Rarity and viability value of different type of ecosystem and plants species in tropical forest ecosystem of Bungoh Catchment, Sarawak, Malaysia

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Abstract: Bungoh catchment is located in the southern part of Sarawak, Malaysia and south east of Kuching town and densely covered by tropical forests. A study was conducted to determine the rarity and viability values of plant species and also the rarity and viability values of the four different types of forest ecosystem of Bungoh Catchment. The four major forest ecosystems include the primary forest, old secondary forest, young secondary forest and agroforestry. The numbers of trees were recorded from the entire three different forest ecosystem using single plant method of size 400 square meters (20m X 20m). A total of 373 individual trees representing 148 species were recorded from the four different types of forest ecosystem. Out of 148 species, 22 species were recorded from the primary forest, 72 species were recorded from old secondary forest whereas 37 species were recorded from young secondary and the remaining 17 species were recorded from agroforestry. The rarity and viability value of plants species or ecosystem types is of immediate importance for the biodiversity conservation. The approach is designed for assessment of the rarity and viability values of plants species in the four major forest ecosystems in Bungoh Catchment. The rarity values are measured based on the frequency of certain plants species or ecosystems types are encountered whereas the viability value is assessed by considering three indicators which includes the core area, isolation and disturbances. The results indicate that the rarity value of all the four types of ecosystem namely the primary forest, old secondary forest, young secondary forest and agroforestry were relatively high indicating that the species in the ecosystem are distributed equitably and reflect the commonness of the species. Conversely, the viability value of the entire four ecosystems relatively low indicating that the species are prone to extinction.

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1. Introduction

In its broadest definition ecosystem rarity refers to how frequently an ecosystem type is found within a given area which includes limited geographic distribution and limited population size (Wood, 2002; Geneletti, 2003; and Nageswara Roa, 2012). The phenomenon of rarity in tropical tree communities has been known qualitatively in Western scientific circles at least since the writings of Alfred Russel Wallace (1878). However, not until recently have bio geographers and ecologists systematically quantified diversity, rarity and viability in tropical tree communities (Hubbell, 2013). According to Fiedler (2001) and Nageswara Roa (2012) there are two distinct types of rarity namely natural rarity and anthropogenic rarity. The natural rarity occurs because the species lives in a very limited habitat and those species have always been rare during their evolutionary history whereas the anthropogenic rarity occurs because its habitat has been converted by humans to other uses agriculture, dams and other form of land development. The conservation of biodiversity focus on the rare species has been further justified by the potential role that rare species may play in maintaining overall ecosystem functionality (Curtis et al. 2007). Being the basic goal of biodiversity conservation to maintain the full richness of life on earth, it appears logical that the actual cover and distribution of an ecosystem type influence its relevance and protection worthiness. As a result, the use of rarity as criteria in biodiversity conservation is due to the fact that the rarer is the feature the higher is its probability of disappearance (Geneletti, 2003 and Flather et al. 2007).

The viability value of the species is affected by the relative increase of the edge length of the habitat fragment (Ryszkowski, 1992; Restrepo et al. 1999; Honnay et. al, 2005). Viability assessment is viewed as an integral part of the on-going forest service and land management as well as decision process, and, in turn, monitoring is an integral component of the overall process used by the forest service to manage species viability, including selected species whose likelihood of extinction is minimal, to ensure they remain so (Sandy et. al, 2001). Thus, the population viability is of immediate importance for plant conservation. Nevertheless, the current documentation of viability assessments of plants species particularly in the tropical forest ecosystem is inadequate (Sandy et. al, 2001).

In this study, rarity value is a measure based on how frequently certain species or ecosystem types are encountered (Edwards-Jones et al.2000, Geneletti 2003; Flather et al. 2007; Thonoir 2010). The rarity value is in the form of numerical and the value ranging between zero and one. One corresponds to the highest relevance, i.e., to ecosystems whose remnant cover has dramatically decreased, posing a serious threat to their chances of conservation within the Bungoh Catchment whereas zero corresponds to the lowest relevance, i.e., to ecosystems whose original cover is virtually entirely preserved with the area. The ecosystem viability is to be assessed by considering three indicators which include the core area, isolation and disturbance (Geneletti 2003; Monavari 2010). The value function of the three indicators are first generated, and then summed up. Weights can be used to express the relative relevance of each indicator. The function assigns a dimensionless score between zero and one. Such a score is a numerical representation of the degree to which the indicator value contributes to the ecosystem viability. A score of zero indicates the worst possible condition, whereas a score of one indicates the ideal ones.

2. Material and Methods

2.1 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 (Figure 1).

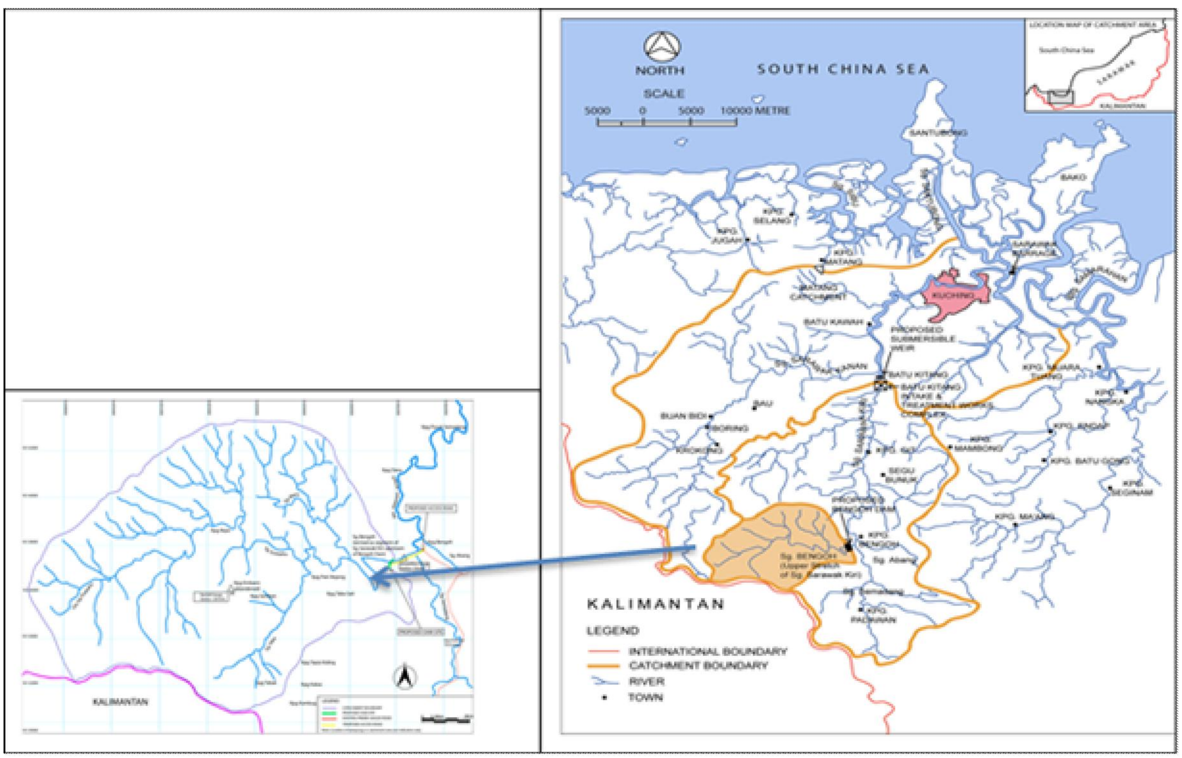

Figure 1 : Locality of Bungoh Catchment area.

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 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 the mean 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 were 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.

2.2 Field Sampling

A survey was carried out by the single plot method based on 29 random sampling plots. Each plot (20 m x 20 m) was divided into four subplots (10 m x 10 m). In each quadrate, the parameters recorded during the vegetation survey include circumference (diameter at breast height, dhb ≥5 cm), trees height, type of forests ecosystem and plant species. All terrestrial plant species encountered during field survey were identified and when it was impossible to do so, the voucher specimens were collected and identified in the herbarium and a list of plant species that occurred within the study boundary were compiled.

2.3 Rarity Value

Rarity value is a measure of how frequently certain species or ecosystem types are encountered (Tallis et al. 2011) and can be calculated as:

$$RE_i = 1 - \left(\frac{\sum_{j=1}^{n} Rj}{\sum_{j=1}^{n} Nj}\right)$$

REi = Rarity value of species *i*

$\sum Rj$ = Total value of species in ecosystem *j*

$\sum Nj$ = Total number of species in ecosystem *j*

2.4 Viability values

Three patch indicators have been selected to measure ecosystem viability. The indicators are the core area, isolation and disturbance.

(a) Core

This indicator can be calculated as follows:

$$Sc_i = Sj - Fj$$

Sci = Core area of species *i*

Sj = Actual area of species *j*

Fj = Fragment area of species *j*

$$Vc_i = \frac{SCj}{HVj} \quad (0 \leq Vci \leq 1)$$

Vci = Core value of species *i*

Scj = Core area of species *j*

Hvj = The highest value core area of ecosystem *j*

(b) Isolation

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

$$I_i = \frac{Fj}{\sum_{j=1}^{n} Aj} \, x \sum_{j=1}^{n} Ij$$

Ii = Isolation of species *i*

Fj = Fragment area of species *j*

$\sum Aj$ = Total area remaining of species *j*

$\sum Ij$ = Total isolation of species in ecosystem *j*

$$Iv_i = -\left(\frac{I_j}{HIV_j}\right) + 1 \quad (0 \leq Iv_j \leq 1)$$

Iv_i = Isolation value of species *i*

Ij = Isolation of species *j*

HIVj = highest isolation value of species in ecosystem *j*

(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).

$$D_i = \frac{F_j}{P_j} \, x \sum_{j=1}^{n} D_j$$

Di = Disturbance of species *i*

Fj = Fragment area of species *j*

P_j = Remaining perimeter of species *j*

$\sum D_j$ = Total disturbance of species in ecosystem *j*

$$DV_i = \frac{D_j}{HD_j}$$

DVi = Disturbance value of species *i*

Dj = Disturbance of species *j*

HD_j = Highest disturbance value of species in ecosystem *j*

(d) Viability value

Ecosystem viability can be calculated using the following expression (Geneletti 2003):

$$VL_i = \sum_{j=1}^{n}(0.42 * VC_j + 0.36 * IV_j + 0.22 * DV_j)$$

3. Results and Discussion

A total of 373 individual trees representing 148 species were recorded from the four different types of forest ecosystem namely the primary forest, the old secondary forest, the young secondary forest and agroforestry of Bungoh catchment. Out of 148 species, 22 species were recorded from the primary forest (Table 1), 72 species were recorded from old secondary forest (Table 2) whereas 37 species were recorded from young secondary (Table 3) and the remaining 17 species were recorded from agroforestry (Table4).

Table 1. Rarity and viability values of Primary forest

Species	Rarity Value	Viability value
Koompassia excelsa	0.939	0.451
Tristaniopsis whiteana	0.939	0.481
Shorea scabrida	0.954	0.451
Shorea macrobalanos	0.957	0.601
Syzygium sp.	0.962	0.475
Artocarpus kemando	0.964	0.486
Ilex cissoidea	0.965	0.576
Dryobalanops beccarii	0.969	0.653
Alphitonia excelsa	0.970	0.677
Ficus sp.	0.972	0.777
Sterculia sp.	0.979	0.454
Mangifera foetida	0.982	0.475
Shorea angustifolia	0.982	0.608
Cratoxylum glaucum	0.983	0.464
Litsea sp.	0.983	0.549
Knema sp.	0.984	0.466
Artocarpus sarawakensis	0.985	0.469
Myristica lowiana	0.985	0.625
Pometia pinnata	0.985	0.780
Ixonanthes reticulata	0.986	0.569
Alangium kurzii	0.987	0.462
Xylopia ferruginea	0.987	0.505

Table 2 : Rarity and viability values of old secondary forest

Species	Rarity Value	Viability Value
Alstonia angustifolia	0.936	0.612
Artocarpus kemando	0.972	0.469
Artocarpus elasticus	0.976	0.456
Litsea sp.	0.980	0.440
Nephelium maingayi	0.985	0.380
Campnosperma auriculatum	0.986	0.414
Garcinia nitida	0.986	0.416
Aporosa sp.	0.988	0.409
Adinandra dumosa	0.988	0.369
Castanopsis pedunculata	0.989	0.403
Artocarpus integer	0.990	0.399
Syzygium sp.	0.990	0.391
Sterculia rubignosa	0.990	0.368
Pternandra cognianxii	0.991	0.396
Xylopia sp.	0.992	0.392
Ochanostachys amentacea	0.992	0.383
Pellacalyx lobbii	0.992	0.374
Canarium sp.	0.994	0.383
Cratoxylum arborescens	0.994	0.385
Cratoxylum cochinchinense	0.994	0.384
Albizia dolichadena	0.994	0.385
Koompassia malaccensis	0.994	0.384
Norrisia malaccensis	0.994	0.382
Carallia coriifolia	0.994	0.393
Sarcotheca glauca	0.994	0.369
Baccaurea maingayi	0.995	0.380
Parkia speciosa	0.995	0.378
Castanopsis hypophoenicea	0.995	0.381
Ardisia sp.	0.995	0.381
Nephelium subfalcatum	0.995	0.399
Elaeocarpus sp.	0.996	0.375
Dialium indum var. indum	0.996	0.375
Cantleya corniculata	0.996	0.375
Lasianthus sp.	0.996	0.368
Saurauia acuminata	0.997	0.371
Melanochyla speciosa	0.997	0.370
Cratoxylum formosum	0.997	0.370
Cratoxylum glaucum	0.997	0.372
Dillenia sp.	0.997	0.371
Archidendron jiringa	0.997	0.370
Gnetum gnemon	0.997	0.372
Ixonanthes petilolaris	0.997	0.373
Fagraea borneensis	0.997	0.370
Prainea frutescens	0.997	0.371
Knema galeata	0.997	0.371
Knema latifolia	0.997	0.372
Morinda elliptica	0.997	0.368
Eugenia elliptilimba	0.997	0.385
Saurauia myrmecoidea	0.998	0.368
Alangium javanicum	0.998	0.369
Vernonia arborea	0.998	0.370
Garcinia bancana	0.998	0.369
Ardisia sp.	0.998	0.368
Archidendron borneense	0.998	0.368
Xanthophyllum griffithii	0.998	0.368
Lithocarpus havilandii	0.998	0.370
Ficus grossularioides	0.998	0.368
Artocarpus odoratissimus	0.998	0.369
Horsfieldia crassifolia	0.998	0.368
Ardisia macrophylla	0.998	0.368
Syzygium bankense	0.998	0.398
Porterandia sessiliflora	0.998	0.375
Porterandia sp.	0.998	0.369
Tarenna winkleri	0.998	0.368
Canthium glabrum	0.998	0.368
Meliosma rufo- pilosa	0.998	0.420
Eurya nitida	0.998	0.406
Gironniera parvifolia	0.998	0.368
Vitex pubescens	0.998	0.369
Vitex vestita	0.998	0.369
Timonius flavescens	0.998	0.382
Pithecellobium jiringa	0.998	0.373

Table 3: Rarity and viability values of young secondary forest

Species	Rarity Value	Viability value
Endospermum diadenum	0.940	0.640
Gaetnera vaginans	0.952	0.625
Alstonia spatulata	0.958	0.590
Macaranga becceriana	0.971	0.521
Macaranga hosei	0.977	0.487
Helicia attenuate	0.979	0.477
Adinandra dumosa	0.981	0.462
Litsea varians	0.987	0.430
Cratoxylum arborescens	0.988	0.428
Glochidion borneense	0.989	0.420
Fagraea fagrans	0.990	0.413
Horsfieldia grandis	0.990	0.416
Sarcotheca glauca	0.992	0.402
Macaranga gigantean	0.992	0.405
Helicia petiolaris	0.992	0.406
Vernonia arborea	0.993	0.398
Xylopia furruginea	0.993	0.400
Kostermanthus heteropetala	0.994	0.393
Cratoxylum formosum	0.994	0.395
Pithecellobium jiringa	0.995	0.385
Ploiarium alternifolium	0.995	0.388
Elaeocarpus nitidus	0.995	0.388
Timonius borneensis	0.995	0.389
Euodia latifolia	0.995	0.389
Anthocephalus cadamba	0.996	0.382
Hevea brasiliensis	0.997	0.375
Artocarpus elasticus	0.997	0.376
Barringtonia sarcostachys	0.997	0.377
Macaranga pruinosa	0.997	0.378
Millettia chaperii	0.997	0.379
Dillenia suffroticosa	0.998	0.372
Anisophyllus disticha	0.998	0.372
Garcinia havilandii	0.998	0.372
Lepisanthes alata	0.998	0.372
Vitex pubescens	0.998	0.373
Adinandra acuminate	0.998	0.373
Parkia javanica	0.998	0.373

Table 4 : Rarity and viability values of agroforestry

Spcies	Rarity Value	Viability Value
Hevea brasiliensis	0.806	0.640
Durio zibethinus	0.883	0.529
Nephelium lappaceum	0.920	0.476
Elateriospermum tapos	0.936	0.453
Shhorea macrophylla	0.975	0.396
Artocarpus integer	0.979	0.390
Garcinia mangostana	0.981	0.387
Shorea palembanica	0.983	0.385
Mangifera foetida	0.987	0.379
Baccaurea angulata	0.987	0.379
Artocarpus heterophyllus	0.987	0.379
Shorea splendida	0.989	0.376
Parkia speciosa	0.991	0.373
Theobroma cacao	0.991	0.373
Nephelium maingayi	0.993	0.369
Annona foetida	0.994	0.369
Artocarpus elasticus	0.994	0.369

3.1 Rarity value

In the primary forest ecosystem, the lowest value of rarity is shown by Tristaniopsis whiteana and Kompossia excelza with the rarity value of 0.939 and the highest rarity value is shown by Alangium kurzii and Xylopia ferruginea with the value of 0.987 (Table 1). In the old secondary forest, Alstonia angustifolia gives the lowest rarity value (0.936) followed by Artocarpus kemando (0.972) and Artocarpus elasticus (0.976) and 20 species exhibit the highest rarity value which is 0.998 (Table 2), whereas in young secondary forest, Endospermum diadenum gives the lowest rarity value(0.940) followed by Gaetnera vaginans (0.952) and the third lowest is shown by Alstonia spatulata with the rarity value 0.958 and seven species exhibit the highest rarity value which is 0.998 (Table 3). In the Agroforestry ecosystem, the lowest rarity value is shown by Hevea brasilienis which is 0.806 followed by Durio zibethinus with the rarity value 0.883 and Nephelium lappaceum with the rarity value of 0.920 whereas the highest rarity value is given by Annona foetid and Artocarpus elasticus which is 0.94 (Figure 4). Among the four types of forest ecosystem, secondary forest shows the highest (Table 5) rarity value (0.994) followed by the young secondary forest (0.989). Agroforestry gives the lowest rarity value which is 0.963 whereas primary forest exhibits the second lowest with the rarity value of 0.973. Hubbell(2013) state that species in tropical forests demonstrate high value of rarity particularly in the lowland tropical forest. A similar result shows in this study where the old secondary forest and young secondary forest which dominate the entirely lowland area of the Bungoh Catchment exhibit the highest rarity value which is 0.994 and 0.989 respectively. This provides a significant challenge for conservation of tropical forest tree diversity.

Generally, all the four forest ecosystem exhibit high rarity values. This corresponds to the highest relevance, i.e. to ecosystem where remnant cover has dramatically decreased posing a serious threat to their chances of conservation within the area. The driving force behind plant rarity in Bungoh Catchment is the destruction, degradation, and fragmentation of habitat by anthropogenic activities which include a huge dam projects. Similar to our results, Noss and Peters(1995) and Nageswara Roa (2012) found out that the common cause of rarity for plant species include conversion of their natural habitat into other unsuitable habitats by agriculture, forestry, dams, harvesting of plants, and recreation.

Table 5 : Rarity and viability values of four different types of forest ecosystem of Bungoh catchment

Ecosystem types	Rarity value	Viability value
Primary forest	0.973	0.548
Old secondary forest	0.994	0.398
Young secondary forest	0.989	0.420
Agroforestry	0.963	0.413

3.2 Viability values

In primary forest, Koompassia excelsa and Shorea scabrida give the lowest viability value which is 0.451 followed by Sterculia sp (0.454) whereas the highest viability value is shown by Pometia pinnata (0.780). In the old secondary forest, thirteen species exhibit the lowest viability which is 0.368. Those species encompass of Sterculia rubignosa, Lasianthus sp. Morinda elliptica, Saurauia myrmecoidea, Ardisia sp, Ardisia macrophylla, Archidendron borneense, Xanthophyllum griffithii, Ficus grossularioides, Horsfieldia crassifolia, Tarenna winkleri, Canthium glabrum and Gironniera parvifolia whereas the highest viability value is shown by alstonia angustifolia (0.612). In the young secondary forest ecosystem, four species show the lowest viability value which is 0.372. Those species are Dillenia suffroticosa, Anisophyllus disticha, Garcinia havilandii and Lepisanthes alata. The highest viability value is shown by Endospermum diadenum (0.625). In agroforestry ecosystem, three species exhibit the lowest viability value which is 0.369. Those species are Nephelium maingayi, Annona foetida and Artocarpus elasticus. Hevea brasiliensis shows the highest viability value which is 0.640 whereas Durio zibethinus gives the second highest viability value (0.529). Out of the four types of forest ecosystem, primary forest shows the highest viability value which is 0.548 whereas the young secondary forest gives the second highest with the viability value of 0.420. Old secondary forest shows the lowest viability value (0.398) followed by agroforestry with the viability value of 0.413.

The low viability value of the old secondary forest, agroforestry and young secondary forest is mainly due to the high fragmented area caused by anthropogenic activities such as selective logging, agriculture, i.e. shifting cultivation and dam projects. The effects of ecosystem fragmentation at the landscape and habitat scale are important for assessing the species viability values which is vital for the population viability (Belinda J.N. et al 2013). Fragmentation of an ecosystem particularly due to anthropogenic activities produced different size of an ecosystem patches which is thought to play an important role in its long-term viability (Gilfedder and Kirkpatrick 1998; Lonsdale 1999; Parkes et al. 2011), with longer patches having a better prognosis for long-term survival(Drayton and Primack 1996; Ranjito 1999; Parkes et al. 2011).

4. Conclusion

This work is an attempt to describe the importance of rarity value and viability value of an ecosystem with respect to biodiversity conservation of Bungoh catchment. The area is badly affected by the dam projects. As a result, forest edges and fragments are becoming dominant features affecting the area and consequently threatening the native populations and communities and the function of the ecosystem. The rarity value of all the four types of ecosystem namely the primary forest, old secondary forest, young secondary forest and agroforestry is relatively high indicating that the species in the ecosystem is distributed equitably which reflects the commonness of the species. Conversely, the viability value of the entire four ecosystems relatively is low indicating that the species are prone to extinction. This is due to the fact that the entirely ecosystem is being affected by anthropogenic activities which the dam projects contribute the most adverse impact to the ecosystem resulting in the loss and fragmentation of ecosystem. The rarity value and viability value of species of an ecosystem is vital not merely for academic exercise, but has profound implication for conservation and it is detrimental for the maintenance of biodiversity as the species in the entirely ecosystem needs functional ecosystem to survive.

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