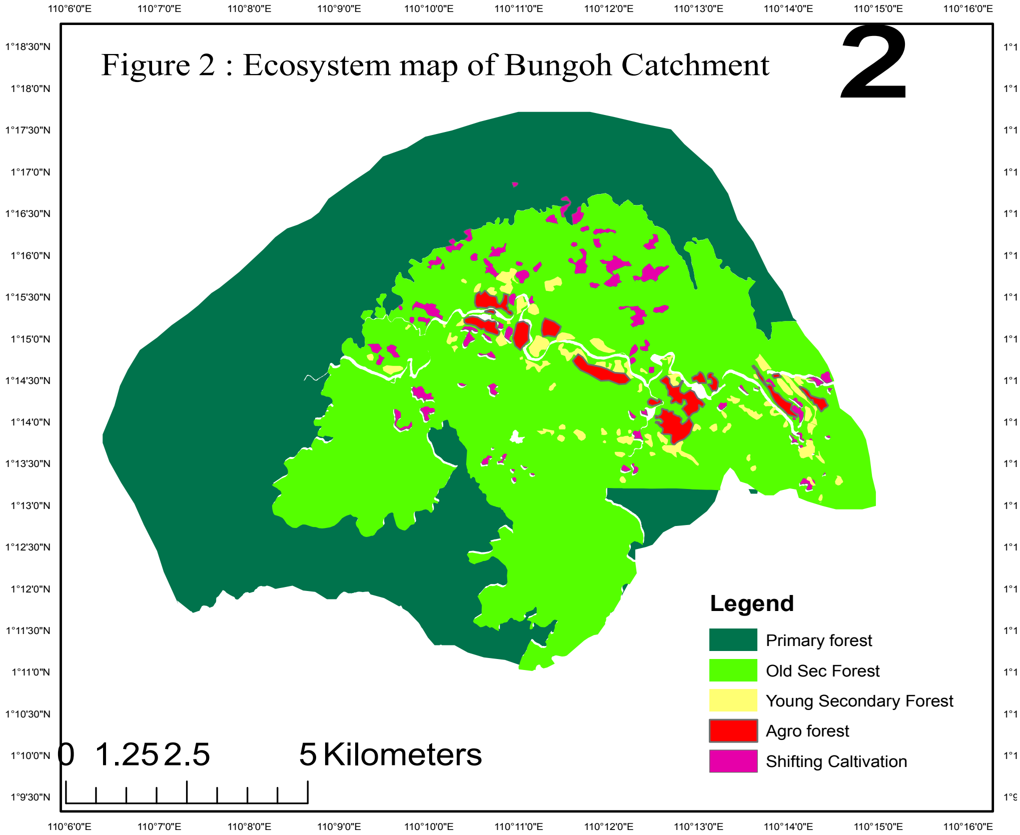


Table 1. Rarity Values of Ecosystem types of Bungoh Catchment

Alt.	Rarity Values			
	Young Secondary Forest	Old Secondary forest	Agro forestry	Primary Forest
Alt.1	0.992	0.986	0.941	0.955
Alt.2	0.993	0.997	0.941	0.955
Alt.3	0.993	0.986	0.941	0.955
Alt.4	0.973	0.999	0.996	1.000
Alt.5	0.994	0.999	0.996	1.000

Table 2. Ecosystem loss impact score (Eli) of vegetation type

Alt.	Young Secondary forest (weighted km^2)	Old Secondary forest (weighted km^2)	Agroforestry (weighted km^2)	Primary forest (weighted km^2)	Total Ecosystem loss score (weighted km^2)
Alt.1	0.5310	8.9640	0.3560	0.0000	9.8510
Alt.2	0.5130	8.7600	0.3560	0.0000	9.6290
Alt.3	0.4750	4.5230	0.1496	0.0000	5.1476
Alt.4	0.4150	2.7850	0.1080	0.0000	3.3080
Alt.5	0.4120	3.6710	0.1080	0.0000	4.1910

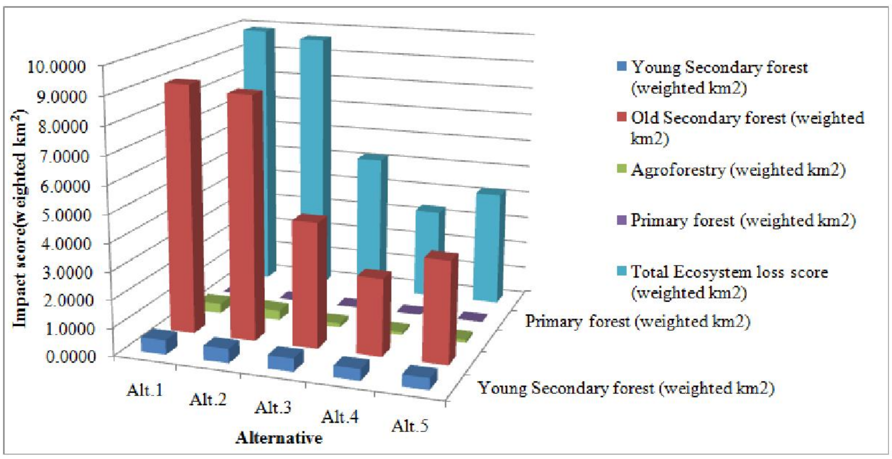
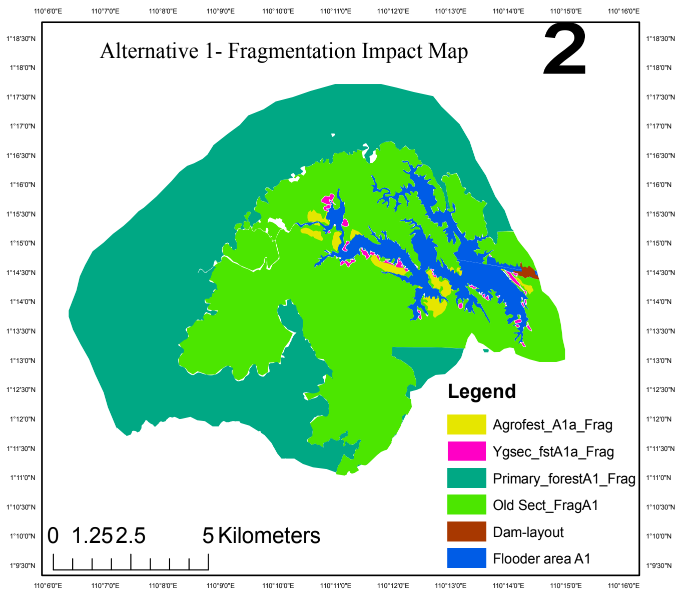
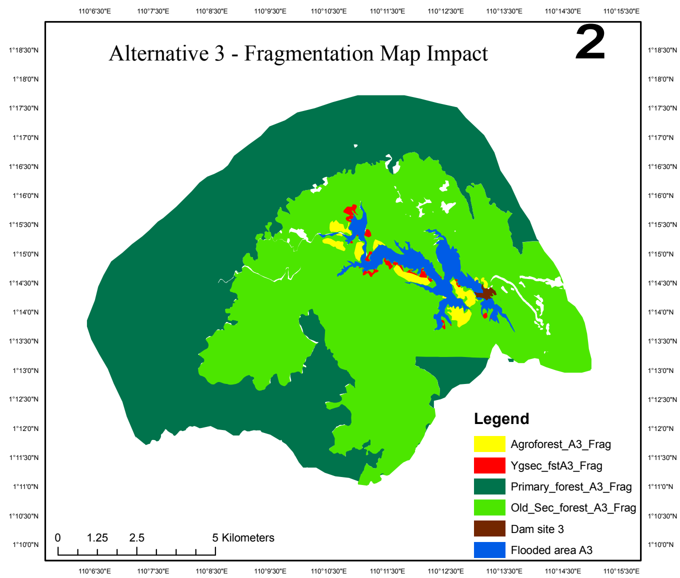
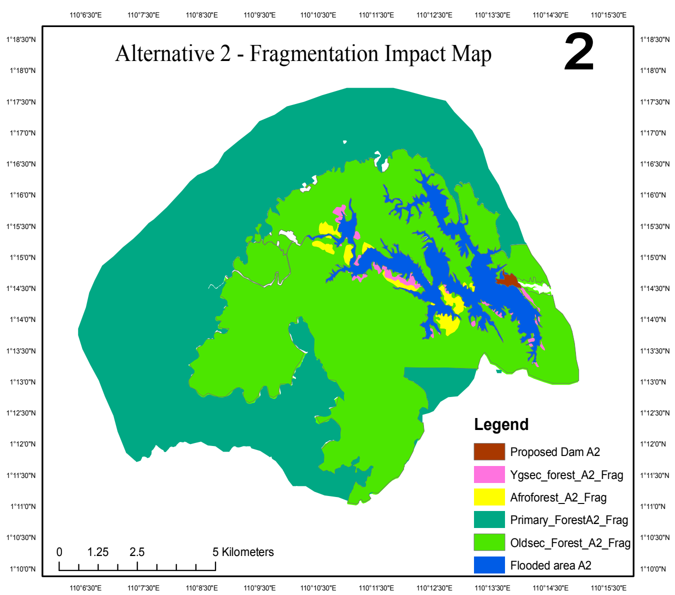
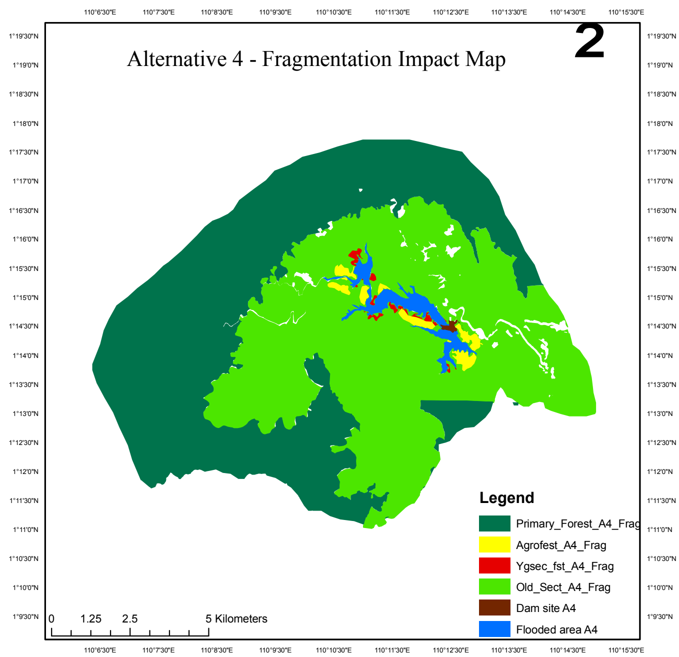


Figure 3. Comparison of ecosystem loss impact score of vegetation type between the five alternative of the proposed dam site









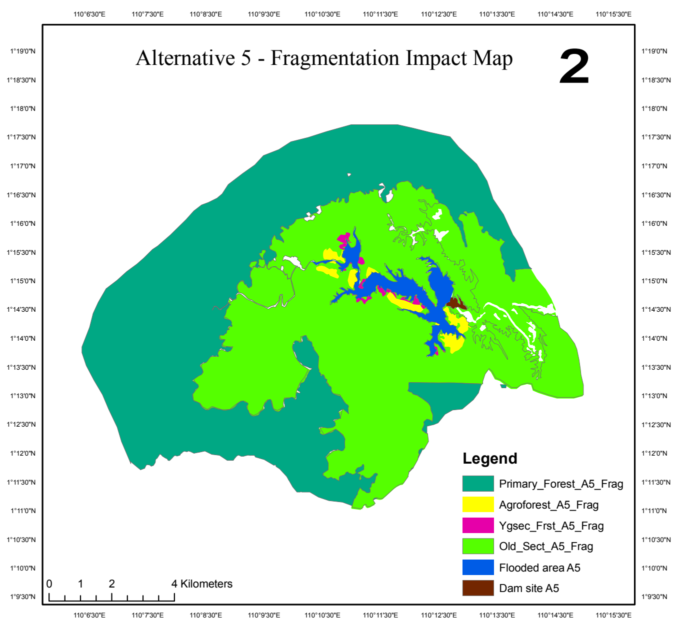


Figure 4. Fragmentation Impact map of five alternatives of the proposed dam site

Table 3. Viability Value of Ecosystem types of Bungoh Catchment

Alt.	Viability Values			
	Young Secondary Forest	Old Secondary forest	Agro forestry	Primary Forest
Alt.1	0.411	0.374	0.413	0.099
Alt.2	0.452	0.388	0.413	0.099
Alt.3	0.411	0.388	0.413	0.099
Alt.4	0.411	0.388	0.413	0.188
Alt.5	0.411	0.387	0.413	0.188

impact map was aggregated into a synthetic impact score. The fragmentation impact scores as shown in Table 3 is quantified by multiplying the loss in viability of each ecosystem by its area and by its rarity value as shown by the expression given in 3.6(e). The viability value range between zero (unviable ecosystem) and one (best possible conditions for an ecosystem

Table 4. Ecosystem fragmentation impact score of vegetation type

Alt.	Young Secondary forest (weighted km^2)	Old Secondary forest (weighted km^2)	Agroforestry (weighted km^2)	Primary forest (weighted km^2)	Total Ecosystem fragmentation score(weighted km^2)
Alt.1	0.2570	3.9200	0.1760	0.0000	4.3530
Alt.2	0.2890	3.8310	0.1760	0.0000	4.2960
Alt.3	0.2300	1.9800	0.0760	0.0000	2.2860
Alt.4	0.2010	1.2200	0.0550	0.0000	1.4760
Alt.5	0.8840	1.6000	0.0550	0.0000	2.5390

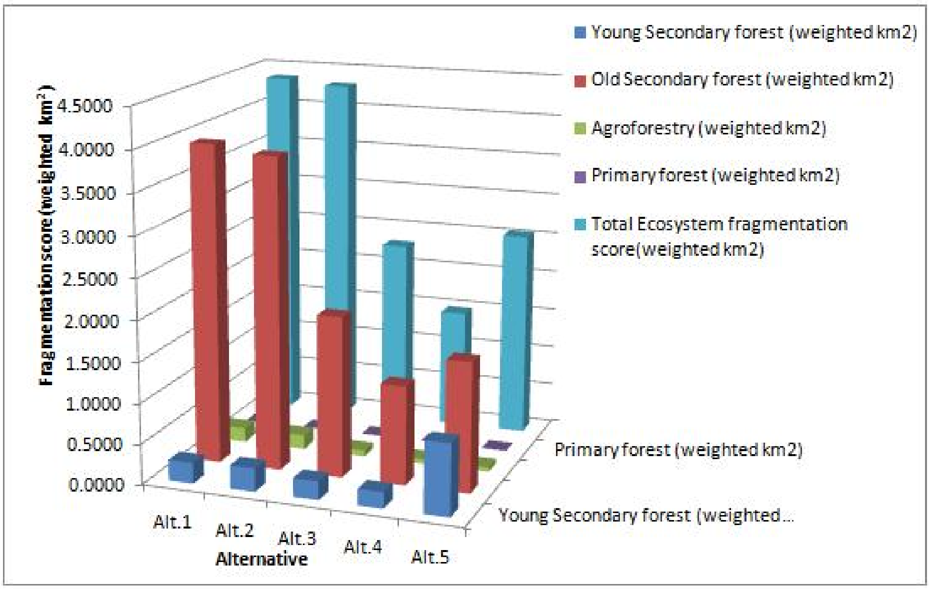


Figure 5. Comparison of ecosystem fragmentation impact score of vegetation type between the five alternatives of the proposed dam site

to preserve its functions and biodiversity), and are obtained by weighted summation of the indicator scores. Figure 5 shows the comparison of ecosystem fragmentation impact score of vegetation type between the five alternatives of the proposed dam site. The impact analysis has generated the ecosystem-loss impact scores (Figure 2) and ecosystem-fragmentation impact scores (Figure 4) for each of the five alternatives of dam project. The result shows there is no correlation between the two types of impacts caused by the alternatives dam project. For instance, Alternative 5 has rather low impact based on ecosystem loss (4.191) compared to that of Alternative 3(5.1476), but shows higher impact of ecosystem fragmentation (2.539) to that of Alternative 3 (2.286). Alternative 1 shows the worst-performing which rank 5th in both ecosystem loss and ecosystem fragmentation (Table 5). The results are as expected as the flooded area cover majority of the highly valuable vegetation that cover the area where the elevation is less than 80 meters above sea level.

Table 5. Performance of Alternative 1

	Ecosystem loss	Ecosystem Fragmentation
Impact Score	9.851	4.353
Position	5th	5th

Alternative 2 represents the second-to-worst performing with respect to both impacts. Both rank 4th in term of ecosystem loss and ecosystem fragmentation (Table 6). This is due to the fact that alternative 2 is only 2 km up-stream from the 1st Alternative. Thus, most of the highly valuable vegetation that constitutes the young secondary forest, old secondary forest and agro forestry are being affected by the dam project.

Table 6. Performance of Alternative 2

	Ecosystem loss	Ecosystem Fragmentation
Impact Score	9.629	4.296
Position	4th	4th

Alternative 3 ranks 3rd in term of ecosystem-loss impact and rank in a rather high position (2nd) in term of ecosystem-fragmentation impact (Table 7). The effect of the project on the highly valuable vegetation particularly along the North West of Bungoh River is rather limited.

Table 7. Performance of Alternative 3

	Ecosystem loss	Ecosystem Fragmentation
Impact Score	5.1476	2.286
Position	3rd	2nd

Alternative 4 shows the best-performing based on both types of impact (Table 8). The flooded areas which cover the upper part of the Bungoh River inclusive young secondary forest, old secondary forest and agro forestry is rather limited compared to that of other alternatives.

Table 8. Performance of Alternative 4

	Ecosystem loss	Ecosystem Fragmentation
Impact Score	3.308	1.476
Position	1st	1st

Alternative 5 rank 2nd in term of ecosystem loss and rank 3rd in term of ecosystem-fragmentation (Table 9). The higher position of Alternative 5 in term of ecosystem-loss lays in the fact that, most of the highly valuable vegetation that constitute the young secondary forest, old secondary forest and agro forestry along the eastern part of Bungoh River was not affected by the projects.

Table 9. Performance of Alternative 5

	Ecosystem loss	Ecosystem Fragmentation
Impact Score	4.191	2.539
Position	2nd	3rd

Based on the analysis of the impact score of the five alternatives, alternative 4 is the best-performing in term of both the ecosystem-loss and the ecosystem-fragmentation impact. It can be concluded that the alternative 4 appears to be the most appropriate site for the dam project. However the analysis carried out in this study only represents potion of the disciplinary study that constitute the overall Environmental Impact Statement.

Conclusion

This study focuses on the assessment process which explores the interaction between the dam development and biodiversity. Thus, the Biodiversity Impact Assessment has been considered to estimate the loss and fragmentation ecosystem posed by Bungoh Dam project. The impact analysis carried out in this study which generate 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. For instance, in term of ecosystem preservation, the quantified data shows that alternative 4 is preferable to be the most appropriate site for the dam project. The result 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 form the Environmental Impact Assessment. Other factors such as economic, social and political scenario may be at odd with the results of the environmental assessment.

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