Mount Silam Scientific Expedition
Lahad Datu, Sabah
13th-18th January, 2020

Compilation of Papers

SABAH FORESTRY DEPARTMENT

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MINISTRY OF ENERGY & NATURAL RESOURCES

Mount Silam Scientific Expedition
Lahad Datu, Sabah

13th–18th January, 2020

Compilation of Papers

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Foreword

Mount Silam, located some 10 km from Lahad Datu town in eastern Sabah, is an ultramafic coastal mountain facing the Darvel Bay, rising from sea level up to 884 m. Ultramafic soils are dark-coloured and contain high concentration of magnesium, iron and other metals, which are toxic to plants. Hence, the vegetation here is unique, adapted to low nutrient environment, such as pitcher plants and orchids. Another interesting ecological phenomenon occurring on Mount Silam is the 'Massenerhebung Effect' where its vegetation at the summit bears a striking resemblance to Mount Kinabalu's montane cloud forests. It is indeed an interesting mountain with a myriad of intriguing flora and fauna to explore.

Having that in mind, the Sabah Forestry Department conducted the Mount Silam Scientific Expedition from 13th to 18th of January, 2020, with funding from the National Conservation Trust Fund (NCTF) under the then Ministry of Water, Land & Natural Resources (now Ministry of Energy & Natural Resources) through the Sustainable Forest Management (SFM) Division of SFD Headquarters. This is part of the Payment for Ecosystem Services (PES) project of the Department on Mount Silam and its surrounding forests. I was informed that some 65 participants, comprising researchers, officers and staff of Forest Research Centre (FRC), Rainforest Discovery Centre (RDC) and District Forestry Office (DFO) of Lahad Datu, and a few university interns participated in this expedition.

The research findings are presented here in this compilation, comprising 12 scientific papers, focussing on (1) forest ecosystem assessment, (2) soil science, (3) plant diversity, (4) dipterocarp assessment, (5) macrofungus diversity, (6) mammal diversity, (7) bird diversity, (8) fish diversity, (9) anuran diversity, (10) insect diversity, (11) social science and (12) forest recreation. Such information will definitely contribute towards sustainable forest management of Mount Silam, including promoting responsible and sustainable nature tourism.

I thank all those involved in the planning and implementation of this PES project, execution of the scientific expedition and the online publication of this technical report. Keep up the good work!

Datuk Mashor Mohd. Jaini
Chief Conservator of Forests
Sabah Forestry Department

Summary

The Mount Silam Scientific Expedition was organized by the Sabah Forestry Department (SFD) from 13th to 18th of January, 2020. It was funded from the National Conservation Trust Fund (NCTF) under the then Ministry of Water, Land & Natural Resources (now Ministry of Energy & Natural Resources) through the Sustainable Forest Management (SFM) Division of SFD Headquarters. This is part of the Payment for Ecosystem Services (PES) project of the Department on Mount Silam and its surrounding forests. Some 65 participants, comprising researchers, officers and staff of FRC, RDC and DFO Lahad Datu, and a few university interns participated in this expedition. The multidisciplinary expedition involved 12 research scopes, namely (1) forest ecosystem assessment, (2) soil science, (3) plant diversity, (4) dipterocarp assessment, (5) macrofungus diversity, (6) mammal diversity, (7) bird diversity, (8) fish diversity, (9) anuran diversity, (10) insect diversity, (11) social science and (12) forest recreation.

Mount Silam is an ultramafic mountain which is situated at the coastal area overlooking the picturesque Darvel Bay in Lahad Datu, Sabah. The peak is the highest within Lahad Datu district, at a height of 884 m above the sea level. Despite being a low height level mountain, its vegetation at the summit bears a striking resemblance to Mount Kinabalu's montane cloud forests at 2,100 – 3,000 m a.s.l. This ecological phenomenon is called the 'Massenerhebung Effect'. Four forest ecosystems were assessed in this study, namely (1) upper montane ultramafic forest, (2) lower montane ultramafic forest, (3) upland ultramafic forest and (4) lowland mixed dipterocarp forest. The major soil association in Mount Silam and its surrounding areas is Bidu-bidu while the southern part is of Gumpal association.

A total of 149 plant taxa were recorded, of which 32 species are endemic to Borneo, including seven species endemic to Sabah. For dipterocarps, 18 species were recorded with 60% of them are Bornean endemics and about 50% are listed under threatened species in the IUCN Red List. The forests - contain high conservation value plant species, which should be a key conservation target for this area. Adequate knowledge of plant diversity is vital for the formulation of the Forest Management Plan. The survey on macrofungi recorded 57 specimens from nine orders, 13 families and 22 genera.

Camera trapping and recce transect methods recorded 21 mammal species, including five Bornean endemics. Of this, seven are threatened species, including the Sunda pangolin (*Manis javanica*) and the Bornean gibbon (*Hylobates muelleri*). A total of 115 bird species from 43 families were recorded, with eight species endemic to Borneo. Bird feeding guild in Mt. Silam was dominated by insectivorous species, followed by frugivores. The anuran survey yielded 14 species, with 11 of them endemic to Borneo. For fish, 18 species from six families were recorded from the adjacent Sg. Sepagaya and Sg. Taliwas. At least eight fish species are Bornean endemic. An average of 108 nocturnal insect species from 148 individuals was recorded from a one-metre-square area of the light-trapping cloth. At least 15 Bornean endemic insect species were recorded.

A survey on the socio-economics and community's perception on forest conservation was conducted for the community living adjacent to Mount Silam. The community staying inside the forest reserves is quite large and increasing. It is a challenging issue for the department. A common ground needs to be agreed upon by the community and the stakeholders involved. They understand the importance of the forest as their source of water comes from the forest, and they acknowledge that the forest needs to be conserved and protected.

Located adjacent to Lahad Datu town, Mount Silam is ideal and important for sustainable nature tourism, recreation and environmental education. The beautiful landscapes, unique ecological 'Massenerhebung' phenomenon and interesting ultramafic flora and fauna are the major attractions for tourists to this mountain. However, the road to Mount Silam, facilities and trails would have to be properly maintained to ensure the safety and convenience of visitors.

From the compilation of the research findings, Mount Silam and its surrounding forests are categorised as high conservation value areas as they provide viable habitats for a wide range of significantly important biodiversity and ecosystem services from the conservation perspective. However, land use activities by adjacent communities may give an impact to the integrity of Mount Silam, especially on encroachment, illegal harvesting of natural resources and spread of fire at the forest edge. There should be a concerted effort on forest monitoring and enforcement, as well as environmental education to enhance awareness on the importance and services of the ecosystem that address issues on ecosystem integrity and safeguarding the continuous water supply, including diversity of unique plant and wildlife species in Mount Silam.

It is hoped that this compilation would benefit the general public, local surrounding communities, scientists, administrators and policy makers not only in the context of PES, but would also serve as a guide for best practices in sustainably managing Mount Silam and its surrounding forests.

Group photo at the base camp, at the Sepagaya Waterfall Recreational Area (Photo: Viviannye Paul).

Group photo in front of Menara Kayangan, Mount Silam (Photo: Viviannye Paul).

Assessment of forest ecosystems in Mount Silam, Lahad Datu, Sabah

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Abstract. This paper reports the findings from the forest ecosystem assessment in Mount Silam, Lahad Datu, Sabah. A total of seven permanent sample plots (PSPs) were set up in the mountain and its surrounding areas. Four forest ecosystems were sampled throughout this study, namely (1) upper montane ultramafic forest, (2) lower montane ultramafic forest, (3) upland ultramafic forest and (4) lowland mixed dipterocarp forest. Forest structure and tree species composition among these forests varied. The mountain itself exhibited Massenerhebung Effect (a compression of vegetation zones relative to those found in the large mountain ranges). This study highlighted several threats to forest ecosystems within the study area. Mitigative measures relevant to the mentioned threats were also included.

INTRODUCTION

Majority of tall mountains beyond 1000 m a.s.l. in Sabah are located in the West Coast Division and Interior Division. Mountains in the eastern part of the state are generally isolated as they are not part of any large mountain ranges (i.e. Crocker and Trusmadi ranges). Mount Silam is one of the most famous mountains in the east coast of the state. Much is not known about the biodiversity and ecology of this mountain. Hence, the unknown of this mountain is worth discovering.

The Forest Research Centre of the Sabah Forestry Department organized a scientific expedition to Mount Silam from the 13th to 18th of January 2020. This scientific expedition is one the components of the Development of Payment for Ecosystem Services (PES) Project, funded by Ministry of Water, Land and Natural Resources (KATS). The multidisciplinary expedition involved 12 research scopes, namely (1) forest ecosystem assessment, (2) soil science, (3) plant diversity, (4) dipterocarp assessment, (5) macrofungus diversity, (6) mammal diversity, (7) bird diversity, (8) fish diversity, (9) anuran diversity, (10) insect diversity, (11) social science and (12) forest recreation.

This paper is intended to present the findings on forest ecosystem assessment. This study aimed to set up permanent sample plots for a long-term ecological research and to assess forest structure as well as tree species composition. The study adhered to the state-wide biodiversity monitoring programme of which its research output can be integrated in the continuous conservation efforts of protecting the integrity and functionality of forest ecosystems in Sabah.

MATERIALS AND METHODS

Study area

The term study area refers to Mount Silam and its surrounding areas. The main ridges are extended to four forest reserves (FRs), namely (1) Sapagaya (Ext.) FR, (2) Sapagaya FR, (3) Sepagaya FR and (4) Ulu Segama FR (Figure 1). Mount Silam (880 m asl) is the highest point in the Darvel Bay coastal area. The study area is accessible from the Lahad Datu-Tawau main road and approximately 15 km from Lahad Datu town. The area is also in the vicinity of Danum Valley Conservation Area, one of last bastions of pristine forest in Sabah.

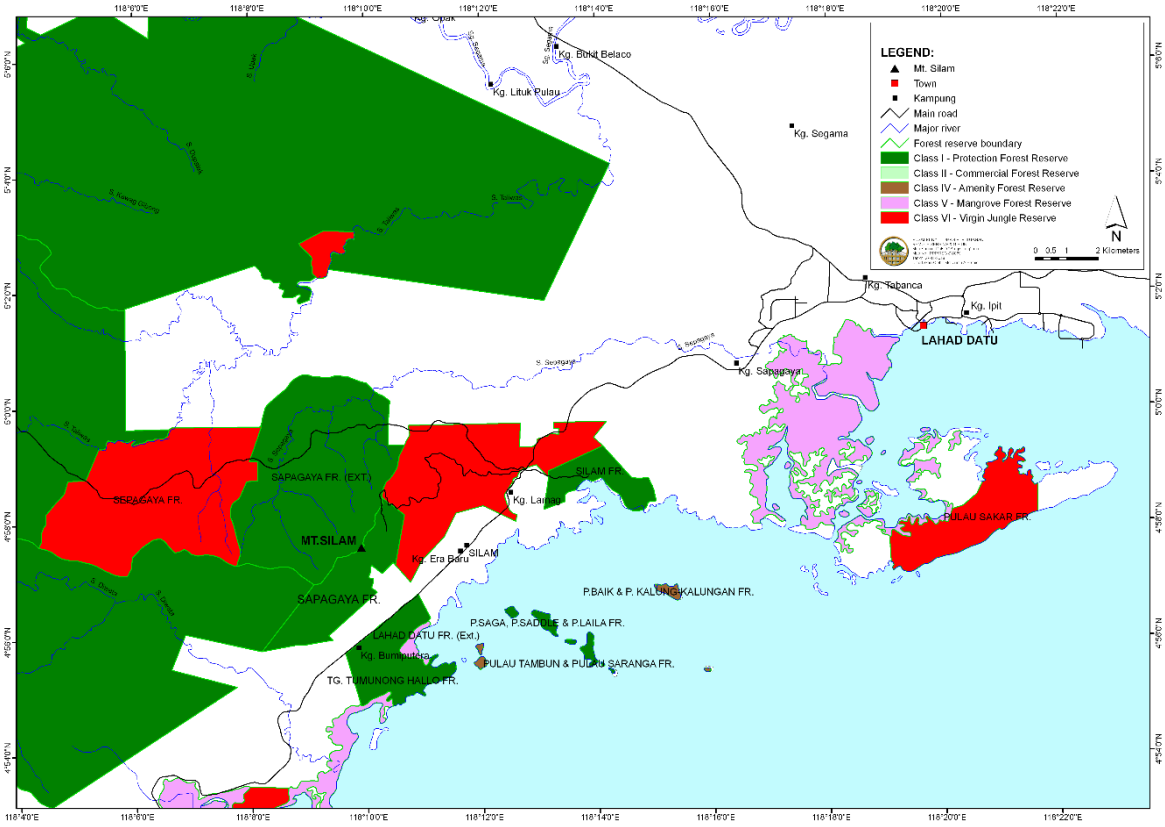

Figure 1. Location of the Mount Silam in the Lahad Datu, Sabah.

Major soil association of Mount Silam is Bidu-Bidu, making it as one of the few examples of ultramafic mountains in Sabah. Other prominent ultramafic mountains are Mount Tambuyukon and Mount Nambuyukong within the Kinabalu highlands, and Mount Tinkar and Mount Tawai in Telupid highland. Anthropogenic disturbances including media and telecommunication towers and placement of mountain trigs in the past have altered the original vegetations of the mountain. Nevertheless, the mountain still harbours considerable patches of old-growth forest mainly at the upper elevations.

Establishment of permanent sample plot and tree enumeration

A total of seven permanent sample plots (PSPs) were established in the study area (Table 1). The position of each PSP is based on the elevation, forest quality and

safety of the team. Relative elevations and distances between PSPs ranged from 153-880 m a.s.l. and 0.2-5 km, respectively. These PSPs are borderless and circular in shape with15-20 m radius. Within the plot, trees with diameter at breast height (DBH) of ≥10 cm were sampled. Standard field equipment for forest ecosystem assessment was utilized.

Table 1. Details of each permanent sample plot established in Mount Silam, Lahad Datu, Sabah.

Plot Label	Establishment Date	Coordinates (Datum: WGS 84)		Elevation (m a.s.l.)	Radius (m)
		Latitude	Longitude		
PSP 01	14th January 2020	04°57'31.5"	118°10'01.2"	883	15
PSP 02	15th January 2020	04°58'03.7"	118°10'14.7"	743	20
PSP 03	15th January 2020	04°57'59.2"	118°10'22.1"	680	20
PSP 04	16th January 2020	04°58'21.6"	118°10'23.6"	558	20
PSP 05	16th January 2020	04°58'19.6"	118°10'40.2"	398	20
PSP 06	17th January 2020	04°58'47.5"	118°12'00.0"	246	20
PSP 07	17th January 2020	04°58'46.2"	118°12'32.3"	159	20

Tree identification

Trees were identified on site by referring to their physical morphologies, such as leaf, tree bark, resin, fruit and flower. In some cases when the identity is difficult to be ascertained, voucher specimens were collected for further identification process at the Sandakan Herbarium (SAN).

Data analysis

The importance value index of each tree family and species enumerated from the PSPs were calculated (see appendices). It is defined as the average of relative tree density and relative basal area. The equation is based on Brower & Zar (1997):

Relative tree density = [∑ tree density of species or family I / ∑ tree density of all species or families] × 100

Relative basal area = [∑ basal area of species or family I / ∑ basal area of all species or families] × 100

Relative dominance = (Relative tree density + Relative basal area)/2

Cluster analysis based on Bray Curtis distance was computed to measure the dissimilarity in tree species composition between PSPs. The distance is equal to the value of 1.0 in case of complete dissimilarity. It is also sensitive towards species abundance as well as species occurrence. A dendrogram was constructed within the MVSP v3.22.

RESULTS AND DISCUSSION

Forest ecosystems

The PSPs can be grouped based on their soil associations. PSP 6 and 7 are affiliated to Gumpal association whereas the other PSPs are located within the Bidu-Bidu association. The Gumpal association is extensive in the Lahad Datu and Tawau districts, while the Bidu-Bidu association occurred on mountains of ultrabasic igneous rocks. The enumerated tree communities are further classified into four unique forest ecosystems, namely (1) upper montane ultramafic forest, (2) lower montane ultramafic forest, (3) upland ultramafic forest and (4) lowland mixed dipterocarp forest (Figure 2).

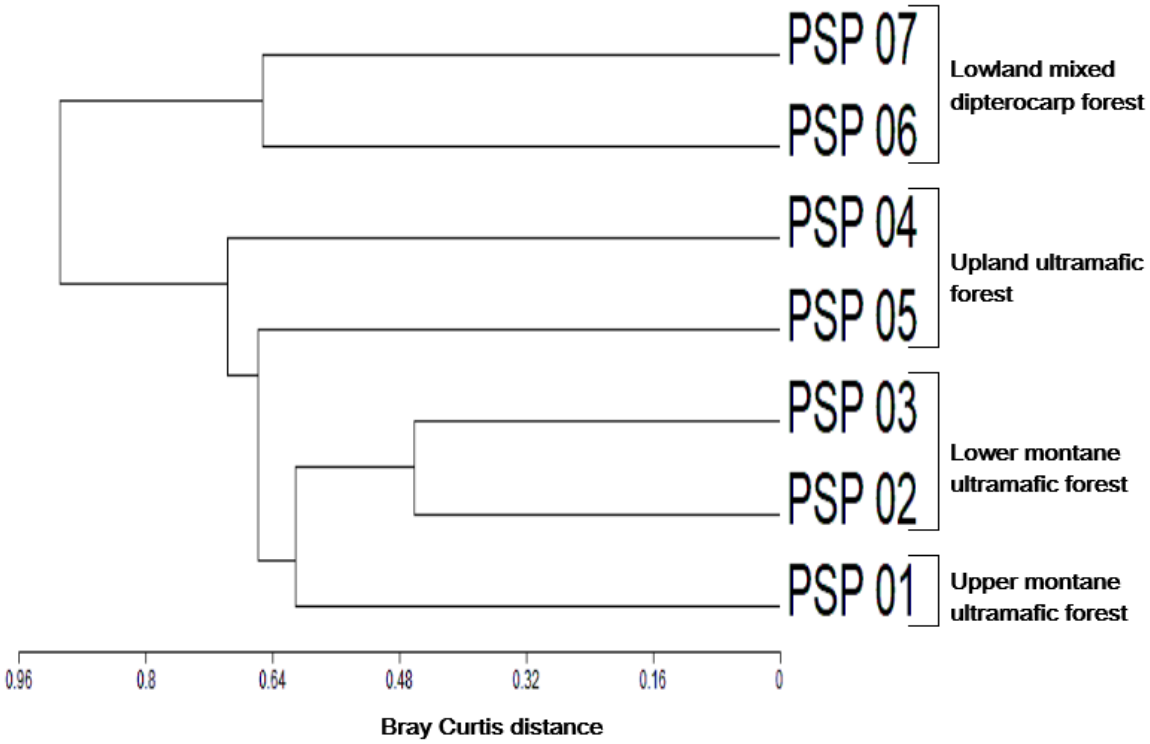

Figure 2. A cluster dendrogram of the enumerated tree communities in Mount Silam, Lahad Datu.

Forest structure and species composition

A total of 592 individuals were enumerated from all PSPs. These trees belonged to 46 families, 77 genera and 111 taxa. A total of 92 trees of 26 taxa, 25 genera and 20 families were recorded in the upper montane forest. In the lower montane ultramafic forest, a total of 139 stems of 29 families, 39 genera and 43 taxa whereas, in the upland ultramafic forest, a total of 237 individuals of 31 families, 42 genera and 59 taxa were accounted for. We also recorded a total of 124 trees of 22 families, 31 genera and 40 taxa in the lowland mixed dipterocarp forest.

A. Upper montane ultramafic forest

The upper montane ultramafic forest is represented by PSP 01 with a radius of 15 m. Even though the radius is smaller than the other PSPs, the comparative descriptions are still valid. Proctor *et al*. (1988a) pointed that the scale of forest variation diminished with elevation.

The upper montane ultramafic forest is sampled at 880 m asl (Table 3). There were no dipterocarps recorded in this forest. Our findings corroborated Proctor *et al*. (1988a) who observed the absence of dipterocarp species at the peak. This forest is dominated by Burseraceae with a relative abundance of 11.97%, followed by Sapotaceae (11.04%) and Rutaceae (10.20%). *Santiria* sp., *Maclurodendron* sp. and *Pouteria* sp. are among the most dominant species. The upper montane ultramafic forest is densely populated by trees with DBH ≤ 30.0 cm. Majority of the trees exhibited a stunted growth (i.e. low tree height) due to the extreme environment at the summit.

B. Lower montane ultramafic forest

We set up two PSPs in the lower montane ultramafic forest, namely PSP 02 and PSP 03. We recorded two dipterocarp species in this ecosystem which are *Shorea venulosa* and *Shorea atrinervosa*. The former is a common dipterocarp in both ultramafic and heath forests. In term of dominance, *Syzygium* sp. is on the top with 14.72% relative dominance, closely followed by *Shorea venulosa* (11.97%) and *Borneodendron aenigmaticum* (9.71%). The top five most dominant tree families are Myrtaceae, Dipterocarpaceae, Euphorbiaceae, Rubiaceae and Sapotaceae (Table 3). Similar to the forest condition at the mountain's peak, the lower montane ultramafic forest has high tree density. DBH of most trees in this forest ranged from 10.00-40.00 cm.

C. Upland ultramafic forest

PSP 04 and PSP 05 were established at 558 m a.s.l. and 398 m a.s.l., respectively. The relative dominance of Dipterocarpaceae (30.59%) can be easily observed in the upland ultramafic forest (Table 3). It is followed by Myrtaceae (17.03%) and Euphorbiaceae (7.09%). Trees in the upland ultramafic forest are high in density. However, their DBH are considerably larger than trees in montane ultramafic forests.

D. Lowland mixed dipterocarp forest

The lowland mixed dipterocarp forest occurred at the lowest elevations of the mountain. We established two PSPs in this forest and these plots can be accessed from the natural trail that starts from the main entrance. This typical mixed dipterocarp forest occurred on Gumpal soil association and has distinct ecological features compared to other ultramafic forests at the upper elevations. Trees in this forest are low in density but many of them have large stems.

Dipterocarpaceae recorded the highest relative dominance with 36.24%, followed by Anacardiaceae (18.60%) as well as Ebenaceae (9.29%). At species level,

Hopea sp., *Gluta oba*, *Diospyros* sp., *Vatica mangachapoi* and *Teijsmanniodendron* sp. are the top most dominant trees (Table 3).

Table 3. Ecological features of the three forest ecosystems in Mount Silam, Lahad Datu.

	Upper montane ultramafic forest	**Lower montane ultramafic forest**	**Upland ultramafic forest**	**Lowland Mixed Dipterocarp Forest**
Altitude (m asl)	880	680-743	398-558	159-246
Number of taxa (*S*)	26	43	59	40
Estimated density per hectare (*N* ha^{-1})	1297	556	948	496
Estimated basal area per hectare (BA m^2 ha^{-1})	32.94	23.66	47.21	39.57
Top five most dominant families	Burseraceae Sapotaceae Rutaceae Fagaceae Myrtaceae	Myrtaceae Dipterocarpaceae Euphorbiaceae Rubiaceae Sapotaceae	Dipterocarpaceae Myrtaceae Euphorbiaceae Anacardiaceae Rubiaceae	Dipterocarpaceae Anacardiaceae Ebenaceae Malvaceae Lamiaceae
Top five most dominant species	*Santiria* sp. *Maclurodendron* sp. *Pouteria* sp. *Syzygium* sp. *Gynotroches axillaris*	*Syzygium* sp. *Shorea venulosa* *Borneodendron aenigmaticum* *Timonius* sp. *Shorea* sp.	*Shorea venulosa* *Syzygium* sp. *Borneodendron aenigmaticum* *Timonius* sp. *Syzygium* sp. 3	*Hopea* sp. *Gluta oba* *Diospyros* sp. *Vatica mangachapoi* *Teijsmanniodendron* sp.
Top five most abundant families	Burseraceae Rhizophoraceae Rutaceae Fagaceae Myrtaceae	Dipterocarpaceae Myrtaceae Rubiaceae Sapotaceae Ulmaceae	Myrtaceae Dipterocarpaceae Rubiaceae Anacardiaceae Simaroubaceae	Dipterocarpaceae Ebenaceae Anacardiaceae Lamiaceae Malvaceae
Top five most abundant species	*Santiria* sp. *Gynotroches axillaris* *Maclurodendron* sp. *Syzygium* sp. *Ixonanthes* sp.	*Syzygium* sp. *Shorea* sp. *Shorea venulosa* *Timonius* sp. *Gironniera subaequalis*	*Syzygium* sp. *Timonius* sp. *Shorea venulosa* *Ailanthus* sp. *Vatica micrantha*	*Diospyros* sp. *Teijsmanniodendron* sp. *Vatica mangachapoi* *Scaphium parviflorum* *Cynometra* sp.

Elevational limit of forest ecosystem and treeline of mountains that are surrounded by large ranges often occurred at high elevations. Mount Silam is an isolated mountain as it is not part of any major ranges. The vegetation of the upper montane ultramafic forest in Mount Silam bears a striking resemblance to that of the Mount Kinabalu montane forest at 2133-3048 m a.s.l. (Proctor *et al*. 1988a). This phenomenon is known as the Massenerhebung Effect (Grubb 1971), a compression of vegetation zones relative to those found in the large mountain ranges.

Proctor *et al*. (1988a) highlighted the Massenerhebung Effect phenomenon in Mount Silam. He pointed that elucidating the forest changes across elevational gradient in Mount Silam is not an easy task. Nonetheless, in another article, he discussed the phenomenon from chemical perspective (i.e. litterfall and leaf chemical analysis) (Proctor *et al*. 1988b). Other possible explanations are mean temperature and cloud formation (Flenley 1995). We noticed that the mountain's summit is daily capped by a thick cloud formation (see appendices). The daily cloud formation could increase the humidity to 100% and reduce total insolation received by about 30% compared with unclouded sites in other parts of Sabah (Bruijnzeel *et al*. 1993).

CONSERVATION SIGNIFICANCE

Threatened and endangered forest ecosystems

Based on the local IUCN ecosystem red-list assessment for Sabah, lowland mixed dipterocarp forest is categorized as Vulnerable due to loss of more than 30% of the total original extend in the state, hence the lowland mixed dipterocarp forest in the conservation area is categorized as High Conservation Value for ecosystem (HCV 3). The resilience of the forest to alteration of structure after series of timber extraction activities is the key ecological process to maintain the forest system function and ecosystem integrity.

Forest ecosystem services

Biological diversity maintenance – mixed dipterocarp and ultramafic forest are important in providing habitat for endemic and threatened as well as endangered species. Forested areas are identified as HCV 1 for flora as the ecosystem integrity is likely to be maintained and supported viable population of endemic and threatened and endangered species of flora.

Nutrient cycling – each forest ecosystem, have a unique biogeochemical cycle or nutrient cycling that are largely influenced by climate, abiotic (topography and soil parent materials) and biotic communities (Foster & Bhatti 2016). The intricate interaction of the forest alongside other biological entities within the ecosystems with the physical environment maintain large portion of nutrient movements from soil to vegetation are typically returned to forest floor and soil, ensuring forest productivity is maintained.

Primary productivity – The forest ecosystem structure of the project area that mainly consists of multitude forms of photosynthetic species and they are primary producers that harness solar energy from the sun and utilized elements from the atmosphere and the soil to produce matter and energy. This ecosystem structure is important for distributing matter and energy to other biotic or trophic levels.

Erosion control – forest ecosystem structure intercept rain water velocity and reduced water runoff rates, hence reduced soil erosion and nutrient leaching or loss. Water purification – both forest and soil organisms regulate water movement and naturally controlled water flows and quality, and also mitigating the occurrence of flood. Climate regulation – the regenerating forests have profound role in sequester and store carbon thus partially mitigate local climate change concerns.

THREATS

Forest simplification

Forest simplification is the reduction of compositional and structural diversity from forest stands and landscapes. Some part of the study area is dominated by secondary vegetation with various degrees of degradation due to timber extraction in

the past. These areas are very much degraded with low diversity and productivity that the threat of forest simplification may be inevitable. The simplification of the forest could have a direct impact on the physical and terrestrial ecosystem at the peripheral areas.

Forest fire

In Southeast Asian tropical rain forests, long drought events are associated with the atmospheric and oceanic anomaly known as the El Niño-Southern Oscillation (ENSO) phenomenon (Walsh 1996). Frequent occurrences of these severe drought events have increased the susceptibility of vegetation to wildfire. Over the period 1957–1998, Sabah experienced at least eight significant drought events, and those in 1983, 1986–87, 1992 and 1998 were identified as the most extreme (Walsh 1996, Walsh & Newbery 1999). During these climatic extremes, drought-induced fire burnt large areas of forest in Borneo (Leighton & Wirawan 1986, Woods 1989, Sabah Forestry Department Annual Reports). For example, the ENSO-associated drought induced-fires event in 1982–83 had damaged 5 × 106 ha in Borneo (Goldammer *et al*. 1996). The conservation area comprised secondary vegetation of various successional stages and would likely to be susceptible to wildfire. It is known that secondary vegetation or disturbed forest is more susceptible to fire in comparison to pristine forest (Woods 1989). Therefore, fire is considered as a major threat to natural forest conservation and management, especially in areas bordered agricultural activities.

RECOMMENDATIONS

Protection of forest ecosystem

Monitoring extent of forest

Remote sensing and GIS have been used as a management tool to examine spatio-temporal processes such as old growth forest, disturbance, and species dynamics. This tool should be used to produce a stand-based mapping of vegetation type and structure as baseline for monitoring purposes in the management of this production area.

Forest fire prevention programme

The goal of the programme is to create and use environmentally sound and economically efficient strategies that minimize the total cost to protect ecosystem's functionality from wildfire. The formulation of this programme should maintain multi-faceted activities, such as fire prevention, detection, control and suppression activities, in order to provide effective protection from fire to other forest values, such as water and watersheds, fisheries, wildlife, recreation, aesthetics, soil productivity and soil stability. The programme should encourage cooperation with public agencies with similar goals, and inform the general public of current and potential forest fire danger in the effort to protect people, property, and natural resources from the risk of wildfire.

Maintaining forest health and functionality

To monitor forest health and overall functionality of the existing forested areas, establishment of PSPs is a scientific approach in documenting detailed changes

in forest structure and composition. The output of the plot could provide baseline distributions for high conservation value species and detailing habitats of a particular site. The long-term monitoring activities, such as assessment of the standing trees of these plots would provide invaluable information of changes in plant diversity and richness, growth, mortality, regeneration and dynamics of the sampled forest. This information on forest changes is an indicator of forest health and functionality. Therefore, the existing PSPs, and perhaps several more need to be established, are important to be included in the monitoring activities in the areas.

Environmental awareness

Land use activities adjacent to the conservation area by communities may give an impact to the integrity of the forest ecosystem, especially on encroachment, illegal harvesting of natural resources and spread of fire at the forest edge. There should be an effort to make them aware of the importance and services of the ecosystem by designing environmental awareness programmes that address issues on ecosystem integrity and safeguarding the continuous water supply, including diversity, abundance and distribution of unique plant and wildlife species in this forest ecosystems.

CONCLUSION

Despite of its low-lying summit and isolated range, Mount Silam has unique ecological features that are not recorded in most Bornean mountains. Fortunately, we have established long-term ecological research plots in this mountain. Threats to the forest ecosystems and mitigation measures, have also been addressed. Mount Silam contains forest ecosystems that are categorised as high conservation value areas as they provide viable habitats for a wide range of significantly important biodiversity and ecosystem services for conservation perspective. This study is expected to benefit the general public, local surrounding communities, scientists and policy makers in general.

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REFERENCES

Brower, J.E. & Zar, J.H. (1977*). Field and laboratory methods of general ecology*. Iowa: Brown Company Publishers.

Bruijnzeel, L.A., Waterloo, M.J., Proctor, J., Kuiters, A.T. & Kotterink, B. (1993). *Journal of Ecology*. (81): 145-167.

Flenley J.R. (1995). Cloud forest, the Massenerhebung Effect, and Ultraviolet Insolation. In: Hamilton L.S., Juvik J.O., Scatena F.N. (eds) Tropical Montane Cloud Forests. Ecological Studies (Analysis and Synthesis), vol 110. Springer, New York, NY

Foster, Neil W. & Jagtar S. Bhatti (2016). Forest ecosystems: nutrient cycling. In *Encyclopedia of Soil Science* by Rattan Lal, Taylor & Farncis Inc., 2804 pp.

Goldammer, J.G., Seibert, B. & Schindele, W. (1996). Fire in dipterocarp forests. In: Schulte, A. & Schöne, D. (eds.). *Dipterocarp forest ecosystems: towards sustainable management.* World Scientific Publication, Singapore-New Jersey-London-Hong Kong. Pp. 155–185.

Grubb, P.J. (1971). Interpretation of the 'Massenerhebung" Effect on tropical mountains. *Nature*. (229): 44-45.

Leighton, M. & Wirawan, N. (1986). Catastrophic drought and fire in Borneo tropical rain forest associated with the 1982–1983 El Niño Southern Oscillation event. In: Prance, G.T. (ed.). *Tropical rain forests and the world atmosphere*. Westview Press, Boulder, CO. Pp. 75–102.

Proctor, J., Lee, Y.F., Langley, A.M., Munro, W.R.C. & Nelson, T. (1988a) Ecological studies on Gunung Silam, a small ultrabasic mountain in Sabah, Malaysia. I. environment, forest structure and floristics. *Journal of Ecology* (76): 320-340.

Proctor, J., Phillips, C., Duff, G., Heaney, A. & Robertson, F.M. (1988b) Ecological studies on Gunung Silam, a small ultrabasic mountain in Sabah, Malaysia. II. Some forest processes. *Journal of Ecology* (77): 317-331.

Walsh, R.P.D. (1996). Drought frequency changes in Sabah and adjacent parts of northern Borneo since the late nineteenth century and possible implications for tropical rainforest dynamics. *Journal of Tropical Ecology* (12): 385-407.

Walsh, R.P.D. & Newbery, D.M. (1999). The ecoclimatology of Danum, Sabah, in the context of the world's rainforest regions, with particular reference to dry periods and their impact. *Philosophical Transactions of the Royal Society of London Series* B 354: 1869–1883.

Woods, P. (1989). Effect of logging, drought, and fire on structure and composition of tropical rainforest in Sabah, Malaysia. *Biotropica* (21): 290-298.

APPENDIX I Photo Gallery

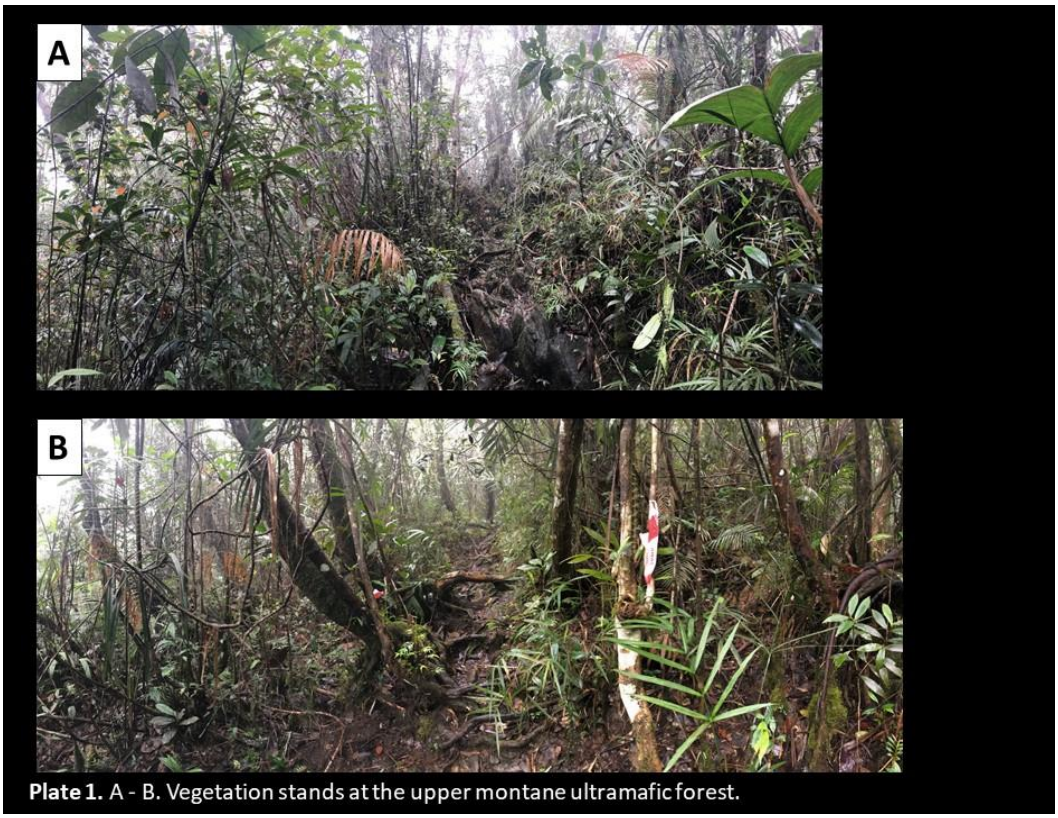

Plate 1. A - B. Vegetation stands at the upper montane ultramafic forest.

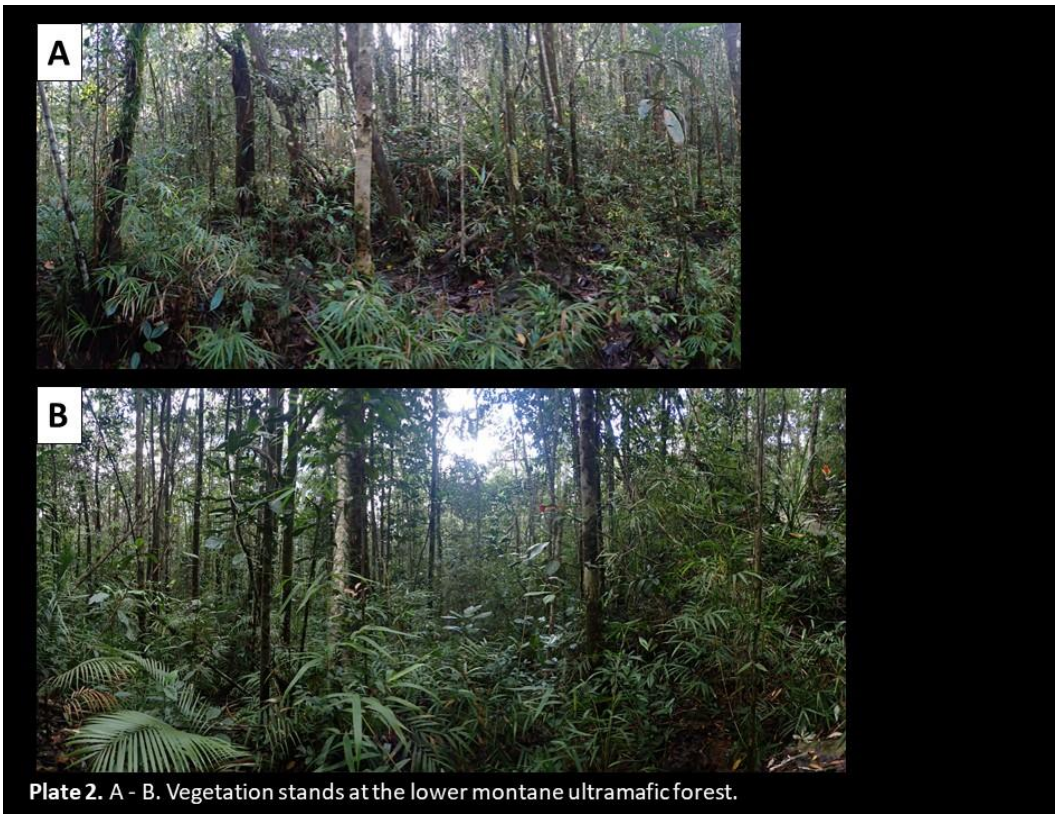

Plate 2. A - B. Vegetation stands at the lower montane ultramafic forest.

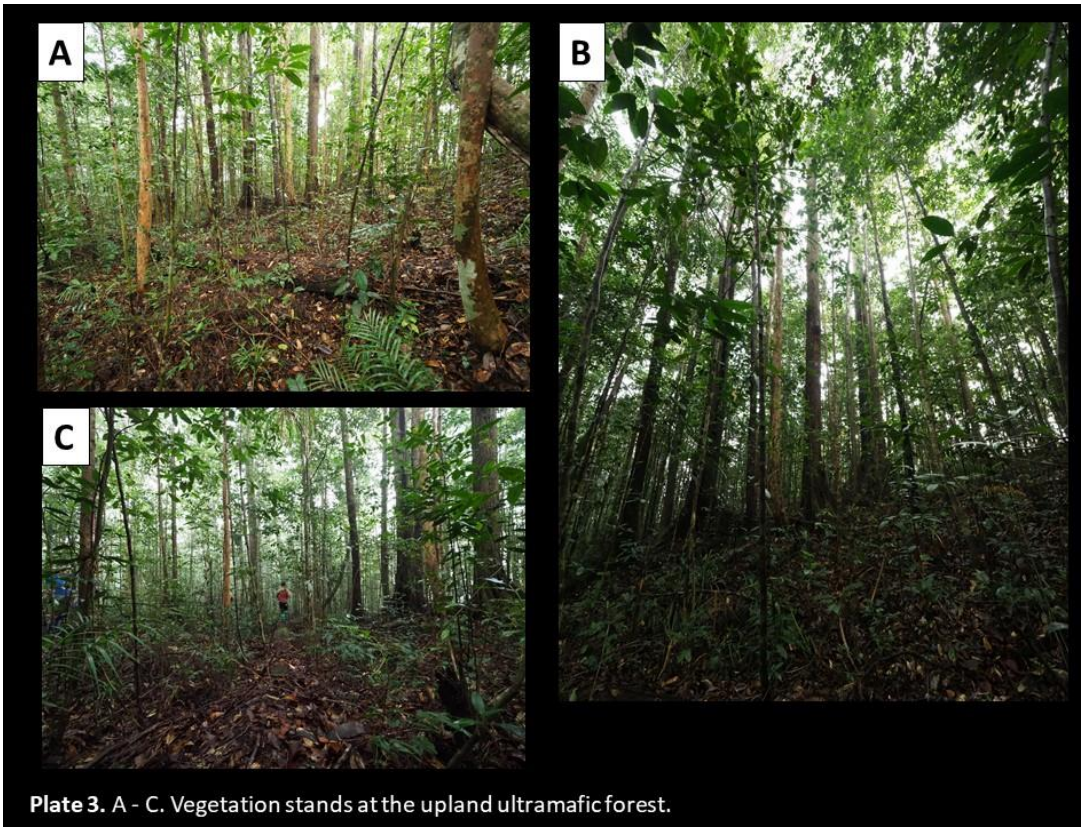

Plate 3. A - C. Vegetation stands at the upland ultramafic forest.

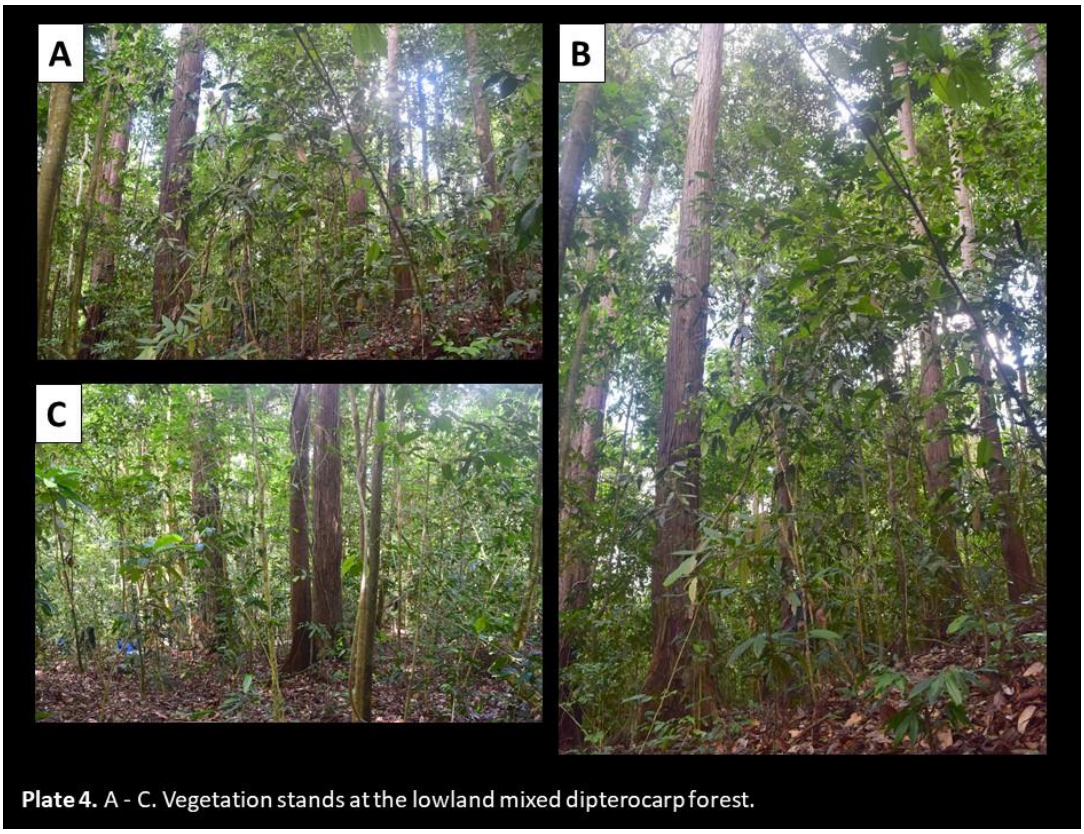

Plate 4. A - C. Vegetation stands at the lowland mixed dipterocarp forest.

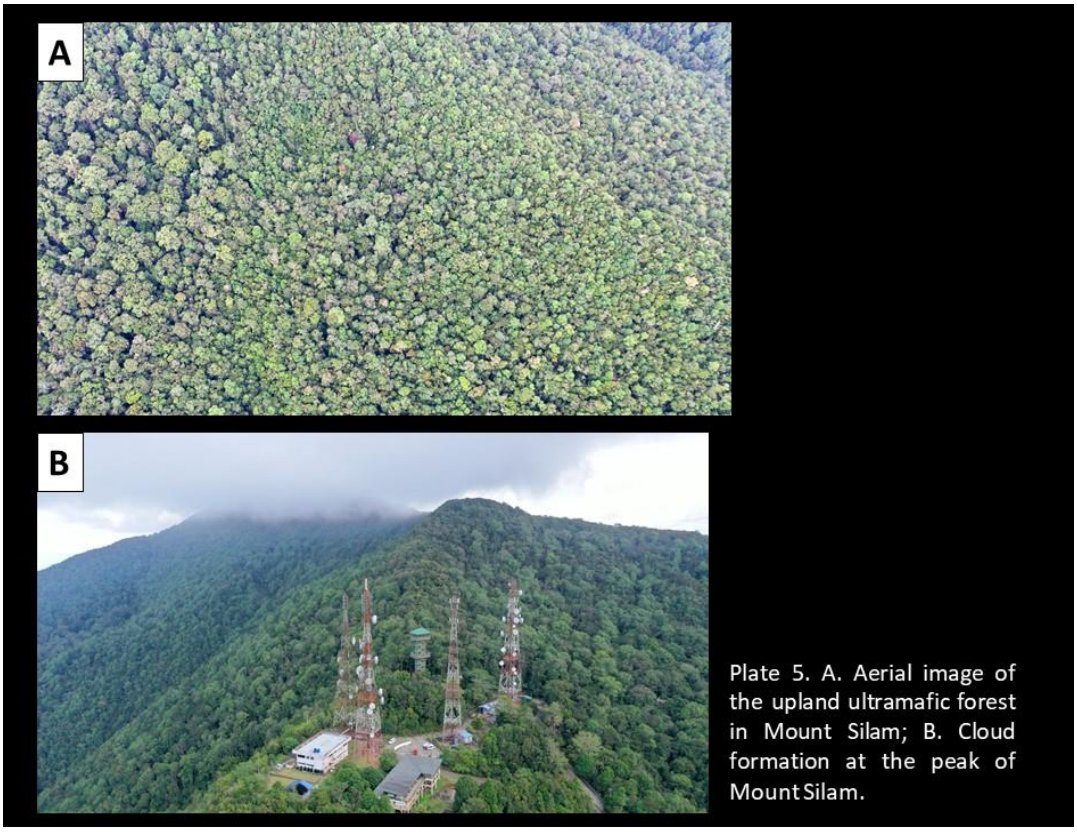

Plate 5. A. Aerial image of the upland ultramafic forest in Mount Silam; B. Cloud formation at the peak of Mount Silam.

APPENDIX II Familial Importance Value Index

Forest Ecosystem	Family	Basal Area (m^2ha^{-1})	Density (ha^{-1})	Rel. BA.	Rel. Den.	Rel. Dom.	10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9	≥90.0
Upper montane ultramafic forest	Burseraceae	3.23	183.3	9.81	14.13	11.97	155.1	28.2	0	0	0	0	0	0	0
	Sapotaceae	5.84	56.4	17.72	4.35	11.04	28.2	0	0	14.1	14.1	0	0	0	0
	Rutaceae	3.50	126.9	10.63	9.78	10.20	70.5	56.4	0	0	0	0	0	0	0
	Fagaceae	3.16	112.8	9.60	8.70	9.15	70.5	42.3	0	0	0	0	0	0	0
	Myrtaceae	3.03	112.8	9.20	8.70	8.95	84.6	28.2	0	0	0	0	0	0	0
	Rhizophoraceae	1.99	141	6.05	10.87	8.46	141	0	0	0	0	0	0	0	0
	Ixonanthaceae	1.89	84.6	5.73	6.52	6.12	56.4	28.2	0	0	0	0	0	0	0
	Theaceae	2.05	56.4	6.21	4.35	5.28	28.2	14.1	14.1	0	0	0	0	0	0
	Rubiaceae	1.63	70.5	4.96	5.43	5.20	56.4	14.1	0	0	0	0	0	0	0
	Podocarpaceae	1.50	70.5	4.56	5.43	5.00	56.4	14.1	0	0	0	0	0	0	0
	Clusiaceae	1.06	70.5	3.23	5.43	4.33	70.5	0	0	0	0	0	0	0	0
	Aquifoliaceae	0.81	42.3	2.44	3.26	2.85	42.3	0	0	0	0	0	0	0	0
	Pentaphylacaceae	1.04	28.2	3.15	2.17	2.66	14.1	14.1	0	0	0	0	0	0	0
	Elaeocarpaceae	0.65	28.2	1.97	2.17	2.07	28.2	0	0	0	0	0	0	0	0
	Anacardiaceae	0.59	28.2	1.78	2.17	1.98	28.2	0	0	0	0	0	0	0	0
	Salicaceae	0.36	28.2	1.10	2.17	1.64	28.2	0	0	0	0	0	0	0	0
	Proteaceae	0.19	14.1	0.57	1.09	0.83	14.1	0	0	0	0	0	0	0	0
	Lauraceae	0.18	14.1	0.55	1.09	0.82	14.1	0	0	0	0	0	0	0	0
	Myrsinaceae	0.12	14.1	0.38	1.09	0.73	14.1	0	0	0	0	0	0	0	0
	Putranjivaceae	0.12	14.1	0.36	1.09	0.73	14.1	0	0	0	0	0	0	0	0
	Grand Total	32.94	1297.2	100.00	100.00	100.00	1015.2	239.7	14.1	14.1	14.1	0	0	0	0

Forest Ecosystem	Family	Basal Area (m^2ha^{-1})	Density (ha^{-1})	Rel. BA.	Rel. Den.	Rel. Dom.	10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9	≥90.0
Lower montane ultramafic forest	Myrtaceae	4.92	96	20.78	17.27	19.02	32	44	16	4	0	0	0	0	0
	Dipterocarpaceae	4.44	104	18.78	18.71	18.74	60	24	8	12	0	0	0	0	0
	Euphorbiaceae	3.95	20	16.69	3.60	10.14	8	0	0	8	0	0	0	0	4
	Rubiaceae	1.63	56	6.89	10.07	8.48	44	4	8	0	0	0	0	0	0
	Sapotaceae	1.24	40	5.25	7.19	6.22	24	12	4	0	0	0	0	0	0
	Ulmaceae	0.71	36	3.01	6.47	4.74	32	4	0	0	0	0	0	0	0
	Clusiaceae	0.50	24	2.11	4.32	3.21	20	4	0	0	0	0	0	0	0
	Rutaceae	0.53	20	2.24	3.60	2.92	12	8	0	0	0	0	0	0	0
	Fagaceae	0.86	12	3.62	2.16	2.89	0	8	0	4	0	0	0	0	0
	Burseraceae	0.37	20	1.55	3.60	2.57	16	4	0	0	0	0	0	0	0
	Picrodendraceae	0.75	8	3.17	1.44	2.30	0	4	0	4	0	0	0	0	0
	Ebenaceae	0.24	20	1.00	3.60	2.30	20	0	0	0	0	0	0	0	0
	Calophyllaceae	0.88	4	3.70	0.72	2.21	0	0	0	0	4	0	0	0	0
	Putranjivaceae	0.34	16	1.43	2.88	2.16	12	4	0	0	0	0	0	0	0
	Rhizophoraceae	0.57	8	2.42	1.44	1.93	0	4	4	0	0	0	0	0	0
	Anacardiaceae	0.32	8	1.34	1.44	1.39	4	4	0	0	0	0	0	0	0
	Chrysobalanaceae	0.17	8	0.73	1.44	1.09	8	0	0	0	0	0	0	0	0
	Theaceae	0.14	8	0.60	1.44	1.02	8	0	0	0	0	0	0	0	0
	Lauraceae	0.11	8	0.46	1.44	0.95	8	0	0	0	0	0	0	0	0
	Magnoliaceae	0.22	4	0.92	0.72	0.82	0	4	0	0	0	0	0	0	0
	Elaeocarpaceae	0.15	4	0.64	0.72	0.68	0	4	0	0	0	0	0	0	0
	Casuarinaceae	0.12	4	0.53	0.72	0.62	4	0	0	0	0	0	0	0	0
	Myristicaceae	0.11	4	0.48	0.72	0.60	4	0	0	0	0	0	0	0	0
	Podocarpaceae	0.10	4	0.41	0.72	0.56	4	0	0	0	0	0	0	0	0
	Aquifoliaceae	0.10	4	0.40	0.72	0.56	4	0	0	0	0	0	0	0	0
	Sapindaceae	0.07	4	0.29	0.72	0.50	4	0	0	0	0	0	0	0	0
	Melastomataceae	0.06	4	0.26	0.72	0.49	4	0	0	0	0	0	0	0	0
	Ixonanthaceae	0.04	4	0.16	0.72	0.44	4	0	0	0	0	0	0	0	0
	Salicaceae	0.04	4	0.15	0.72	0.44	4	0	0	0	0	0	0	0	0
	Grand Total	23.66	556	100.00	100.00	100.00	340	136	40	32	4	0	0	0	4

Forest Ecosystem	Family	Basal Area (m^2ha^{-1})	Density (ha^{-1})	Rel. BA.	Rel. Den.	Rel. Dom.	10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9	≥90.0
Upland ultramafic forest	Dipterocarpaceae	20.51	168	43.45	17.72	30.59	80	24	16	12	12	4	4	12	4
	Myrtaceae	6.32	196	13.39	20.68	17.03	128	48	16	4	0	0	0	0	0
	Euphorbiaceae	4.50	44	9.53	4.64	7.09	16	8	8	4	0	8	0	0	0
	Anacardiaceae	2.32	48	4.92	5.06	4.99	24	12	8	4	0	0	0	0	0
	Rubiaceae	1.17	64	2.47	6.75	4.61	56	8	0	0	0	0	0	0	0
	Simaroubaceae	1.13	48	2.38	5.06	3.72	36	12	0	0	0	0	0	0	0
	Celastraceae	1.62	36	3.42	3.80	3.61	16	16	4	0	0	0	0	0	0
	Fagaceae	1.37	28	2.90	2.95	2.93	20	4	0	0	4	0	0	0	0
	Sapotaceae	0.70	36	1.49	3.80	2.64	24	12	0	0	0	0	0	0	0
	Ebenaceae	0.51	36	1.07	3.80	2.43	36	0	0	0	0	0	0	0	0
	Ctenolophonaceae	1.01	24	2.14	2.53	2.33	8	12	4	0	0	0	0	0	0
	Clusiaceae	0.99	24	2.09	2.53	2.31	8	12	4	0	0	0	0	0	0
	Rutaceae	0.76	24	1.62	2.53	2.08	12	12	0	0	0	0	0	0	0
	Melastomataceae	0.35	24	0.74	2.53	1.64	24	0	0	0	0	0	0	0	0
	Burseraceae	0.59	16	1.25	1.69	1.47	8	8	0	0	0	0	0	0	0
	Theaceae	0.56	12	1.19	1.27	1.23	4	4	4	0	0	0	0	0	0
	Calophyllaceae	0.33	16	0.69	1.69	1.19	16	0	0	0	0	0	0	0	0
	Pentaphylacaceae	0.33	12	0.70	1.27	0.98	8	4	0	0	0	0	0	0	0
	Myristicaceae	0.27	12	0.56	1.27	0.91	8	4	0	0	0	0	0	0	0
	Stemonuraceae	0.39	8	0.82	0.84	0.83	0	8	0	0	0	0	0	0	0
	Chrysobalanaceae	0.18	12	0.37	1.27	0.82	12	0	0	0	0	0	0	0	0
	Putranjivaceae	0.23	8	0.48	0.84	0.66	8	0	0	0	0	0	0	0	0
	Elaeocarpaceae	0.22	8	0.46	0.84	0.65	4	4	0	0	0	0	0	0	0
	Olacaceae	0.17	8	0.37	0.84	0.61	8	0	0	0	0	0	0	0	0
	Crypteroniaceae	0.17	8	0.35	0.84	0.60	4	4	0	0	0	0	0	0	0
	Magnoliaceae	0.09	8	0.19	0.84	0.52	8	0	0	0	0	0	0	0	0
	Malvaceae	0.20	4	0.43	0.42	0.43	0	4	0	0	0	0	0	0	0
	Rhizophoraceae	0.11	4	0.24	0.42	0.33	4	0	0	0	0	0	0	0	0
	Podocarpaceae	0.06	4	0.13	0.42	0.28	4	0	0	0	0	0	0	0	0
	Myrsinaceae	0.04	4	0.08	0.42	0.25	4	0	0	0	0	0	0	0	0
	Lecythidaceae	0.03	4	0.07	0.42	0.25	4	0	0	0	0	0	0	0	0
	Grand Total	47.21	948	100.00	100.00	100.00	592	220	64	24	16	12	4	12	4

Forest Ecosystem	Family	Basal Area (m^2ha^{-1})	Density (ha^{-1})	Rel. BA.	Rel. Den.	Rel. Dom.	10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9	≥90.0
Lowland mixed dipterocarp forest	Dipterocarpaceae	17.19	144	43.45	29.03	36.24	56	28	24	4	4	20	4	0	4
	Anacardiaceae	10.57	52	26.72	10.48	18.60	8	16	4	4	4	8	0	4	4
	Ebenaceae	2.25	64	5.69	12.90	9.29	36	20	8	0	0	0	0	0	0
	Malvaceae	2.43	48	6.15	9.68	7.91	20	16	12	0	0	0	0	0	0
	Lamiaceae	2.19	48	5.55	9.68	7.61	20	16	12	0	0	0	0	0	0
	Fabaceae	0.59	40	1.49	8.06	4.78	40	0	0	0	0	0	0	0	0
	Calophyllaceae	0.59	12	1.50	2.42	1.96	4	4	4	0	0	0	0	0	0
	Moraceae	0.38	12	0.96	2.42	1.69	8	4	0	0	0	0	0	0	0
	Myrtaceae	0.69	8	1.75	1.61	1.68	0	4	4	0	0	0	0	0	0
	Phyllanthaceae	0.16	12	0.41	2.42	1.41	12	0	0	0	0	0	0	0	0
	Meliaceae	0.78	4	1.98	0.81	1.39	0	0	0	4	0	0	0	0	0
	Sapindaceae	0.53	4	1.33	0.81	1.07	0	0	0	4	0	0	0	0	0
	Euphorbiaceae	0.17	8	0.42	1.61	1.02	4	4	0	0	0	0	0	0	0
	Sapotaceae	0.16	8	0.40	1.61	1.01	8	0	0	0	0	0	0	0	0
	Lecythidaceae	0.29	4	0.73	0.81	0.77	0	0	4	0	0	0	0	0	0
	Myristicaceae	0.14	4	0.36	0.81	0.58	0	4	0	0	0	0	0	0	0
	Celastraceae	0.13	4	0.33	0.81	0.57	0	4	0	0	0	0	0	0	0
	Stemonuraceae	0.12	4	0.30	0.81	0.55	4	0	0	0	0	0	0	0	0
	Putranjivaceae	0.06	4	0.16	0.81	0.48	4	0	0	0	0	0	0	0	0
	Rubiaceae	0.06	4	0.15	0.81	0.48	4	0	0	0	0	0	0	0	0
	Simaroubaceae	0.04	4	0.11	0.81	0.46	4	0	0	0	0	0	0	0	0
	Annonaceae	0.03	4	0.08	0.81	0.44	4	0	0	0	0	0	0	0	0
	Grand Total	39.57	496	100.00	100.00	100.00	236	120	72	16	8	28	4	4	8

APPENDIX III Species Importance Value Index

Forest Ecosystem	Species	Basal Area (m^2ha^{-1})	Density (ha^{-1})	Rel. BA.	Rel. Den.	Rel. Dom.	10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9	≥90.0
Upper montane ultramafic forest	*Santiria* sp.	3.23	183.3	9.81	14.13	11.97	155.1	28.2	0	0	0	0	0	0	0
	Maclurodendron sp.	3.50	126.9	10.63	9.78	10.20	70.5	56.4	0	0	0	0	0	0	0
	Pouteria sp.	5.38	28.2	16.32	2.17	9.25	0	0	0	14.1	14.1	0	0	0	0
	Syzygium sp.	3.03	112.8	9.20	8.70	8.95	84.6	28.2	0	0	0	0	0	0	0
	Gynotroches axillaris	1.99	141	6.05	10.87	8.46	141	0	0	0	0	0	0	0	0
	Ixonanthes sp.	1.89	84.6	5.73	6.52	6.12	56.4	28.2	0	0	0	0	0	0	0
	Castanopsis sp.	2.36	56.4	7.17	4.35	5.76	14.1	42.3	0	0	0	0	0	0	0
	Schima wallichii	2.05	56.4	6.21	4.35	5.28	28.2	14.1	14.1	0	0	0	0	0	0
	Garcinia sp.	1.06	70.5	3.23	5.43	4.33	70.5	0	0	0	0	0	0	0	0
	Timonius sp.	1.25	56.4	3.78	4.35	4.07	42.3	14.1	0	0	0	0	0	0	0
	Falcatifolium falciforme	0.78	56.4	2.37	4.35	3.36	56.4	0	0	0	0	0	0	0	0
	Ilex sp.	0.81	42.3	2.44	3.26	2.85	42.3	0	0	0	0	0	0	0	0
	Ternstroemia aneura	1.04	28.2	3.15	2.17	2.66	14.1	14.1	0	0	0	0	0	0	0
	Lithocarpus sp.	0.65	42.3	1.98	3.26	2.62	42.3	0	0	0	0	0	0	0	0
	Elaeocarpus sp.	0.65	28.2	1.97	2.17	2.07	28.2	0	0	0	0	0	0	0	0
	Madhuca sp.	0.46	28.2	1.40	2.17	1.79	28.2	0	0	0	0	0	0	0	0
	Homalium sp.	0.36	28.2	1.10	2.17	1.64	28.2	0	0	0	0	0	0	0	0
	Podocarpus sp.	0.72	14.1	2.18	1.09	1.64	0	14.1	0	0	0	0	0	0	0
	Gluta sp.	0.39	14.1	1.19	1.09	1.14	14.1	0	0	0	0	0	0	0	0
	Porterandia postarii	0.39	14.1	1.18	1.09	1.13	14.1	0	0	0	0	0	0	0	0
	Melanochyla sp.	0.20	14.1	0.59	1.09	0.84	14.1	0	0	0	0	0	0	0	0
	Helicia sp.	0.19	14.1	0.57	1.09	0.83	14.1	0	0	0	0	0	0	0	0
	Beilschmiedia sp.	0.18	14.1	0.55	1.09	0.82	14.1	0	0	0	0	0	0	0	0
	Castanopsis cf. *kinabaluensis*	0.15	14.1	0.45	1.09	0.77	14.1	0	0	0	0	0	0	0	0
	Myrsine sp.	0.12	14.1	0.38	1.09	0.73	14.1	0	0	0	0	0	0	0	0
	Drypetes sp.	0.12	14.1	0.36	1.09	0.73	14.1	0	0	0	0	0	0	0	0
	Grand Total	32.94	1297.2	100.00	100.00	100.00	1015.2	239.7	14.1	14.1	14.1	0	0	0	0

Forest Ecosystem	Species	Basal Area (m^2ha^{-1})	Density (ha^{-1})	Rel. BA.	Rel. Den.	Rel. Dom.	10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9	≥90.0
Lower montane ultramafic forest	*Syzygium* sp.	3.73	76	15.77	13.67	14.72	24	40	8	4	0	0	0	0	0
	Shorea venulosa	3.62	48	15.30	8.63	11.97	4	24	8	12	0	0	0	0	0
	Borneodendron aenigmaticum	3.92	16	16.55	2.88	9.71	4	0	0	8	0	0	0	0	0
	Timonius sp.	1.47	48	6.22	8.63	7.43	36	4	8	0	0	0	0	0	0
	Shorea sp.	0.71	48	2.99	8.63	5.81	48	0	0	0	0	0	0	0	0
	Gironniera subaequalis	0.71	36	3.01	6.47	4.74	32	4	0	0	0	0	0	0	0
	Madhuca sp.	0.95	28	4.00	5.04	4.52	16	8	4	0	0	0	0	0	0
	Tristaniopsis musa-amanii	1.09	12	4.60	2.16	3.38	0	4	8	0	0	0	0	0	0
	Garcinia sp.	0.50	24	2.11	4.32	3.21	20	4	0	0	0	0	0	0	0
	Maclurodendron sp.	0.53	20	2.24	3.60	2.92	12	8	0	0	0	0	0	0	0
	Austrobuxus sp.	0.75	8	3.17	1.44	2.30	0	4	0	4	0	0	0	0	0
	Calophyllum sp.	0.88	4	3.70	0.72	2.21	0	0	0	0	4	0	0	0	0
	Lithocarpus sp.	0.69	8	2.91	1.44	2.18	0	4	0	4	0	0	0	0	0
	Drypetes sp.	0.34	16	1.43	2.88	2.16	12	4	0	0	0	0	0	0	0
	Santiria sp.	0.33	16	1.41	2.88	2.14	12	4	0	0	0	0	0	0	0
	Gynotroches axillaris	0.57	8	2.42	1.44	1.93	0	4	4	0	0	0	0	0	0
	Diospyros sp.	0.17	12	0.73	2.16	1.44	12	0	0	0	0	0	0	0	0
	Gluta sp.	0.32	8	1.34	1.44	1.39	4	4	0	0	0	0	0	0	0
	Licania splendens	0.17	8	0.73	1.44	1.09	8	0	0	0	0	0	0	0	0
	Shorea atrinervosa	0.11	8	0.48	1.44	0.96	8	0	0	0	0	0	0	0	0
	Litsea cylindrocarpa	0.11	8	0.46	1.44	0.95	8	0	0	0	0	0	0	0	0
	Rhodamnia cinerea	0.10	8	0.40	1.44	0.92	8	0	0	0	0	0	0	0	0
	Diospyros elliptifolia	0.07	8	0.28	1.44	0.86	8	0	0	0	0	0	0	0	0
	Magnolia cf. *bakunensis*	0.22	4	0.92	0.72	0.82	0	4	0	0	0	0	0	0	0
	Pouteria sp.	0.22	4	0.92	0.72	0.82	0	4	0	0	0	0	0	0	0
	Castanopsis sp.	0.17	4	0.71	0.72	0.71	0	4	0	0	0	0	0	0	0
	Elaeocarpus cf. *pedunculatus*	0.15	4	0.64	0.72	0.68	0	4	0	0	0	0	0	0	0
	Gymnostoma sumatranum	0.12	4	0.53	0.72	0.62	4	0	0	0	0	0	0	0	0
	Myristica sp.	0.11	4	0.48	0.72	0.60	4	0	0	0	0	0	0	0	0
	Schima wallichii	0.10	4	0.42	0.72	0.57	4	0	0	0	0	0	0	0	0
	Falcatifolium falciforme	0.10	4	0.41	0.72	0.56	4	0	0	0	0	0	0	0	0
	Ilex sp.	0.10	4	0.40	0.72	0.56	4	0	0	0	0	0	0	0	0
	Porterandia postarii	0.08	4	0.35	0.72	0.53	4	0	0	0	0	0	0	0	0
	Canthium sp.	0.08	4	0.33	0.72	0.52	4	0	0	0	0	0	0	0	0
	Guioa sp.	0.07	4	0.29	0.72	0.50	4	0	0	0	0	0	0	0	0
	Memecylon sp.	0.06	4	0.26	0.72	0.49	4	0	0	0	0	0	0	0	0
	Palaquium gutta	0.05	4	0.19	0.72	0.46	4	0	0	0	0	0	0	0	0
	Gordonia sp.	0.04	4	0.18	0.72	0.45	4	0	0	0	0	0	0	0	0
	Ixonanthes sp.	0.04	4	0.16	0.72	0.44	4	0	0	0	0	0	0	0	0
	Casearia sp.	0.04	4	0.15	0.72	0.44	4	0	0	0	0	0	0	0	0
	Canarium littorale	0.03	4	0.14	0.72	0.43	4	0	0	0	0	0	0	0	0
	Macaranga cf. *kinabaluensis*	0.03	4	0.14	0.72	0.43	4	0	0	0	0	0	0	0	0
	Palaquium sp.	0.03	4	0.14	0.72	0.43	4	0	0	0	0	0	0	0	0
	Grand Total	23.66	556	100.00	100.0	100.00	340	136	40	32	4	0	0	0	0

Forest Ecosystem	Species	Basal Area (m^2ha^{-1})	Density (ha^{-1})	Rel. BA.	Rel. Den.	Rel. Dom.	10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9	≥90.0
Upland montane ultramafic forest	*Shorea venulosa*	15.76	56	33.39	5.91	19.65	8	0	12	4	8	4	4	12	4
	Syzygium sp.	3.16	108	6.69	11.39	9.04	72	32	4	0	0	0	0	0	0
	Borneodendron aenigmaticum	4.50	44	9.53	4.64	7.09	16	8	8	4	0	8	0	0	0
	Timonius sp.	1.05	60	2.22	6.33	4.28	52	8	0	0	0	0	0	0	0
	Syzygium sp. 3	1.99	40	4.21	4.22	4.21	16	16	4	4	0	0	0	0	0
	Ailanthus sp.	1.13	48	2.38	5.06	3.72	36	12	0	0	0	0	0	0	0
	Vatica micrantha	1.08	48	2.30	5.06	3.68	36	12	0	0	0	0	0	0	0
	Lophopetalum subovatum	1.62	36	3.42	3.80	3.61	16	16	4	0	0	0	0	0	0
	Shorea multiflora	1.96	24	4.15	2.53	3.34	12	4	0	4	4	0	0	0	0
	Gluta oba	1.14	24	2.41	2.53	2.47	8	8	8	0	0	0	0	0	0
	Garcinia sp.	0.99	24	2.09	2.53	2.31	8	12	4	0	0	0	0	0	0
	Diospyros sp.	0.47	32	1.00	3.38	2.19	32	0	0	0	0	0	0	0	0
	Maclurodendron sp.	0.76	24	1.62	2.53	2.08	12	12	0	0	0	0	0	0	0
	Ctenolophon parvifolius	0.85	20	1.80	2.11	1.95	8	8	4	0	0	0	0	0	0
	Lithocarpus sp.	0.39	24	0.82	2.53	1.67	20	4	0	0	0	0	0	0	0
	Memecylon sp.	0.35	24	0.74	2.53	1.64	24	0	0	0	0	0	0	0	0
	Palaquium gutta	0.53	20	1.13	2.11	1.62	8	12	0	0	0	0	0	0	0
	Syzygium sp. 4	0.49	20	1.04	2.11	1.58	16	0	4	0	0	0	0	0	0
	Shorea atrinervosa	0.65	16	1.37	1.69	1.53	8	4	4	0	0	0	0	0	0
	Santiria sp.	0.59	16	1.25	1.69	1.47	8	8	0	0	0	0	0	0	0
	Shorea andulensis	0.74	12	1.56	1.27	1.41	8	0	0	4	0	0	0	0	0
	Castanopsis sp.	0.98	4	2.09	0.42	1.25	0	0	0	0	4	0	0	0	0
	Gluta cf. *oba*	0.66	8	1.40	0.84	1.12	4	0	0	4	0	0	0	0	0
	Parishia maingayi	0.44	12	0.93	1.27	1.10	8	4	0	0	0	0	0	0	0
	Horsfieldia sp.	0.27	12	0.56	1.27	0.91	8	4	0	0	0	0	0	0	0
	Calophyllum nodosum	0.24	12	0.51	1.27	0.89	12	0	0	0	0	0	0	0	0
	Gordonia sp.	0.39	8	0.83	0.84	0.84	4	0	4	0	0	0	0	0	0
	Stemonurus grandifolius	0.39	8	0.82	0.84	0.83	0	8	0	0	0	0	0	0	0
	Rhodamnia cinerea	0.12	12	0.25	1.27	0.76	12	0	0	0	0	0	0	0	0
	Ternstroemia sp.	0.29	8	0.61	0.84	0.72	4	4	0	0	0	0	0	0	0
	Drypetes sp.	0.23	8	0.48	0.84	0.66	8	0	0	0	0	0	0	0	0
	Elaeocarpus sp.	0.22	8	0.46	0.84	0.65	4	4	0	0	0	0	0	0	0
	Anacolosa sp.	0.17	8	0.37	0.84	0.61	8	0	0	0	0	0	0	0	0
	Axinandra beccariana	0.17	8	0.35	0.84	0.60	4	4	0	0	0	0	0	0	0
	Syzygium sp. 5	0.35	4	0.75	0.42	0.59	0	0	4	0	0	0	0	0	0
	Atuna cordata	0.12	8	0.26	0.84	0.55	8	0	0	0	0	0	0	0	0
	Magnolia sp.	0.09	8	0.19	0.84	0.52	8	0	0	0	0	0	0	0	0
	Pouteria sp.	0.08	8	0.17	0.84	0.51	8	0	0	0	0	0	0	0	0
	Durio acutifolius	0.20	4	0.43	0.42	0.43	0	4	0	0	0	0	0	0	0
	Schima wallichii	0.17	4	0.35	0.42	0.39	0	4	0	0	0	0	0	0	0
	Ctenolophon sp.	0.16	4	0.34	0.42	0.38	0	4	0	0	0	0	0	0	0
	Shorea cf. *venulosa*	0.14	4	0.30	0.42	0.36	0	4	0	0	0	0	0	0	0
	Syzygium sp. 2	0.12	4	0.25	0.42	0.34	4	0	0	0	0	0	0	0	0
	Diplospora borneensis	0.12	4	0.25	0.42	0.33	4	0	0	0	0	0	0	0	0
	Carallia brachiata	0.11	4	0.24	0.42	0.33	4	0	0	0	0	0	0	0	0
	Shorea beccariana	0.10	4	0.20	0.42	0.31	4	0	0	0	0	0	0	0	0
	Hopea beccariana	0.09	4	0.19	0.42	0.30	4	0	0	0	0	0	0	0	0
	Calophyllum cf. *nodosum*	0.09	4	0.18	0.42	0.30	4	0	0	0	0	0	0	0	0
	Swintonia acuta	0.08	4	0.17	0.42	0.30	4	0	0	0	0	0	0	0	0
	Podocarpus rumphii	0.06	4	0.13	0.42	0.28	4	0	0	0	0	0	0	0	0
	Syzygium caudatilimbum	0.06	4	0.12	0.42	0.27	4	0	0	0	0	0	0	0	0
	Licania splendens	0.05	4	0.11	0.42	0.27	4	0	0	0	0	0	0	0	0
	Palaquium sp.	0.05	4	0.10	0.42	0.26	4	0	0	0	0	0	0	0	0
	Ternstroemia aneura	0.04	4	0.09	0.42	0.26	4	0	0	0	0	0	0	0	0
	Madhuca sp.	0.04	4	0.09	0.42	0.26	4	0	0	0	0	0	0	0	0
	Myrsine sp.	0.04	4	0.08	0.42	0.25	4	0	0	0	0	0	0	0	0
	Syzygium bankensis	0.03	4	0.07	0.42	0.25	4	0	0	0	0	0	0	0	0
	Diospyros elliptifolia	0.03	4	0.07	0.42	0.25	4	0	0	0	0	0	0	0	0
	Barringtonia sp.	0.03	4	0.07	0.42	0.25	4	0	0	0	0	0	0	0	0
	Grand Total	47.21	948	100.00	100.00	100.00	592	220	64	24	16	12	4	12	4

Forest Ecosystem	Species	Basal Area (m^2ha^{-1})	Density (ha^{-1})	Rel. BA.	Rel. Den.	Rel. Dom.	10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9	≥90.0
Lowland mixed dipterocarp forest	*Hopea* sp.	7.05	32	17.82	6.45	12.14	12	4	0	0	4	8	0	0	4
	Gluta oba	7.20	16	18.19	3.23	10.71	0	0	0	0	4	4	0	4	4
	Diospyros sp.	2.22	60	5.60	12.10	8.85	32	20	8	0	0	0	0	0	0
	Vatica mangachapoi	2.93	44	7.41	8.87	8.14	20	8	12	0	0	4	0	0	0
	Teijsmanniodendron sp.	2.19	48	5.55	9.68	7.61	20	16	12	0	0	0	0	0	0
	Scaphium parviflorum	1.82	36	4.61	7.26	5.93	16	12	8	0	0	0	0	0	0
	Parishia maingayi	2.44	28	6.17	5.65	5.91	8	12	4	0	0	4	0	0	0
	Shorea falciferoides	2.64	16	6.68	3.23	4.95	4	0	4	4	0	0	4	0	0
	Cynometra sp.	0.49	32	1.24	6.45	3.84	32	0	0	0	0	0	0	0	0
	Vatica albiramis	0.77	28	1.94	5.65	3.79	16	12	0	0	0	0	0	0	0
	Shorea sp.	1.72	8	4.34	1.61	2.98	0	0	4	0	0	4	0	0	0
	Shorea gratissima	1.47	4	3.72	0.81	2.26	0	0	0	0	0	4	0	0	0
	Mangifera sp.	0.93	8	2.35	1.61	1.98	0	4	0	4	0	0	0	0	0
	Artocarpus odoratissimus	0.38	12	0.96	2.42	1.69	8	4	0	0	0	0	0	0	0
	Cleistanthus myrianthus	0.16	12	0.41	2.42	1.41	12	0	0	0	0	0	0	0	0
	Dysoxylum sp.	0.78	4	1.98	0.81	1.39	0	0	0	4	0	0	0	0	0
	Brownlowia stipulata	0.24	8	0.61	1.61	1.11	4	4	0	0	0	0	0	0	0
	Dimocarpus longan	0.53	4	1.33	0.81	1.07	0	0	0	4	0	0	0	0	0
	Neoscortechinia philippinensis	0.17	8	0.42	1.61	1.02	4	4	0	0	0	0	0	0	0
	Syzygium caudatilimbum	0.47	4	1.19	0.81	1.00	0	0	4	0	0	0	0	0	0
	Crudia cf. *reticulata*	0.10	8	0.25	1.61	0.93	8	0	0	0	0	0	0	0	0
	Shorea cf. *falciferoides*	0.38	4	0.97	0.81	0.89	0	0	4	0	0	0	0	0	0
	Mesua sp.	0.38	4	0.96	0.81	0.88	0	0	4	0	0	0	0	0	0
	Pentace adenophora	0.37	4	0.93	0.81	0.87	0	0	4	0	0	0	0	0	0
	Barringtonia sp.	0.29	4	0.73	0.81	0.77	0	0	4	0	0	0	0	0	0
	Syzygium sp.	0.22	4	0.55	0.81	0.68	0	4	0	0	0	0	0	0	0
	Calophyllum sakarium	0.16	4	0.40	0.81	0.60	0	4	0	0	0	0	0	0	0
	Myristica sp.	0.14	4	0.36	0.81	0.58	0	4	0	0	0	0	0	0	0
	Hopea cf. *beccariana*	0.14	4	0.35	0.81	0.58	0	4	0	0	0	0	0	0	0
	Lophopetalum cf. *beccarianum*	0.13	4	0.33	0.81	0.57	0	4	0	0	0	0	0	0	0
	Stemonurus grandifolius	0.12	4	0.30	0.81	0.55	4	0	0	0	0	0	0	0	0
	Payena ferruginea	0.09	4	0.23	0.81	0.52	4	0	0	0	0	0	0	0	0
	Shorea multiflora	0.08	4	0.21	0.81	0.51	4	0	0	0	0	0	0	0	0
	Madhuca sp.	0.07	4	0.17	0.81	0.49	4	0	0	0	0	0	0	0	0
	Drypetes sp.	0.06	4	0.16	0.81	0.48	4	0	0	0	0	0	0	0	0
	Canthium sp.	0.06	4	0.15	0.81	0.48	4	0	0	0	0	0	0	0	0
	Calophyllum nodosum	0.06	4	0.14	0.81	0.47	4	0	0	0	0	0	0	0	0
	Ailanthus sp.	0.04	4	0.11	0.81	0.46	4	0	0	0	0	0	0	0	0
	Diospyros wallichii	0.03	4	0.08	0.81	0.44	4	0	0	0	0	0	0	0	0
	Popowia sp.	0.03	4	0.08	0.81	0.44	4	0	0	0	0	0	0	0	0
	Grand Total	39.57	496	100.00	100.00	100.00	236	120	72	16	8	28	4	4	8

Field soil assessment of Mount Silam and its surrounding areas in Lahad Datu, Sabah

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Abstract. A field soil assessment was conducted during the scientific expedition to Mt. Silam and its surrounding areas in Lahad Datu, Sabah. This study was to assess and evaluate the soil condition of this particular area. Throughout the expedition, soil assessment was carried out at 7 different locations within 4 types of forest formations in Mt. Silam, namely lowland ultramafic forest, upland ultramafic forest, lowland montane forest and upper montane forest. Soils within study areas were investigated based on soil and site characteristics which include depth, colour, texture, parent material, drainage condition and slope gradient. Soil in this area is mainly covered by Bidu-bidu Association and in the southern part of Mt. Silam is covered by Gumpal Association. Bidu-bidu Association formed on mountains and hills with ultrabasic igneous rock as parent material. The association soil units include Rhodic and Orthic Ferralsoils, Eutric Cambisols, Chromic and Orthic Luvisols and as well as Lithosol. For Gumpal Association, it formed on mountains and hills with parent material mudstone, sandstone and miscellaneous rock. The soil units include Orthic Acrisols, Orthic Luvisols, Dystric and Eutric Cambisols and Lithosol. The topography of the area is generally undulating at lower altitudes and getting steeper towards the summit. Soil assessment elevation ranges from 170 m to 878 m a.s.l. The soil colour ranges from very dark grayish brown (10YR 2/3) to yellowish red (5YR 6/4) and it indicates a well-drained soil. Soil texture ranges from sandy loam to clay.

INTRODUCTION

Mt. Silam is located about 10 km from Lahad Datu town and can be accessed by road on the Lahad Datu to Tawau highway. Mt. Silam falls under Sapagaya Forest Reserve and it occupies an area of 698 ha. This reserve was gazetted as Class 1 (Protection Forest Reseve) in 2009. Mt. Silam and its surroundings were previously under stateland, and administrated under Lahad Datu District Forest Office.

Mt. Silam is an ultramafic coastal mountain facing Darvel Bay, with the highest level point of 884 m a.s.l. Mt. Silam presence of compression of vegetation zonation called ‘Masserhebung’ on this small ultramafic mountain. With an elevation ranges between 200 m – 884 m in altitude, Mt. Silam forest can be classfied into 4 forest formations, namely: (1) lowland ultramafic forest (elevation from 200 m – 330 m in altitude) (2) upland ultramafic forest (elevation from 330 – 540 m), (3) lower montane ultramafic forest (elevation from 540 – 770 m) and (4) upper montane forest (mossy forest) with elevation above 770 m.

A scientific expedition organized by Sabah Forestry Department was conducted at this ultramafic site of Mt. Silam from 13th to 18th January 2020, aimed to

compile various research findings for the development of Payment for Ecosystem Services (PES) Project. During this scientific expedition, a field soil assessment study was conducted to assess and evaluate the soil condition of Mt. Silam and its surrounding areas. Soil is the fundamental resource of the forest and it plays an important role in forest growth and management. Soil helps to regulate importance of forest ecosystem which includes decomposition, water availability, nutrient uptake and potential carbon storage through soil organic matter (SOM) management (FAO 2015). Reliable data from soil assessment activity can promote sustainable forest management, soil productivity and watershed conservation.

METHODOLOGY

Study site

Mt. Silam is geographically located between latitude 04°57'- 04°59' and longitude 118°10' - 118°14'. The northern-west part of Mt. Silam is surrounded with private land, mostly planted with oil palm.

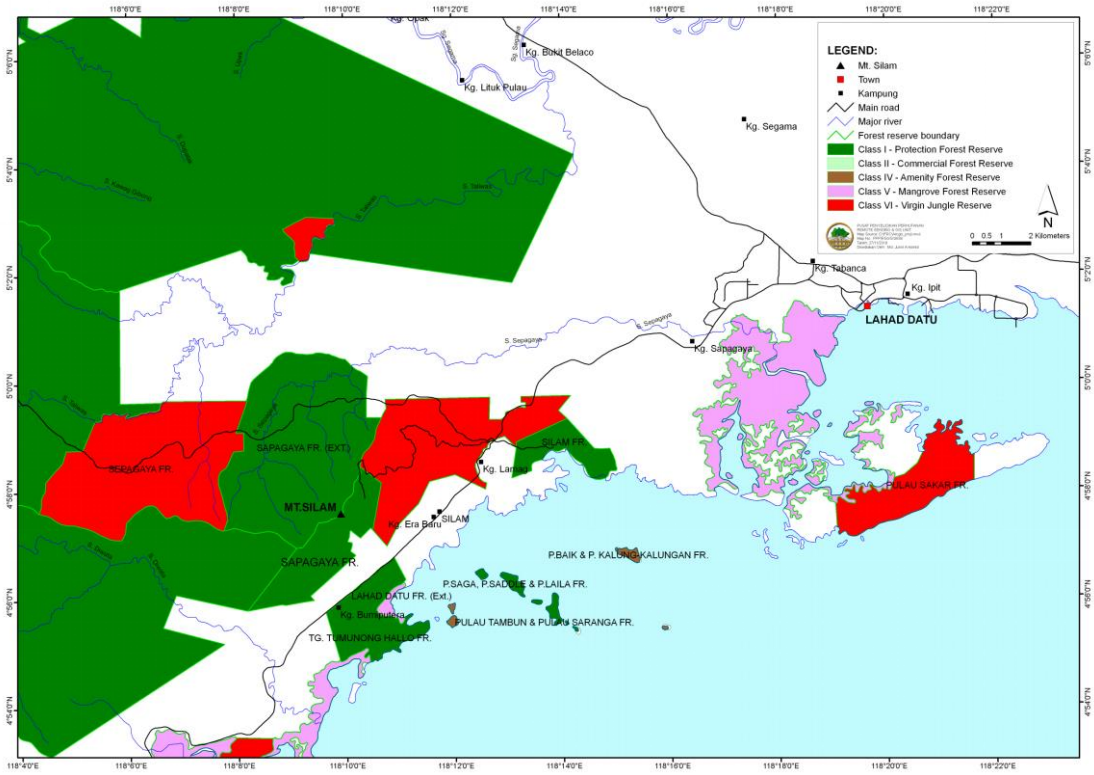

Figure 1. Location map of Mt. Silam in Lahad Datu.

Topography and soil associations

The topography of Mt. Silam is generally undulating at lower altitude and getting steeper at the summit. Soils in Mt. Silam are classified as approximately 90% under Bidu-bidu and 10% Gumpal Associations.

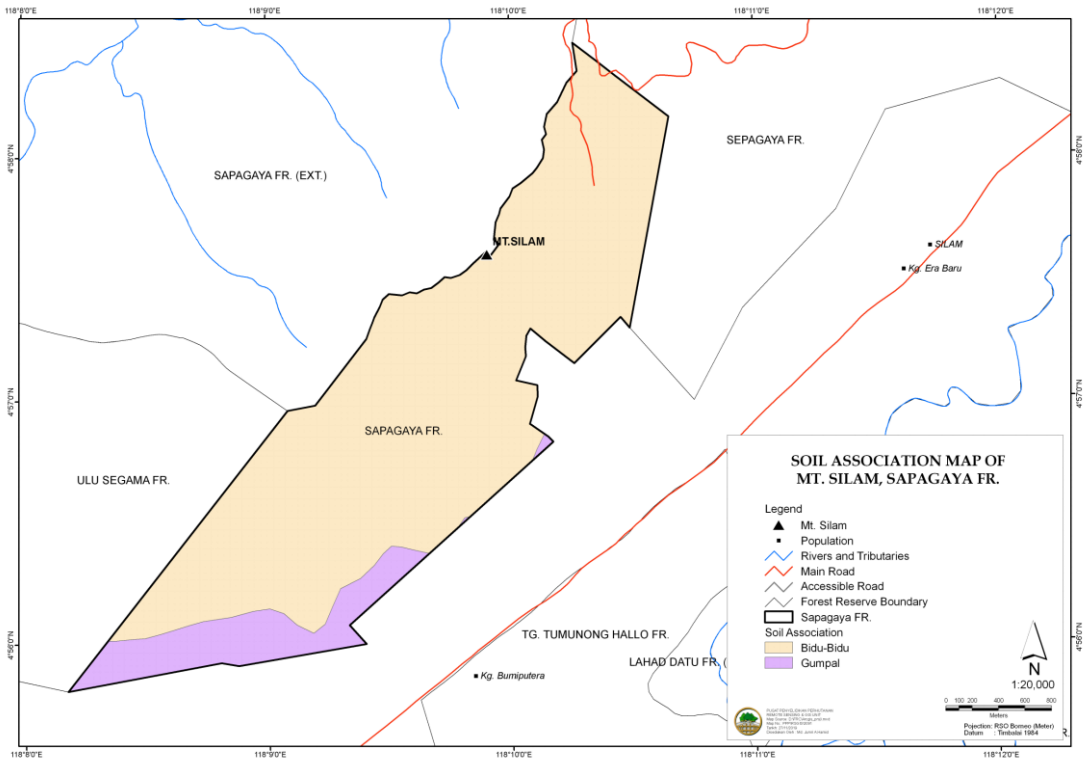

Figure 2. Soil associations in Mt. Silam area.

Materials

Materials used in this study included a soil auger, GPS, Munsell Colour Chart, soil description hand book, plastic bags, camera and measuring tape.

Soil assessment

Soil assessment was conducted at seven different locations within these four forest formations. Soils within the study sites were investigated based on its soil characteristics, such as depth, colour, texture, parent material, drainage condition and slope gradient. Soil profiles were examined using the soil auger. Soil samples (depth 0-15 cm and 15-30 cm) were collected for laboratory analysis. GPS coordinates of all soil assessment points were recorded.

RESULTS AND DISCUSSION

Table 1. Soil assessment GPS point, forest formations, elevations and drainage conditions.

Soil Assessment label	GPS Point	Forest Formation	Elevation (m.a.s.l)	Drainage condition
SA 1	04° 57’ 32.1” 118° 10’ 03.1”	Upper Montane Forest	878 m	Well drained
SA 2	04° 58’ 02.4” 118° 10’ 15.6”	Lowland Montane Forest	746 m	Well drained
SA 3	04° 57’ 59.2” 118° 10’ 21.7”	Lowland Montane Forest	684 m	Well drained
SA 4	04° 58’ 20.8” 118° 10’ 24.3”	Lowland Montane Forest	565 m	Well drained
SA 5	04° 58’ 18.9” 118° 10’ 39.7”	Upland Ultramafic Forest	405 m	Well drained
SA 6	04° 58’ 46.9” 118° 11’ 59.4”	Lowland Ultramafic Forest	249 m	Well drained
SA 7	04° 58’ 46.5” 118° 12’33.0”	Lowland Ultramafic Forest	170 m	Well drained

Table 2. Soil depth, colour and texture.

Soil Assessment Label	Soil Depth (cm)	Soil colour	Soil texture
SA 1	0 - 8	Debris	
	8 -18	Dark brown (10YR 3/3)	Sandy clay loam (M-TS)
	19 - 30	Dark grayish brown (10YR 2/4)	Sandy clay (F-TS)
	30 - 48	Strong brown (7.5YR 8/5)	Clay (F-TS)
SA 2	0 - 4	Debris	
	4 - 21	Brown (7.5YR 3/4)	Sandy loam (C-TS)
	21 - 70	Strong brown (7.5YR 6/4)	Clay loam(F-TS)
	70 - 84	Yellowish red (5YR 6/4)	Clay (F-TS)
SA 3	0 - 3	Debris	
	3 - 14	Dark yellowish brown (10YR 6/4)	Sandy loam (C-TS)
	14 - 46	Yellowish red (5YR 6/4)	Sandy clay (F-TS)
	46 - 84	Reddish brown (5YR 4/4)	Clay (F-TS)
SA 4	0 - 6	Debris	
	6 - 11	Dark reddish brown (5YR 4/3)	Sandy clay (F-TS)
	11 - 67	Yellowish red (5YR 6/4)	Loam (M-TS)
	67 - 100	Reddish brown (5YR 4/4)	Sandy clay loam (M-TS)
SA 5	0 - 2	Debris	
	2 - 6	Dark reddish brown (5YR 2/3)	Loamy sand (C-TS)
	6 - 38	Dark brown (10YR 3/3)	Loam (F-TS)
	38 - 92	Strong brown (7.5YR 6/4)	Clay loam (F-TS)
SA 6	0 - 2	Debris	
	2 - 15	Dark brown (10YR 3/3)	Loam (M-TS)
	15 - 34	Dark yellowish brown (10YR 4/3)	Clay loam (F-TS)
	34 - 50	Brown (7.5Yr 2/4) & Gray (7.5YR 8/5)	Clay (F-TS)
SA 7	0 - 4	Debris	
	4 - 14	Very dark grayish brown (10YR 2/3)	Sandy clay (F-TS)
	14 -25	Dark brown (7.5YR 2/3)	Loam (F-TS)
	25 - 50	Brown (10YR 3/4)	Sandy Clay loam (M-TS)

Remarks: **C-TS** refers to Coarse-Textured Soils, **M-TS** refers to Medium-Textured soils and **F-TS** refers to Fine-Textured soils.

Ultrabasic soil profile of Mt. Silam

Figure 3. Soil profile of SA 1.

Figure 4. Soil profile of SA 2.

Figure 5. Soil profile of SA 3.

Figure 6. Soil profile of SA 4.

Figure 7. Soil profile of SA 5.

Figure 8. Soil profile of SA 6.

Figure 9. Soil profile of SA 7.

Bidu-bidu Association

Bidu-bidu association is the only association mapped on ultrabasic igneous rocks (Acres *et al*. 1975). It formed on parent materials derived from ultrabasic igneous soil and occurs on mountains and hills of ultrabasic rocks. This association comprises soil units Rhodic and Orthic Ferralsols, Eutric Cambisols, Chromic and Orthic Luvisols and Lithosols (Afandy *et al.* 2016).

Gumpal Association

Gumpal association formed on parent materials derived from slump mudstone, sandstone and miscellaneous rock (Acres *et al*. 1975). It occurs on hills and mountains with steep slopes, often greater than 25° and narrow ridges. Dominant soil units comprise Orthic aerisols, Orthic Luvisols, Dystric and Eutric Cambisols and Lithosol (Afandy *et al.* 2016).

Findings, potential treats and recommendations

Ultrabasic soils of Mt. Silam are slightly acidic with high contains of concentration of magnesium, iron, and other metals, such as chromium and cobalt, especially at the deeper horizons (Proctor *et al.* 1988). Mt. Silam soil contains low silica level and lack in major plant nutrient, such as nitrogen, phosphorus and potassium. Due to these soil types, trees in this area are forced to adapt and grow in ultramafic substrates, with nutrient deficiency and some minerals are toxic to the plants/trees. Forest statue in Mt. Silam is relatively shorter as compared to other forests that grow on fertile soils. When the forest stature decreases, stem density increase with increasing elevation.

Darker brown soil found in Mt.Silam indicates the soils are freely drained (well drained) and it has a high proportion of sand, especially in the upper horizon. The soil texture refers to the percentage ratio of sand, silt and clay size particles in the soil layer (Tabor *et al*. 2017). Examining the soil texture is an important component in soil assessment as texture influences the soil characteristics, including structure, water holding capacity and water, air and nutrient availability. Soil texture is divided into 3 main classes, include coarse-textured soils (C-TS), medium-textured soil (M-TS) and fine-textured soils (F-TS). Coarse textured soils (C-TS) have relatively large pores for easy air and water movement, good drainage but low in water holding capacity and poor nutrient. Medium textured soils (M-TS) have good air and water movement where the pore space provides optimal water holding capacity and nutrient availability. For Fine-Textured soils (F-TS), the general characteristic is relatively tiny pores restrict air and water holding, heavy and sticky with high water holding capacity and high nutrient availability. Out of these 3 soil texture classes, the medium textured soils (M-TS) have relatively even mixture of sand, silt and clay. However, F-TS holds high nutrient as compared to C-TS and M-TS. From the assessment, soil texture in Mt. Silam and its surrounding areas is mostly classified to fine-textured soils except in SA 2, 3 and 5 with C-TS at upper horizon/layer, and M-TS found in SA 1 at depth 8-18cm, SA 4 at depth 11cm to 100cm, SA 6 at depth 2-15cm and SA 7 at depth 25-52cm. The soil texture for Mt. Silam ranges from sandy loam to clay. Mt. Silam presences shallow soil thickness at upper montane forest (SA 1) and lowland ultramafic forest (SA 6 & 7), with depth 48cm-50cm. Deeper soil thickness can be

seen at the upland ultramafic forest (SA 5) and lowland ultramafic forest (SA 2-4) with depth from 84 cm-100 cm. Soil depth or thickness defines the root space and the volume of soil from where trees fulfill their water and their nutrient demand (Kosmas *et al.* 1999). Deeper soil generally can provide more water and nutrient to plant than shallow soil. Soil erosion depends largely on the thickness and quality of topsoil and on the nature of the subsoil. Deeper soils with thick topsoil and excellent subsoil properties may eventually unaffected by erosion. Soil in mountains and hilly areas are limited for agriculture, however it forms the main water catchments of the major rivers, and disturbance of its vegetation and soil would increase further adverse effect of flooding on its plains.

Mt. Silam may be proned to the threats by human activities, such as illegal forest harvesting, poaching and open burning as this area is adjacent to oil palm plantations and kampongs. Human encroachment over and over again might trample vegetation and soil, eventually causing damage that can lead to soil erosion, loss of biodiversity and any other negative impacts. Therefore, some recommendations are needed to conserve this forest ecosystem that comprises comprehensive forest fire prevention, especially during long draught, regular patrolling, boundary demarcation, avoid disturbing soil surface, and retain fallen trees, branches and litters for ground cover, nutrient cycling and organic matter retention.

CONCLUSIONS

Soils in Mt. Silam are classified into 2 associations, namely Bidu-Bidu (covered up 90% of entire areas) and Gumpal Association. Bidu- bidu Association formed on mountains and hills with ultrabasic igneous rock as parent material. This association soil units include Rhodic and Orthic Ferralsoils, Eutric Cambisols, Chromic and Orthic Luvisols and as well as Lithosol. For Gumpal association, it is formed on mountains and hills with parent material mudstone, sandstone and miscellaneous rock. The soil units include Orthic Acrisols, Orthic Luvisols, Dystric and Eutric Cambisols and Lithosol. The topography of the area is generally undulating at lower altitudes and getting steeper to the summit. The elevation of soil assessment points were from 170 m a.s.l. to 878 m a.s.l. The soil colour ranges from very dark grayish brown (10YR 2/3) to yellowish red (5YR 6/4) and it indicates a well drained soil. Soil texture ranges from sandy loam to clay. Mt. Silam presents shallow soil thickness at upper montane forest (SA 1) and lowland ultramafic forest (SA 6 & 7), with depth 48 cm-50 cm. Deeper soil thickness can be seen at the upland ultramafic forest (SA 5) and lowland ultramafic forest (SA 2-4) with depth from 84 cm-100 cm. Mt. Silam is subject to human encroahment as this area is adjacent to oil palm land and kampongs. Hence, some recommendation strategies are needed to conserve this unique ecosystem.

ACKNOWLEDGEMENTS

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REFERENCES

Acres, B.P., Bower, R.P., Folland, C.J., Kalsi, M.S., Thomas, P. & Wright, P.S. (1975). The soils of Sabah. Vols. 1-5. In: Land Resources Division (cds) Land Resources Study, Ministry of Overseas Development Survey, United Kingdom.

Afandy, A.M., Zulkifli, H., Khalid, H., Hasnol, O., Nur Zuhaili, H.A.Z.A. & Zuraidah, T. (2016). Oil palm fertiliser recommendation for Sabah soils. *Oil Palm Bulletin* (72): 1-24.

FAO (2015). Forest and forest soils: an essential contribution to agriculture and global food security. Food and Agriculture Organization of the United Nations.

Kosmas, C., Kirkby, M. & Geeson, N. (1999). Manual on: Key indicators of disertification and mapping environmentally sensitive area to disertification. European Commision, Energy, Environment and Sustainable Development, EUR 18882, 87 p.

Proctor, J., Lee, Y.F., Langley, A.M., Munro, W.R.C., Nelson, T. (1988). Ecology studies on Gunung Silam, a small ultrabasic mountain in Sabah, Malaysia. *Journal of Ecology* 76: 320-340.

Tabor, N.T., Myers, T.S. & Michel, L.A. (2017). Sendimentologist's guide for recognition, description, systems classification of Paleosols. Terrestrial Depositional Systems. Http://dx.doi.org/10.1016/B978-0-12-803243-5.00004-2.

APPENDIX: Photo Gallery

Figure 10. Taking sample with soil auger.

Figure 11. Arranging the soil sample in horizontal position.

Figure 12. Examining the soil texture.

Figure 13. Examining the soil colour.

Preliminary report on diversity and conservation status of vascular plants in Mount Silam and surrounding areas, Lahad Datu, Sabah, Malaysia

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Abstract. A study on diversity and conservation status of vascular plants was conducted in Mount Silam and surrounding areas during the Mount Silam Scientific Expedition on the 13th to 18th of January, 2020. The study aimed to document plant diversity and to identify interesting, endemic, rare and threatened plant species which are also considered as high conservation value species. As for a preliminary result from this survey, 149 taxa were recorded from the study areas, of which 32 species are endemic to Borneo, including seven species endemic to Sabah. The forests - contain high conservation value plant species, which should be a key conservation target for any forested area, such as Mount Silam and its surrounding areas. Adequate knowledge of plant diversity in the area is vital for the formulation of the Forest Reserve Management Plan.

Keywords: Borneo, conservation, endemic, forest reserve, plant diversity

INTRODUCTION

A study on diversity and conservation status of vascular plants was conducted in the Mount Silam and surrounding areas, within the Sapagaya Forest Reserve (FR) and Sepagaya FR in the eastern part of Sabah (Figure 1). The areas are located about 10 km from Lahad Datu town, where the key government administrative offices are located and are easily accessible by road from the Lahad Datu-Tawau highway. The summit of Mount Silam is about 884 m a.s.l., making it the highest point in the Lahad Datu district. In terms of botanical collection within Silam areas, there are more than 3,800 herbarium collections were recorded and kept in Sandakan Herbarium (SAN) previously (SAN-BRAHMS 2020). These were collected by several collectors, such as Wood G.H.S., Meijer W., the staff of SAN, etc. The earlier collections were done by Wood G.H.S. in 1955 and recorded a total of 17 taxa out of 20 voucher specimens collected. Followed by Meijer W. in 1959 with single collection (one species), and in 1960 with 37 collections (32 species) by three separate collectors, Eusebio T.V., Meijer W. and Talip A.H.

The ecological work by Proctor *et al.* (1988) recorded a total of 374 species of trees that have a diameter at breast height ≥ 10 cm in an area of 2.6 hectares. The objectives of this present survey are to obtain flora data, including plant diversity and their conservation status for the formulation of Forest Management Plan of the Mount Silam and surrounding areas.

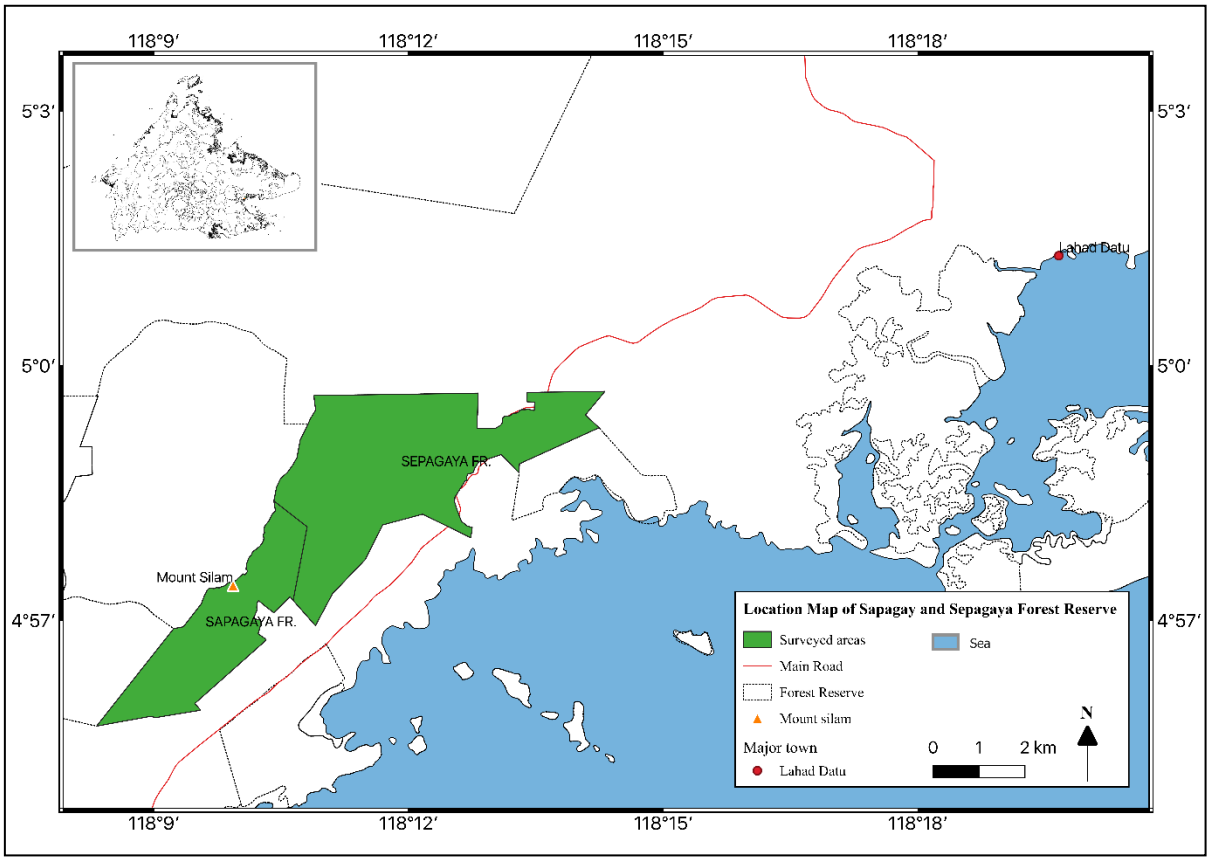

Figure 1. Location of study areas, Mount Silam and surrounding areas within two forest reserves in Sabah (Insert: Sabah map).

Soils

Soils of the area have been broadly classified as Bidu-Bidu Association, an ultrabasic soil, based on the mountainous landform and the parent material of the soil. Generally, the ultrabasic soils are dark-coloured and contain high concentrations of magnesium, iron and other metals such as nickel, chromium, cobalt, and also contain low silica levels and often are lacking in major plant nutrients such as nitrogen, phosphorus, and potassium. This has resulted in the unique forest condition and tree species composition in ultrabasic site compared to other sites (Acres *et al.* 1975).

Vegetation

The natural vegetation of Mount Silam can be classified into four general forest formations, starting with elevation from 200 m until 884 m in altitudes:

a. Lowland ultramafic forests

Generally, this forest is confined to elevation from 200 to 330 m where forest of large stature with wide crown trees that could reach up to 50 m tall are found. Floristically, it is in some ways similar to lowland dipterocarp forest in Sabah and the family Dipterocarpaceae such as *Dipterocarpus lowii, Shorea venulosa, S. kunstleri, S. laxa, S. multiflora, S. venulosa* and *Vatica mangachapoi* with smaller trees of *Hopea nutans, Vatica micrantha* and *Shorea obscura* as dominant group of trees. The family of mango (Anacardiaceae) is also common.

b. Upland ultramafic forest

In this forest, tree species that are well adapted to ultrabasic substrates or poor nutrient habitat, such as heath forest become more prominent. The elevation is confined from 330 to 540 m, where trees of medium stature could reach up to 35 m tall. The dipterocarps are the most dominant tree group, followed by Anacardiaceae as the associates.

c. Lower montane ultramafic forest

The forest is relatively smaller than the lowland and upland forests. In this montane forest, the elevation is confined from 540 to 770 m. The dominant groups of trees that are commonly found in this forest are from the families of Myrtaceae, Dipterocarpaceae, Euphorbiaceae, Anacardiaceae, Clusiaceae and Fagaceae (the oak family).

d. Upper montane forest (Mossy forest)

The forest becomes stunted and the trunks and branches are mostly covered with thick mosses. The ground is often covered by thick mosses when the elevation reaches above 770 m. In this stunted montane forest, its show a classic '*Massenerhebung Effect'* i.e., the compression of forest zones on a small mountain compared with a large one. The ground is often covered by thick humus layer and enveloped with mosses. The gymnosperm tree species such as *Dacrydium pectinatum*, *Falcatifolium falciforme* and *Podocarpus confertus* (all are Podocarpaceae family) become more prominent only in this habitat alongside their co-dominant members i.e., the Myrtaceae.

METHODS

Sampling and plant identification

Prior to field survey, location map of the site expedition was provided by the expedition leader of Forest Research Centre, Sabah Forestry Department. The field surveys were conducted from 14th to 17th of January, 2020. All plant species and trees ≥10 cm diameter at breast height (dbh) were recorded from 7 circular plots ranging from 15-20 m^2 which were established in various forest conditions (Table 1). Plant specimens with reproductive parts were collected (including voucher specimens) and deposited to the Sandakan Herbarium (SAN). Collecting and preserving plant specimens follow Bridson and Forman (1992). The common plant species were identified directly to species level in the field by means of their distinctive field characteristics. For those that could not be readily identified, voucher specimens were collected for subsequent determination at SAN.

The voucher specimen collections were oven-dried to 55°C for several days before determining their identities. All specimens were sorted according to morphospecies and attempted for identification to species level by cross-referencing with the existing specimens in the herbarium and related flora references (e.g., Soepadmo *et al*. 1995, 1996, 2000, 2002, 2004, 2007, 2011 & 2014). Other plant data were obtained from the dipterocarp survey and general botanical collecting teams.

Some plant specimens could not be identified to species level due to the incomplete specimens. Plant classification of the Angiosperm group is based on Stevens, P.F. (2001 onwards), and classification of ferns and lycophytes follows Christenhusz *et al.* (2011) with additional modification based on World of Ferns website (Hassler and Schmitt 2020), and Catalogue of Life website (Roskov *et al*. 2019). Relevant literature materials were also consulted to determine the conservation status of the plants listed, including IUCN (2020); and GBIF.org (2020) to study the distribution of relevant species.

Table 1: Location of plots in Mount Silam and surrounding areas, Lahad Datu, Sabah.

Research Plot	Latitude	Longitude	Elevation	Date	Forest Condition
P1	04°57'31.5"	118°10'01.2"	883	14/1/2020	Upper montane ultramafic forest. Old growth.
P2	04°58'03.7"	118°10'14.7"	743	15/1/2020	Lower montane ultramafic forest. Old growth.
P3	04°57'59.2"	118°10'22.1"	680	15/1/2020	Old growth.
P4	04°58'21.6"	118°10'23.6"	558	16/1/2020	Minimally disturbed.
P5	04°58'19.6"	118°10'40.2"	398	16/1/2020	Old growth.
P6	04°58'47.5"	118°12'00.0"	246	17/1/2020	Minimally disturbed.
P7	04°58'46.2"	118°12'32.3"	159	17/1/2020	Minimally disturbed.

RESULTS AND DISCUSSION

Plant diversity

As preliminary results based on the tree enumeration, dipterocarp survey, herbarium, and voucher specimens, a total of 149 taxa from 61 families were recorded from the study areas (Appendix I). These are represented by the following taxa in brackets of various plant groups, lycophytes (7), ferns (46), gymnosperms (3), angiosperms: monocotyledon (2) and angiosperms: dicotyledon (91) (Table 2).

Table 2. Number of plant taxa by plant groups from Mount Silam and surrounding areas, Sabah, Malaysia.

Plant group	**No. of families**	**No. of taxa**
Lycophytes	2	7
Ferns	14	46
Gymnosperms	1	3
Angiosperms:		
Monocotyledon	2	2
Dicotyledon	41	91
Total	**60**	**149**

The ten most speciose families are Dipterocarpaceae (19), Polypodiaceae (13), Lindsaeaceae (7), Annonaceae (6), Euphorbiaceae (6), Myrtaceae (6), Pteridaceae (6),

Malvaceae (4), Selaginellaceae (4), and Lygodiaceae (3), as shown in Figure 2 in decreasing order.

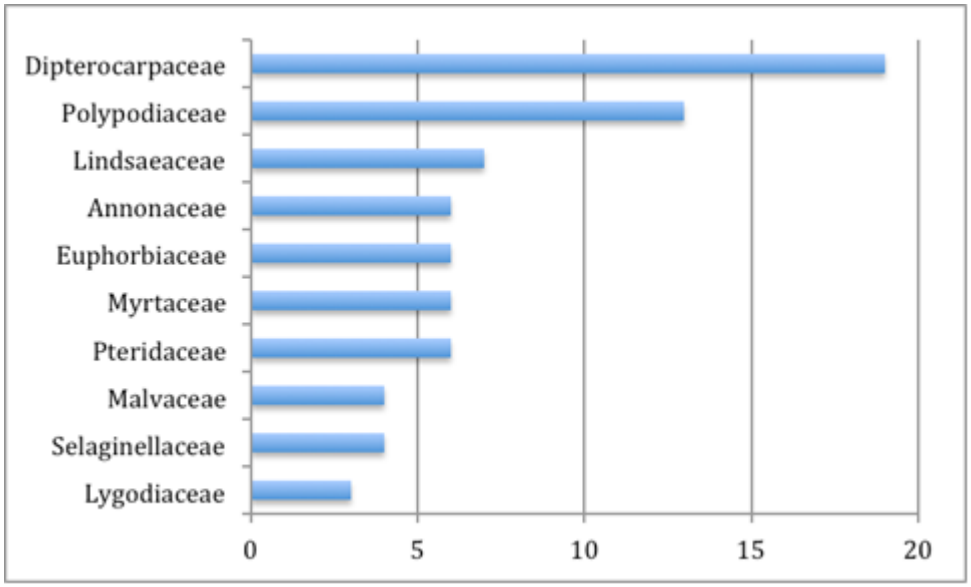

Figure 2. The ten most speciose plant families from Mount Silam and surrounding areas in decreasing order.

Ferns and Lycophytes

Ferns and lycophytes are green plants that lack of flowers. They reproduce by microscopic spores, rather than by seeds as in flowering plants. Ferns can be distinguished from lycophytes by having highly divided fronds with branching veins and spore-bearing structures on the margins or undersides (Smith *et al.* 2006). While in lycophytes their sporangia are on the upper surface of small leaves with unbranched veins. As a preliminary result, there are seven species of lycophytes and 46 taxa of ferns recorded from Mount Silam and the surrounding areas (Plate 1). Previous collections were also extracted from BRAHMS and synchronized in the current checklist. Among interesting finding is an endemic fern of Borneo, *Oreogrammitis reinwardtioides* (Copel.) Parris of Polypodiaceae (Plate 1). This species was only recorded in Sabah, Sarawak and Kalimantan within Borneo. However, there are some specimens yet to be identified and justified due to limited time and SAN was temporarily closed for upgrading. Further investigation needs to be conducted to confirm the occurrence of several species.

Gymnosperms

Gymnosperms are vascular, seed bearing, and non-flowering plants with seeds that are not protected by an ovule. There are four gymnosperm species were encountered during the survey, namely *Dacrydium pectinatum* de Laub., *Falcatifolium falciforme* (Parl.) de Laub., and *Podocarpus rumphii* Blume.

Angiosperms

In terms of plant group, the flowering plants, also known as Angiospermae are the most diverse group in study areas, with 93 species. The flowering plants are divided into two groups, monocotyledon and dicotyledon. The monocotyledons are a class of flowering plants, whose embryo (seed) store only one cotyledon. This includes all aroids, grasses, sedges, gingers, palms, orchids, and etc. There are only two species of monocotyledons recorded from Mount Silam and surrounding areas. The dicotyledons are those plants with a pair of leaves, or cotyledons, in the embryo of the seed. This includes mostly all the trees, some herbs, and shrubs. There are 91 species of dicotyledons recorded during this survey (Plate 2).

Plant conservation

Endemism

Endemism is the ecological state of being unique to a defined geographic location, such as an island, nation or other defined zone, or habitat type; organisms that are indigenous to a place are not endemic to it if they are also found elsewhere. The extreme opposite of endemism is cosmopolitan distribution. Endemics can easily become endangered or extinct if their restricted habitat changes, particularly but not only due to human actions, including the introduction of new organisms.

Out of 150 taxa recorded, 32 species are endemic to Borneo, including seven species endemic to Sabah (Appendix I) (Plate 3). In terms of legal protection, two endemic plants, *Artocarpus odoratissimus* Blanco and *Boschia acutifolia* Mast. are protected by the Sabah Forest Enactment 1968; two species protected by Sabah Wildlife Conservation Enactment 1997, *Cystorchis aphylla* Ridl. and *Podocarpus rumphii* Blume. All the Sabah endemic plants that were recorded from Mount Silam and surrounding areas also found in other places in Sabah, except for *Callophyllum sakarium* P.F. Stevens, which is restricted to Silam and Pulau Sakar (both located in Lahad Datu district).

The IUCN Red List and Malaysia Plant Red List

The IUCN Red List Categories and Criteria were designed for global taxon assessments. There may be difference between the Malaysian Plant Red List and the IUCN Red List, the Malaysian Red Data Book should always take precedence. Conservation status in parenthesis is based on the Malaysian Red List. There are seven plant species that are listed as Vulnerable (VU), two Endangered (EN) and two are Critically Endangered (CR) from the study areas (Appendix I). In terms of legal protection, four threatened species (*Artocarpus odoratissimus*, *Boschia acutifolia*, *Cystorchis aphylla* and *Podocarpus rumphii*) are protected under the state law (Sabah Forest Enactment 1968, and Sabah Wildlife Conservation Enactment 1997).

Wildlife Conservation Enactment 1997, CITES and Sabah Forest Enactment

Sabah Wildlife Conservation Enactment 1997 (SWD, 1997), under part VI (Protection of Plants) listed plants that may not be harvested without a license. There

are two plant species, comprise one orchid species and one Podocarpaceae that fall under Schedule 2, part II, Protected Plant Species (Appendix I). There are two species listed under Appendix II CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) from the orchid and fern families (Appendix I). There are two plant species that are prohibited under Sabah Forest Enactment 1968, mostly of fruits trees and threatened tree species (Appendix I).

Other interesting plant species

Apart from the high conservation plant species, other interesting plant species were also encountered during the survey, such as those with medicinal value, such as *Eurycoma longifolia*, etc.

ISSUES AND RECOMMENDATION

During the survey, there were no pressing issues or threats to both the forests and to the high conservation value plants observed, and also since the forests, Mount Silam and surrounding areas have already been put aside as a Conservation area, the next essential step is to formulate a forest management plan for the conservation area. The forest management plan is essential as a guideline to manage any forested area, such as Mount Silam in order to maintain the integrity of the area, including protection or conservation of plant species of high conservation value.

Plant species of high conservation value may include species that are, e.g. endemic to a locality, threatened and also important as food source for wildlife. These high conservation value plants or plant conservation targets must be identified and monitored, including conducting population studies. However, most of the Sabah endemic plant species as well as the threatened plant species that are found in Mount Silam and surrounding areas, are widely distributed in Sabah, hence there are no urgent measures required. Nevertheless, we propose two species, namely *Atuna cordata* and *Calophyllum sakarium* as the plant species conservation targets to be monitored. The justification for the selection of these species is that they are easily recognizable in the field and both are Sabah endemics. Protection of the forest reserve as a whole, including from poaching and illegal encroachment must also be emphasized in the forest management plan.

The result here is considered as preliminary report because the plant list is incomplete due to matching or identification process of some plant specimens could not be done. This is because the closure of herbarium collection, and further identification will be conducted in the near future, to come out with a complete checklist of vascular plant from Mount Silam and surrounding areas.

CONCLUSION

The survey recorded 149 taxa from the reserve, of which 32 species are endemic to Borneo, including seven endemic to Sabah. The forests in Mount Silam and surrounding areas contain high conservation value plant species that requires conservation attention.

ACKNOWLEDGMENTS

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REFERENCES

Acres, B.D., Bower, R.P., Burrough, P.A., Folland, C.J., Kalsi, M.S., Thomas, P. & Wright, P.S. (1975). The soils of Sabah. Volume I. Classification and description. Land Resources Study 20. Land Resources Division, Ministry of Overseas Development, Tolworth Tower, Surbiton, Surrey, England.

Airy Shaw, H.K. (1975). The Euphorbiaceae of Borneo. *Kew Bulletin* (Additional Series) 4. 245 pp.

Bridson, D. & Forman, L. (1992). *The Herbarium Handbook*. Revised Edition. Royal Botanic Gardens, Kew. 303 pp.

Christenhusz, M.J.M., Zhang, X.-C. & Schneider, H. (2011). A linear sequence of extant families and genera of lycophytes and ferns. *Phytotaxa* 19: 7–54.

Chua, L.S.L, Suhaida, M., Hamidah, M. & Saw, L.G. (2010). *Malaysia Plant Red List. Peninsular Malaysian Dipterocarpaceae*. Forest Research Institute Malaysia. 210 pp.

GBIF.org. (2020). GBIF Home Page. Available from: https://www.gbif.org [13 January 2020]

Hassler, M. & Schmitt, B. (2020). *World Ferns: Checklist of Ferns and Lycophytes of the World (version 8.30 - April 2020).*
http://worldplants.webarchiv.kit.edu/ferns/index.php

IUCN. (2020). The IUCN Red List of Threatened Species. Version 2020-1. <https://www.iucnredlist.org>.

Mabberley, D.J., Pannell, C.M. & Sing, A.M. (1995). Meliaceae. *Flora Malesiana.* Series I. Vol. 12 (1). 407 pp.

Proctor J., Lee, Y.F., Langley, A.M., Munro, W.R.C. & Nelson, T. (1988). Ecological studies on Gunung Silam, a small ultrabasic mountain in Sabah. I. Environment, forest structure and floristics. *Journal of Ecology* 76: 320–340.

Roskov Y., Ower G., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., Nieukerken E. van, Zarucchi J., Penev L., eds. (2019). Species 2000 & ITIS Catalogue of Life, 2019 Annual Checklist. Digital resource at www.catalogueoflife.org/annual-checklist/2019/. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.

SAN-BRAHMS. (2020). Sandakan Herbarium 'Botanical Research and Herbarium Management System' (version 7.9.14).

SFD. (2017). *Fact sheets of forest reserves in Sabah*. Sabah Forestry Department. 48 pp.

Smith, A. R., Kathleen M. Pryer, Eric Schuettpelz, Petra Koral, Harald Schneider & Paul G. Wolf. (2006). A classification for extant ferns. *Taxon* 55 (3): 705–731.

Soepadmo E. & Wong, K.M. (eds.) (1995). *Tree Flora of Sabah and Sarawak.* Vol. 1. Sabah Forestry Department, Sandakan; Forest Research Institute Malaysia and Sarawak Forestry Department. 513 pp.

Soepadmo, E.,Wong, K.M. and L.G. Saw (eds.) (1996). *Tree Flora of Sabah and Sarawak.* Vol.2. Sabah Forestry Department, Sandakan; Forest Research Institute Malaysia and Sarawak Forestry Department. 443 pp.

Soepadmo, E. and Saw, L.G. (eds.) (2000). *Tree Flora of Sabah and Sarawak.* Vol. 3. Sabah Forestry Department, Sandakan; Forest Research Institute Malaysia and Sarawak Forestry Department. 511 pp.

Soepadmo, E., Saw, L. G. and Chung, R.C.K. (eds.) (2002). *Tree Flora of Sabah and Sarawak.* Vol. 4. Sabah Forestry Department, Sandakan; Forest Research Institute Malaysia and Sarawak Forestry Department. 388 pp.

Soepadmo, E., Saw, L.G. and Chung, R.C.K. (eds.) (2004). *Tree Flora of Sabah and Sarawak.* Vol. 5. Sabah Forestry Department, Sandakan; Forest Research Institute Malaysia and Sarawak Forestry Department. 528 pp.

Soepadmo, E., Saw, L.G., Chung R.C.K. and Kiew, R. (eds.) (2007). *Tree Flora of Sabah and Sarawak.* Vol. 6. Sabah Forestry Department, Sandakan; Forest Research Institute Malaysia and Sarawak Forestry Department. 335 pp.

Soepadmo, E., Saw,L.G., Chung, R.C.K. and Kiew, R. (eds.) (2011). *Tree Flora of Sabah and Sarawak.* Vol. 7. Sabah Forestry Department, Sandakan; Forest Research Institute Malaysia and Sarawak Forestry Department. 450 pp.

Soepadmo, E., Saw, L.G., Chung, R.C.K. and Kiew, R. (eds.) (2014). *Tree Flora of Sabah and Sarawak.* Vol. 8. Sabah Forestry Department, Sandakan; Forest Research Institute Malaysia and Sarawak Forestry Department. 248 pp.

Soejatmi Dransfield. (1992). *The Bamboos of Sabah*. Sabah Forest Records. No 14. 94 pp.

Stevens, P.F. (2001 onwards). *Angiosperm Phylogeny Website.*

SWD. (1997). *Sabah Wildlife Conservation Enactment*. Sabah Wildlife Department. 79 pp.

The Herbarium Catalogue, Royal Botanic Gardens, Kew. (2020). Published on the Internet http://www.kew.org/herbcat [accessed on 1 Feb 2020].

The Sabah Wildlife Conservation Enactment (1997). Published on the Internet https://www.sabahlaw.com/Wildliferegulation.htm [accessed on 15 April 2020].

The Sabah Forestry Enactment (1968). Published on the Internet http://www.forest.sabah.gov.my/publications/forest-enactment-1968.html [accessed on 15 April 2020].

The Checklist of CITES Species (2020). http://checklist.cites.org/#/en [accessed on 15 April 2020].

Photo gallery

A. *Oreogrammitis reinwardtioides* (Copel.) Parris (Polypodiaceae).

B. *Actinostachys digitata* (L.) Wall. *ex* Reed (Schizaeaceae)

C. *Taenitis blechnoides* (Willd.) Sw. (Pteridaceae)

D. *Phlegmariurus nummulariifolius* (Bl.) Ching (Lycopodiaceae)

E. *Odontosoria retusa* (Cav.) J.Sm. (Lindasaeaceae)

Plate 1. Ferns and Lycophytes.

A. *Schima wallichii* (DC.) Korth. (Theaceae)

B. *Campylospermum serratum* (Gaertn.) V.Bittrich & M.C.E.Amaral (Ochnaceae)

C. *Utania cuspidata* (Bl.) K.M.Wong, Sugumaran & Sugau (Gentianaceae)

D. *Xanthophyllum pedicellatum* R.Van der Meijden (Polygalaceae)

Plate 2. Angiosperm (Dicotyledon)**.**

A. *Shorea beccariana* Burck (endemic to Borneo)

B. *Vatica micrantha* Slooten (endemic to Borneo)

C. *Borneodendron aenigmaticum* Airy Shaw (endemic to Sabah).

Plate 3. Endemic species from the study area.

Appendix I. List of vascular plant species recorded from Mount Silam and surrounding areas of Lahad Datu, Sabah. The species are arranged by family in alphabetical order.

IdLoc	Family	Species	G	H	End	IUCN	SFDpro	SWCE	CITES
P4, P6, P7	Achariaceae	*Hydnocarpus woodii* Merrill	Ad	t	Not	NE	No	No	No
5,6,7	Anacardiaceae	*Gluta oba* (Merr.) Ding Hou	Ad	t	Borneo	NE	No	No	No
5,6	Anacardiaceae	*Parishia maingayi* Hook.fil.	Ad	t	Not	NE	No	No	No
5	Anacardiaceae	*Swintonia acuta* Engl.	Ad	t	Not	NE	No	No	No
P5	Annonaceae	*Friesodielsia acuminata* (Merr.) Steenis	Ad	t	Sabah	NE	No	No	No
P4, P5	Annonaceae	*Goniothalamus clemensii* Bân	Ad	t	Borneo	NE	No	No	No
P6, P7	Annonaceae	*Marsypopetalum pallidum* (Blume) Kurz	Ad	t	Not	NE	No	No	No
P7	Annonaceae	*Polyalthia borneensis* Merr.	Ad	t	Borneo	NT	No	No	No
P4	Annonaceae	*Popowia hirta* Miq.	Ad	t	Not	NE	No	No	No
P7	Annonaceae	*Sageraea lanceolata* Miq.	Ad	t	Not	LC	No	No	No
P6	Arecaceae	*Calamus caesius* Blume	Am	pt	Not	NE	No	No	No
ML33	Aspleniaceae	*Asplenium anguineum* Christ	F	f	Not	NE	No	No	No
M.A.M.Andi 1454	Aspleniaceae	*Asplenium musifolium* Mett.	F	f	Not	NE	No	No	No
M.A.M.Andi 1461	Aspleniaceae	*Asplenium nidus* L.	F	f	Not	NE	No	No	No
AZ1559	Blechnaceae	*Blechnopsis orientalis* (L.) C.Presl	F	f	Not	NE	No	No	No
3	Burseraceae	*Canarium littorale* Bl.	Ad	t	Not	LC	No	No	No
5,6, P4	Calophyllaceae	*Calophyllum nodosum* Vesque	Ad	t	Not	NE	No	No	No
6	Calophyllaceae	*Calophyllum sakarium* P.F.Stevens	Ad	t	Sabah	NE	No	No	No
2,3	Cannabaceae	*Gironniera subaequalis* Planch.	Ad	t	Not	LC	No	No	No
3	Casuarinaceae	*Gymnostoma sumatranum* (Jungh. ex de Vriese) L.A.S.Johnson	Ad	t	Not	NE	No	No	No
4	Celastraceae	*Lophopetalum subobovatum* King	Ad	t	Not	NE	No	No	No
3,5	Chrysobalanceae	*Angelesia splendens* Korth.	Ad	t	Not	LC	No	No	No
5	Chrysobalanceae	*Atuna cordata* Cockburn *ex* G.T.Prance	Ad	t	Sabah	VU	No	No	No
P6	Combretaceae	*Combretum nigrescens* King	Ad	c	Not	NE	No	No	No
P5	Connaraceae	*Ellipanthus beccarii* Pierre	Ad	t	Not	NE	No	No	No
4	Crypteroniaceae	*Axinandra beccariana* Baill.	Ad	t	Not	NE	No	No	No
P4, P5	Crypteroniaceae	*Axinandra coriacea* Baill.	Ad	t	Borneo	NE	No	No	No
4, P2,P5	Ctenolophonaceae	*Ctenolophon parvifolius* Oliv.	Ad	t	Not	VU	No	No	No
M.A.M.Andi 1440	Cyatheaceae	*Sphaeropteris glauca* (Bl.) R.M.Tryon	F	f	Not	NE	No	No	yes
ML24	Davalliaceae	*Davallia heterophylla* Sm.	F	f	Not	NE	No	No	No
M.A.M.Andi 1430	Davalliaceae	*Davallia repens* (L.fil.) Kuhn	F	f	Not	NE	No	No	No
P4, P5	Dichapetalaceae	*Dichapetalum gelonioides* subsp. *pilosum* Leenh.	Ad	t	Not	LC	No	No	No
P6, P7	Dipterocarpaceae	*Dipterocarpus lowii* Hook.fil.	Ad	t	Not	CR	No	No	No
s.n	Dipterocarpaceae	*Dryobalanops lanceolata* Burck	Ad	t	Borneo	LC	No	No	No
4	Dipterocarpaceae	*Hopea beccariana* Burck	Ad	t	Not	VU	No	No	No
s.n	Dipterocarpaceae	*Hopea wyatt-smithii* G.H.S.Wood *ex* P.S.Ashton	Ad	t	Borneo	NT	No	No	No
s.n	Dipterocarpaceae	*Shorea agamii* P.S.Ashton	Ad	t	Borneo	NT	No	No	No
5	Dipterocarpaceae	*Shorea andulensis* P.S.Ashton	Ad	t	Borneo	VU	No	No	No
3,5	Dipterocarpaceae	*Shorea atrinervosa* Symington	Ad	t	Not	VU	No	No	No
4	Dipterocarpaceae	*Shorea beccariana* Burck	Ad	t	Borneo	LC	No	No	No
6	Dipterocarpaceae	*Shorea falciferoides* Foxw.	Ad	t	Borneo	CR	No	No	No
7	Dipterocarpaceae	*Shorea gratissima* (Wall. *ex* Kurz) Dyer	Ad	t	Not	EN	No	No	No
s.n	Dipterocarpaceae	*Shorea guiso* (Blanco) Bl.	Ad	t	Not	VU	No	No	No
4	Dipterocarpaceae	*Shorea kunstleri* King	Ad	t	Not	CR	No	No	No
5,6, P7	Dipterocarpaceae	*Shorea multiflora* (Burck) Symington	Ad	t	Not	LC	No	No	No
s.n	Dipterocarpaceae	*Shorea obscura* Meijer	Ad	t	Borneo	VU	No	No	No
2,3,4,5	Dipterocarpaceae	*Shorea venulosa* G.H.S.Wood *ex* Meijer	Ad	t	Borneo	LC	No	No	No
6,7	Dipterocarpaceae	*Vatica albiramis* Slooten	Ad	t	Borneo	LC	No	No	No
6, P5	Dipterocarpaceae	*Vatica mangachapoi* Blanco	Ad	t	Not	VU	No	No	No

IdLoc	Family	Species	G	H	End	IUCN	SFDpro	SWCE	CITES
5	Dipterocarpaceae	*Vatica micrantha* Slooten	Ad	t	Borneo	LC	No	No	No
s.n	Dipterocarpaceae	*Vatica oblongifolia* Hook.f.	Ad	t	Borneo	LC	No	No	No
M.A.M.Andi 1422	Dryopteridaceae	*Pleocnemia irregularis* (C.Presl) Holtt.	F	f	Not	NE	No	No	No
3,5	Ebenaceae	*Diospyros elliptifolia* Merr.	Ad	t	Not	NE	No	No	No
P5, P7	Ebenaceae	*Diospyros foxworthyi* Bakh.	Ad	t	Not	LC	No	No	No
P1, P4, P5, P6	Ebenaceae	*Diospyros fusiformis* Kosterm.	Ad	t	Borneo	NE	No	No	No
6	Ebenaceae	*Diospyros wallichii* King & Gamble	Ad	t	Not	NE	No	No	No
2,3,5	Euphorbiaceae	*Borneodendron aenigmaticum* Airy Shaw	Ad	t	Sabah	NE	No	No	No
P5, P6	Euphorbiaceae	*Croton argyratus* Blume	Ad	t	Not	LC	No	No	No
P4, P5	Euphorbiaceae	*Hancea griffithiana* (Müll.Arg.) S.E.C.Sierra, Kulju & Welzen	Ad	t	Not	NE	No	No	No
P7	Euphorbiaceae	*Mallotus korthalsii* Müll.Arg.	Ad	t	Not	LC	No	No	No
7	Euphorbiaceae	*Neoscortechinia philippinensis* (Merr.) Welzen	Ad	t	Not	NE	No	No	No
P6, P7	Euphorbiaceae	*Omphalea bracteata* (Blanco) Merr.	Ad	t	Not	NE	No	No	No
P5	Fabaceae	*Airyantha borneensis* (Oliv.) Brummitt	Ad	c	Not	NE	No	No	No
P6, P7	Fabaceae	*Fordia splendidissima* (Miq.) Buijsen	Ad	t	Not	LC	No	No	No
SAN 160748	Gentianaceae	*Utania cuspidata* (Bl.) K.M.Wong, Sugumaran & Sugau	Ad	t	Not	NE	No	No	No
ML5	Gleicheniaceae	*Dicranopteris curranii* Copel.	F	f	Not	NE	No	No	No
Wood 2006	Hymenophyllaceae	*Abrodictyum meifolium* (Bory *ex* Willd.) Ebihara & K.Iwats.	F	f	Not	NE	No	No	No
ML19	Hymenophyllaceae	*Cephalomanes atrovirens* subsp. *atrovirens*	F	f	Not	NE	No	No	No
SAN 75161	Hymenophyllaceae	*Cephalomanes singaporianum* v.d.Bosch	F	f	Not	NE	No	No	No
P7	Lamiaceae	*Teijsmanniodendron simplicifolium* Merr.	Ad	t	Not	LC	No	No	No
2,3	Lauraceae	*Litsea cylindrocarpa* Gamble	Ad	t	Not	NE	No	No	No
SAN 160751	Leaceae	*Leea indica* (Burm.fil.) Merr.	Ad	t	Not	LC	No	No	No
ML37	Lindsaeaceae	*Lindsaea cultrata* (Willd.) Sw.	F	f	Not	NE	No	No	No
Wood 2010	Lindsaeaceae	*Lindsaea divergens* Wall. *ex* Hook. & Grev.	F	f	Not	NE	No	No	No
M.A.M.Andi 1442	Lindsaeaceae	*Lindsaea ensifolia* Sw.	F	f	Not	NE	No	No	No
SAN 129603	Lindsaeaceae	*Lindsaea gueriniana* (Gaud.) Desv.	F	f	Not	NE	No	No	No
M.A.M.Andi 1441	Lindsaeaceae	*Odontosoria retusa* (Cav.) J.Sm.	F	f	Not	NE	No	No	No
ML18	Lindsaeaceae	*Tapeinidium acuminatum* Kramer	F	f	Not	NE	No	No	No
M.A.M.Andi 1431	Lindsaeaceae	*Tapeinidium luzonicum* (Hook.) Kramer	F	f	Not	NE	No	No	No
M.A.M.Andi 1460	Lycopodiaceae	*Palhinhaea cernua* (L.) Carv.Vasc. & Franco	L	l	Not	NE	No	No	No
M.A.M.Andi 1424	Lycopodiaceae	*Phlegmariurus nummulariifolius* (Bl.) Ching	L	l	Not	NE	No	No	No
SAN 42231	Lycopodiaceae	*Phlegmariurus phlegmaria* (L.) Holub	L	l	Not	NE	No	No	No
M.A.M.Andi 1447, P7	Lygodiaceae	*Lygodium circinnatum* (Burm.fil.) Sw.	F	f	Not	NE	No	No	No
M.A.M.Andi 1445	Lygodiaceae	*Lygodium longifolium* (Willd.) Sw.	F	f	Not	NE	No	No	No
M.A.M.Andi 1449	Lygodiaceae	*Lygodium microphyllum* (Cav.) R.Br.	F	f	Not	NE	No	No	No
4	Malvaceae	*Boschia acutifolia* Mast.	Ad	t	Borneo	VU	Yes	No	No
7	Malvaceae	*Brownlowia stipulata* Kosterm.	Ad	t	Sabah	NE	No	No	No
7	Malvaceae	*Pentace adenophora* Kosterm.	Ad	t	Not	LC	No	No	No
6,7	Malvaceae	*Scaphium parviflorum* P.Wilkie	Ad	t	Borneo	NE	No	No	No
P7	Meliaceae	*Aglaia* cf. *rufinervis* (Bl.) Bentvelzen	Ad	t	Not	NT	No	No	No
P7	Meliaceae	*Walsura pinnata* Hassk.	Ad	t	Not	NE	No	No	No
6,7, P3	Moraceae	*Artocarpus odoratissimus* Blanco	Ad	t	Borneo	NT	Yes	No	No
P1	Moraceae	*Streblus glaber* (Merr.) Corner	Ad	t	Not	LC	No	No	No
6	Myrtaceae	*Decaspermum fruticosum* J.R.Forst. & G.Forst.	Ad	t	Not	NE	No	No	No
2,3,4,5	Myrtaceae	*Rhodamnia cinerea* Jack	Ad	t	Not	LC	No	No	No
4, P1, P2, P5	Myrtaceae	*Syzygium bankense* (Hassk.) Merr. & Perry	Ad	t	Not	NE	No	No	No

IdLoc	Family	Species	G	H	End	IUCN	SFDpro	SWCE	CITES
4,6, P7	Myrtaceae	*Syzygium caudatilimbum* (Merr.) Merr. & L.M.Perry	Ad	t	Borneo	NE	No	No	No
P4, P5	Myrtaceae	*Tristaniopsis microcarpa* P.S.Ashton	Ad	t	Borneo	NE	No	No	No
2	Myrtaceae	*Tristaniopsis musa-amanii* Berhaman & Peter G.Wilson	Ad	t	Sabah	NE	No	No	No
SAN 160706	Ochnaceae	*Campylospermum serratum* (Gaertn.) V.Bittrich & M.C.E.Amaral	Ad	t	Not	LC	No	No	No
M.A.M.Andi 1433	Oleandraceae	*Oleandra neriiformis* Cav.	F	f	Not	NE	No	No	No
SAN 2141	Oleandraceae	*Oleandra pistillaris* (Sw.) C.Chr.	F	f	Not	NE	No	No	No
M.A.M.Andi 1458	Orchidaceae	*Cystorchis aphylla* Ridl.	Am	m	Not	NE	No	Yes	Yes
P1,P2, P3, P5, P7	Pandaceae	*Galearia fulva* (Tul.) Miq.	Ad	t	Not	NE	No	No	No
1,5	Pentaphylacaceae	*Ternstroemia gymnanthera* (Wight & Arn.) Sprague	Ad	t	Not	NE	No	No	No
5	Peraceae	*Chaetocarpus castanocarpus* (Roxb.) Thwaites	Ad	t	Not	LC	No	No	No
7, P6, P7	Phyllanthaceae	*Cleistanthus oblongifolius* (Roxb.) Müll.Arg.	Ad	t	Not	LC	No	No	No
P2, P3	Podocarpaceae	*Dacrydium pectinatum* de Laub.	G	t	Not	EN	No	No	No
1,2	Podocarpaceae	*Falcatifolium falciforme* (Parl.) de Laub.	G	t	Not	NT	No	No	No
5	Podocarpaceae	*Podocarpus rumphii* Blume	G	t	Not	NT	No	Yes	No
SAN 160701	Polygalaceae	*Xanthophyllum pedicellatum* R.Van der Meijden	Ad	t	Borneo	NE	No	No	No
M.A.M.Andi 1437	Polypodiaceae	*Acrosorus streptophyllus* (Bak.) Copel.	F	f	Not	NE	No	No	No
M.A.M.Andi 1453	Polypodiaceae	*Aglaomorpha quercifolia* (L.) Hovenkamp & S.Linds.	F	f	Not	NE	No	No	No
P7	Polypodiaceae	*Aglaomorpha sparsisora* (Desv.) Hovenkamp & S.Linds.	F	f	Not	NE	No	No	No
ML15	Polypodiaceae	*Ctenopterella blechnoides* (Grev.) Parris	F	f	Not	NE	No	No	No
ML8	Polypodiaceae	*Lepisorus longifolius* (Bl.) Holtt.	F	f	Not	NE	No	No	No
ML3	Polypodiaceae	*Oreogrammitis reinwardtii* (Blume) Parris	F	f	Not	NE	No	No	No
M.A.M.Andi 1462	Polypodiaceae	*Oreogrammitis reinwardtioides* (Copel.) Parris	F	f	Borneo	NE	No	No	No
ML1	Polypodiaceae	*Oreogrammitis universa* (Baker) Parris	F	f	Not	NE	No	No	No
ML51	Polypodiaceae	*Phymatosorus scolopendria* (Burm.fil.) Pichi-Serm.	F	f	Not	NE	No	No	No
M.A.M.Andi 1439	Polypodiaceae	*Platycerium coronarium* (D.König *ex* O.F.Müll.) Desv.	F	f	Not	NE	No	No	No
ML43	Polypodiaceae	*Prosaptia alata* (Bl.) Christ	F	f	Not	NE	No	No	No
M.A.M.Andi 1435	Polypodiaceae	*Prosaptia barathrophylla* (Bak.) M.G.Price	F	f	Not	NE	No	No	No
ML4	Polypodiaceae	*Scleroglossum debile* (Mett.) Alderw.	F	f	Not	NE	No	No	No
M.A.M.Andi 1448	Pteridaceae	*Antrophyum callifolium* Bl.	F	f	Not	NE	No	No	No
SAN 146582	Pteridaceae	*Antrophyum semicostatum* Bl.	F	f	Not	NE	No	No	No
R.J. 5082	Pteridaceae	*Haplopteris zosterifolia* (Willd.) E.H.Crane	F	f	Not	NE	No	No	No
M.A.M.Andi 1434	Pteridaceae	*Pteris ensiformis* Burm.	F	f	Not	NE	No	No	No
ML55	Pteridaceae	*Pteris vittata* subsp. *vittata*	F	f	Not	LC	No	No	No
M.A.M.Andi 1425	Pteridaceae	*Taenitis blechnoides* (Willd.) Sw.	F	f	Not	NE	No	No	No
P7	Rhamnaceae	*Ventilago dichotoma* (Blanco) Merr.	Ad	t	Not	NE	No	No	No
4	Rhizophoraceae	*Carallia brachiata* (Lour.) Merr.	Ad	t	Not	NE	No	No	No
1,2	Rhizophoraceae	*Gynotroches axillaris* Bl.	Ad	t	Not	NE	No	No	No
1,2, P3	Rubiaceae	*Porterandia postarii* Zahid	Ad	t	Sabah	NE	No	No	No
7	Sapindaceae	*Dimocarpus longan* Lour.	Ad	t	Not	NT	No	No	No
P4	Sapotaceae	*Madhuca pallida* (Burck) Baehni	Ad	t	Not	NT	No	No	No
2,4,5	Sapotaceae	*Palaquium gutta* (Hook.) Baill.	Ad	t	Not	NT	No	No	No
7	Sapotaceae	*Payena ferruginea* J.T.Pereira	Ad	t	Borneo	LC	No	No	No
M.A.M.Andi 1423	Schizaeaceae	*Actinostachys digitata* (L.) Wall. *ex* Reed	F	f	Not	NE	No	No	No
M.A.M.Andi 1343	Schizaeaceae	*Schizaea dichotoma* (L.) Sm.	F	f	Not	NE	No	No	No

IdLoc	Family	Species	G	H	End	IUCN	SFDpro	SWCE	CITES
s.n	Selaginellaceae	*Selaginella argentea* (Wall. *ex* Hook. & Grev.) Spring	L	l	Not	NE	No	No	No
M.A.M.Andi 1438	Selaginellaceae	*Selaginella intermedia* (Bl.) Spring	L	l	Not	NE	No	No	No
ML2	Selaginellaceae	*Selaginella ornata* (Hook & Grev.) Spring	L	l	Not	NE	No	No	No
ML39	Selaginellaceae	*Selaginella padangensis* Hieron.	L	l	Not	NE	No	No	No
P2, P3, P4, P5	Simaroubaceae	*Eurycoma longifolia* Jack	Ad	t	Not	NE	No	No	No
P3	Smilacaceae	*Smilax corbularia* var. *woodii* (Merr.) T.Koyama	Ad	c	Not	NE	No	No	No
4,6, P7	Stemonuraceae	*Stemonurus grandifolius* Becc.	Ad	t	Borneo	NE	No	No	No
1,2,5	Theaceae	*Schima wallichii* (DC.) Korth.	Ad	t	Not	LC	No	No	No
SAN 134339	Thelypteridaceae	*Christella arida* (D.Don) Holtt.	F	f	Not	NE	No	No	No

Notes:
IUCN/Malaysia Red List: CR=Critically endangered; EN=Endangered; VU=Vulnerable; NT=Near threatened; LC=Least concern; NE=Not Evaluated; G=Plant Group: Ad=Angiosperm (Dicotyledon); Am=Angiosperm (Monocotyledon); G=Gymnosperm; F=Fern; L=Lycophyte; H=habit: t=tree; c=climber; sh=shrub; h=herb; g=grass; sd=sedge; f=fern; ep=epiphyte; l=lycophyte; pt=palm tree; m= mycoheterotrophic; str=strangler
SFDpro=Sabah Forestry Department prohibited species under Sabah Forest Enactment 1968
SWCE=Sabah Wildlife Conservation Enactment 1997
CITES=Convention on International Trade in Endangered Species of Wild Fauna and Flora
IdLoc= Location

A multi-disciplinary study of dipterocarps in Mt. Silam

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Abstract. A multi-disciplinary study was performed to cover three main objectives in documenting dipterocarps in Mt. Silam. These objectives were assessed through surveys using distance transect method which corresponded to the different types of vegetation in Mt. Silam. A total of 18 dipterocarp species from five genera were recorded with 60% of them are Bornean endemics and about 50% are listed under threatened species in the IUCN Red List. The second objective covered regeneration frequency of seedlings and saplings in separate vegetations which recorded three dominant reproductive species of *Shorea venulosa*, *Shorea multiflora* and *Vatica micrantha*. The relationship pattern of the regeneration frequency between the seedlings and saplings in separate vegetations were varied based on *Spearman rank correlation*; a positive significant correlation in lower montane (R1: r_s = 0.414, p = 0.003), while a negative significant correlation was calculated in lowland ultramafic (R2: r_S=-0.66, p =1.21E^{-07}) and no significant correlation was detected in upland ultramafic (R3: r_S=-0.07, p = 0.671). In addition, a 3-Dimensional model for Mt. Silam was constructed using downloaded Digital elevation model (DEM) from Shuttle Radar Topography Mission (STRM) with stepwise herewith explained. The 3D model could be useful to determine certain reference point for future work surveys by real-time visualization on the terrain complexity and slope of Mt. Silam. It is hoped that with the various outputs from this study, it could serve as baseline information to support the forest management in initiating Payment for Ecosystem Services (PES) and other related work in the future.

Keywords: DEM, Dipterocarps, IUCN Red List, Mt. Silam, ultramafic

INTRODUCTION

Ultrabasic or ultramafic vegetation is known to be infertile and phytotoxic due to its extremely high concentrations of nickel and magnesium. The often-used geological term to describe ultramafic is ‘serpentine’ which refers to the ecology of soils derived from ultramafic substrates (Coleman & Jole 1992). It is characterised with low water retention, low concentration of phosphorus and other essential plant nutrients, such as nitrogen and potassium (Baillie *et al.* 2000). The low water retention induces water stress resulting in the uptake of toxicity substrates of nickel and magnesium. With prolonged dry season by *El Nino* and combined effect from water stress, it becomes detrimental in igniting the risk of forest fire as recorded by vegetation communities of Mt. Kinabalu. Despite what is being said, ultramafic vegetation was also known by three main characteristics: a) low stature and biomass production, b) high levels of endemism and c) distinct differences from other vegetation. This has made the ultramafic become a prominent site for extensive research due to its unique vegetation and high endemism of plant species. The

ultramafic vegetation in Sabah is found in Meliau Range, Mt. Tawai, Bidu-bidu Hills, Mt. Silam and around Mt. Kinabalu where researchers from various agencies have contributed their expertise in multi-disciplinary studies for conservation purposes.

A scientific exploration was conducted at one of the ultramafic sites in Mt. Silam, in January of 2020 to develop a baseline study for Payment for Ecosystem Services (PES). Mt. Silam is characterised by hill and lower montane mixed dipterocarp forest vegetation. The mountain itself offers high unique plant diversity from lowland dipterocarp dominated forest to stunted Myrtaceae-dominated vegetation, despite having an elevation at 884m (Proctor & Nagy 1992). As the elevation become higher, the forest stature has decreased while density of stem increases in size. The strategic and good accessibility to Mt. Silam has open up the potential door for ecotourism and platform for research. Moreover, it is near to the town of Lahad Datu and provided good sealed road for vehicle to reach up to the telecommunication towers at 620 m and on par with the entrance point to the peak of Mt. Silam (884 m). Extensive studies have been carried out in Mt. Silam since mid-1980s by John Procter *et al.* up until today. This covered from plant and insect diversity, checklist of mammals, vegetation to soil and geology (Bruijnzeel *et al.* 1993, Ketol *et al.* 2009, Ebin & Chung 2012).

The geology base of Mt. Silam encompasses ultrabasic intrusive rocks mainly formed by serpentine, dunite and periodotite rocks. These rocky formations derived from magnesium, iron, chromium and nickel which are classified as Bidu-Bidu soil association of Sabah. Similar soils were recorded in Gunung Tambuyukon, Meliau Range, Bidu Bidu Hills, Gunung Rara and Tawai Range (SFD - Caims 2004). The vegetation around Mt. Silam was characterised by tree species from the families of Dipterocarpaceae and Anacardiaceae which ranged from lowland to upland forest. Due to the mountain stature, other groups of tree species inhabited at the higher elevation at 700 m are from the family Casuarinaceae, Epacridaceae, Escalloniaceae, Podocarpaceae, Rutaceace and Theaceae. The forest formations are classified into four forest types namely, lowland ultramafic, upland ultramafic, lower montane ultramafic and upper montane forest (mossy forest). Dominance of Dipterocarp species was recorded to be available from 200 m to 770 m, excluding the upper montane forest.

The aim of this study is to document dipterocarps species in Mt. Silam by numerous approaches. The aim will be fulfilled by the objectives as follows:

1. To perform a checklist of dipterocarp species in Mt. Silam
2. To determine the regeneration frequency of dipterocarp seedlings and saplings based on different vegetations
3. To construct a 3-D digital elevation (DEM) of Mt. Silam

MATERIALS AND METHODS

Study area

The Mt Silam occupies an area of 698 ha. and is located inside Sapagaya Forest Reserve which was gazetted as Class 1 (Protected Forest Reserve) in 2009. The northern-west of Mt. Silam was surrounded by private lands and largely planted with cash crops, especially oil palm. The ultramafic coastal mountain is located next to the

main road of Lahad Datu-Tawau while facing Darvel Bay, at the eastern-south (Figure 1). Hence, survey of dipterocarps was conducted within the established trails of Mt. Silam ranges from 200 m up to the mountain's peak at 884 m.

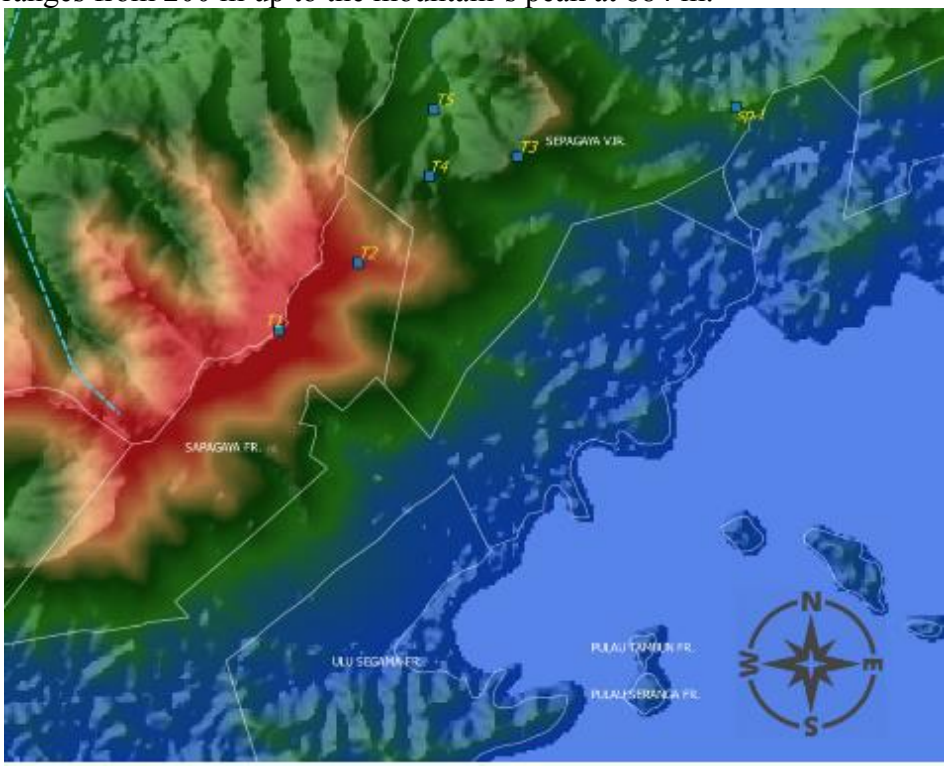

Figure 1. Topography map of Mt. Silam with boundaries and name of forest reserves (white line), while dashed blue line indicates riverine. Points of interest with *T* abbreviation are referred in Table 1. *T1* = Summit of Mt. Silam, *T2* = Telecom tower, *T3* = Kubu Jepun trail, *T4* = Kubang Badak trail, *T5* = Water catchment dam & *Sp.1* = *Vatica* cf. *pachyphylla.*

Materials used in survey

Devices such as GPS Garmin model GPSmap 62st, Monarch binocular, diameter tape and Nikon Coolpix AW120 compact camera were used while the data on the dipterocarp findings were compiled.

Methods based on objectives

1. To perform a checklist on dipterocarp species in Mt. Silam

Method 1: Survey was carried out to conduct a checklist of dipterocarp species along 10 m wide line transects. Transects were conducted on different trails and altitudes. Dipterocarp species that are present on both sides of the line transect will be GPS recorded and DBH measured. In addition, a rapid assessment using road survey by vehicle was performed to capture the species distribution that presence alongside the road. Voucher specimens were collected for unidentified or unconfirmed species for further identification at the SAN Herbarium, Forest Research Centre, Sandakan. Details of the transects are shown in Table 1. Based on the procured data, qualitative analyses were performed for species diversity indices and richness, Shannon-Wiener index (H′) (Shannon & Weaver 1963), Simpson's index

(CD) (Simpson 1949), Fisher's α (Magurran 1998), Margalef (Margalef 1958) and Pielou's evenness index (e) (Pielou 1966), were calculated using PAST (Hammer *et al.* 2001). For statistical analysis, normality of DBH data based on transects was tested using Shapiro-Wilk (W) and mean differences among groups were further determined using T-test (normal) and Kruskal-Wallis test (non-parametric).

In addition, cluster analysis was performed using presence-absence (P-A) data between species and transects/vegetations. The analysis was measured using Jaccard's (P-A) similarity index and bootstrapped (999 permutations) using PAST program. The significant differences between clusters or groups were further determined using One-way ANOSIM. Data from rapid assessment by road survey (T_4) was excluded from the statistical analysis to avoid biased but pooled in assessing Global IUCN RED LIST of dipterocarp conservation status in Mt. Silam.

2. To determine the regeneration frequency by dipterocarp seedlings and saplings based on typed vegetation.

Method 2: The method is designed in parallel with method 1, in order to utilise the survey time and effort conducted. Practically, quadrat was established by 1m x 1m in 20 m intervals to capture the dipterocarp seedling and sapling frequency. The regeneration quadrat (RQ) were placed alternately on both sides (right and left) with 10 m distance from the transect node. Length of regeneration quadrat is 1000 m in separate vegetations. However due to terrain difficulty, only 600 m of RQ in transect 3 was performed. Observed seedlings (height < 50 cm) and saplings (DBH > 5 mm) inside the quadrat were species identified and counted. Illustration in Figure 2 showed the details on the quadrat setup. Regeneration frequency of seedling and sapling were spatially observed at 100 m intervals using simple qualitative analysis by MS excel. Subsequently, a non-parametric test using Kruskal-Wallis test was used to determine if there are significant differences in regeneration frequency by both seedling and sapling data between vegetation types. *Spearman rank correlation* was used to determine if there was a significant relationship of regeneration frequency between seedlings and saplings that were grouped by vegetation.

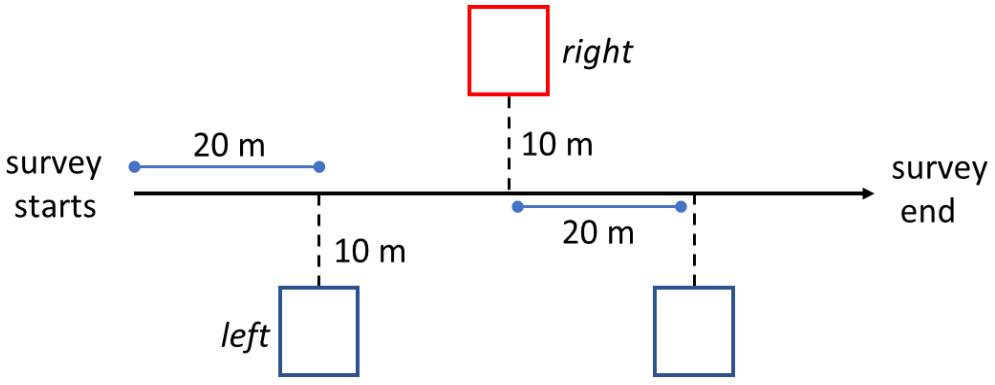

Figure 2. Diagram on the quadrat setup used in Method 2.

3. To construct a 3-D digital elevation model (DEM) of Mt. Silam

Method 3: The estimated area of Mt. Silam was plotted using QGIS ver. 3.6 while the Shuttle Radar Topography Mission (SRTM) dataset of digital elevation model of the area was downloaded from https://earthexplorer.usgs.gov. The image produced from STRM produced an elevation data of worldwide coverage at a resolution of 1 arc-second (30 meters) and provided open distribution of this high-resolution global data set. The DEM data was clipped to the extent of Mt. Silam area and modeled using multiple layers of terrain analysis (hillshade, ruggedness index and relief index) and google satellite image. To produce a 3D effect, vertical exaggeration was set from 1.5 to 6.5 using a separate QGIS Phyton Plugins Repository.

Additional shapefiles of forest reserve boundaries, riverlines (new_forest_reserve.shp, MYS_waterline.shp, developed by SFD) and GPS point of interest (POI) during the survey, were incorporated and labeled to the DEM model for reference. The final model was converted to an image file (png format) and was later exported to Photoshop ver. 12.0 for image editing.

Table 1. Survey details in Mt. Silam.

T	Altitude (m.a.s.l)	*T* Start	Dist.	ECA	N_RQ	Vegetation
T_1: Trail to summit	624 – 884	N4.96522 E118.17495	3.2	0.2	51 (1km)	Lower montane to Mossy forest
T_2: Kubang badak trail to water catchment	357 - 180	N4.97942 E118.18210	2.7	0.03	51 (1km)	Lowland ultramafic
T_3: Kubu Jepun trail	455 – 290	N4.97510 E118.18987	3.1	0.04	31 (0.6km) *Upland only	Upland to lowland ultramafic
T_4: Road survey (by vehicle)	670 – 170	N4.96528 E118.17497	10	2.6	NA	Lower montane to lowland ultramafic

Abbreviation. T = transect, Dist = estimated distance in km, ECA = estimated covered area in km^2, N_RQ = number of regeneration quadrat performed; parenthesis is referring to length of transect; NA = not available.

RESULTS

***Objective 1**: To a perform checklist of dipterocarp species in Mt. Silam*

From the surveys conducted, 18 dipterocarp species from five genera were recorded. Four unconfirmed *Shorea* species and one *Hopea* species were excluded from the checklist for further identification in SAN Herbarium (Forest Research Centre, Sandakan). Based on the completed transects, T_2 has the highest species recorded with 11 species, while T_1 has the lowest species recorded with four species

(Table 2: taxa_S). In addition, 11 species with 105 of individuals were recorded using rapid assessment survey by vehicle, covering the elevation from 170 to 670 m a.s.l. with an estimated 10 km in distance (Table 1). This data, however, were not included in the alpha diversity indices due to different approaches applied.

Species richness and diversity indices based on three transects (*T*) were determined in Table 2. The reported value for Shannon-Wiener index (H') ranged from 0.43 to 1.79, Fisher's alpha from 4.26 to 1.16 while Simpson (1-D) varied from 0.82 - 0.22. Proximity values of diversity indices between T_2 and T_3 observed due to diversify species compared to the highest dominance recorded in T_1. The reported evenness index (e) varied from 0.75 to 0.38; indicated the highest homogeneity among the completed transects was in T_3.

Table 2. Importance value indices for dipterocarp species in Mt. Silam.

Alpha diversity indices	T_1	T_2	T_3
Taxa_S	4	11	8
Individuals	35	52	54
Dominance_D	0.78	0.19	0.16
Simpson_1-D	0.22	0.81	0.84
Shannon_H	0.43	1.78	1.79
Evenness_e^H/S	0.38	0.54	0.75
Margalef	0.84	2.53	1.76
Fisher_alpha	1.16	4.26	2.60

Abbreviation, *T* = transect

Cluster analysis

The dendrogram in Chart 1, based on similarity index by species presence-absence (P-A) data suggested there were two separated groups according to species as follow:

- Cluster 1: *Hopea wyatt-smithiana, Shorea falciferoides, Shorea obscura, Shorea* sp.3, *Vatica mangachapoi, Dipterocarpus lowii, Shorea kunstleri, Shorea multiflora, Vatica albiramis, Vatica micrantha, Hopea* sp.1, *Shorea agamii, Shorea beccariana.*
- Cluster 2: *Shorea* sp.1, *Shorea* sp.2, *Shorea venolusa, Vatica oblongifolia*

These observations may suggest species were characterized into two vegetations or ecological zones. To test the level of differences between the two clusters, statistical analysis of One-way ANOSIM using Jaccard's similarity index was performed using 9999 permutations. The result indicated that there were significant differences between the clusters (p = 0.0008) with R-value shows high separation between the levels of factors (R = 0.738).

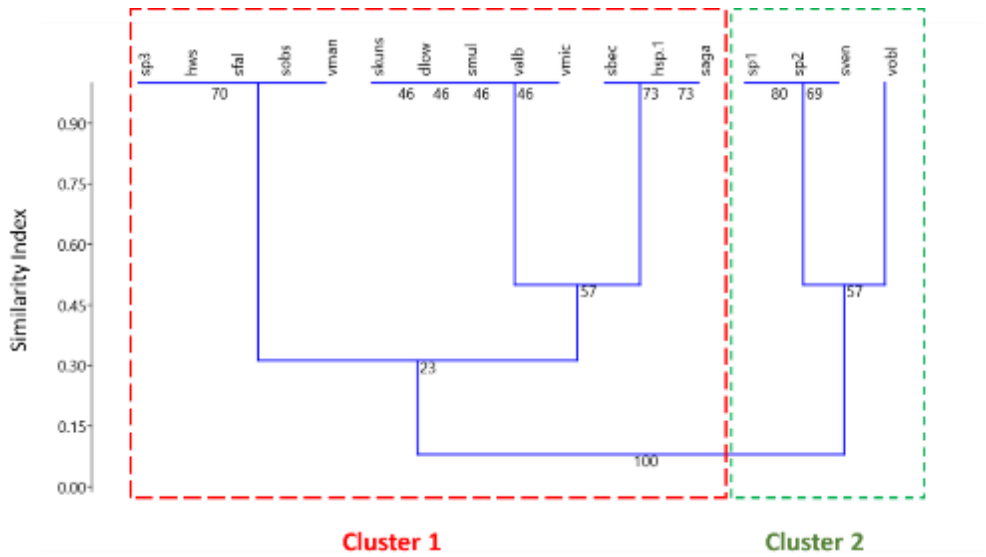

Chart 1. Dendrogram (UPGMA) based on species presence-absence (P-A) data using Jaccard's similarity index. Result shows two main clusters were formed and highlighted by dashed red and green lines.

Global IUCN Red List

Of the 18 species recorded, four species registered as Vulnerable (VU), one species was Endangered (EN) and four species listed as Critically Endangered (CR). Seven other species were registered as Least Concern (LC; Table 3). With this, 50 % out of the total species recorded were categorised as Threatened species with VU, EN and CR combined. Interestingly, more than 60% of the species recorded in Mt. Silam were Bornean endemics as highlighted in Table 3. *Vatica* cf. *pachyphylla*, a species that is endemic to the Philippines, was newly discovered in 2019 remarked as rare due to the possibility of it to be found in Mt Silam, Sabah. There were six individuals of the species recorded and specimens were taken. The distribution of the individuals was proximity aggregated near to the roadside at N4.97971, E118.21020 by 160 m.a.s.l. The DBH of the individuals ranged from 46.5 to 15.5 cm with two flowering individuals (refer to appendix).

Table 3. Global IUCN Red List assessment of dipterocarp species in Mt. Silam.

No.	Species	Frequency	IUCN
1	***Shorea venulosa***	55	LC
2	*Dipterocarpus lowii*	49	CR
3	*Shorea multiflora*	44	LC
4	*Shorea kunstleri*	35	CR
5	***Vatica micrantha***	10	LC
6	***Shorea beccariana***	10	LC
7	***Shorea falciferoides***	8	CR
8	*Vatica* cf. *pachyphylla* *	6	CR
9	***Shorea agamii***	5	NT
10	***Hopea wyatt-smithii***	4	NT
11	*Shorea gratissima*	3	EN
12	***Vatica mangachapoi***	3	VU
13	***Vatica oblongifolia***	2	LC

14	***Vatica albiramis***	2	LC
15	***Dryobalanops lanceolata***	2	LC
16	*Shorea atrinervosa*	1	VU
17	***Shorea obscura***	1	VU
18	*Shorea guiso*	1	VU

*rare species and newly discovered in 2019; **Bold** = Bornean endemics

***Objective 2**: To determine the regeneration frequency of dipterocarp seedlings and saplings based on vegetation type.*

Regeneration frequency

Pooled data from seedling and sapling revealed that R_2 has the most regeneration frequency (187) followed by R_3 (178), while the lowest regeneration frequency was observed in R_1 (Table 4). As such, *Shorea venulosa* was recorded as the only single dominant reproductive species (RS) for lower montane vegetation (R_1, Table 5). Among the nine reproductive species in R_2, *Shorea multiflora* registered as the highest RS for lowland ultramafic (R_2), while *Vatica micrantha* was the dominant RS out of the ten species recorded in upland ultramafic (R_3). Statistical analysis using *Kruskal-Wallis* test showed that there were significant different between the vegetations (R_1, R_2 & R_3) according to the regeneration frequency by seedling and sapling ($\chi^2 = 10.34$, $p = 0.0002$). Not only ranked among the dominant reproductive species, both species of *Shorea multiflora* and *Vatica micrantha* were also recorded in two vegetations, the lowland and upland ultramafic (Table 5). Other reproductive species that were recorded in two vegetations were *Dipterocarpus lowii*, *Vatica albiramis*, *Shorea kunstleri* and *Shorea obscura*. Reproductive species that were only observed in single vegetation were *Hopea whatt-smithii*, *Vatica mangachapoi*, *Shorea agamii and Shorea beccariana* (with three unconfirmed taxa, Table 5).

Table 4. Regeneration frequency by vegetation.

Vegetation	Seedlings	Saplings	Pooled	N_sp	RS
R_1	12	10	22	1	*Shorea venulosa*
R_2	144	43	187	9	*Shorea multiflora*
R_3	152	26	178	10	*Vatica micrantha*

Abbreviation. N_sp = number of species; RS = reproductive species

Table 5. Regeneration frequency by species.

No.	Species	Seedling	Sapling	Pooled	Vegetation
1	*Shorea multiflora*	173	17	190	R2, R3
2	*Vatica micrantha*	67	15	82	R2, R3
3	*Shorea venulosa*	12	10	22	R1
4	*Dipterocarpus lowii*	13	5	18	R2, R3
5	*Hopea whatt-smithii*	2	9	11	R2
6	*Shorea* sp. 1	2	8	10	R2
7	*Hopea* sp.1	5	4	9	R3
8	*Vatica albiramis*	6	2	8	R2, R3
9	*Vatica mangachapoi*	7	1	8	R2
10	*Shorea kunslerii*	7	0	7	R2, R3
11	*Shorea obscura*	3	4	7	R2, R3

12	*Shorea agamii*	6	0	6	R3
13	*Shorea beccariana*	5	0	5	R3
14	*Shorea* sp. 4	1	0	1	R3

Seedling and sapling regeneration pattern

The regeneration pattern by seedling and sapling were shown in Figure 3, for each vegetation type. The regeneration pattern was observed at peak of 100 m by the single dominant reproductive species in lower montane, *Shorea venulosa* (Figure 3A). As elevation increased, the regeneration pattern of *Shorea venulosa* was discontinued from 500 m and onwards due to the transition forest from lower montane to upper montane of mossy forest. Figure 3B showed the regeneration pattern in lowland ultramafic was inconsistent with detection of small patch frequency. The regeneration pattern corresponded to the decreased elevation from 357 m (the entrance points of Kubang Badak trail) to 180m (located at water catchment reservoir), indicated in the reduction of forest quality from 600 m and onwards. This is supported by the observation made during the survey as the lower part of the forest has been previously logged, thus reducing the number of reproductive trees.

The regeneration quadrat (RQ) in upland ultramafic was only established up to 600 m due to stiff downhill terrain as transition began into lowland ultramafic by 400 m a.s.l. Moreover, the regeneration quadrat (RQ) has to be in single vegetation for comparison study. In upland ultramafic, the regeneration pattern by seedlings was observed at moderate to high while low regeneration frequency recorded by saplings throughout the distance (Figure 3C). Figure 3D showed the overall patterns produced by three different vegetations. It explained that both regeneration frequency of seedlings and saplings were uniform in lower montane (R1), while increased regeneration frequency in seedlings and saplings in lowland ultramafic (R2). Interestingly, the regeneration frequency increased in seedling while decreased in sapling performance observed in upland ultramafic (R3).

Statistical analysis using a non-parametric *Spearman rank correlation* was conducted to determine if there is a correlation between the frequency of seedlings and saplings in each vegetation. Based on the result, there was a positive significant correlation of regeneration frequency between the seedlings and saplings in lower montane (R1: r_s = 0.414, p = 0.003), while a negative significant correlation was calculated in lowland ultramafic (R2: r_S=-0.66, p =1.21E^{-07}) and no significant correlation was detected in upland ultramafic (R3: r_S=-0.07, p = 0.671).

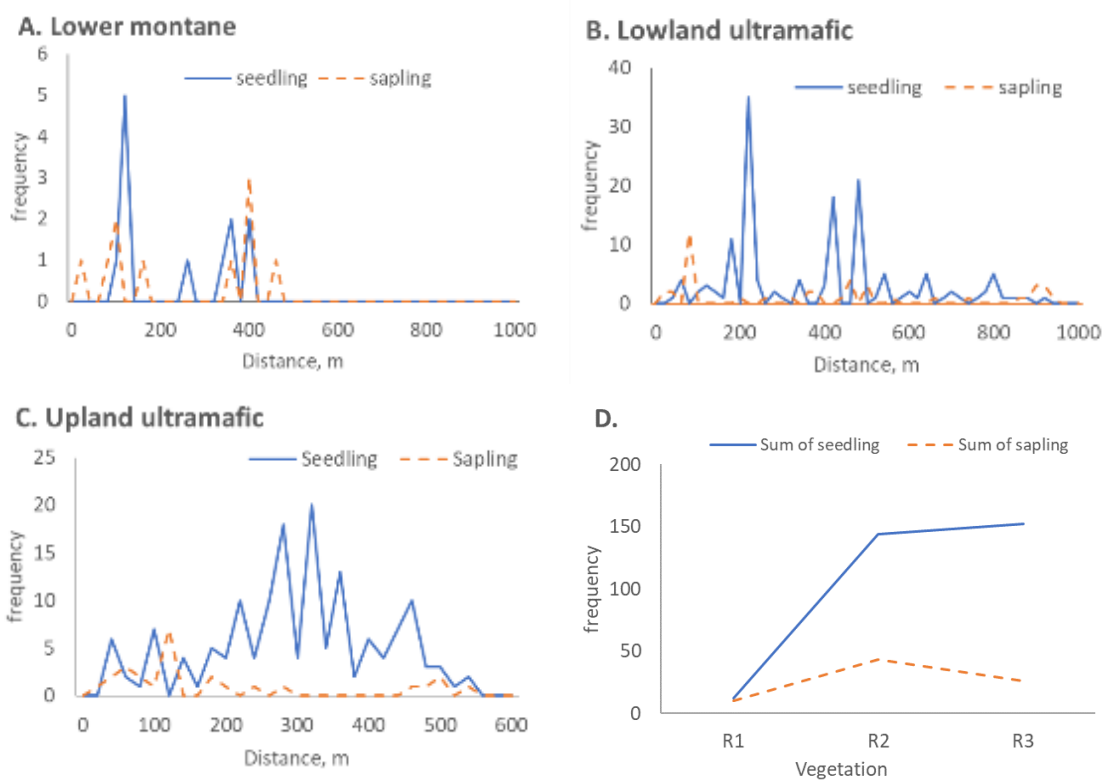

Figure 3. (A-C). Pattern of the frequency regeneration for seedlings and saplings based on vegetation and (D) comparison in the three vegetations. Note: R1 = fig. A, R2 = fig. B and R3 = fig. C.

Objective 3: *To construct a 3-D digital elevation model (DEM) of Mt. Silam*

Digital elevation model (DEM) is the digital representation of the land surface elevation which is also referred to topographic surface. It is best to determine terrain attributes, such as elevation, slope and aspect which is widely used in hydrologic and geologic analyses and in other relevant studies (Sulebak 2000). In ecology, ecological modelling and DEM are combined to explore possibilities for vegetation mapping (altitudinal vegetation zones) in predicting species occurrences. In this study, DEM was constructed in a 3-Dimensional model for Mt. Silam to visualise the details of topography, slope and vegetation structure according to completed transects. DEM data was obtained from SRTM that was produced by NASA has the accessibility of high-quality elevation data.

Stepwise in constructing DEM with mixed details was explained in Figure 4. The first step was extracting DEM data to the extent of Mt. Silam area and converting it into raster file through QGIS. Subsequently, terrain analysis was performed to create multiple layers of hillshade, ruggedness index and relief index before superimposed to single-band pseudocolor of the extracted raster DEM. In addition, GPS points of interest (POI) and shapefiles from SFD (New_Forest_reserve and MYS waterline) were overlaid into the raster data. A complete DEM was produced after multiple layers, POI and shapefile references were combined, as shown previously in Figure 1.

The next step was transforming the completed DEM into a 3-Dimensional model. Based on Figures 5 & 6, different versions of QGIS and plugin repository were used in modelling these DEMs into a 3-Dimensional model. The 3D model in **Figure 5** was using QGIS ver. 2.14 with plugin repository from Qgis2threejs 3D visualization powered by WebGL technology and three.js JavaScript library (developed by Minoru Akagi). Figure 6 shows a 3D model that was created using QGIS ver. 3.6 through the built-in plugin repository by XYZ Tiles. This specific plugin enabled Google satellite to merge with DEM, in creating a 3D DEM model with features from Google earth. The different versions of QGIS were used due to incompatibility for specific plugin repositories towards programming modules.

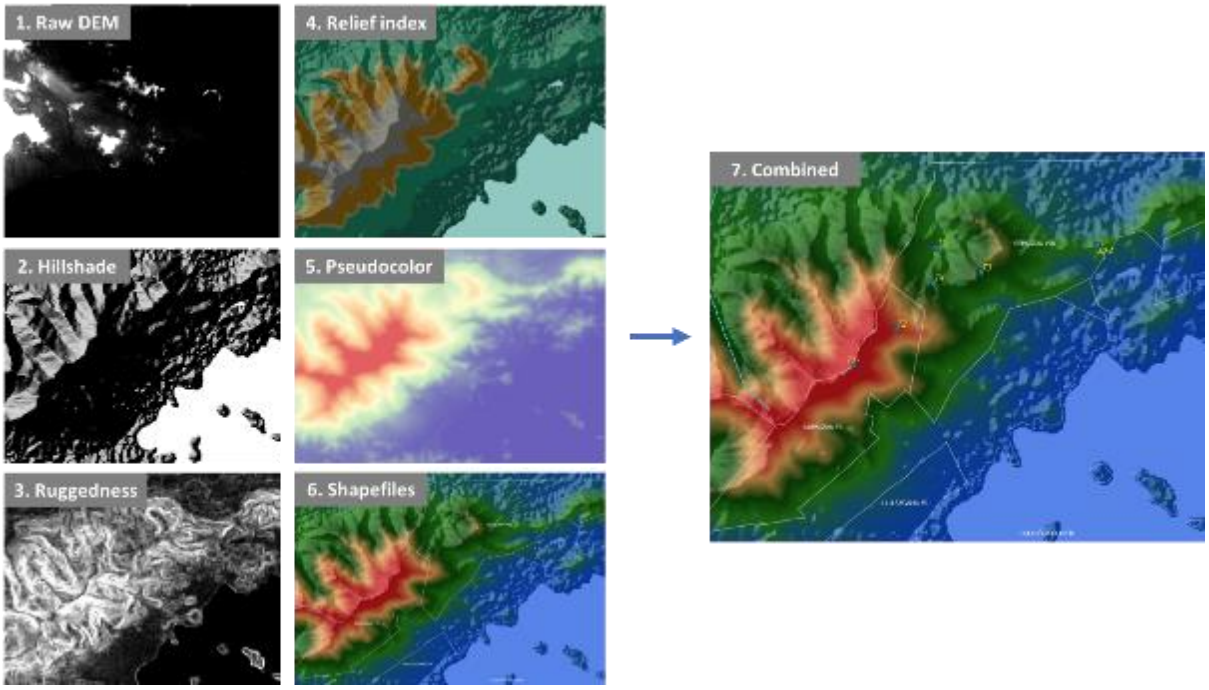

Figure 4. Stepwise in constructing DEM into a 3-dimensional model.

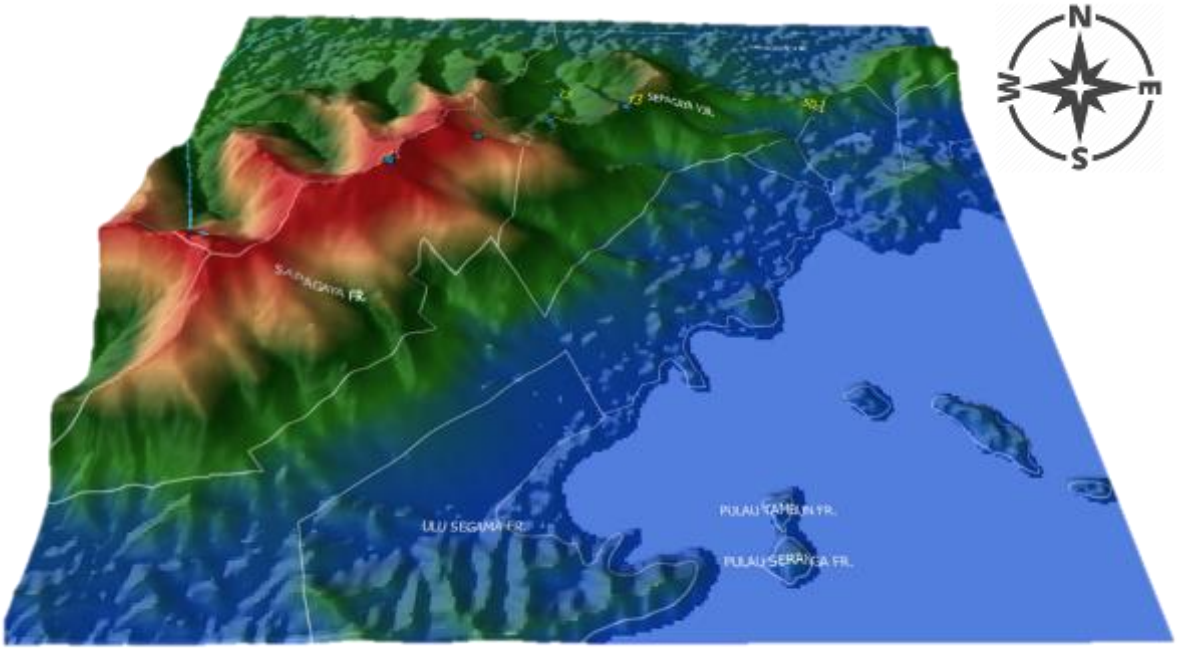

Figure 5. A 3-dimensional model created using Qgis2threejs plugin repository by QGIS version 2.14.

Figure 6. A 3-dimensional model created using XYZ Tiles plugin repository in QGIS version 3.6.

CONCLUSION

The recorded dipterocarp species in Mt. Silam suggested to be differed in relative vegetation, as it was supported by results from the cluster analysis that shows two divided groups. The result indicated segregation between lower montane species with upland and lowland ultramafic was relatively by elevation and forest stature. Dominant species, such as *Shorea venulosa*, *Shorea multiflora* and *Vatica micrantha* were observed to be the most reproductive adults in producing seedlings and saplings based on the frequency obtained through regeneration quadrats, by different transects/vegetation. Although the recorded dipterocarp species was lower compared to other sites, more than 60% of the species compiled were Bornean endemics and about half of them are listed under threatened species in the IUCN Red List. Interestingly, four more individuals of *Vatica* cf. *pachyphylla* were spatially aggregated recorded during the survey. It is one of the rare species that was discovered in 2019, endemic to the Philippines and was first to be found in Sabah (Mt. Silam). In addition, a 3-dimensional DEM was created to represent additional details as a guideline for future surveys, in understanding the terrain complex and slope of Mt. Silam.

ACKNOWLEDGEMENTS

We would like to thank the Chief Conservator of Forests, Datuk Mashor Mohd. Jaini, the Deputies to the Chief Conservator, Frederick Kugan and Dr Robert Ong, for their continual support in this expedition. Special thanks are extended to Mohd. Aminur Faiz and the committee who facilitated the expedition arrangement and to the District Forestry Officers of Lahad Datu and staff for logistics support and assistance.

REFERENCES

Baillie, I., Evangelista, P. & Inciong, N. (2000). Differentiation of upland soils on the Palawan ophiolitic complex, Philippines. *Catena* 39: 283–299.

Bruijnzeel, L.A., Waterloo, M.J., Proctor, J., Kuiters, A.T. & Kotterink, B. (1993). Hydrological observations in montane rain forests on Gunung Silam, Sabah, Malaysia, with special reference to the 'Massenerhebung' effect. *Journal of Ecology* 81:145-167.

Chung, A.Y.C. & Ebin, J. (2012). Revisiting the elegant Bornean endemic crab of Mt. Silam, Sabah. *Malayan Naturalist* 65 (4), 50–51.

Coleman, R.G. & Jole, C. (1992). Geological origin of serpentinites. *The Vegetation of Ultramafic (Serpentine) Soils.* Andover: Intercept Limited.

Hammer, Ø., Harper, D.A.T. & Ryan, P.D. (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica,* 4, 9 pp.

Ketol, B., Anwarali, F.A., Marni, W., Sait, I., Lakim, M., Yambun, P.I., Salleh, M.A., Rahman, M.A. & Abdullah, M.T. (2009). Checklist of mammals from Gunung Silam, Sabah, Malaysia. *Journal of Tropical Biology and Conservation* 5: 61-65.

Magurran, A.E. (2004). Measuring biological diversity. Oxford: Blackwell.

Margalef, R. (1958). Information theory in Ecology. *Gen. Syst.* 3:36–71.

Pielou, E.C. (1975). *Ecological diversity*. New York: Wiley Interscience.

Proctor, J., Lee, Y.F., Langley, A.M., Munro, W.R.C. & Nelson, T. (1988). A small ultrabasic mountain in Sabah, Malaysia. I. Environment, Forest Structure and Floristic. *Journal of Ecology* 76(2): 320-340.

Proctor, J. & Nagy, L. (1992). Ultramafic rocks and their vegetation: an overview. In: Baker, A., Proctor, J. & Reeves, R.D. (eds) *The Vegetation of Ultramafic (Serpentine) Soils: Proceedings of the First International Conference on Serpentine Ecology*. Andover, U.K.: Intercept Ltd.

Sabah Forestry Department (2005). Sabah Forestry Department [Online]. URL: http://www.forest.sabah.gov.my/caims/Class%20I/A_FR1/bidu%20bidu.htm [*Accessed April 26, 2020*].

Shannon, C.E. & Weaver, W.W. (1963). The mathematical theory of communications. University of Illinois Press. *Urbana*, 117 pp.

Simpson, E.H. (1949). Measurement of diversity. *Nature (London) 163:688*

Sulebak, J.R. (2000). *Applications of digital elevation models. DYNAMAP "White Paper".* SINTEF.

APPENDIX

Figure 7. Assessing DBH of *Vatica* cf. *pachyphylla.*

Figure 8. Inflorescense of *Vatica* cf. *pachyphylla.*

Figure 9. A specimen of *Vatica* cf. *pachyphylla.*

Figure 10. The team assessed the abundance of dipterocarp seedlings and saplings inside a regeneration quadrat.

Figure 11. A small pool at Kubang Badak trail.

A preliminary study on macrofungi of Mount Silam, Lahad Datu, Sabah

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Abstract. A survey on macrofungi at Mount Silam which is located in the district of Lahad Datu was carried out on 14th to 17th January 2020. Mt. Silam is located within the Sapagaya Forest Reserve and is declared as Class 1 Protection Forest to establish baseline data on fungal richness in the area. Macrofungi sighted were photographed and samples were collected to serve as voucher specimens. A total of 57 specimens comprising 9 orders, 13 families and 22 genera were recorded. The order Polyporaceae was the most numerically abundant, making up (39%) of the specimens collected. Most of the fungi sighted were on woody debris on the dead branches. Several noteworthy fungi including *Cookeina* spp. were documented.
Keywords: Fungi, Mount Silam, Sapagaya Forest Reserve

INTRODUCTION

Fungi are not animals, nor plants. Unlike the animals and plants, their cell walls are made up of chitin. Fungi cannot produce their own food, hence, they feed on dead organic matters to get the nutrients (saprophytic). Ascomycota and Basidiomycota are the two main classes in the fungi kingdom. Ascomycota cannot be seen under naked eyes except for the cup fungi. While fungi under the class Basidiomycota mostly can be consumed such as from the genus Auricularia, Pleurotus and Volvariella (Dewi *et al.* 2019). The bolete, puffball, gilled, coral, toothed, bracket, and jelly fungi are some examples of the basidiomycetes. Each type of these fungi has its own characteristic and appearance and are useful in the identification of fungi (Branco 2011). Fungi play an important role in the ecosystem in which they are the main decomposer of dead organic matter, such as dead trees, woods and leaves (Hyde *et al.* 1998). They are the food sources for certain animals, insects and even humans (Zainuddin *et al.* 2010).

The Forest Research Centre team has been assigned to conduct the PES (Payment for Ecosystem Services) study in Mt. Silam on 13th to 18th of January 2020. Mt. Silam is situated within the Class I Protection Forest, which is Sapagaya Forest Reserve. Since its existence, Mt. Silam contributes to the ecotourism revenue. It also attracts nature photographers including those who are keen to capture nature photo and "Tower of Heaven" or well known as "Menara Kayangan" is the most popular spot where people can get the view of Lahad Datu town and its surrounding mountains, forest and the beautiful Darvel Bay. Hence, a baseline study of the fungi diversity in Mt. Silam was carried out and the data collected were used to generate a checklist of fungi.

MATERIALS & METHODS

Study area

This study was conducted in Mt. Silam which is located within the Sapagaya Forest Reserve area. Mt. Silam is easily accessible by Lahad Datu-Tawau main road and it is just situated approximately 10 km from Lahad Datu town. Being classified as Class I Protection Forest Reserves, the Sapagaya covers about 698 ha and acts as a shelter or home to the wildlife in that area. Samplings were conducted at the 4 trails in Mt. Silam and Sapagaya water falls (Figure 1).

Field surveys and collection of fungi

The fieldwork was conducted from 14th January to 17th January 2020. Opportunistic sampling method was used wherein the team walked through the area (GPS were recorded as in Table 1) and collected conspicuous specimens of fungi when sighted. The macroscopic fungi were identified in the field and photographed from the top and bottom (camera: DSLR Nikon D3200). Information on the latitude, longitude and altitude of the fungi was also recorded using the GPS (Model: Garmin GPSMAP 64S).

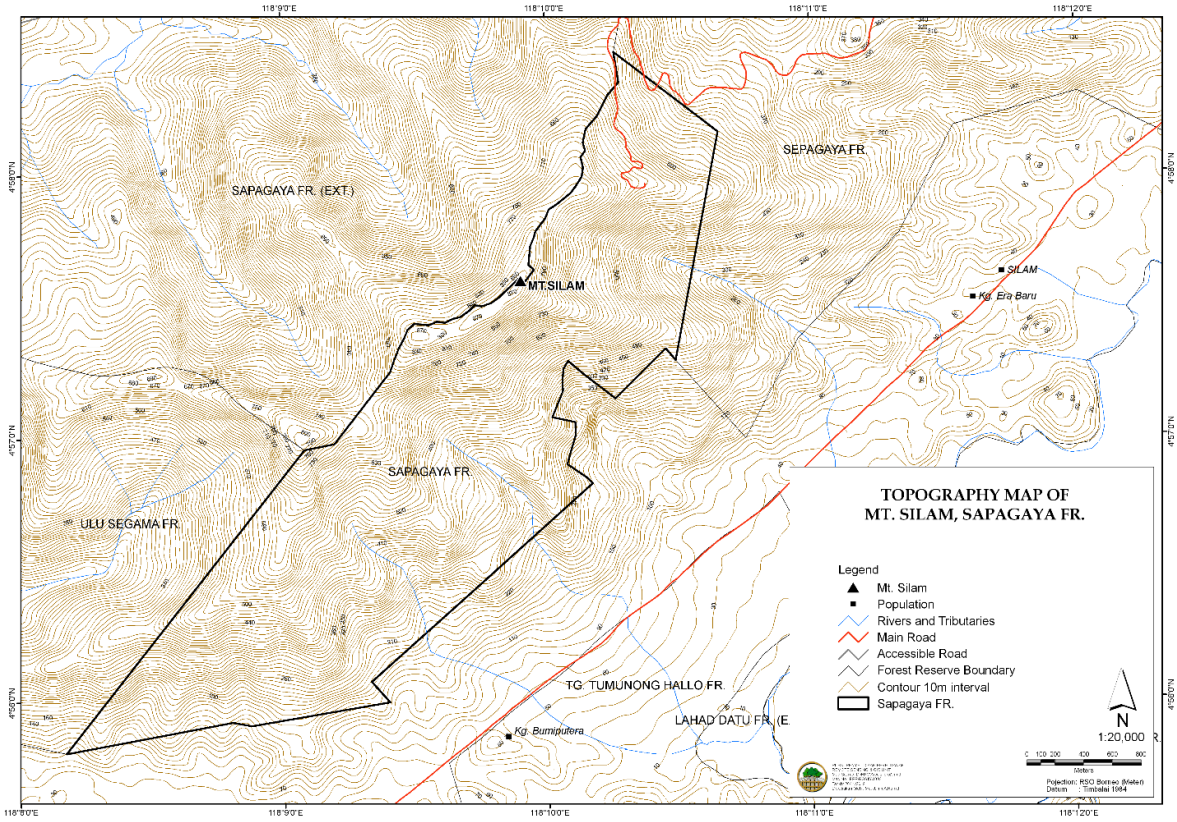

Figure 1. The map of Mt. Silam which is located within the Sapagaya Forest Reserve.

Table 1. Location of sampling plots in Mt. Silam and its surrounding area.

Research Plot	Starting Point Latitude Longitude	End Point Latitude Longitude	Elevation (m.a.s.l.)	Date	Forest Types
P1	04° 59' 01.7" 118° 08' 44.8"	04° 57' 52.6" 118° 10' 13.7"	698-787	14/01/2020	Upper montane ultramafic forest
P2	04° 59' 02.6" 118° 08' 44.2"	04° 58' 36.3" 118° 10' 50.7"	144-207	15/01/2020	Lowland forest
P3	04° 58' 19.9" 118° 10' 24.7"	04° 58' 19.6" 118° 10' 40.6"	546-391	16/01/2020	Minimally disturbed forest
P4	04° 58' 50.3" 118° 12' 48.9"	04° 58' 44.8" 118° 12' 12.4"	161-197	17/01/2020	Lowland forest

Taxonomic identification

The identification of macrofungi was made possible with the aid of current keys and descriptions in field guides (Singer *et al.*, 1983, Pegler 1997, Zainuddin *et al.* 2010 & Lee 2012). When specimens could not match to the known species descriptions, they were assigned to a genus and given a species number, for example, *Hyphodontia* sp. 1. The taxonomic status and description of these species will be examined later or when fungus specialist are available. The specimens were later brought back and dried in an incubator or oven at 45°C for 24–48 hours. The moderate temperature was set for drying in order not to kill the fungi but to keep them dormant for culture isolation in the future. The dried specimens were deposited at the Pathology Laboratory in the Forest Research Centre, Sepilok, Sandakan for further study.

RESULTS AND DISCUSSION

A total of 22 genera from 13 families belonging to 9 orders of fungi were recorded in Mt. Silam (Figure 2). Order Polyporaceae (39%) had the highest number, followed by Ganodermataceae (16%), Marasmiaceae (15%), Agaricaceae (8%), Stereaceae (5%), Lentariaceae and Sarcoscyphaceae share the same percentage which is 3%, meanwhile, Amylocorticiaceae, Boletaceae, Cantharellales, Dacrymycetaceae, Meripilaceae and Russulaceae share the same percentages (2%), respectively. The family Polyporaceae was the most dominant (24 individuals) whilst the least dominant were that of the Amylocorticiaceae, Boletaceae, Cantharellales, Dacrymycetaceae, Meripilaceae and Russulaceae where only one individual representing each family. The genus *Microporus* had the highest number of individuals found in Mt. Silam, in which 14 specimens were collected, followed by *Marasmius* and *Ganoderma* with 9 and 6 specimens, respectively.

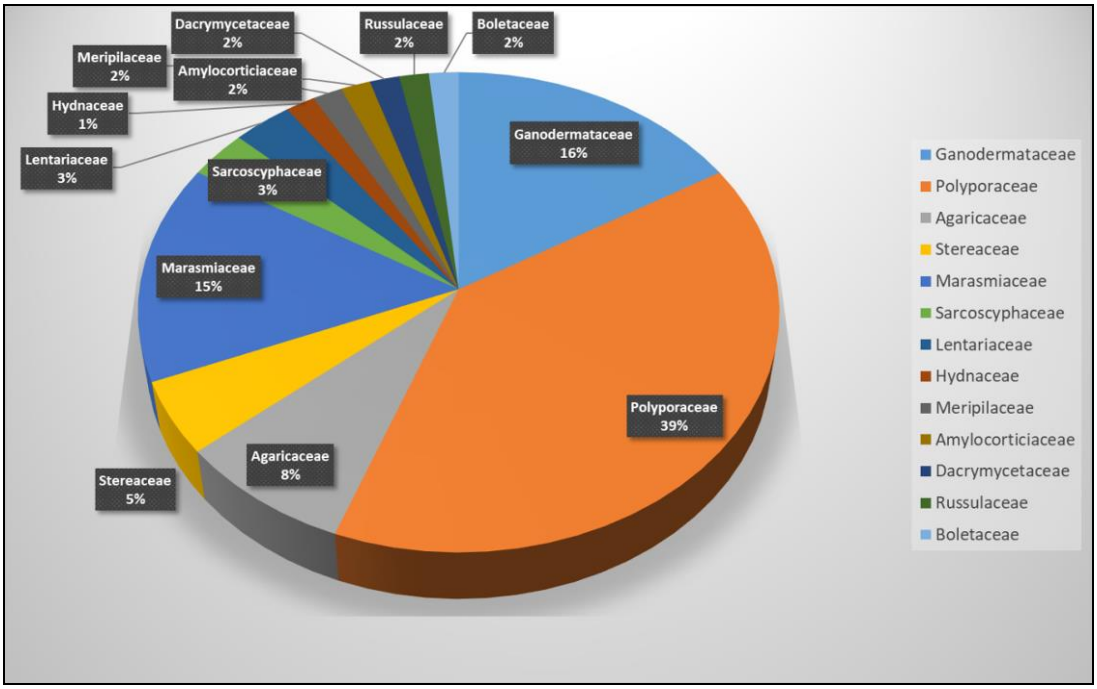

Figure 2. Percentage of families of macrofungi by families in Mt. Silam, Lahad Datu, Sabah.

The findings of this study with the Order Polyporales having the highest number recorded concurs with Yamashita *et al.* (2015) in that the species diversity of polypores in the primary forests is relatively high in the tropical region compared with that in temperate or boreal regions. The fruiting bodies of polypores is pivotal to the anthropods in which they provide food and habitat resources (Yamashita *et al.* 2015). Malaysia lack the resources and expertise in studying macrofungi (Lee *et al.* 2008, Chang & Lee 2004, Hyde 2003), with only few suitable keys and monographs available for the identification of fungi in Borneo, to date, hence there are fungi that cannot be identified up to the species level. Nevertheless, there is a marked interest to study fungi whereby a number of studies have been carried out in Sabah in recent years. Macrofungi survey was carried out from 21st to 26th of August, 2017 during the Imbak Canyon Conservation Area (ICCA) Scientific Expedition at Batu Timbang Area, Imbak Canyon, Sabah. A total of 106 species from 13 different families within Basidiomycota and Ascomycota were documented in this study (Paul *et al.* 2019). Besides that, a study on ethnomycological knowledge of wild mushrooms has been conducted within the indigenous communities of Sabah (Foo *et al.* 2018). Through this study, documentation of wild edible mushrooms in Sabah were recorded.

Photographs of selected macrofungi are shown in Plates 1 to 4. The fungi were found predominantly growing on woody debris (coarse and fine).

Notes on selected species

Mt. Silam is home to several fascinating taxa that are ecologically vital to the forest ecosystem and may be economically important. The followings are description of the fungi found in Mt. Silam.

Yellow-footed polypore (Plate 1a)

Microporus xanthopus is a very common fungi that can be found in all the nine trails in RDC. The "*xanthopus*" derives from two Greek words and literally means yellow foot (Lepp 2008) hence they are called yellow footed due to their yellow stipe. The fruiting bodies are funnel-shaped and sometimes the two fruiting bodies grow together to formed a bigger body. The surface is concentrically zoned with brown, yellow and black colour. The margin is wavy. Its underside is white in colour and the pores are minuscule to be seen by naked eyes. They are usually found growing on the dead branches. According to Chang & Lee (2004), *Microporus xanthopus* can be used in weaning process for babies.

Ganoderma sp. (Plate 2a,b,c)

Ganoderma sp. or well known as "Lingzhi" in Chinese are the second abundant genus that can be found in Mt. Silam after *Microporus* sp. from the family Polyporaceae. This genus can be easily spotted near to dead logs and distinctive basidiocarps can be observed clearly. Ganoderma sp. is really popular for over two millenia in the usage of Chinese Traditional Medicine as special teas or concoctions in China, Japan, and other Asian countries (Sudheer *et al.* 2018).

Cup fungi (Plate 4e)

Cookeina is commonly known as cup fungi or "*Kulat mangkuk*" in Malay, belonging to the class Agaricamycota (Order: Pezizales; Family: Sarcosyphaceae). The species found in the survey were *C. sulcipes* and it is fairly easy to differentiate based on their morphology. *Cookeina tricholoma* is usually red to peach colour with short stipe and white hairs covering the cup surface. The colour of *Cookeina sulcipes* is between peach to light pink or from light yellow to white and it usually has a long stipe where tiny hairs that can be seen at the edge of the cup surface (Abdulah & Rusea 2009, Denison 1967 & Zainuddin *et al.* 2010). *Cookeina* sp. can be used as fish bait by rubbing it against the fish hook (Chang & Lee 2004).

CONCLUSIONS

The order Polyporales had the highest number of fungi in Mt. Silam with most (39%) of the specimens collected were from this order. It is recommended that further studies on fungi be carried out for a more comprehensive documentation in Mt. Silam. Research need to be further intensified to gather and document the many fungi that have yet discovered in Borneo too. It is hopeful that the findings of this study may generate further interest to work or conduct comprehensive study on fungi.

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We would like to thank the Deputy Chief Conservator of Forests (Research & Development), Dr. Robert C. Ong and the Deputy of Forest Research Centre (Research and Publications), Dr. Arthur Chung for their support and guidance throughout this study. Appreciation also goes to Dr. Jayaseelan Sathiya Seelan for some of the identification of the fungi for the preparation of this manuscript.

REFERENCES

Abdulah, F. & Rusea, G. (2009). Document of inherited knowledge on wild edible fungi
from Malaysia. *Blumea* (54): 35-38.

Branco S. (2011). Fungal Diversity-an overview. *The Dynamical Processes of Biodiversity - Case Studies of Evolution and Spatial Distribution*. https://www.intechopen.com/books/the-dynamical-processes-of-biodiversity-case-studies-of-evolution-and-spatial-distribution/fungal-diversity-an-overview. Accessed on 16th November 2018.

Chang, Y.S. & Lee, S.S. (2004). Utilisation of macrofungi species in Malaysia. *Fungal Diversity*, *15*: 15-22.

Denison, W.C. (1967). Central American Pezizales. II. The genus *Cookeina*. *Mycologia* 59(2): 306-317.

Dewi, M., Aryantha, I.N.P., Kandar, M. (2019). The diversity of Basidiomycota fungi that have the potential as a source of nutraceutical to be developed in the concept of integrated forest management. *International Journal of Recent Technology and Engineering (IJRTE)* 8(2): 81-85.

Foo, S.F., Saikim, F.H., Kulip, J., Seelan, J.S.S. (2018). *Journal of Tropical Biology and Conservation* 15: 203-222.

Hyde, K.D., Jones, E.B.G., Leano E., Pointing, S.B., Poonyth, A.D. & Vrijmoed L.L.P. (1998). Role of fungi in marine ecosytems. *Biodiversity & Conservation* 7: 1147-1161.

Hyde, K.D. (2003). Mycology and its future in the Asia region. *Fungal Diversity* 13: 59-68.

Lee, S.S., Horak, E., Alias, S.Aa, Thi, B.K., Nazura, Z., Jones, E.B.G. & Nawawi, A. (2008). Checklist of literature on Malaysian macrofungi. https://webcache.googleusercontent.com/search?q=cache:ZHzI6H3zEmwJ:https://www.mybis.gov.my/pd/70+&cd=3&hl=en&ct=clnk&gl=my&client=firefox-b-d. Accessed on 16 November 2018.

Lee, S. S. (2012). *Checklist of fungi of Malaysia*. Forest Research Institute Malaysia. 556 pp.

Lepp, H. (2008). Case studies: *Microporus xanthopus* - growth and sporing. https://www.anbg.gov.au/fungi/case-studies/microporus-xanthopus-growth.html. Accessed on 15th November 2018.

Paul, V., Sudin, M., Foo, S.F., Kassim, M.H.S. & Seelan, J.S.S. (2019). *Journal of Tropical Biology and Conservation* 16: 107-117. https://jurcon.ums.edu.my/ojums/index.php/jtbc/issue/view/216. Accessed on 16th December 2019.

Pegler, D.N. (1997). *The larger fungi of Borneo*. Natural History Publications, Kota Kinabalu. 91 pp.

Singer, R., Araujo, I. & Ivory M.H. (1983). The ectotrophically mycorhizzal fungi of the neotropical lowlands, especially Central Amazonia (Litter Decomposition and ectomycorrhizal. *Beiheftezur Nova Hedwigia* 77: 1-339.

Sudheer S., Alzorqi I., Manickam S., Ali A. (2018). Bioactive compounds of the wonder medicinal mushroom "Ganoderma lucidum". (Mérillon, Ramawat, eds.). Bioactive Molecules in Food, Reference Series in Phytochemistry. Switzerland. Springer International Publishing AG. 31 p. Online ISBN: 978-3-319-54528-8.

Yamashita, S., Hattori, T., Lee, S.S. & Okabe, K. (2015). Estimating the diversity of wood-decaying polypores in tropical lowland rainforests in Malaysia: the effect of sampling strategy. *Biodiversity and Conservation* 24: 393-406.

Zainuddin, N., Lee, S.S., Chan, H.T. & Thi, B.K. (2010). A guidebook to the macrofungi of Tasik Bera. Malaysia, Selangor Darul Ehsan: Forest Research Institute Malaysia. 80 pp.

Appendix A: Checklist of macrofungi in Mt. Silam, Lahad Datu, Sabah.

Division	Order	Family	Genus	*n*	Plate
Basidiomycota	Polyporales	Polyporaceae	*Microporus*	14	Pl. 1: a
			Polyporus	3	Pl. 1: b
			Coriolopsis	1	Pl. 1: c
			Favolus	2	Pl. 1: d
			Pycnoporus	1	Pl. 1: e
			Lentinus	1	Pl. 1: f
		Ganodermataceae	*Ganoderma*	6	Pl. 2: a,b,c
			Amauroderma	4	Pl. 2: d,e
		Lentariaceae	*Lentaria*	2	Pl. 3: a,b
		Meripilaceae	*Rigidoporus*	1	Pl. 3: c
	Agaricales	Marasmiaceae	*Marasmius*	9	Pl. 3: d
		Agaricaceae	*Agaricus*	1	Pl. 3: e
			Coprinus	1	Pl. 3: f
	Russulales	Russulaceae	*Russula*	1	Pl. 3: g
		Stereaceae	*Stereum*	3	Pl. 3: h
	Boletales	Boletaceae	*Boletus*	1	Pl. 4: a
	Cantharellales	Cantharellaceae	*Hydnum*	1	Pl. 4: b
	Amilocorticiales	Amylocorticiaceae	*Podoserpula*	1	Pl. 4: c
	Dacrymycetales	Dacrymycetaceae	*Dacryopinax*	1	Pl. 4:d
Ascomycota	Pezizales	Sarcoscyphaceae	*Cookeina*	2	Pl. 4: e

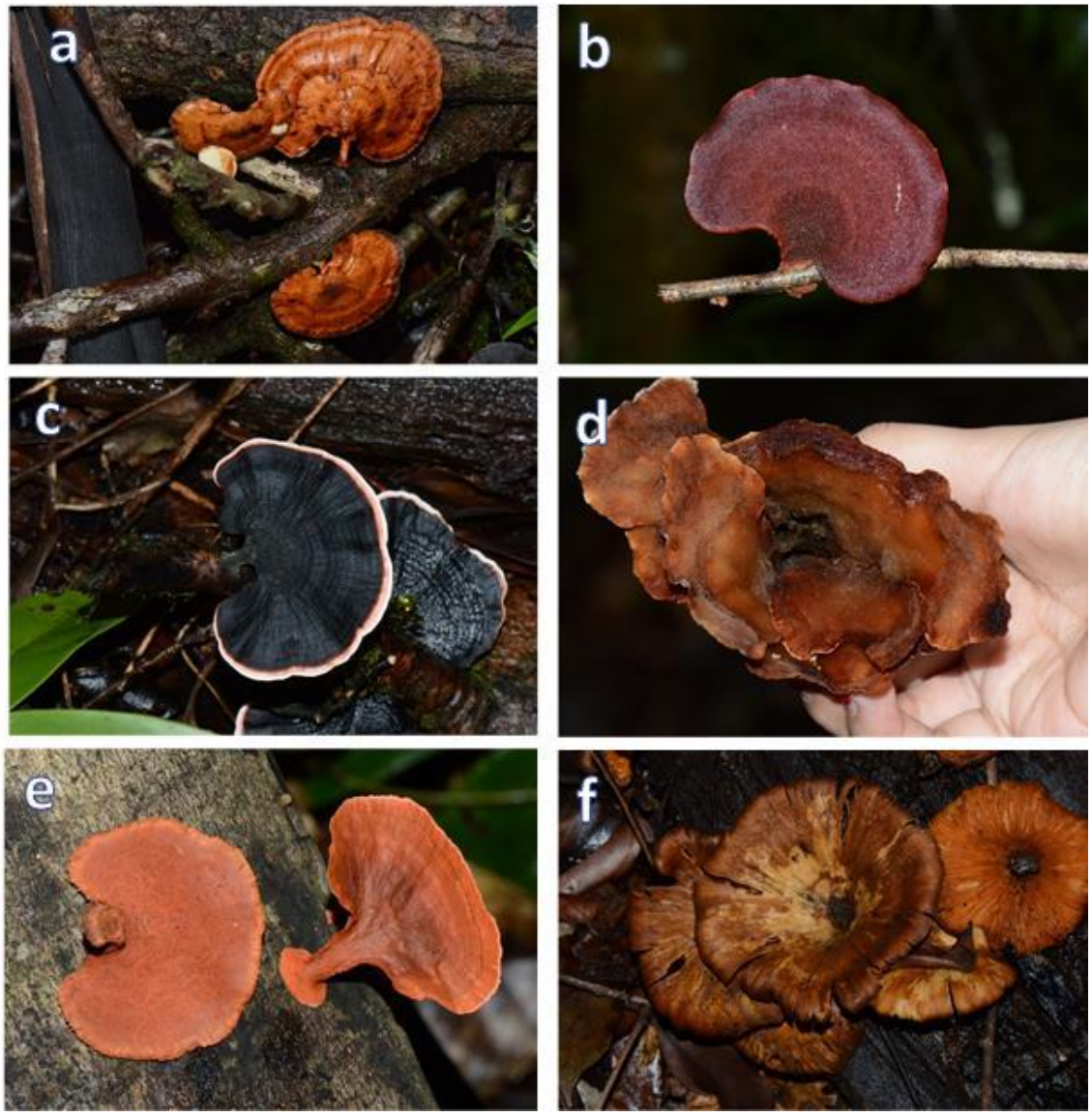

Plate 1 (a) ***Microporus xanthopus***; (b) ***Polyporus* sp.**; (c) ***Coriolopsis* sp.**; (d) ***Favolus* sp.**; (e) ***Pycnoporus* sp.**; (f) ***Lentinus* sp.**

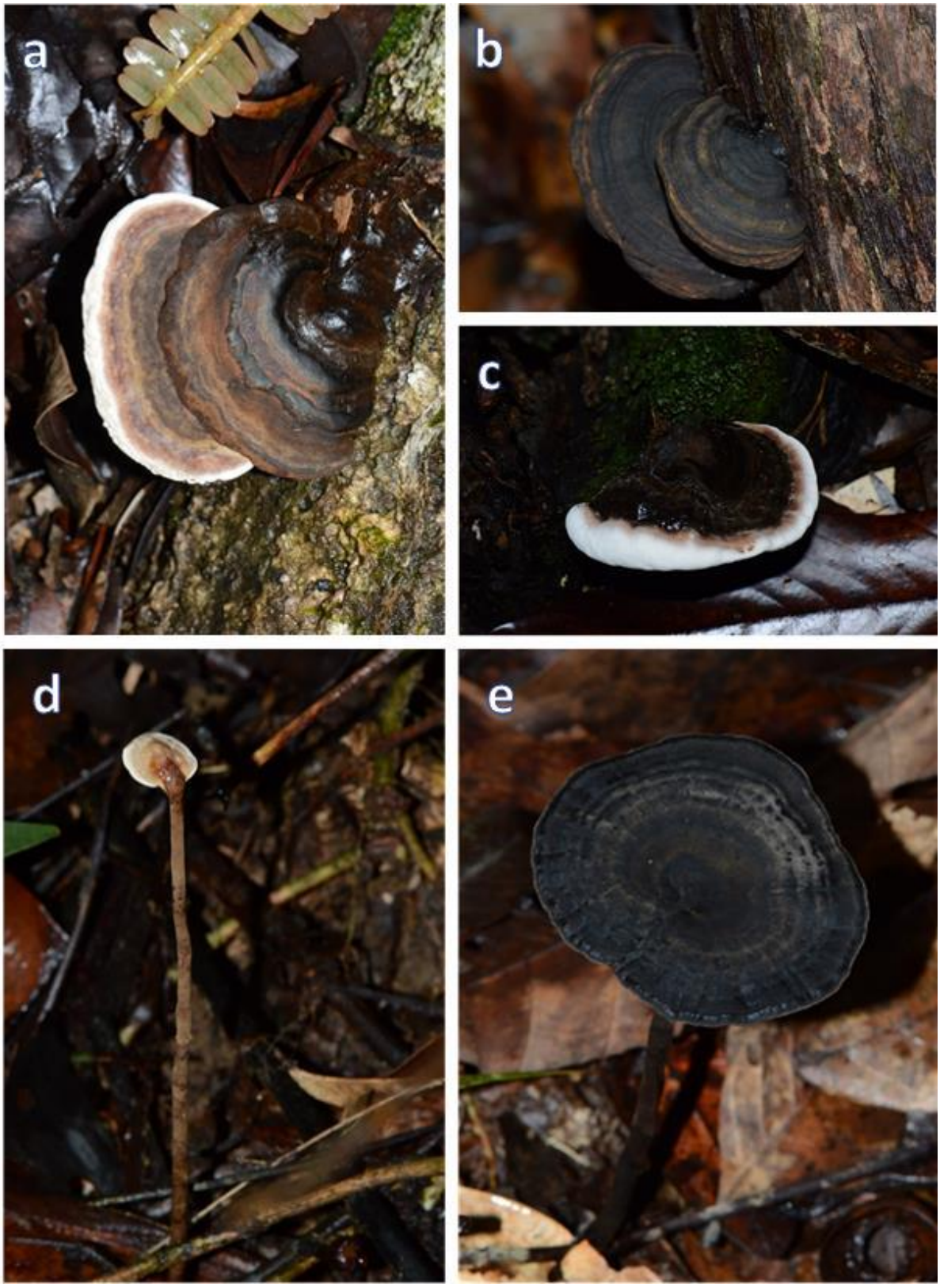

Plate 2 (a,b,c) ***Ganoderma* sp.**; (d,e) ***Amauroderma* sp.**

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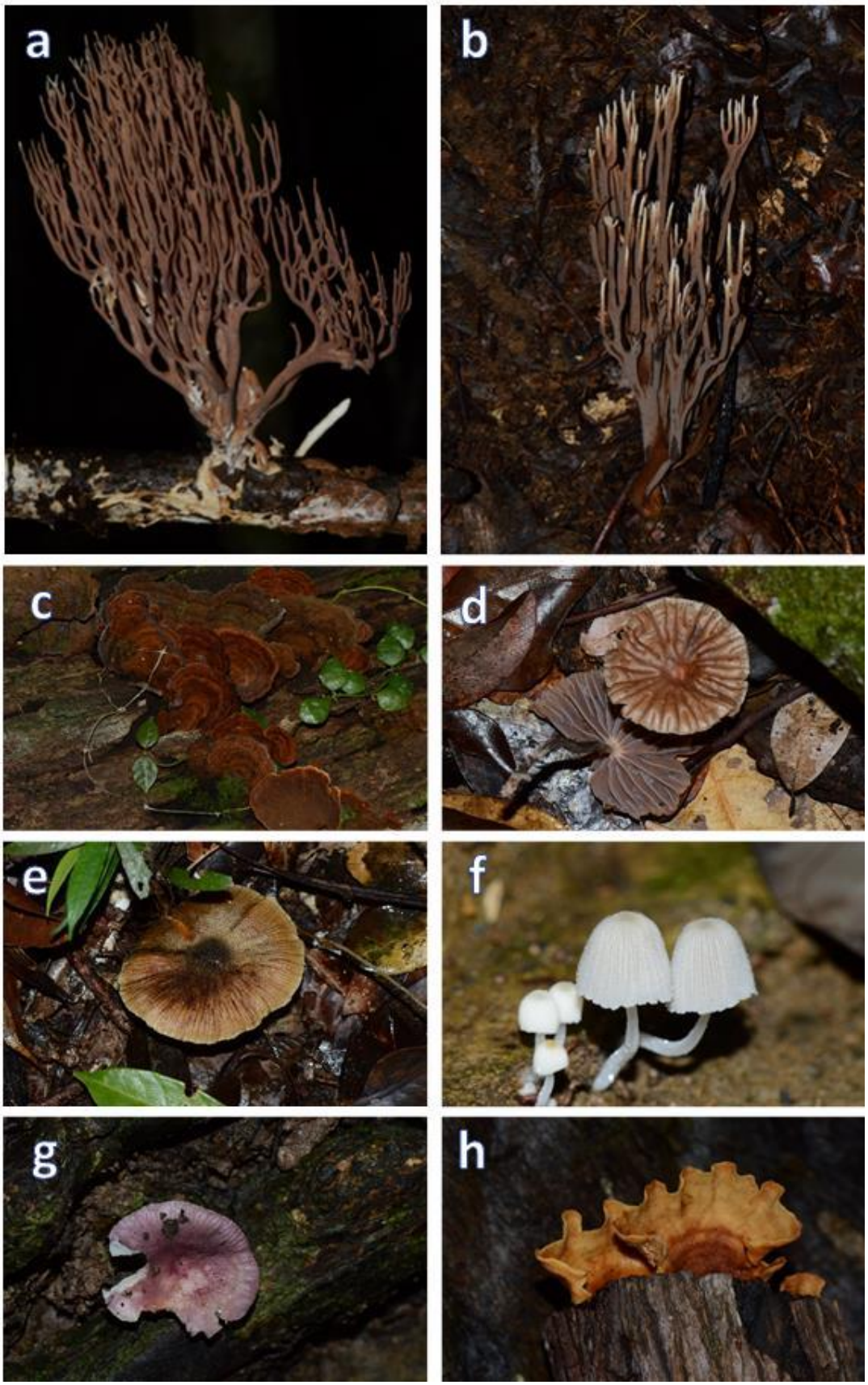
a
b
c
d
e
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Plate 3 (a,b) ***Lentaria* spp.**; (c) ***Rigidoporus sp***; (d) ***Marasmius* sp.;** (e) ***Agaricus* sp.**; (f) ***Coprinus* sp.**; (g) ***Russula* sp.**; (h) ***Stereum* sp.**

Plate 4 (a) ***Boletus* sp.**; (b) ***Hydnum* sp.**; (c) ***Podoserpula* sp.**; (d) ***Dacryopinax* sp.**; (e) ***Cookeina* sp.**

Additions to the current checklist of mammals in Mount Silam, Lahad Datu

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Abstract. A rapid mammal survey was conducted in Mount Silam Lahad Datu from the 11th – 17th of January, 2020. The survey was intended to update the current inventory of mammals within the mountain. Camera trapping and recce transect methods were applied. A total of 21 species were recorded throughout the field survey. When merged with previous study, Mount Silam is home to at least 35 mammal species. Of this, seven are treated as threatened species, for example, the Sunda pangolin (*Manis javanica*) and Bornean gibbon (*Hylobates muelleri*). The latter is a Bornean endemic including four other mammal species. This paper has listed mammals that were not spotted previously. Research findings of this study are relevant to policy makers and scientists.

Keywords: mammalian inventory, tropical mountain, Sabah, Borneo

INTRODUCTION

Mount Silam is one of the famous mountains in Sabah. The mountain is easily accessible to tourists due to its strategic location. Despite being a low height level mountain (i.e. with a summit of just 870 m a.s.l.), its vegetation on the top bears a striking resemblance to Mount Kinabalu's montane cloud forests at 2,100 – 3,000 m a.s.l. This ecological phenomenon is called the 'Massenerhebung Effect'. Apart from Mount Silam, the phenomenon is also reported in Mount Palung of West Kalimantan, Indonesia.

Contrary to Mount Kinabalu, the mammals of Mount Silam are understudied. The first mammalian checklist compiled for Mount Silam was published by Ketol *et al.* (2009) based on their field survey in 1995. Hence, this study is designed to update the mammalian checklist for Mount Silam as well as to establish baseline information for the prescription of a future management plan and for the advancement of research. Potential and imminent threats faced by mammals of Mount Silam and their conservation significance are also highlighted. The fieldwork of this study was conducted during the Mount Silam Scientific Expedition, and sponsored by the then Ministry of Water, Land and Natural Resources (KATS).

MATERIALS AND METHODS

Study site

The summit of Mount Silam lies in Sapagaya FR. However, the main ridges extend into other forest reserves, namely Sapagaya (Ext.) FR, Ulu Segama FR and Sepagaya FR (Figure 1). Therefore, the term study site refers to both Mount Silam and its surrounding areas.

The study site is accessible from the Lahad Datu-Tawau main road and is approximately 15 km from Lahad Datu town. The site is also in the vicinity of Danum Valley Conservation Area, one of the well-studied areas in Sabah. Soil associations of the study site are of Bidu-Bidu and Gumpal.

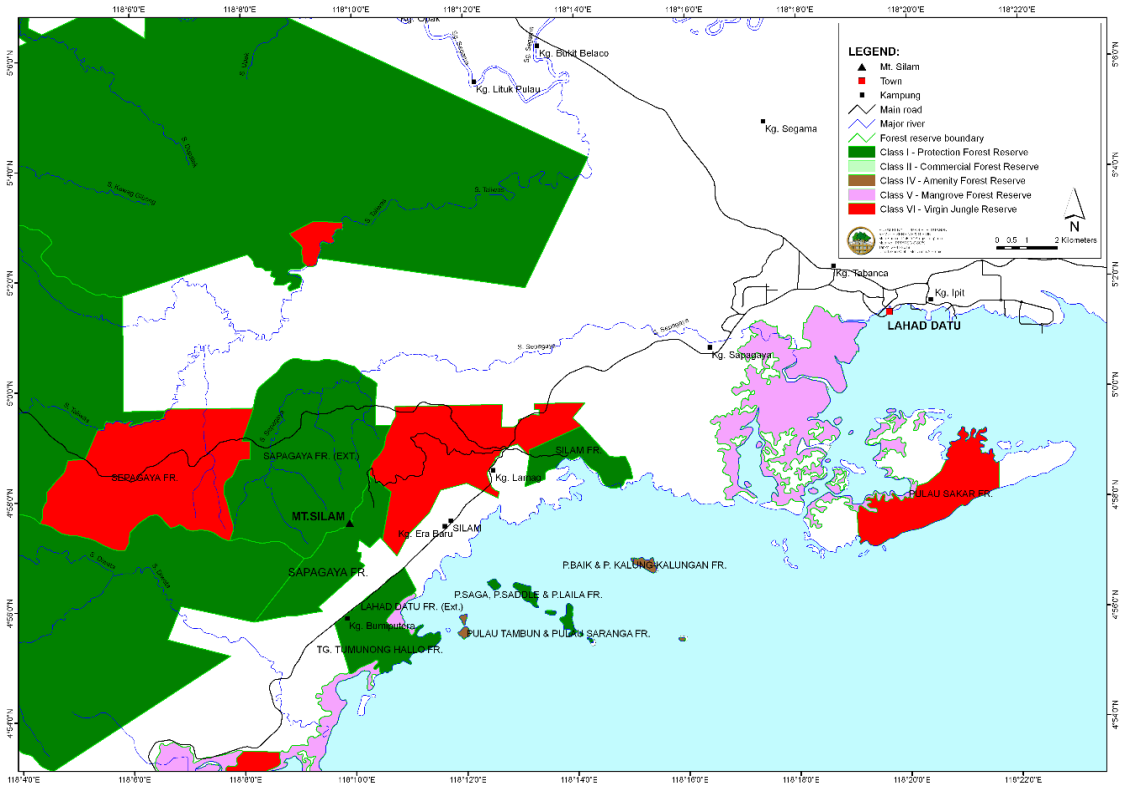

Figure 1. Location map of the Mount Silam in the Lahad Datu district.

The natural vegetation of Mount Silam has been disturbed in the past. Most of the disturbances occurred at lower elevations. However, there are still patches of undisturbed forest in the upper elevations.

Data collection on mammals

This study applied camera trapping as well as recce transect methods to spot and record mammals of Mount Silam.

Camera trapping method

A total of seven cameras (Bushnell Trophy Cam HD Aggressor No Glow Model: 119776C) were deployed. Each of them was designated to seven camera-trapping stations which were at least 300 m apart (Table 1). The location of camera-trapping stations was pre-determined, intended to maximize the mammal detection rate. The altitude gap between stations ranged from 64 – 791 m a.s.l.

Table 1. Details of the camera trapping sampling period and location throughout the scientific expedition to Mount Silam, Lahad Datu.

Camera Label	Date of Installation	Date of Retrieval	Trap-nights	Coordinates (Datum: WGS 84)		Altitude (m)
				Latitude	Longitude	
CT 01	11/01/2020	16/01/2020	5	N 04°58’37.6”	E 118°11’28.6”	393
CT 02	11/01/2020	16/01/2020	5	N 04°58’50.4”	E 118°11’33.1”	446
CT 03	11/01/2020	16/01/2020	5	N 04°57’56.3”	E 118°10’16.9”	791
CT 04	11/01/2020	17/01/2020	6	N 04°59’09.8”	E 118°10’52.9”	224
CT 05	11/01/2020	17/01/2020	6	N 04°59’05.2”	E 118°10’44.5”	152
CT 06	11/01/2020	16/01/2020	5	N 04°57’54.2”	E 118°10’31.9”	600
CT 07	13/01/2020	17/01/2020	4	N 04°59’25.5”	E 118°12’05.6”	64

The camera trapping survey commenced from the 11th to 17th of January 2020. All cameras were positioned at the base of trees, approximately 0.5 m above the ground to ensure good photographs of mammals. The cameras are motion-sensitive in that they are triggered to take photos and videos every time movement is detected. No baits were used and the cameras were set to operate for 24 hours, continuously.

Recce transect method

A total of six recce or reconnaissance transects were surveyed, with a total distance surveyed of 4.23 km, but they were not carried out consecutively (Table 2). Each survey usually takes about 2 – 5 h daily and is initiated before 10.00 am and ended at noon. Both direct observations (i.e. opportunistic sightings) and indirect signs (i.e. footprints, dungs or droppings, calls and nests) were applied, accordingly.

Table 2. Details of the recce transect sampling period and location throughout the scientific expedition to Mount Silam, Lahad Datu.

Transect Label	Date	Duration	Coordinates (Datum: WGS 84)		Distance Covered (km)
			Starting Point	End Point	
1	11/01/2020	9.30 am – 12.10 pm	N 04°59’08.0” E 118°11’00.7”	N 04°59’05.2” E 118°10’44.5”	0.62
2	11/01/2020	9.58 am – 11.40 am	N 04°58’30.5” E 118°11’23.5”	N 04°58’50.4” E 118°11’33.1”	0.75
3	13/01/2020	03.30 pm – 04.42 pm	N 04°59’19.3” E 118°11’59.6”	N 04°59’25.5” E 118°12’05.6”	0.42
4	14/01/2020	9.30 am – 10.45 am	N 04°58’24.5” E 118°10’53.9”	N 04°59’01.2” E 118°10’56.6”	1.14
5	15/01/2020	8.20 am – 10.50 am	N 04°59’08.9” E 118°12’09.3”	N 04°59’11.7” E 118°12’24.4”	0.50
6	16/01/2020	8.44 am – 10.30 am	N 04°57’56.1” E 118° 10’25.3”	N 04°57’44.4” E 118°10’05.3”	0.80

Data analysis

Identification of taxa

The species of observed mammals and birds were identified directly in the field and occasionally, by referring to field guides on mammals (Phillips & Phillips 2018). The local protection status of each species was determined by referring to the Schedules 1, 2 and 3 in the Sabah Wildlife Conservation Enactment (1997) while their extinction risks were based on the IUCN Red List of Threatened Species (IUCN 2020).

Analysis of photographic data

The camera detection rate of each mammal species and all species combined were determined based on the following equation:

$$Camera\ detection\ rate = \frac{Number\ of\ independent\ photographs}{Total\ trap\ nights} \times 100$$

RESULTS & DISCUSSION

Findings on the recent mammal survey

The recent survey has recorded 21 mammal species. Of this, six species (28.6%) were photographically captured using camera traps with a calculated total of 36 trap-nights (Figure 2). The remaining species were registered while walking along the recce transects, with a total distance of 4.23 km. Bearded pig (*Sus barbatus*), sambar deer (*Rusa unicolor*) and pig-tailed macaque (*Macaca nemestrina*) were recorded by both methods.

All mammals that were detected by camera traps are terrestrial species, except the pig-tailed macaque which is arboreous in nature. This method is inefficient in targeting other tree-dwelling species especially squirrels. Therefore, the recce transect is a complement method to maximise the detection rate.

Bearded pigs and pig-tailed macaques recorded a relatively high camera detection rate throughout the survey (Table 3). On the contrary, the sambar deer and red muntjac (*Muntiacus muntjac*) were the least recorded species, each with only one independent photograph. There were no mammal species registered by Camera 2 (CT 02) and Camera 3 (CT 03).

Table 3. Camera detection rates (number of independent photographs/100 camera trap-nights) of each mammal species recorded through the camera trapping method in Mount Silam, Lahad Datu.

No.	Species	Camera Detection rate
1.	Bearded pig	52.8
2.	Pig-tailed macaque	44.4
3.	Greater mousedeer	5.6
4.	Malay civet	5.6
5.	Red muntjac	2.8
6.	Sambar deer	2.8

Figure 3. Some of the photographic data captured through the camera trapping method in Mount Silam, Lahad Datu. **A** – Sambar deer; **B** – Greater mousedeer; **C** – Red muntjac; **D** – Pig-tailed macaque.

Mammals of Mount Silam

By merging the findings of the present study with Ketol *et al.* (2009), the total documented mammals of Mount Silam are 35 species (Table 4). Of the total documented mammals, seven are treated as threatened species by the IUCN Red List of Threatened Species (IUCN 2020). Sunda pangolin (*Manis javanica*) is the only documented species that is listed under the Critically Endangered category. About 68% of the documented mammals belong to the Least Concern species. According to the local law's perspective (Sabah Wildlife Enactment 1997), 21 species are listed either under Schedule 1 (totally protected animals) or Schedule 2 (game animals) with the majority belonging to the latter. In terms of endemism, five species, namely the Bornean gibbon (*Hylobates muelleri*), red leaf monkey (*Presbytis rubicunda*), Jentink's flying squirrel (*Sundasciurus jentiki*), tufted-ground squirrel

(*Rheithrosciurus macrotis*) and Thomas's flying squirrel (*Aeromys thomasi*) are endemic to Borneo.

The recent survey is short of two documented species when compared to Ketol *et al*. (2009) (23 species) but a majority of it are newly detected. This is attributed to the variations in field methodologies. The present study applied both camera-trapping and recce transect methods while excluding Chiropterans in the field survey. In comparison, Ketol *et al*. (2009) practised indirect methods (i.e. vocalization, defecation, feeding signs and foot prints) and direct methods (i.e. cage trap, mist-net and spot lighting). The time frame of the recent survey is close to eight days, whereas the previous survey by Ketol *et al*. (2009) could not be ascertained, though it was mentioned to have been conducted in September 1995.

The total number of documented mammals in Mount Silam does not represent the actual mammalian richness of the area. The Ulu Segama-Malua Sustainable Forest Management Project area which is adjacent to the study site has the total documented mammals of 58 species (SFD 2017). The mountain itself comprises at least four forest ecosystems, namely lowland mixed dipterocarp, lowland ultramafic, upland ultramafic and lower montane ultrabasic forests. All species have their own preferred ecosystems for shelter and food (Figure 4).

Figure 4. A forest wallow is a favourite spot for terrestrial mammals such as bearded pigs and deer. This photo was taken at the lower part of Mount Silam.

Table 4. Updated mammalian checklist for Mount Silam, Lahad Datu.

Order	Family	Scientific name	Vernacular name	1995 Survey (Ketol *et al.* 2009)	2020 Survey (This study)	Detection methods (This study)	IUCN	Sabah Wildlife Conservation Enactment 1997
Carnivora	Herpestidae	*Urva brachyurus*	Short-tailed mongoose		√	RT	NT	Schedule 2
	Viverridae	*Viverra tangalunga*	Malay civet		√	CT	LC	Schedule 2
	Viverridae	*Paradoxurus hermaphroditus*	Common palm civet	√	√	RT	LC	Schedule 2
	Viverridae	*Paguma larvata*	Masked palm civet	√		-	LC	Schedule 2
	Felidae	*Prionailurus bengalensis*	Leopard cat	√		-	LC	Schedule 2
	Mephitidae	*Mydaus javanensis*	Sunda stink badger	√		-	LC	Schedule 2
	Urusidae	*Helarctos malayanus*	Sun bear		√	RT	VU	Schedule 1
Artiodactyla	Suidae	*Sus barbatus*	Bearded pig	√	√	CT & RT	VU	Schedule 3
	Cervidae	*Tragulus napu*	Greater mousedeer		√	CT	LC	Schedule 3
	Cervidae	*Rusa unicolor*	Sambar deer	√	√	CT & RT	VU	Schedule 3
	Cervidae	*Tragulus kanchil*	Lesser mousedeer	√	√	RT	LC	Schedule 3
	Cervidae	*Muntiacus muntjak*	Red muntjac	√	√	CT & RT	LC	Schedule 3
Primates	Cercopithecidae	*Macaca nemestrina*	Pig-tailed macaque	√	√	CT & RT	VU	Schedule 2
	Cercopithecidae	*Presbytis rubicunda*	Red leaf monkey*		√	RT	LC	Schedule 2
	Cercopithecidae	*Macaca fascicularis*	Long-tailed macaque		√	RT	LC	Schedule 2
	Hylobatidae	*Hylobates muelleri*	Bornean gibbon*	√	√	RT	EN	Schedule 2
	Lorisidae	*Nycticebus* sp.	Slow loris	√		-	VU	Schedule 2
Pholidota	Manidae	*Manis javanica*	Sunda pangolin	√	√	RT	CR	Schedule 1
Rodentia	Sciuridae	*Callosciurus prevostii*	Prevost's squirrel		√	RT	LC	Not Listed
	Sciuridae	*Ratufa affinis*	Giant squirrel		√	RT	NT	Schedule 2
	Sciuridae	*Sundasciurus jentinki*	Jentink's flying squirrel*		√	RT	LC	Not Listed
	Sciuridae	*Sundaciurus lowii*	Low's squirrel	√		-	LC	Not Listed
	Sciuridae	*Rheithrosciurus macrotis*	Tufted-ground squirrel*		√	RT	VU	Schedule 2
	Sciuridae	*Callosciurus notatus*	Plaintan squirrel		√	RT	LC	Not Listed
	Sciuridae	*Aeromys thomasi*	Thomas's flying squirrel*	√		-	LC	Schedule 2
	Muridae	*Maxomys surifer*	Red spiny rat		√	RT	LC	Not Listed
	Muridae	*Maxomys rajah*	Brown spiny rat	√		-	VU	Not Listed
	Muridae	*Leopoldamys sabanus*	Long-tailed giant rat	√		-	LC	Not Listed
Scandentia	Tupaiidae	*Tupaia tana*	Large treeshrew		√	RT	LC	Not Listed
	Tupaiidae	*Tupaia glis*	Common treeshrew	√		-	LC	Not Listed
	Tupaiidae	*Tupaia minor*	Lesser treeshrew	√		-	LC	Not Listed
Chiroptera	Pteropodidae	*Cynopterus brachyotis*	Short-nosed fruit bat	√		-	LC	Not Listed
	Pteropodidae	*Eonycteris spelaea*	Cave nectar bat	√		-	LC	Not Listed
	Pteropodidae	*Macroglossus minimus*	Long-tounged nectar bat	√		-	LC	Not Listed
	Rhinolophidae	*Rhinolophus acuminatus*	Acuminate horseshoe bat	√		-	LC	Not Listed

Note: IUCN Red List of Threatened Species, CR – critically endangered, EN – endangered, VU – vulnerable, NT – near threatened, LC – least of concern. Sabah Wildlife Conservation Enactment 1997, Schedule 1 – totally protected animals, Schedule 2 – protected animals, Schedule 3 – game animals. Detection method, CT – detected via camera trapping method; RT – detected via recce transect method. * - Endemic to Borneo.

Managerial implications

Although no poaching signs were observed throughout the expedition, possibilities of illegal hunting is still a main concern since Mount Silam is within the vicinity of Ulu Segama FR where multiple cases of forest crimes have been reported in the past (SFD 2017). Previous anthropogenic activities, such as construction of road and telecommunication network towers have also altered the original vegetation of Mount Silam. Secondary vegetations are common growing along the paved road that starts from the main entrance of Mt Silam to the Menara Kayangan at 700 m a.s.l. The secondary vegetation is generally prone to wildfires due to their simplicity (i.e. forest structure and grassy area). The road networks within and in the surrounding areas of Mount Silam also poses a danger to wildlife. These man-made structures hamper mammal movements and often result in roadkill.

With regards to the aforementioned threats, this study suggests a number of counter measures to curb or mitigate the impacts. Illegal activities within the forest reserve can only be minimized if there is continuous patrolling and monitoring efforts. Fortunately, the special anti-poaching squad under the Sabah Forestry Department is in the midst of establishing their observation post in the study site. The presence of local villages in the adjacent areas highlighted the importance implementing practical awareness programmes. In order to reduce roadkill incidents, more warning signages should be placed along the roads.

Due to pragmatic reasons, the Bornean gibbon is proposed as a species of outstanding conservation value. The species is highly detectable, especially through the recce transect method. The gibbon can also be easily detected through its loud vocal displays. This Bornean endemic is also an endangered species (IUCN 2020) and is listed under the totally protected species of the Sabah Wildlife Conservation Enactment 1997.

CONCLUSION

This study has shed some light on the presence of mammals that were unrecorded previously. Threats to the forest ecosystems and mitigation measures, have also been addressed. This study is expected to benefit the general public, local surrounding communities, scientists and policy makers in general.

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REFERENCES

IUCN Red List (International Union for Conservation of Nature and Natural Resources.). (2020). *The IUCN Red List of Threatened Species*. Version 2018.1. www.iucnredlist.org. Downloaded on 29 February 2020.

Ketol, B., Anwarali, F.A., Marni, W., Sait, I., Lakim, M., Yambun, P.I., Salleh, M.A., Rahman, M.A. & Abdullah, M.T. (2009). Checklist of mammals from Gunung Silam, Sabah, Malaysia. *Journal of Tropical Biology and Conservation* 5: 61-65.

Phillips, Q. & Phillips, K. (2018). Phillips' field guide to the mammals of Borneo and their ecology: Sarawak Edition. United Kingdom: John Beaufoy Publishing.

SFD (2017). Annual Report 2017: Ulu Segama-Malua Sustainable Forest Management Project. Sabah Forestry Department. 43 pp.

Avifaunal survey of Mt. Silam and surrounding areas in Lahad Datu, Sabah, Malaysia

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Abstract. The main objective of the avifaunal survey was to provide a brief description of the avian community in Mt. Silam and its surrounding lowland mixed dipterocarp forests. It is hoped that the survey results will be used to support future forest management initiatives, especially concerning Payment for Ecosystem Services. The MacKinnon List method was used. The four-day survey recorded a total of 24 lists with 624 individuals detected. A total of 115 species from 43 families were recorded, with H=6.44 and E_H=0.65. The eight species of Bornean endemics observed were the Bornean Banded Kingfisher, Black-crowned Pitta, Bornean Banded Pitta, Bornean Brown Barbet, Bornean Necklaced Partridge, Dusky Munia and the White-crowned Shama. The most diverse families were Cuculidaedae and Pycnonotidaee, both with 9 species each. The Plume-toed Swiftlet had the highest relative abundance index of 0.106. It was followed by the Green Iora (28 individuals, 0.045) and the Orange-bellied Flowerpecker (23 individuals, 0.037). Feeding guild in Mt. Silam was dominated by insectivorous species (62 spp., 54.4%), followed by frugivores (29 spp., 25.4%). Approximately 94 % of the species were forest dwellers (including species living near forest edges), a majority of which were insectivorous (56 spp.).

Keywords: avifaunal survey, MacKinnon List method, scientific expedition, Sapagaya Forest Reserve, feeding guilds

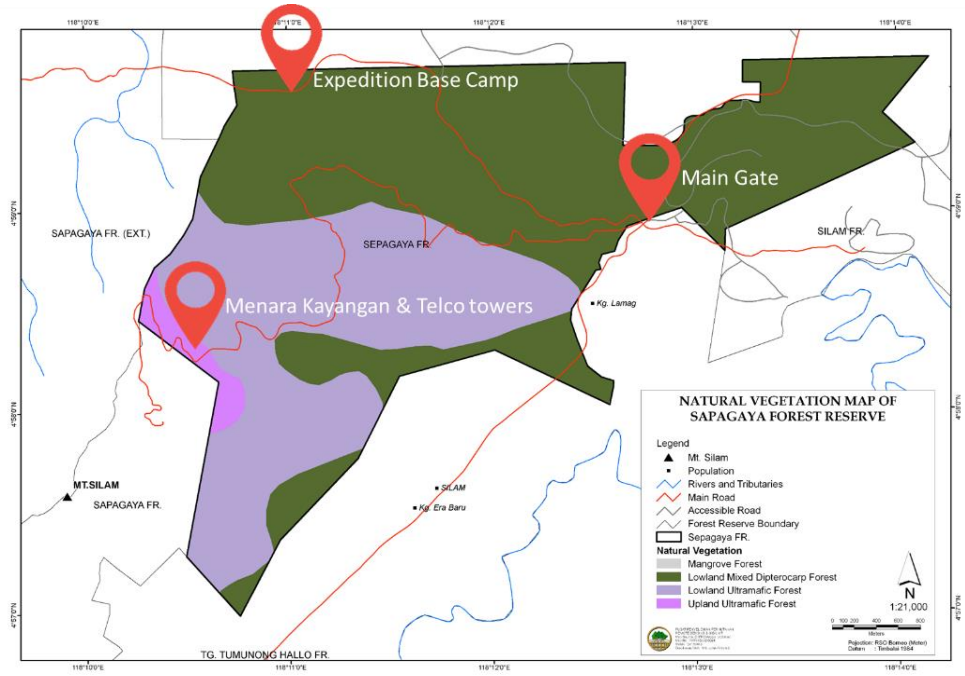
INTRODUCTION

Birds are important indicators of forest health and have been included when surveying biodiversity. This report documents the outcomes of a rapid avifaunal assessment conducted on Mt Silam and its surrounding areas during the Sepagaya Forest Reserve Scientific Expedition on the 13th-18th of January 2020. The expedition was organised by the Forest Research Centre, the R&D division of the Sabah Forestry Department, with funds from the Ministry of Water, Land and Natural Resources. The Mt. Silam massif is situated within two different forest reserves, i.e. Sapagaya Virgin Jungle Reserve (Class 6) and Sepagaya Forest Reserve (Class 1) in the Lahad Datu District. The survey was conducted to assess the avifaunal community of the general area, using a modified version the MacKinnon List (ML) method.

METHODOLOGY

Site description

Mt Silam is an ultramafic mountain situated about 22 km west of Lahad Datu town within the Lahad Datu district. Its forest structure and floristics has been studied and documented in the past (Fox 1972 & Proctor *et. al.* 1988). The mountain itself is situated within two different forest reserves, i.e. Sapagaya Virgin Jungle Reserve (Class 6) and Sepagaya Forest Reserve (Class 1) in the Lahad Datu District. The peak of Mt. Silam is situated within Sepagaya Forest Reserve (FR). The Lahad Datu District Forestry Office administers these forest reserves. Sapagaya VJR (Class 6) The FR was first gazetted in 1962 under the Ulu Segama FR. It consisted of 4 blocks of land and was internally classified as Virgin Jungle Reserve (VJR) by the Sabah Forestry Department. Blocks 1 and 2 were part of one bigger VJR called VJR 10. Blocks 3 and 4 were called VJR 78A and VJR 67 respectively. Parts of Ulu Segama FR were later regazetted as Kawang Gibong VJR and Sapagaya VJR in 14/3/1984.



Map 1. Natural vegetation map of Sapagaya Forest Reserve and location of main marker points during the survey.

Survey methods

The four-day survey was conducted using a modified version the MacKinnon List (ML) method. The method is a rapid assessment method has been gaining popularity in the past decade as a cost-effective method of conducting bird surveys in the tropics. It was designed for those who have limited time, resources and personnel for surveys (MacKinnon & Phillips 1993), such as government agencies, non-governmental organisations, citizen scientists and forest concessionaires. It also accounts for differences in effort, observer experience and knowledge, and weather (Poulsen *et al*. 1997). Because the method relates species richness to the number of observations rather than to time, area or walking speed, this method allows for comparison of data obtained by different observers or under varying field conditions

(Herzog *et al*. 2002). The Forest Research Centre of the Sabah Forestry Department aims to develop a rapid assessment methodology based on a modified ML method specifically for the department's researchers and field staff with limited time (3-4 days) for field work. This survey was part of a series of on-going field trials.

Both aural and visual observations were grouped into consecutive lists of 15 species, and a species accumulation curve was generated from the addition of those species not recorded on any of the previous lists to the total species number, which is then plotted as a function of the list number. In addition, the number of individuals of species detected within each list was recorded.

Observation methods

The survey team comprised the authors and assisted by three interns of the Rainforest Discovery Centre (RDC), Sepilok. The interns were diploma-level students from Universiti Putra Malaysia, Bintulu Campus and had a two-month training in bird identification and bird survey (ML method) at the RDC prior to the expedition. In addition, two ex-Sepilok Junior Rangers from RDC also participated in the survey. Every observer had a pair of NIKON binoculars (8 x 42s). The 'Phillips' Field Guide to the Birds of Borneo', 3rd edition, 2014 was the reference used for species identification. Audio playback equipment (consisting of an mp3 player connected to a small, battery-powered Bluetooth® loudspeaker) was used to verify species from the vocalisations heard.

A designated person recorded all visual and aural observations daily. Care was taken to prevent intra-list and inter-list double-counts of individuals. As most species were detected by their calls/vocalizations, potential individuals were not recorded again in subsequent lists unless the observers were certain that they were different individuals, *e.g.*, when the calls originate from a different direction and/or there were more than one call heard from a similar direction of the previously recorded species. At least two members of the survey team must be excellent in bird identification, both visually and aurally. Unidentified species were not recorded.

Surveys were conducted for 4-4.5 hours beginning at 6:00-7:30 am, and again for 2 hours in the evenings from 5 pm onwards. All survey durations were dependent on the weather. For the first three days, the survey was conducted along the main tarmac road that leads from the main gate (141 m elevation) up to the Menara Kayangan Tower at Km 9 (645 m elevation). On the fourth day, the survey was carried out along the main gravel road, popularly known as the Danum Road, beginning from the expedition base camp.

Table 1. Schedule of surveys during the expedition.

Date	Survey site	Observation times	No. of 15-species lists
14th January	Main gate to Km 2.5	8:00am – 11:45 am, 5:00 – 7:00 pm	5 lists
15th January	Km 2.5 to Km 7.5	6:45am – 12:00 pm, 5:00 – 7:00 pm	5 lists
16th January	Km 8 to Menara Kayangan Tower	7:35 am – 11:50 pm, 5:00 – 7:00 pm	4 lists
17th January	Base camp main road	6:15 am – 10:30 am	9 lists

Analyses

A species accumulation curve was generated from the addition of those species not recorded on any of the previous lists to the total species number, which was then plotted as a function of the list number. To estimate true species richness of the area, the authors used the SuperDuplicates® online calculator developed by Chao *et al*. (2017), which requires only the total number of species observed and the number of species observed only once (uniques/singletons).

Analyses of feeding guilds provide information on how communities of species utilize certain forest resources (*e.g.* fruits, insects, arthropods and seeds) within SFR and may indicate the condition or health of the forest ecosystem. Thus, the species were categorised according to six feeding guilds based on their preferred diet; carnivores (Car), frugivores (Fru), insectivores (Ins), nectarivores (Nec), granivores (Gra) and omnivores (Omn). Species are considered as omnivores if they are known to consume roughly similar amounts of animal- and plant-based food resources, such as Ins/Gra, Fru/Ins and Nec/Fru/Ins. Guild information was mainly from Phillipps (2014) and Wells (1999 & 2007). The feeding guilds were then described according to habitat types (forest, forest edge and open area) to examine the importance of habitats to different guilds.

RESULTS

Avifaunal composition and species richness

The four-day survey yielded 24 lists and 634 individuals detected. About 60.1% or 375 individuals were detected aurally. A total of 115 species belonging to 43 families were recorded, with a Shannon-Weiner index (H) of 6.44. In comparison, co-author Vivian Rudolf documented 183 species over an eight-year period. The eight species of Bornean endemics and their respective categories in the IUCN Red List of Threatened Species are listed in Table 2. Table 3 lists all 30 species that were not categorized as Least Concern. The top five most diverse families were shared amongst 10 families (Table 4).

Table 2. Species endemic to Borneo and their respective categories in the IUCN Red List of Threatened Species.

No.	Species	Category
1	Bornean Banded Kingfisher	CR
2	Black-crowned Pitta	LC
3	Bornean Banded Pitta	LC
4	Bornean Brown Barbet	LC
5	Bornean Necklaced Partridge	VU
6	Dusky Munia	VU
7	White-crowned Shama	LC
8	Chestnut-crested Yuhina	LC

Table 3. Species listed as Critically Endangered (CR), Near Threatened (NT) and Vulnerable (VU) in the IUCN Red List of Threatened Species (Bornean endemics in bold).

No.	Species	Category	No.	Species	Category
1	**Bornean Banded Kingfisher**	CR	16	Chestnut-rumped Babbler	NT
2	Chestnut-bellied Malkoha	NT	17	Diard's Trogon	NT
3	Reddish Scops Owl	NT	18	Moustached Hawk-cuckoo	NT
4	Buff-vented Bulbul	NT	19	Red-naped Trogon	NT
5	Dark-throated Oriole	NT	20	Rufous-tailed Shama	NT
6	Great Argus	NT	21	Scarlet-rumped Trogon	NT
7	Green Broadbill	NT	22	Sooty-capped Babbler	NT
8	Puff-backed Bulbul	NT	23	White-chested Babbler	NT
9	Streaked Bulbul	NT	24	Crested Jay	NT
10	Red-throated Barbet	NT	25	Green Iora	NT
11	Yellow-crowned Barbet	NT	26	Lesser Green Leafbird	NT
12	Black-and-yellow Broadbill	NT	27	Asian Black Hornbill	VU
13	Black-bellied Malkoha	NT	28	**Bornean-necklaced Partridge**	VU
14	Black-crowned Pitta	NT	29	Rhinoceros Hornbill	VU
15	Brown Fulvetta	NT	30	Great Slaty Woodpecker	VU

Table 4. Top five most diverse families (with shared rankings).

Rank	Family	No. of species
1	Cuculidae	9
	Pycnonotidae	9
2	Nectariniidae	7
	Picidae	7
3	Accipitridae	6
4	Pellorneidae	5
5	Dicaeidae	4
	Eurylaimidae	4
	Megalaimidae	4
	Timaliidae	4

Table 5. Top 10 families with the highest number and percentage of individuals detected.

Rank	Family	No. of individuals	Percentage (%)
1	Apodidae	68	10.9
2	Pycnonotidae	57	9.1
3	Cuculidae	49	7.9
4	Nectarinidae	39	6.3
5	Dicaeidae	29	4.6
6	Aegithinidae	28	4.5
7	Hemiprocnidae	24	3.8
8	Cisticolidae	23	3.7
9	Timaliidae	22	3.5
10	Pellorneidae	21	3.4

Table 5 shows the 10 most detected families in terms of number of individuals. The high number of Plume-toed Swiftlets was mainly responsible for Apodidae to be ranked number one. Out of the nine species of bulbuls (Pycnonotidae), the Buff-vented Bulbul and the Red-eyed Bulbul, each with 18 individuals detected, were mainly responsible for the high numbers of individuals detected from that family. Although the Cuculidae (cuckoos) had a similar number of species as the bulbul family, it was the almost ubiquitous calls of the Plaintive Cuckoo that made it the most detected species (22 individuals) within the family. For the Nectarinidae (7 spp.), the Little Spiderhunter and the Eastern Crimson Sunbird were the most detected with 20 and 9 individuals respectively. From the four species of flowerpeckers (Dicaeidae), the Orange-bellied Flowerpecker was the most detected with 23 individuals, of which 18 were detected solely by their unmistakable calls. A sighting of note was that of the

Speckled Piculet, a member of the woodpecker family. It is a widespread species found from the Indian subcontinent, Indochina and Southeast Asia. However, it is very rare in Sabah.

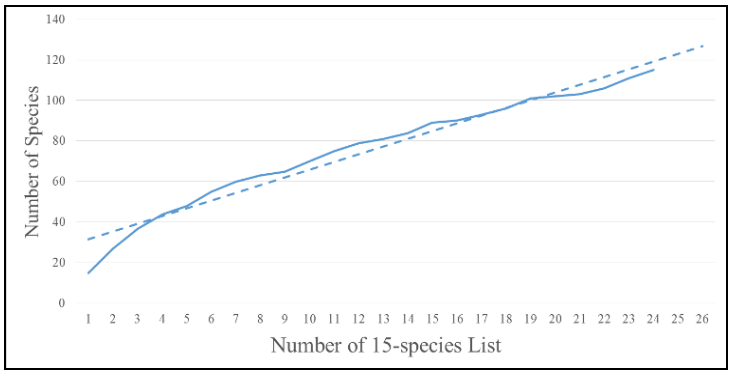


Figure 1. Species accumulation curve and linear regression line of bird species in SFR.

As expected for the ML rapid assessment method, and with a four-day duration of the survey, the species accumulation curve (Figure 1) had not achieved asymptote. The curve was the steepest in Day One from List 1 to List 5, *i.e.* 48 species were detected within the first five lists. On Day Two, 27 species were detected (List 6 to 11). Day Three yielded the lowest species count, i.e. 19 species. On the final day, with the survey being carried out on the main gravel road near Base Camp, 26 species were detected in nine lists (List 16 to 24).

To estimate the true species richness, the total number of species (115) detected and the number of singletons (34 spp.) was input into the SuperDuplicates ® online calculator (Table 6). The Chao1 (estimated species richness using abundance data) was approximately 147 species, with an upper and lower threshold of approximately 134 and 168 species respectively, at 95% confidence interval. The estimated number of doubletons was 17 species while the actual number was 20 species. The calculator also estimated that approximately 32 species were undetected, *i.e.* the survey managed to detect approximately 78 % of the total species in the area. Based on the linear regression line in Figure 1, approximately six survey days were needed to detect the estimated 147 species of birds.

Table 6. Results from SuperDuplicates®.

Estimated number of doubletons	Estimated species richness	Standard error	95% C.I. lower	95% C.I. upper	Number of undetected species	Undetected percentage (%)
17.09	146.56	8.56	133.73	167.19	31.56	21.54

Relative abundance index

A total of 624 individuals from 115 species were detected. The Evenness (E_H) value was 0.65. The Plume-toed Swiftlet, with 66 individuals detected, had the highest RAI of 0.106 (Table 7). The 17 highest ranked species accounted for 50% of the individuals detected. The 50 species with four or more individuals accounted for approximately 83% of all individuals detected.

Table 7. Top 5 relative abundances of bird species in SFR.

Rank	Species	No. of Individuals detected	Abundance Index
1	Plume-toed Swiftlet	66	0.106
2	Green Iora	28	0.045
3	Orange-bellied Flowerpecker	23	0.037
4	Plaintive Cuckoo	22	0.035
5	Little Spiderhunter	20	0.032

Habitat types and feeding guilds

The species were categorised according to their preferred habitats (i.e. forest, forest edges, open area, etc.) and respective feeding guilds (Figure 2). The majority of the species (105 species, 91.3% of total species) detected were forest and forest-dependent species. Of these, 85 species were strictly forest birds. The high number of forest and forest-dependent species reflected the relatively intact forest ecological functions. The seven open area specialists were the Mossy-nest Swiftlet, Large-tailed Nightjar, Yellow-bellied Prinia, Pacific Swallow, Olive-backed Sunbird, Yellow-vented Bulbul, and the Dusky Munia, a Bornean endemic.

Insectivores comprised the main feeding guild in SFR with 61 species, or 53% of total number of species, from 27 families. Frugivores ranked second with 29 species (25.2%) from 11 families. The remaining four guilds comprised 22 species (19%). The high dominance of insectivorous and frugivorous species indicated that SFR had high insect and fruit resources to support these species. This is a good indication of a positive forest ecosystem health.

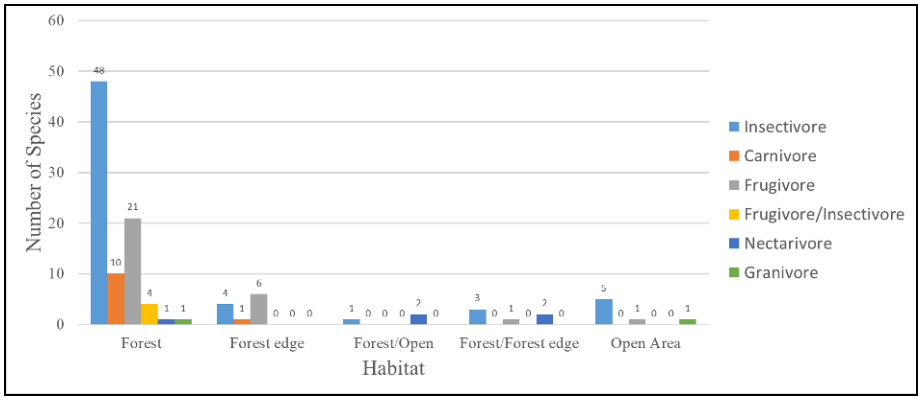


Figure 2. Number of species in preferred habitats and feeding guilds in SFR

CONCLUSION

The survey team managed to obtain a preliminary insight on the species richness and abundance of avifauna within SFR. Although the species richness (115 species from 43 families) was lower compared to other large intact lowland rain forests such as the Kabili-Sepilok Virgin Jungle Reserve, Sepilok, Sandakan, the species were well represented according to their families. SFR also harbour Bornean

endemic species, although the 8 species detected were fairly common endemics. However, the Blue-banded Pitta and the Bornean Bristlehead, both regarded as a trophy species by birders, were not detected although Mt. Silam is a popular site to spot the former.

The survey team opined that the 9-km road up to the telecommunications towers and Menara Kayangan was an excellent site for birders and bird photographers to spot birds. Of the more interesting bird groups there were raptors, treeswifts, sunbirds, flowerpeckers and woodpeckers. The few forest trails that branched off the main road may undoubtedly have more interesting species, such as trogons, flycatchers and the endemic Bornean Bristlehead.

In general, the SFR is an excellent site to monitor avian ecology, with future surveys giving emphasis to its steep forest trails.

ACKNOWLEDGEMENTS

We thank the Chief Conservator for Forests, Datuk Mashor bin Mohd. Jaini, for supporting the expedition. Our appreciation also goes to the research officers and staff of the Forest Research Centre who organised the Sapagaya Forest Reserve Scientific Expedition. The authors would like to thank our interns from UPM Kampus Bintulu (Amirul Mukminin Bin Shamsul Miza, Nurzayanah Adilah Binti Mohd. Zain and Adira Jainis) and volunteers (Fernandez Joel and Frizario Demsray Bin Sufri) for their invaluable assistance in data recording, data entry and the preliminary data analyses.

REFERENCES

Bibby, C., Burgess, N., Hill, D., Mustoe, S., (2000). *Bird Census Techniques*. Academic Press London.

Chao, A., Colwell, R. K., Chiu, C.-H. & Townsend, D. (2017). *Seen once or more than once: applying Good-Turing theory to estimate species richness using only unique observations and a species list*. Methods in Ecology and Evolution, British Ecological Society.

Duerr, Adam E., Miller, Tricia A., Dunn, L., Bell, Douglas A., Bloom, Peter H., Fisher, R., Tracey, Jeffrey A. & Katzer & Todd E. (2019). *Topographic drivers of flight altitude over large spatial and temporal scales.* Auk, 136, Vol. 2.

Fox, J. E. D. (1972). *The natural vegetation of Sabah and natural regeneration of the dipterocarp forests.* PhD thesis, University of Wales.

Herzog, S.K., Kessler, M. & Cahill, T.M. (2002). *Estimating species richness of tropical bird communities from rapid assessment data*. Auk, 119:749-769.

MacKinnon, S. & Phillips, K. (1993). *A field guide to the birds of Borneo, Sumatra, Java and Bali*, Oxford University Press. 491 pp.

Petol, G.H. & Ong, R.C., 2013. *A photographic guide to the lowland birds of Sepilok.* Sabah Forestry Department publication, Sabah, Malaysia.

Phillipps, Q. & Phillipps, K. (2014). *Phillipps' field guide to the birds of Borneo, 3rd Edition*. John Beaufoy Publishing Ltd., Oxford, England.

Poulsen, B.O. Krabbe, N. Frølander, A. Hinojosa, B.M. & Quiroga, O.C. (1997). A rapid assessment of Bolivian and Ecuadorian montane avifaunas using 20-species lists: efficiency, biases and data gathered. *Bird Conservation International* 7:53-67.

Proctor, John; Lee, Y. F.; Langley, A. M.; Munro, W. R. C. & Nelson, T. (1988). A small ultrabasic mountain in Sabah, Malaysia. I. Environment, Forest Structure and Floristic. *Journal of Ecology* 76(2): 320-340, British Ecological Society.

Wells, D. R. (1999). *Birds of the Thai-Malay Peninsula: Volume I: Non-Passerines*. Academic Press London, UK.

Wells, D. R. (2007). *The birds of the Thai-Malay Peninsula. Volume II: Passerines*. Christopher Helm, London.

A study on Anurans (frogs and toads) of Sapagaya Forest Reserve, Sabah

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Abstract. The species richness and abundance of frogs and toads were studied within Sapagaya FR. This study is to provide useful baseline information for future studies on anurans in Sapagaya FR, as well as to contribute to our current knowledge of anuran diversity and distribution in Sabah. Specimens were sampled by Visual Encounter Survey (VES) with the help of a torchlight to pinpoint sample locations; and where possible, hand-grabbing technique. A total of 141 individuals were recorded, consisting of 14 species, belonging to six families, were recorded. The mean Shannon Index was 2.31 while Simpson Index was 8.6 and Fisher Alpha Index was 3.86. Eleven Bornean endemic species were recorded during the survey. The endemic anuran species recorded during the survey provide significant information to enhance the conservation of Sapagaya FR. At the scale of this study, the diversity of anurans in Sapagaya FR is moderately high compared to other forest reserve in Sabah.

Keywords: anuran survey, Visual Encounter Servay (VES), scientific expedition, Sapagaya Forest Reserve.

INTRODUCTION

The global amphibian decline is a well-documented phenomenon, with up to 40% of species threatened with extinction (Stuart *et al*. 2004). Due to their environmental and physiological limitations, tropical anurans are highly sensitive to changes in their environment, and are thus highly susceptible to habitat loss and degradation (Gibbon *et al*. 2000). The island of Borneo, contains high anuran diversity (over 180 species), but it is adversely affected by deforestation and habitat degradation (Gaveau *et al*. 2014). Whilst the central regions of the island consist of protected areas and sustainably managed landscapes, the lowland areas of eastern Sabah, comprise a mosaic of forest fragments and oil palm plantations (Stuebig *et al*. 2017). Forest fragments in such mosaics, can support high anuran diversity. Determining the anuran diversity of small forested areas, is paramount for ensuring the protection of forest patches which may not support large mammalian populations, but can serve as valuable sites of anuran diversity in disturbed landscapes.

The anuran survey was conducted from 13th to 18th of Jan, 2020 within the Sapagaya FR areas during the Mount Silam Scientific Expedition. The expedition was organised by the Forest Research Centre, the R&D division of the Sabah Forestry Department, with funds from the Ministry of Water, Land and Natural Resources. The objectives of this study were to determine the species diversity of frogs and toads in the Sapagaya FR, and to provide useful baseline information to build future studies on

anurans in that area, as well as to contribute to our current knowledge of anuran diversity and distribution in Sabah.

MATERIALS & METHODS

Site description

Mt Silam is an ultrabasic mountain situated about 22 km west of Lahad Datu town within the Lahad Datu district. Its forest structure and floristics have been studied and documented in the past (Fox 1972 & Proctor *et al*. 1988). The mountain itself is situated within two different forest reserves, i.e. Sapagaya Virgin Jungle Reserve (Class 6) and Sapagaya Forest Reserve (Class 1) in the Lahad Datu District. The peak of Mt. Silam is situated within Sapagaya Forest Reserve (FR). The Lahad Datu District Forestry Office administers these forest reserves. Sapagaya FR has four types of natural vegetation, such as mangrove forest, lowland mixed dipterocarp forest, lowland ultramafic forest, and ultramafic forest.

Sampling methods

Specimens were sampled by Visual Encounter Survey (VES) with the help of a torchlight to pinpoint sample locations; and where possible, hand grabbing techniques. All Visual Encounter Surveys (VES) were conducted between 19:00 hrs and 22:00 hrs to coincide with the peak anuran activity period (Inger *et al.* 2017). Three sample sites were selected within the forest areas. Areas along the location such as leaf litter piles, on tree branches, stumps, puddles, small streams, waterfalls and tree holes were searched for individuals (Muslim 2017 & Yong *et al*. 2013) with help of torchlight to pinpoint their location. Hand-grabbing technique was used to catch reachable individuals (Yong *et al*. 2013).

Anuran identification

All specimens visually detected were identified to species and their respective microhabitat and GPS locations were recorded. Amphibians were identified to species based on Inger *et al*. (2017). All previously undetected species were captured, placed in a clear plastic bag, and transported to indoor controlled conditions for specimen photography (Kueh 2006). After being photographed, specimens were released at the site of capture.

Manual Collection

The individuals sampled in this study were caught, identified (according to Inger *et al.* 2017) and noted in small notebook. Some representative individuals were put inside transparent plastic bags for preservation purpose. The individuals were later euthanized, fixed in 10% formalin and then preserved in 70% ethanol (Ehwan *et al.* 2018). All preserved specimens were deposited in Forest Research Centre, Sepilok.

Diversity indices

Diversity indices, namely Shannon Wiener, Simpson and Fisher Alpha were calculated through a diversity analysis software by Henderson & Seaby (1998), based on Magurran (2004).

RESULTS AND DISCUSSION

During the four night survey, a total of 141 individuals caught, consisting of 14 frogs and toads species, belonging to five families, were recorded from four sampling sites in Sapagaya FR. The most common species was *Meristogenys jerboa*, 20.0% of total individuals followed by other species; a) *Limnonectes kuhlii* (18.4%), b) *Leptrobracella itiokai* (14.5%). The mean Shannon Index was 2.31 while Simpson Index was 8.6 and Fisher Alpha Index was 3.86. When the anuran richness is compared with other forest reserves in Sabah, Sg Sapagaya FR anuran richness shows the second highest diversity after Trusan Sugut FR (Figure 1). The total number of individuals is slightly higher because of a more dominant species, hence, diversity decreased.

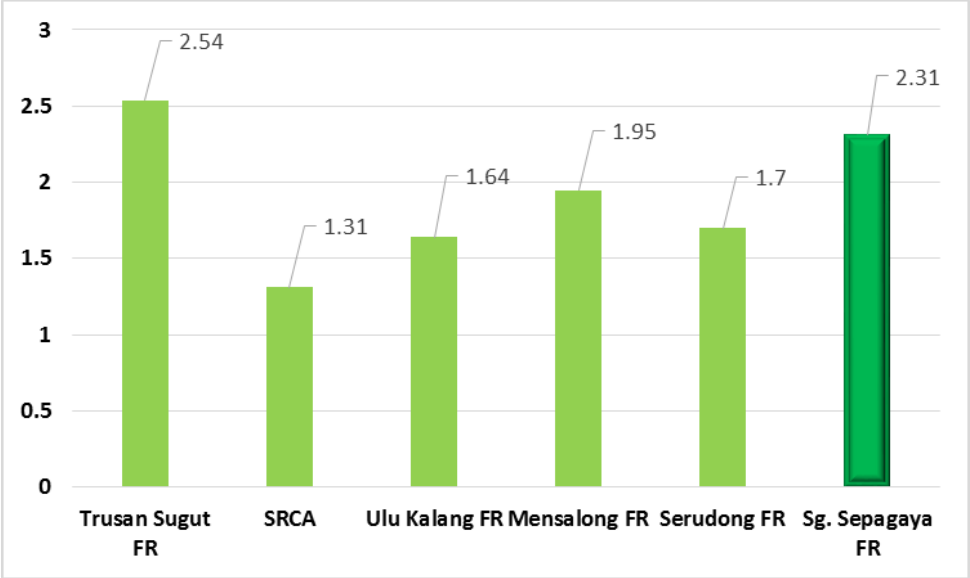

Figure 1. Shannon Wiener Index of anuran diversity within six forest reserves in Sabah.

Eleven Bornean endemic species were recorded during the survey, namely *Staurois guttatus* (Ranidae), *Staurois latopalmatus* (Ranidae), *Feihyla kajau* (Rhacophoridae), *Alcalus baluensis* (Ceratobatrachidae), *Metaphrynella sundana* (Microhylidae), *Limnonectes finchii* (Dicroglossidae), *Meristogenys jerboa* (Ranidae), *Polypedates otilophus* (Rhacophoridae), *Leptrobrachium abboti* (Megophryidae), *Leptrobracella itiokai* (Megophryidae), *Megophrys* nasuta(Megophryidae). A new highland species of the dwarf litter frog (*Leptrobracella itiokai*) was found in Sapagaya FR. It was described from Gunung Mulu National Park, northern Sarawak in 2016. One species was recorded as a vulnerable status according to the IUCN Redlist, namely *Meristogenys jerboa*, another species was recorded as a Near Threatened species, namely *Feihyla kajau.* This preliminary finding can be used to

promote nature tourism in the conservation area. Bornean endemic and interesting anuran species, such as the *Staurois guttatus, Feihyla kajau, Polypedates otilophus*, and *Metaphrynella sundana* can attract nature lovers.

It is acknowledged that the method used was not strong enough; more surveys can be made throughout the years to ensure solid data to be acquired. This study is still lacking an important part in most anuran studies: preservations of specimens. This was to ensure that any changes in the future could be applied to specimens found in this study and also for future references in any study. However, it is hoped that in the future, more research would be able to be done with a full and holistic methods including ecological parameters, such as the diversity and abundance, fulfilling the gaps left open in this study. It was also realized that small number of members of sampling party may affect the efficiency of the sampling effort, thus, demanding more manpower needed in future researches.

CONCLUSION

As a conclusion for this preliminary study, it was found that Sapagaya FR is home to a variety of species of anurans and likely more, had the sampling period been longer. The Bornean endemic anuran species recorded provide salient information to enhance the conservation of Sapagaya FR. Continuous monitoring and enforcement within the reserve are important to minimize the threats and adverse issues. This will ensure that the forest quality would be improved in order to maintain the interesting biodiversity, including anurans.

ACKNOWLEDGEMENTS

We thank the Chief Conservator Forests, Datuk Mashor bin Mohd. Jaini, for supporting the expedition. Special thanks to the research officers and staff of the Forest Research Centre who organised this expedition. Grateful to all of those with whom I had the pleasure to work with during this survey.

REFERENCES

Ehwan, N., Nur Johana, J., Shukor, M.N., Yaakop, S., Grismer, L.L. & Norhayati, A. (2018). Species richness and distributional pattern of amphibians along an elevational gradient at Gunung Raya, Pulau Langkawi, Kedah, Malaysia. *Sains Malaysiana* 47(8): 1635–1644.

Fox, J.E.D. (1972). *The natural vegetation of Sabah and natural regeneration of the dipterocarp forests*. PhD thesis, University of Wales.

Gaveau, D.L., Sloan, S., Molidena, E., Yaen, H., Sheil, D., Abram, N.K., Ancrenaz, M., Nasi, R., Quinones, M., Wielaard, N. & Meijaard, E. (2014). Four decades of forest persistence, clearance and logging on Borneo. *Plos ONE* 9(7): 1-11.

Gibbon, J.W., Scott, D.E., Ryan T.J., Buhlmann, K.A., Tuberville T.D., Metts, B.S., Greene, J.L., Mills, T., Leiden, Y., Poppy, S., & Winne, C.T. (2000). The global decline of reptiles, Déjà Vu amphibians. American Institute of Biological Sciences.

Henderson, P.A. & Seaby, R.M.H. (1988). Diversity ver. 2. Pisces Conservation Ltd., Lymington, UK.

Inger, R. F, R. B. Stuebing, T. U Grafe, & Dehling, J.M. (2017). *A field guide to the frogs of Borneo*, (3rd edition). The Natural History Publications (Borneo), Kota Kinabalu.

Kueh, B.H. (2006). Frogs of populated localities at West Coast and Kudat Divisions, Sabah, Malaysia: *Journal of Tropical Biology and Conservation*, 2 (1): 9-16.

Magurran, A.E. (2004). *Measuring biological diversity*. Blackwell, UK.

Muslim, T. (2017). Herpetofauna community establishment on the micro habitat as a result of land mines fragmentation in East Kalimantan, Indonesia. Volume 18, Number 2, April 2017. Pp: 709-714. *Biodiversitas*. Department of Forestry Science, Faculty of Forestry, Universitas Mulawarman. 18(2): 709-714.

Proctor, J., Lee, Y.F., Langley, A.M., Munro, W.R.C. & Nelson, T. (1988). A small ultrabasic mountain in Sabah, Malaysia. I. Environment, Forest Structure and Floristic. *Journal of Ecology* 76(2): 320-340.

Struebig, M.J., Wilting, A., Gaveau, D.L., Meijaard, E., Smith, R.J., Abdullah, T., Abram, N., Alfred, R., Ancrenaz, M., Augeri, D.M. & Belant, J.L. (2015). Targeted conservation to safeguard a biodiversity hotspot from climate and land-cover change. *Current Biology* 25(3): 372-378.

Stuart, S. N., J. S. Chanson, N. A. Cox, B. E. Young, A. S. Rodrigues, D. L. Fischman, & R.W. Waller (2004). Status and trends of amphibian declines and extinctions worldwide. *Science* 306(5702): 1783-1786

Yong, H., Ahmad, S. & Helpis, I. (2013). A survey of amphibians at Liwagu Water Catchment Area, Tambunan, Sabah, Malaysia. *Journal of Tropical Biology and Conservation*, 10: 27-29.

APPENDIX 1: List of frog and toad species in Sapagaya FR.

No.	Family	Species		No. of Individual				Bornean Endemic	IUCN
		Scientific name	Common name	Location					
				A	B	C	D		
1	Ranidae	*Staurois guttatus*	Black-Spotted Rock Skipper	2	4	5	0	Yes	NE
2	Ranidae	*Staurois latopalmatus*	Rock Skipper	0	0	0	3	Yes	LC
3	Rhacophoridae	*Feihyla kajau*	White-eared Tree Frog/Charming Tree Frog	7	0	0	0	Yes	NT
4	Rhacophoridae	*Kurixalus appendiculatus*	Fringed Tree Frog	12	0	0	0	No	LC
5	Ceratobatrachidae	*Alcalus baluensis*	Dwarf Mountain Frog	1	1	3	3	Yes	LC
6	Microhylidae	*Metaphrynella sundana*	Hole-tree Frog	0	6	0	3	Yes	LC
7	Dicroglossidae	*Limnonectes kuhlii*	Kuhl's Creek Frog	0	18	3	5	No	LC
8	Dicroglossidae	*Limnonectes finchii*	Rough Guardian Frog	0	3	0	3	Yes	LC
9	Ranidae	*Meristogenys jerboa*	Slender Torrent Frog	0	8	11	9	Yes	VU
10	Rhacophoridae	*Polypedates otilophus*	File-eared Tree Frog	0	1	1	2	Yes	LC
11	Megophryidae	*Leptrobrachium abboti*	Lowland Large-eyed Litter Frog	0	0	1	1	Yes	LC
12	Megophryidae	*Leptrobracella itiokai*	Dwarf Litter Frog	0	0	5	16	Yes	LC
13	Megophryidae	*Megophrys nasuta*	Bornean Horned Frog	0	0	0	1	Yes	LC
14	Dicroglossidae	*Fejervarya limnocharis*	Crab-eating Frog	0	0	1	2	No	LC
				22	41	30	48		
				TOTAL = 141					

Plate 1. A new highland species of the Dwarf Litter Frog, *Lebtrobracella itiokai*, was found in Sapagaya FR, was described from Gunung Mulu National Park, Sarawak in 2016.

Plate 2. Some of Bornean endemic anurans sampled from Sapagaya FR. (Left) *Staurois latopalmatus* (Rock Skipper); *Staurois guttatus* (Black-spotted Rock Skipper).

(Left) *Leptrobrachium abboti* (Lowland Large-eyed Litter Frog); *Alcalus baluensis* (Dwarf Mountain Frog).

(Left) *Polypedates otilophus* (File-eared Tree Frog); *Megophrys nasuta* (Bornean Horn Frog).

Meristogenys jerboa (Slender Torrent Frog)

Plate 3. More Bornean endemic anurans sampled from Sapagaya FR.

Freshwater fish diversity of Sg. Sepagaya and Sg. Taliwas in Lahad Datu, Sabah

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Abstract. The objectives of the present survey were to evaluate the diversity of freshwater fishes and to establish an inventory of the freshwater fish fauna in Sabah water. Sampling was done in six sites of Sg. Taliwas in Sepagaya FR and Sg. Sepagaya in Sapagaya FR (ext.) from 14th January to 17th January 2020. Each sampling site took place along about 200m reach comprising both lotic and lentic ecosystem to represent the species composition. A total of 376 individual of fishes comprising 18 species and six families were recorded. Among fishes collected, 86% were from the family Cyprinidae and *Nematabramis everetti* was the most abundant species. At least nine species are Bornean endemic. The Shannon diversity index of fishes in Sg. Taliwas was 3.201, higher than Sg. Sepagaya's value of 2.738. While the Simpson-index analysis showed that Sg. Sepagaya was recorded high, Ds= 0.263 compared with Sg. Taliwas, Ds=0.134. In terms of evenness, Sg. Taliwas has recorded higher with 0.865 compared with Sg. Sepagaya with 0.7.

Keywords: small streams, aquatic biodiversity, pisces, Southeast Asia, forest reserves.

INTRODUCTION

Information on the freshwater fishes of Sabah is still lacking, including the IUCN status. Fish may be the only vertebrate fauna in Malaysia that has received little attention in terms of conservation. With limited research data available from studies, it is yet possible to fully understand the population and species diversity, especially in forest reserves. This report presents the freshwater fish diversity of Sg. Sepagaya and Sg. Taliwas in Lahad Datu. Hence, the findings may be used as a base-line information for any conservation work in the future.

METHODOLOGY

Survey sites

The Sepagaya FR and Sapagaya FR (ext.) are both located adjacently and situated about 22 km west of Lahad Datu district. The survey was conducted for four days from 14th January to 17th January 2020 at two tributaries namely SPG1, SPG2, SPG3 and SPG4 in Sg. Sepagaya while TLW1, TLW2 and TLW3 in Sg. Taliwas (Figure 1). They were chosen based on following conditions: an easy accessible route along the tributary and absence of previous study. The water current of the stream is mostly slow flowing and the substrate comprised leaf litter, dead wood and deep peat. The area is mostly shaded and covered with riparian vegetation.

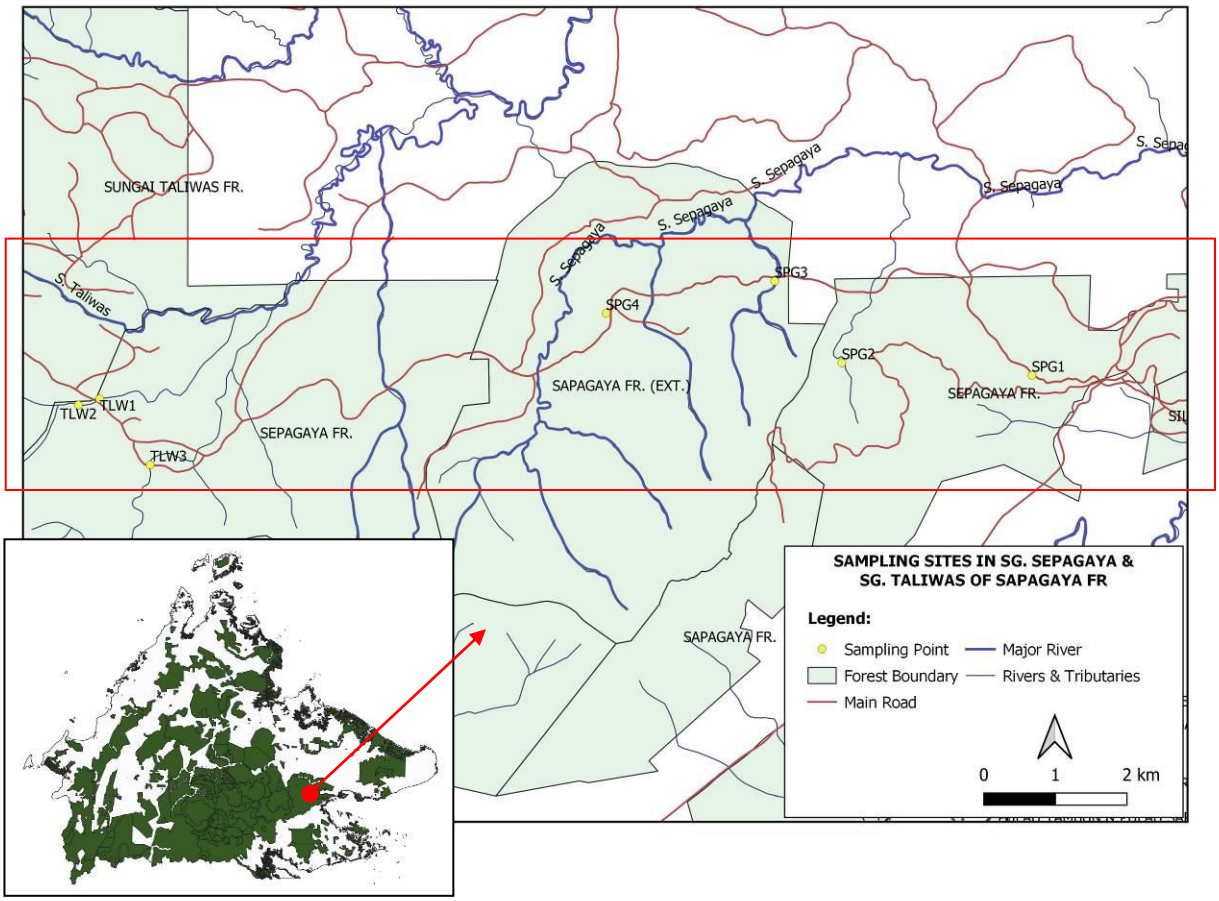

Figure 1. Bottom left box shows the location of Sepagaya Forest Reserve in Sabah, Malaysia. Top right and highlighted is Sg. Sepagaya and Sg. Taliwas.

The size of each stream ranges from 2 m to more than 10 m with the water level ranges from a few centimetres to more than a meter deep. Water was relatively clear, flowing smoothly and well oxygenated in most of the streams. Although both streams are located at different forest reserves, the environment were relatively the same where riparian plants growing well on the banks of the streams and not disturbed although anthropogenic activities present in all streams.

Fish sampling

Fishes were caught using various fishing gears, such as gill nets, fish traps (*bubu*) baited with oil palm fruits, cast nets and scoop nets. The techniques were based on the physical characteristics of the sampling sites. Cast netting with stretched mesh of 1.5 cm, 2 m long was used during the sampling. For scoop net sampling, drifting method was used where the net was carried along in the upper part of the water. At least two persons were required to set up the gill nets which will be left overnight. To minimize mortality, all captured fishes were placed in collapsible nets and immersed in flowing water. Small fishes were placed in an aerated bucket separately.

Taxonomic procedure

All fishes were counted and identified *in situ* to species level and released upon positive identification, except for voucher specimens which were preserved in 10% formalin for one or two weeks and transferred into 75% ethanol for long term storage (Martin-Smith & Tan 1998). Specimens examined are deposited at the Forest Research Centre. Fishes were identified using standard taxonomy references such as Kottelat *et al.* (1993), Inger & Chin (2002), Tan (2006) and Mohsin & Ambak (2015). Specimens that could not be positively identified to species level were indicated with open nomenclature terms "cf." and "sp.". Certain species are based on literature records.

Data Analysis

All species parameters were calculated using the software Community Ecology Parameter Calculator (ComEcoPac) Version 1.0. The formulae used by this software are as follows:

H' - Shannon-Wiener diversity index

$$H' = \sum_{i=1}^{s} p_i \cdot \log_2 p_i$$

S - species richness (number of species), p_i - proportion of species i

$$p_i = \frac{n_i}{N}$$

n_i - abundance of species i, N - total abundance

D - Simpson's index

$$D = \sum_{i=1}^{s} p_i^2$$

S - species richness, p_i - proportion of species i

E, E' - evenness and corrected evenness

$$E = \frac{H'}{H_{\max}} \qquad E' = \frac{H' - H'_{\min}}{H'_{\max} - H'_{\min}} \qquad H'_{\max} = \log_2 S$$

$$H'_{\min} = -\frac{N-S+1}{N}\log_2 \frac{N-S+1}{N} + \frac{S-1}{N}\log_2 N$$

RESULTS AND DISCUSSION

Fish composition

Checklist of fish species recorded in this survey was presented in Table 1. A total of 18 species of freshwater fishes were recorded from seven small streams sampled in this survey. Most of the species were caught using casting and push netting techniques, while one species, *Channa* cf. *baramensis* was positively identified from visual observation and was spotted in a pool where less occurrence of water flow and oxygen. The family has an additional respiratory organ called

diverticula which could make the species highly adaptable to adverse environment (Muchlisin & Azizah 2009).

The most dominant family in this survey is Cyprinidae represented by 10 species (55.6%) followed by family Gastromyzontidae with three species (16.7%). The high species richness of Cyprinidae in the local water bodies can be related to habitat suitability and the abundance of food sources. Since the Cyprinids are the most common and abundant group of freshwater fishes in Southeast Asia (Ismail 1990), high species richness of the group is also expected in the study area. Family of Nemacheilidae contributed two species while families of Anguilidae, Osphronemidae and Channidae were represented by single species. Most of the species recorded at both Sg. Sepagaya and Sg. Taliwas were commonly found in many small streams elsewhere in Sabah.

Table 1. The occurrence of fish species from the six tributaries of two main rivers surveyed.

No.	Family/Species	Locality		IUCN/Remarks
		Sg. Sepagaya	Sg. Taliwas	
	ANGUILLIDAE			
1	*Anguilla borneensis*	X	✓	n/a
	CYPRINIDAE			
2	*Barbodes sealei*	✓	✓	n/a/Endemic
3	*Crossocheilus elegans*	X	✓	n/a/Endemic
4	*Garra borneensis*	X	✓	n/a
5	*Hampala sabana*	✓	✓	LC
6	*Lobocheilos erinaceus*	✓	X	n/a
7	*Nematabramis everetti*	✓	✓	n/a/Endemic
8	*Osteochilus ingeri*	✓	✓	n/a
9	*Osteochilus chini*	✓	✓	n/a/Endemic
10	*Rasbora pycnopeza*	✓	✓	n/a/Endemic
11	*Tor tambra*	✓	X	DD
	GASTROMYZONTIDAE			
12	*Gastromyzon borneensis*	✓	X	n/a/Endemic
13	*Protomyzon borneensis*	✓	✓	DD
14	*Gastromyzon lepidogaster*	✓	✓	n/a
	NEMACHEILIDAE			
15	*Nemacheilus* cf. *elegantissimus*	✓	X	n/a/Endemic
16	*Nemacheilus olivaceus*	✓	✓	n/a/Endemic
	OSPHRONEMIDAE			
17	*Betta ocellata*	✓	✓	n/a/Endemic
	CHANNIDAE			
18	*Channa* cf. *baramensis*	✓	X	n/a

IUCN status key: DD= Data Deficient; LC= Least Concern; NA= Not available

The species of genera *Nemacheilus* and *Channa* that could not be identified with confidence were recorded with the term "cf.". Nine endemic species were recorded in this survey of which five were from family Cyprinidae (*Barbodes sealei*, *Nematabramis everetti*, *Rasbora pycnopeza*, *Osteochilus chini* and *Crossocheilus elegans*), two were from family Nemacheilidae (*Nemacheilus* cf. *elegantissimus* and *Nemacheilus olivaceus*) and one from each family Gastromyzontidae (*Gastromyzon borneensis*) and Osphronemidae (*Betta ocellata*).

Based on the IUCN categorization, out of 18 species, 15 species are yet to be accessed, two species are identified as DD and one species is identified as LC. This indirectly shows that most species are scantily known and their extinction risk status is hardly to be accessed (Ng, *et al.* 2017).

Fish diversity

Sg. Sepagaya recorded the higher abundance of fish trapped over the sampling period and found to be more diverse in comparison Sg. Taliwas. The diversity of both sampling sites was moderately high where Sg. Sepagaya has recorded 2.738 while Sg. Taliwas has recorded 3.201. The higher diversity index shows the existence of a balance between total species and total individual of every species. Meanwhile, in terms of species dominance (D), Sg. Sepagaya was higher with 0.263 compared with Sg. Taliwas with 0.134. In terms of evenness, Sg. Taliwas was higher with 0.865 compared with Sg. Sepagaya with 0.700.

Table 2. Fish diversity indices of Sg. Sepagaya and Sg. Taliwas, Lahad Datu, Sabah.

Sampling Sites	Number of Species	Shannon-Weiner	Simpson	Evenness
Sg. Sepagaya	15	2.738	0.263	0.700
Sg. Taliwas	13	3.201	0.134	0.865

CONCLUSION

The present survey has resulted in a collection of 18 species from six families of freshwater fishes. At least nine Bornean endemic species were recorded. Six sampling sites in Sepagaya FR and Sapagaya FR were dominated by the Cyprinids. *Nematabramis everetti* was the most abundant species among the two tributaries sampled. This survey only represents a preliminary work mainly in Sg. Sepagaya and Sg. Taliwas. It is likely that the number of species would be higher if the sampling period was longer and with proper gears used. A more thoroughly survey will eventually reveal more species. Further survey of fish with water quality sampling to determine species diversity and distribution, population status is recommended for conservation and planning future programme.

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REFERENCES

Inger, R.F. & Chin, P.K. (2002). *The fresh-water fishes of North Borneo.* Kota Kinabalu, Natural History Publications (Borneo). 263 pp. + 78 pp.

Ismail, M.Z. (1990). Cyprinids fishes of the Genus *Cyclocheilichthys* in Peninsular Malaysia. *Malayan Nature Journal* 44: 109-121.

Martin-Smith, K. & Tan, H.H. (1998). Diversity of freshwater fishes from eastern Sabah: annotated checklist for Danum Valley and a consideration of inter- and intra-catchment variability. *Raffles Bulletin of Zoology*. 46(2): 573-604.

Mohsin, A.M. & Ambak, M.A. (2015). *Ikan air tawar di Semenanjung Malaysia.* Kuala Lumpur, Dewan Bahasa dan Pustaka. 281 pp.

Muchlisin, Z.A. & Azizah, N.S. (2009). Diversity and distribution of freshwater fishes in Aceh Water, Northern-Sumatra, Indonesia. *International Journal of Zoological Research* 5(2): 62-79.

Ng, C. K.-C., Abdullah, F., Biun, H., Ibrahim, M. K., Mustapha, S., & Sade, A. (2017). Review: A working checklist of the freshwater fish diversity for habitat management and conservation work in Sabah, Malaysia, North Borneo. *BIODIVERSITAS, 18*(2): 560-574.

Tan, H.H. (2006). *The Borneo suckers.* Kota Kinabalu, Natural History Publications (Borneo). 245 pp.

Insect diversity of Mount Silam and its surrounding forests in Lahad Datu, Sabah

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Abstract. This insect survey was conducted from 13th to 18th of January, 2020 in Mount Silam forest, Lahad Datu, Sabah. An average of 108 nocturnal insect species from 148 individuals was recorded from a one-metre-square area of the light-trapping cloth. The mean Shannon Index was 4.17 while Simpson Index was 129.84 and Fisher Alpha Index was 193.60. At least 15 Bornean endemic species were recorded during the brief survey. These pioneer data will serve as baseline information for other research work in future. The data will further strengthen the management of Mount Silam within Sapagaya Forest Reserve as a Class I Forest Reserve (Protection). The information on insect diversity and the aesthetic value of some of the flagship species can be used to promote sustainable nature tourism in Mount Silam since this area is a tourist attraction in Lahad Datu.

Keywords: insects, diversity, Mount Silam, conservation

INTRODUCTION

As a group, insects are very significant in the tropical rainforests because of their high diversity and abundance (Godfray *et al*. 1999). They are essential for the functioning of the forest ecosystem (Cardoso *et al*. 2020 & Kitching *et al*. 2020). Many are pollinators, seed dispersers, nutrient recyclers, decomposers while others are food source for other animals. However, some insects are pests in forestry, causing damages to living trees and also forest products. Insects can be used as a tool in generating revenue for the state. Among the potentials of insects that can contribute to the Sabah state economy are the use of insects in nature tourism, bioindicators in environmental studies and insect products, such as honey and beewax. The forest in Mount Silam is also teeming with insect lives. This is the second survey on insects from this area. The first was conducted in September, 2010.

Mount Silam is located within the Sapagaya Forest Reserve (Class I – Protection), some 10 km from Lahad Datu town in eastern Sabah. It is an ultramafic coastal mountain facing the Darvel Bay, rising from sea level to 884 m a.s.l., making it the highest point in the Lahad Datu district. There are a few telecommunication towers and the observation tower (Menara Kayangan) located at 620 m a.s.l. Menara Kayangan is a tourist attraction in Lahad Datu, officially opened in 2012 and it is managed by the Lahad Datu District Forestry Office.

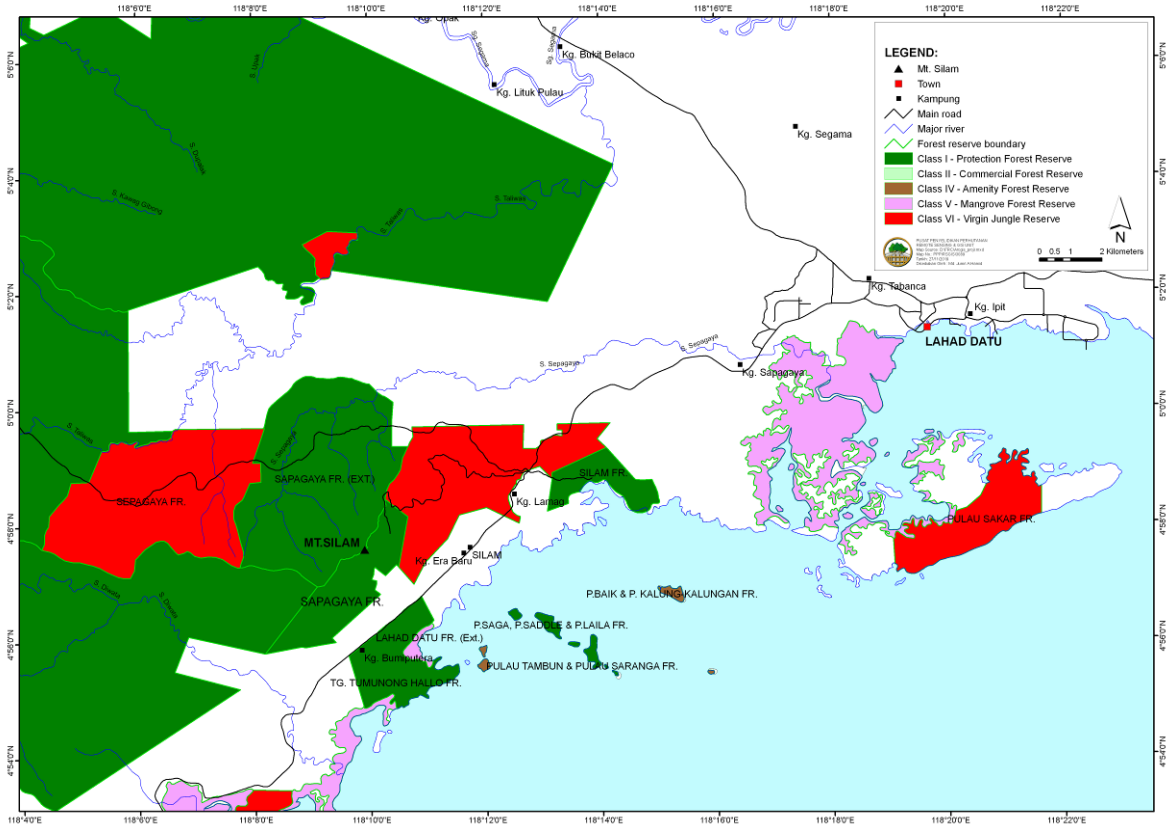

Figure 1. Location of Mount Silam in Lahad Datu, Sabah.

Purpose of the survey

This survey was conducted from 13th to 18th of January, 2020, with the expedition base camp at the Sepagaya Waterfall recreational area, about 30-mins drive to Menara Kayangan. The objectives of this study were to document the insect fauna of Mount Silam forest and to investigate the threats affecting insect diversity, as well as to provide recommendations that would contribute towards biodiversity conservation and promoting nature tourism for the study area. Funded by the Ministry of Water, Land & Natural Resources through the SFM Division of SFD HQ, it was participated by researchers, officers and staff of FRC, RDC and DFO Lahad Datu. This is part of the Payment for Ecosystem Services (PES) project of the department.

MATERIALS & METHODS

Light trap

Light trap was used to sample nocturnal insects. The trap consists of a vertical white sheet (2 X 2 m) illuminated by a 250W mercury-lithium bulb, powered by a portable generator. The trap was set up in an open area facing the forest reserve from 7:00 to 9:00 p.m. A GPS (Model: Garmin GPSMAP 60CSx) was used to determine the coordinates of each sampling site. Temperature and humidity were taken with a digital hygrometer from Extech Instruments (model no. 445702).

To evaluate diversity of the sampling area, insect species and individuals (≥ 5 mm) within the 1 X 1 m square of the white cloth were enumerated from 8:30 to 9:00 pm. This is a rapid biodiversity assessment method because by the end of the sampling time, species and individual numbers can be obtained, and the data can be used to calculate diversity indices, i.e. Shannon Wiener, Simpson and Fisher Alpha, using the Species Diversity & Richness version IV (Seaby & Henderson 2007). This method is simple, fast and can be carried out by non-insect specialist. To avoid compounding human error, the same staff was assigned to count the species and individual numbers throughout the sampling period at different sites. Light-trapping sites are shown in Table 1.

Table 1. Light-trapping sites in Mount Silam.

Sampling site	Coordinates	Elevation (m)	Temp. (°C)	Humidity (%)	Sampling date	Remarks
A	N 04°57'32.3" E 118°10'03.6"	610	22.1	82	14 Jan	Cloudy weather
B	N 04°58'52.3" E 118°12'52.9"	500	21.9	87	15 Jan	Fine weather
C	N 04°58'29.4" E 118°10'24.2"	481	24.5	83	16 Jan	Drizzling

Sweep net and manual collection

Sweep nets were used to collect day-flying insects while other insects were sampled using fine forceps. Butterflies were put in triangle papers while other specimens were put in vials with 75% ethanol solution. Sampling was conducted along the trails established by the villagers and also old skid trails. Details of the daytime sampling sites are listed in Table 2.

Table 2. Daytime sampling sites in Mount Silam.

Sampling site	Starting point coordinates	Elevation (m)
1 (Menara Kayangan to Silam Peak)	N 04°57'53.6" E 118°10'28.7"	620-884
2 (Trail Kubu Jepun)	N 04°58'30.6" E 118°11'22.9"	366-144
3 (Trail Kubang Badak)	N 04°58'24.1" E 118°10'54.1"	324-227

Insect specimens and identification

In this survey, focus was given to certain insect groups, i.e., butterflies, moths, beetles and dragonflies. Only interesting and potential indicator insect species were sampled. Macro photographs were taken with DSLR and mirrorless cameras to facilitate identification.

Selected specimens were dry-mounted and sorted to family and some to the genus and species level. The specimens sampled from this survey are deposited at the Forest Research Centre, Sepilok, Sabah. Dry-mounted specimens were identified based on the FRC Entomology Collection and various reference materials, e.g. Otsuka (1988 & 2001) and Kirton (2014) for butterflies; Holloway (1983, 1985, 1986, 1988, 1989, 1993, 1996, 1997, 1998a & b, 1999, 2001, 2003, 2005, 2008, 2009 & 2011), Robinson *et al.* (1994) and Sutton *et al*. (2015) for moths; Fujita (2010), Makihara (1999) and Tung (1983) for beetles, Seow-Choen (2016) for stick insects; Orr (2003) and Tang *et al*. (2010) for dragonflies and damselflies. Some other insects were identified based on Hill and Abang (2005). Unidentified specimens were morphotyped.

RESULTS & DISCUSSION

Overall insect diversity

The nocturnal insect diversity is as shown in Table 3. The mean Shannon Index was 4.17. The value for Simpson Index was 129.84 while Fisher Alpha Index was 193.60. During light-trapping, the temperature was cold, between 21^0C and 25^0C with relatively high humidity, between 82% and 87% (Table 2). The distribution of insect species from the light-trapping sites is reflected in the species-rank abundance curves in Figure 2. Site C recorded exceptional high number of species, hence, the very long horizontal line of the graph. On the other hand, Site A has pulled down the overall diversity value because of its low number of species and the presence of a dominant moth species, *Calymera* nr *vinacea*, with 34 individuals. This is reflected in the Simpson's Index (6.61) in Table 3 and the very steep curve of Site A in Figure 2. Interestingly, *C.* nr *vinacea* is endemic to Borneo.

Table 3. Insect diversity within a one-metre-square area, as sampled through light-trapping in Mount Silam forest.

No.	Sampling site	Species	Ind.	Shannon	Simpson	Fisher Alpha
1.	A	50	87	3.02	6.61	48.9
2.	B	108	139	4.54	159.8	222.6
3.	C	165	218	4.95	223.1	309.3
	Mean	108±58	148±66	4.17±1.02	129.84±111.31	193.60±132.60

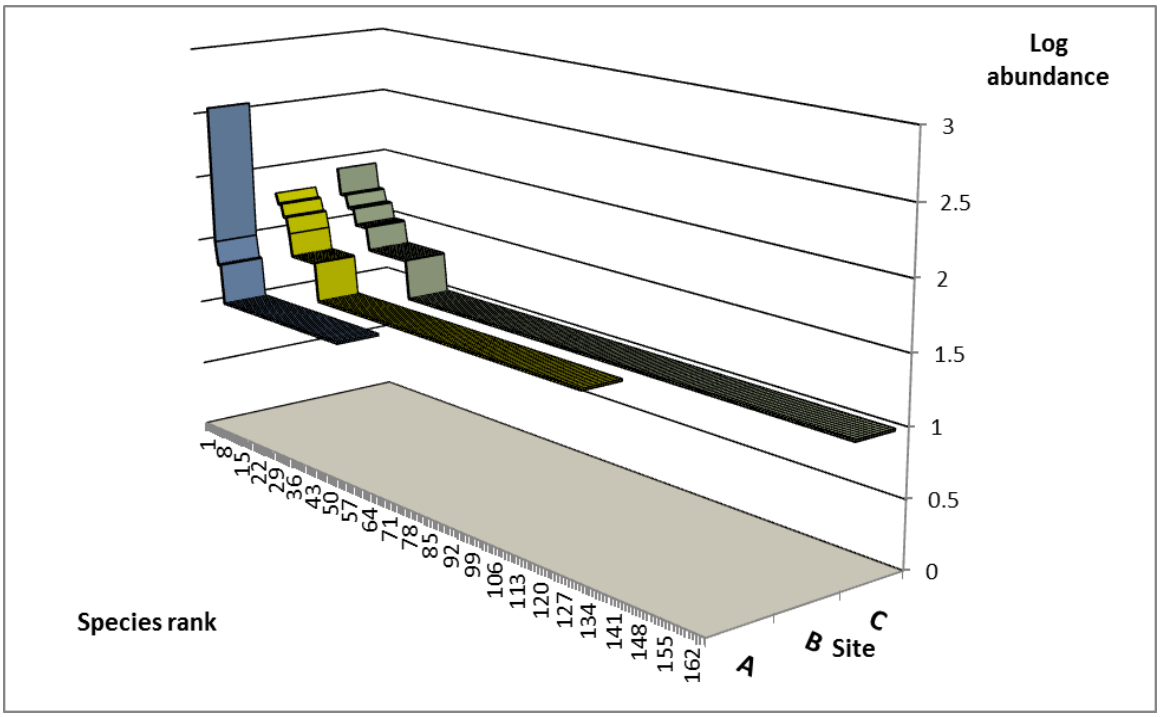

Figure 2. Species-rank abundance curves of the light-trapping sites in Mount Silam forest.

When the nocturnal insect richness is compared with other forest reserves sampled in the past using similar method, Mount Silam appeared to be high as shown in Figure 3a. It is ranked third of the 27 sites, but with a big standard deviation. In terms of nocturnal insect diversity, it is moderately high, as indicated in Figure 3b. It is ranked 9th of the 27 sites.

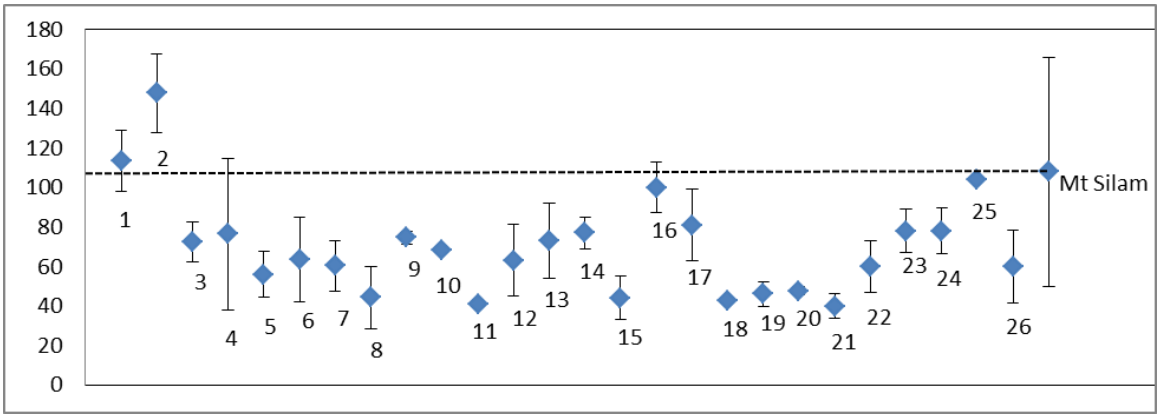

Figure 3a. Species number (±standard deviation) within a one-metre-square area, as assessed through light-trapping in various forest reserves in Sabah (1 = Bkt Hampuan, 2 = Crocker Range, 3 = Rafflesia, 4 = Gn. Lumaku, 5 = Gunong Lumaku, 6 = Milian Labau, 7 = Kawag, USM Office, 8 = Sg. Kapur, 9 = Sg. Siliawan, 10 = Nurod Urod, 11 = Punggol & Sansiang, 12 = Gg Tinkar, 13 = Sg Imbak 2a&2b, 14 = Tim-Bot, 15 = T. Bohangin, 16 = Sg Imbak 2c&2d, 17 = Kungkular, 18 = Pensiangan,19 = Nuluhon Trusmadi, 20 = Batu Timbang, 21 = Tambulanan, 22 = Trusan Sugut, 23= IJM SG, 24 = Ulu Kalang, 25 = Sg Rawog & 26 = Merisuli).

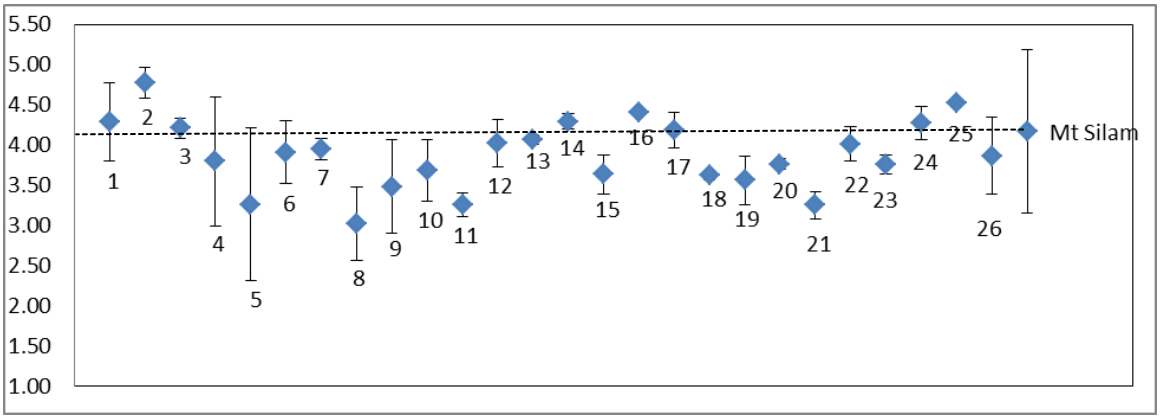

Figure 3b. Shannon Index (±standard deviation) within a one-metre-square area, as assessed through light-trapping in various forest reserves in Sabah.

At least 15 Bornean endemic species were recorded from Mount Silam during the survey, as listed in Table 4. The endemics included 10 moth species, two damselfly species and one each for beetle, butterfly and stick insect species. Some of the endemics are shown in Plate 1. This information provides input towards recommendations on high conservation values (HCV) of the area, based on HCV 1 as stipulated in HCVRN (2013).

Table 4. Bornean endemic insect species from Mount Silam forest during the survey.

No.	Species	Author	Order	Family	Photo code
1	*Lilioceris sandakana*	Achard	Coleoptera	Chrysomelidae	FRCS0418
2	*Amata prepuncta*	Holloway	Lepidoptera	Erebidae	FRCS0243
3	*Calliteara box*	Holloway	Lepidoptera	Erebidae	FRCS0155
4	*Lygniodes schoenbergi*	Guenee	Lepidoptera	Erebidae	SNP_8579
5	*Nishada syntomioides*	Walker	Lepidoptera	Erebidae	FRCS0384
6	*Herochroma clariscipta*	Holloway	Lepidoptera	Geometridae	FRCS0244
7	*Lassaba vinacea*	Prout	Lepidoptera	Geometridae	SNP_8576
8	*Spaniocentra apatelloides*	Holloway	Lepidoptera	Geometridae	SNP_8593
9	*Spaniocentra lobata*	Holloway	Lepidoptera	Geometridae	FRCS0344
10	*Eooxylides etias*	Druce	Lepidoptera	Lycaenidae	FRCS0434
11	*Calymera* nr *vinacea*	Holloway	Lepidoptera	Nolidae	SNP_8442
12	*Antheraea alleni*	Holloway	Lepidoptera	Saturniidae	FRCS0280
13	*Libellago phaeton*	Laidlaw	Odonata	Chlorocyphidae	DSCN0998
14	*Coeliccia nigrohamata*	Laidlaw	Odonata	Platycnemididae	DSCN1177
15	*Aretaon* nr *asperimus*	Redtenbacher	Phasmida	Heteropterygidae	SNP_8417

Butterflies (Lepidoptera)

Some 16 butterfly species were sampled during this brief survey (Appendix 1). One endemic species was recorded, namely *Eooxylides etias*, which is from the Lycaenidae family. This species was actually spotted after the suspension bridge at the Sepagaya Waterfall in the lowland forest. The Black and White Helen, *Papilio nephelus*, was spotted a number of times on Mount Silam. Hence, it is a common

species there. The Archdukes, *Lexias pardalis* and *L. dirtea* were also frequently encountered while trekking along the trails before the telecommunication station.

Moths (Lepidoptera)

Some 49 moth species were selectively recorded from this study (Appendix 2) and ten are endemic to Borneo; four from the family Erebidae and Geometridae respectively, one each from Saturniidae and Nolidae. The largest among the endemics is the Emperor Moth, *Antheraea alleni*, with a wingspan of 110 mm, and this was recorded at about 500 m a.s.l. Other unique moths with interesting patterns include *Sundwarda dohertyi* (Noctuidae) with Zebra-like pattern and *Tama lala* (Erebidae) with map-like pattern.

Beetles (Coleoptera)

Only five species of macro-beetles were recorded (Appendix 3). Among them, the interesting one is *Lilioceris sandakana*, which is a Leaf Beetle (Chrysomelidae, Criocerinae) recorded adjacent to the suspension bridge at the Sepagaya Waterfall (base camp area). It is an endemic species, found only in Sabah and Sarawak.

Dragonflies and damselflies (Odonata)

At least 14 species of Odonates were recorded (Appendix 4), with two Bornean endemics. Both endemics are damselflies, namely *Libellago phaeton* and *Coeliccia nigrohamata*. *L. phaeton* is known to be very common but localized on small clear streams and *C. nigrohamata* is also confined to small forest streams (Orr 2003).

Other insects

At least 13 species of other insects were recorded during the survey (Appendix 5). There was no concerted effort in sampling other insects. They were recorded while sampling the core insect groups during this survey. A stick insect endemic to Borneo, *Aretaon* nr *asperimus*, was recorded on the ornamentals at Menara Kayangan at about 620 m a.s.l. Other insects include a giant forest cockroach (*Mophna* sp.), resin bug (*Ectinoderus* sp.), lacewing (*Protohermes* sp.), some ants and termites.

Insect diversity and tourism in Mount Silam forest

From the survey, Mount Silam is a very interesting forest because it is one of the very few ultramafic forests that are located at the coastal area. Although the Silam peak is only 884 m a.s.l., the temperature is generally cold and misty much of the time due to ‘Masserhebung’ effect that affected the compression of vegetation zonation with the presence of montane forest towards the upper part of the mountain. This effect could also be the reason for the relatively high diversity of insects, with many interesting and endemic species. Therefore, Mount Silam should be further protected for the biodiversity conservation, from the perspective of insects.

The information on insect diversity procured from the survey can be used to promote sustainable nature tourism. Not many people would appreciate the beauty of insects compared to the big and iconic wildlife, such as orang utans and elephants. Nevertheless, this is one of those areas with potentials and should be given priority in due course, as nature appreciation is gaining momentum in many countries. This include butterfly and dragonfly watching. A video clip featuring some of the beautiful insects from Mount Silam has been produced after the field trip (Figure 4), and this could be used to support nature tourism of this area.

Figure 4: The QR code for the video clip on insects (left) and its cover.

Lahad Datu is known to many for its natural attraction, such as Danum Valley, Tabin and the Silam Coast. Located only about 10 km from the town centre and airport, Mount Silam is an ideal nature tourism destination which can boost the local economy and the state in general. However, it is utmost important that nature tourism should not overshadow the importance of biodiversity conservation, and in this case, it refers to insect conservation, as highlighted by Samways *et al.* (2020).

CONCLUSION

From this survey, the nocturnal insect diversity from Mount Silam was moderately high when compared to other forest reserves surveyed earlier. A number of endemic species were recorded. This pioneer data will serve as baseline information for other research work in future. The endemic and interesting insect species recorded during the survey provide salient information to enhance the conservation of Mount Silam as well as to provide input for better management of the reserve. The information will further strengthen the protection of this mountain as a Class I (Protection) Forest Reserve which was gazetted in 2009 from a stateland status. Efforts have to be taken to safeguard and maintain the forest quality in order to increase its biodiversity. The adjacent villagers and communities would have to be well-informed of the status of the forest reserve. It is important for them to work hand-in-hand with the department to protect Mount Silam forest as the water catchment area for Lahad Datu.

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REFERENCES

Cardoso, P., *et al*. (2020). Scientists' warning to humanity on insect extinctions. *Biological Conservation*. https://doi.org/10.1016/j.biocon.2020.108426.

Fujita, H. (2010). *The lucanid beetles of the world*. Mushi-Sha's Iconographic Series of Insects 6. Tokyo, Japan.

Godfray, H.C.J., Lewis, O.T. & Memmott, J. (1999). Studying insect diversity in the tropics. *Phil. Trans. R. Soc. Lond.* B 354:1811-1824.

HCVRN (2013). High Conservation Value Resource Network – common guidance for HCV identification for high conservation values. The Proforest Initiative, Oxford, UK.

Hill, D. & Abang, F. (2005). *The insects of Borneo (including South-east and East Asia)*. Universiti Malaysia Sarawak. 435 pp.

Holloway, J.D. (1983). Moths of Borneo (part 4): family Notodontidae *Malayan Nature Journal* 37: 1-107.

Holloway, J.D. (1985). Moths of Borneo (part 14): Family Noctuidae: subfamilies Euteliinae, Stictopterinae, Plusiinae, Pantheinae *Malayan Nature Journal* 38: 157-317.

Holloway, J.D. (1986). Moths of Borneo (part 1): key to families: families Cossidae, Metarbelidae, Ratardidae, Dudgeoneidae, Epipyropidae and Limacodidae. *Malayan Nature Journal* 40: 1-166.

Holloway, J.D. (1988). *The moths of Borneo (part 6): family Arctiidae, subfamilies Syntominae, Euchromiinae, Arctiinae; Noctuidae misplaced in Arctiidae (*Camptoloma, *Aganainae).* Southdene Sdn. Bhd., Kuala Lumpur. 101 pp.

Holloway, J.D. (1989). *The moths of Borneo (part 12): family Noctuidae, trifine subfamilies: Noctuinae, Heliothinae, Hadeninae, Acronictinae, Amphipyrinae, Agaristinae*. Southdene Sdn. Bhd., Kuala Lumpur. 226 pp.

Holloway, J.D. (1993). *The moths of Borneo (part 11): family Geometridae, subfamily Ennominae*. Southdene Sdn. Bhd., Kuala Lumpur. 309 pp.

Holloway, J.D. (1996). The moths of Borneo (part 9): family Geometridae, subfamilies Oenochrominae, Desmobathrinae and Geometrinae. *Malayan Nature Journal* 49: 147-326.

Holloway, J.D. (1997). The moths of Borneo (part 10): family Geometridae, subfamilies Sterrhinae & Larentiinae. *Malayan Nature Journal* 51: 1-242.

Holloway, J.D. (1998a). The moths of Borneo (part 8): families Castniidae, Callidulidae, Drepanidae & Uraniidae. *Malayan Nature Journal* 52: 1-155.

Holloway, J.D. (1998b). *The moths of Borneo (part 3): superfamily Bombycoidea: families Lasiocampidae, Eupterotidae, Bombycidae, Brahmaeidae, Saturniidae, Sphingidae*. Southdene Sdn. Bhd., Kuala Lumpur. 199 pp.

Holloway, J.D. (1999). The moths of Borneo (part 5): family Lymantriidae. *Malayan Nature Journal* 53: 1-188.

Holloway, J.D. (2001). *The moths of Borneo (part 7): family Arctiidae, subfamily Lithosiinae.* Southdene Sdn. Bhd., Kuala Lumpur. 486 pp.

Holloway, J.D. (2003). *The moths of Borneo (part 18): family Nolidae.* Southdene Sdn. Bhd., Kuala Lumpur. 279 pp.

Holloway, J.D. (2005). The moths of Borneo: family Noctuidae, subfamily Catocalinae. *Malayan Nature Journal* 58(1-4): 1-529.

Holloway, J.D. (2008). The moths of Borneo: family Noctuidae, subfamilies Rivulinae, Phytometrinae, Herminiinae, Hypeninae and Hypenodinae. *Malayan Nature Journal* 60(1-4): 1-268.

Holloway, J.D. (2009). The moths of Borneo (part 13): family Noctuidae, subfamily Pantheinae (part), Bagisarinae, Acontiinae, Aediinae, Eustrotiinae, Bryophilinae, Araeopteroninae, Aventiinae, Eublemminae and further miscellaneous genera. *Malayan Nature Journal* 62(1&2): 1-240.

Holloway, J.D. (2011). The moths of Borneo: families Phaudidae, Himantopteridae and Zygaenidae; revised and annotated checklist. *Malayan Nature Journal* 63(1-2): 1-548.

Kirton, L.G. (2014). *A naturalist's guide to the butterflies of Peninsular Malaysia, Singapore and Thailand*. John Beaufoy Publ. Ltd., UK & FRIM, Malaysia. 176 pp.

Kitching, R.L., Dahlsjo, C.A.L. & Eggleton, P. (2020). Invertebrates and the complexity of tropical ecosystems. *Biotropica* DOI: 10.1111/btp.12768.

Makihara, H. (1999). Atlas of longicorn beetles in Bukit Soeharto Education Forest, Mulawarman University, East Kalimantan, Indonesia. *PUSREHUT Special Publication No. 7.* Mulawarman University & JICA. 140 pp.

Orr, A.G. (2003). *A guide to the dragonflies of Borneo: their identification and biology*. Natural History Publications (Borneo), Kota Kinabalu. 195 pp.

Otsuka, K. (1988). *Butterflies of Borneo.* Vol. I. Tobishima Corporation, Tokyo, Japan. 61 pp.

Otsuka, K. (2001). *A field guide to the butterflies of Borneo and South East Asia*. Hornbill Books. 224 pp.

Robinson, G.S., Tuck, K.R. & Shaffer, M. (1994). *A field guide to smaller moths of South-east Asia.* The Natural History Museum, London & Malaysian Nature Society. 309 pp.

Samways, M.J., *et al*. (2020). Solutions for humanity on how to conserve insects. *Biological Conservation*. https://doi.org/10.1016/j.biocon.2020.108427.

Seaby, R.M.H. & Henderson, P.A. (2007). Species Diversity and Richness version 4.1.2, Pisces Conservation Ltd., Lymington, England.

Seow-Choen, F. (2016). *A taxonomic guide to the stick insects of Borneo*. Natural History Publications (Borneo), Kota Kinabalu, Sabah. 454 pp.

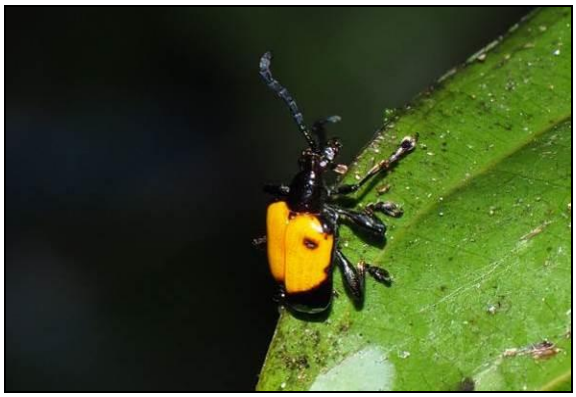
Sutton, S., Barlow, H. & Whitaker, T. (2015). *A preliminary guide to pyralids of Borneo (part 1)*. Natural History Publications (Borneo) & Southdene Sdn. Bhd., Kuala Lumpur. 89 pp.

Tang, H.B., Wang, L.K. & Hamalainen, M. (2010). *A photographic guide to the dragonflies of Singapore*. The Raffles Museum of Biodiversity Research, Singapore. 222 pp.

Tung, V. W-Y. (1983). *Common Malaysian beetles*. Longman, Kuala Lumpur. 142 pp.

Emperor Moth, *Antheraea alleni*

Erebidae Moth, *Lygniodes schoenbergi*



Leaf Beetle, *Lilioceris sandakana*

Damselfly, *Libellago phaeton*

Damselfly, *Coeliccia nigrohamata*

Plate 1: Selected Bornean endemics from Mount Silam during the survey.

Appendix 1: Butterflies recorded from Mt. Silam, Lahad Datu (13-18 January, 2020).

No.	Species	Author	Family	Photo no.	Remarks
1	*Eooxylides etias*	Druce	Lycaenidae	FRCS0434	Endemic
2	*Athyma nefte subrata*	Moore	Nymphalidae	FRCS0078	
3	*Cupha erymanthis erymanthis*	Drury	Nymphalidae	FRCS0420	
4	*Euploea mulciber portia*	Fruhstorfer	Nymphalidae	FRCS0098	
5	*Hypolimnas bolina philippensis*	Butler	Nymphalidae	FRCS0100	
6	*Junonia hedonia ida*	Cramer	Nymphalidae	FRCS0108	
7	*Lexias dirtea chalcenoides*	Fruhstorfer	Nymphalidae	FRCS0059	
8	*Lexias pardalis dirteana*	Corbet	Nymphalidae	SNP_8501	
9	*Moduza procris agnata*	Fruhstorfer	Nymphalidae	FRCS0331	
10	*Parantica aspasia aspasia*	Fabricius	Nymphalidae	FRCS0104	
11	*Ragadia makuta umbrata*	Fruhstorfer	Nymphalidae	FRCS0320	
12	*Vindula dejone dejone*	Erichson	Nymphalidae	FRCS0096	
13	*Ypthima pandocus sertorius*	Fruhstorfer	Nymphalidae	FRCS0109	
14	*Discophora necho*	C & R Felder	Nymphalidae	DSCN1151	
15	*Papilio helenus enganius*	Doherty	Papilionidae	FRCS0317	
16	*Papilio nephelus albolineatus*	Forbes	Papilionidae	SNP_8635	

Appendix 2: Selected moths recorded from Mt. Silam, Lahad Datu (13-18 January, 2020).

No.	Species	Author	Family	Photo no.	Remarks
1	*Amata prepuncta*	Holloway	Erebidae	FRCS0243	Endemic
2	*Amerila astreus*	Rothschild	Erebidae	FRCS0270	
3	*Anisoneura aluco*	Fabricius	Erebidae	FRCS0397	
4	*Asota egens*	Walker	Erebidae	FRCS0370/FRCS0392	
5	*Asota heliconia*	Linneaus	Erebidae	FRCS0171/FRCS0382	
6	*Barsine cruciata*	Walker	Erebidae	FRCS0381	
7	*Barsine roseororatus*	Butler	Erebidae	FRCS0351/FRCS0379	
8	*Calliteara box*	Holloway	Erebidae	FRCS0155	Endemic
9	*Cyana conclusa*	Walker	Erebidae	SNP_8520	
10	*Cyana costifimbria*	Walker	Erebidae	SNP_8539	
11	*Cyana malayensis*	Hampson	Erebidae	SNP_8585	
12	*Eugoa trifascia*	Walker	Erebidae	SNP_8505	
13	*Lygniodes schoenbergi*	Guenee	Erebidae	SNP_8579	Endemic
14	*Lymantria minora*	van Eecke	Erebidae	FRCS0274	
15	*Nishada syntomioides*	Walker	Erebidae	FRCS0384	Endemic
16	*Nyctemera muelleri*	Vollenhoven	Erebidae	FRCS0172/FRCS0176	
17	*Tamba lala*	Swinhoe	Erebidae	FRCS0389	
18	*?Petelia* sp.		Geometridae	FRCS0339	
19	*Agathia codina*	Swinhoe	Geometridae	FRCS0167/FRCS0183	
20	*Amblychia hymenaria*	Guenee	Geometridae	FRCS0259	
21	*Cleora determinata*	Walker	Geometridae	FRCS0181/SNP_8542	

22	*Cleora pendleburyi*	Prout	Geometridae	FRCS0160	
23	*Cleora repetita*	Butler	Geometridae	SNP_8420	
24	*Herochroma clariscipta*	Holloway	Geometridae	FRCS0244	Endemic
25	*Lassaba vinacea*	Prout	Geometridae	SNP_8576	Endemic
26	*Lomographa luciferata*	Walker	Geometridae	SNP_8433	
27	*Ornithospila bipunctata*	Prout	Geometridae	SNP_8533	
28	*Ornithospila submonstrans*	Walker	Geometridae	FRCS0153	
29	*Orothalassodes* nr *hypocrites*	Prout	Geometridae	FRCS0184	
30	*Pelagodes* nr *cochlearis*	Holloway	Geometridae	SNP_8438/SNP_8445	
31	*Petelia delostigma*	Prout	Geometridae	SNP_8512	
32	*Pingasa lariaria*	Walker	Geometridae	FRCS0391	
33	*Plutodes moultoni*	Guenee	Geometridae	FRCS0263	
34	*Spaniocentra apatelloides*	Holloway	Geometridae	SNP_8593	Endemic
35	*Spaniocentra lobata*	Holloway	Geometridae	FRCS0344	Endemic
36	*Takanea diehli*	Lajonquiere	Lasiocampidae	FRCS0355	
37	*Chrysodeixis* sp.		Noctuidae	FRCS0386	
38	*Lopharthrum comprimens*	Walker	Noctuidae	FRCS0250	
39	*Ramadasa pavo*	Walker	Noctuidae	FRCS0366	
40	*Sundwarda dohertyi*	Druce	Noctuidae	FRCS0254	
41	*Blenina malachitis*	Hampson	Nolidae	FRCS0158	
42	*Calymera* nr *vinacea*	Holloway	Nolidae	SNP_8442	Endemic
43	*Diehlea ducalis*	Bryk	Nolidae	FRCS8418	
44	*Antheraea alleni*	Holloway	Saturniidae	FRCS0280	Endemic
45	*Acherontia lachesis*	Fabricius	Sphingidae	FRCS0346	
46	*Ambulyx pryeri*	Distant	Sphingidae	FRCS0373	
47	*Ambulyx subocellata*	Felder	Sphingidae	FRCS0340/FRCS0349	
48	*Daphnis hypothous*	Cramer	Sphingidae	FRCS0368	
49	*Lyssa menoetius*	Hopffer	Uraniidae	FRCS0170	

Appendix 3: Macro beetles recorded from Mt. Silam, Lahad Datu (13-18 January, 2020).

No.	Species	Author	Family	Photo no.	Remarks
1	*Cryiopalus wallacei*	Pascoe	Cerambycidae	FRCS0401	
2	*Aulacophora* sp.		Chrysomelidae	SNP_8551	
3	*Lilioceris sandakana*	Achard	Chrysomelidae	FRCS0418	Endemic
4	Unidentified		Cicindelidae	FRCS0137	
5	*Lycostomus* sp.		Lycidae	FRCS0091	

Appendix 4: Odonata recorded from Mt. Silam, Lahad Datu (13-18 January, 2020).

No.	Species	Author	Family	IUCN Redlist	Photo No.	Remarks
1	*Neurobasis longipes*	Hagen, 1887	Calopterygidae	LC	DSCN1013	
2	*Vestalis* sp.	Selys, 1853	Calopterygidae		DSCN1010	
3	*Libellago phaeton*	Laidlaw, 1931	Chlorocyphidae		DSCN0998	Endemic
4	*Xyphiagrion cyanomelas*	Selys, 1876	Coenagrionidae		DSCN1128	
5	*Euphaea* sp.	Selys, 1840	Euphaeidae		DSCN1008	
6	*Diplacodes trivalis*	Rambur,1842	Libellulidae		DSCN1133	
7	*Macrodiplax cora*	Brauer, 1867	Libellulidae	LC	DSCN0920	
8	*Orthetrum glaucum*	Brauer, 1865	Libellulidae	LC	FRCS0106	
9	*Orthetrum sabina*	Drury,1773	Libellulidae	LC	DSCN1135	
10	*Orthetrum testaceum*	Brumeister,1839	Libellulidae	LC	DSCN1136	
11	*Trithemis aurora*	Burmeister,1839	Libellulidae	LC	DSCN1124	
12	*Coeliccia nigrohamata*	Laidlaw,1918	Platycnemididae		DSCN1177	Endemic
13	To be identified later				SNP_8629	
14	To be identified later				SNP_8559	

Appendix 5: Other insects recorded from Mt. Silam, Lahad Datu (13-18 January, 2020).

No.	Species	Author	Order	Family	Photo no.	Remarks
1	*Morphna* sp.		Blattodea	?Blattidae	FRCS0138	
2	*Dicuspiditermes* sp.		Blattodea	Termitidae	FRCS0204	
3	*Hospitalitermes* sp.		Blattodea	Termitidae	SNP_8359	
4	*Macrocerotermes* sp.		Blattodea	Termitidae	FRCS0206	
5	Unidentified		Diptera	Micropezidae	SNP_8597	
6	Unidentified (Nymph)		Homoptera	Fulgoridae	SNP_8605	
7	*Ectinoderus* sp.		Homoptera	Reduviidae	SNP_8469/67	
8	*Colobopsis saundersi*	Emery	Hymenoptera	Formicidae	SNP_8504	
9	*Leptogenys* sp.		Hymenoptera	Formicidae	SNP_8388	
10	*Myrmicaria* sp.		Hymenoptera	Formicidae	SNP_8623	
11	*Deroplatys dessicata*	Beier	Mantodea	Mantidae	FRCS0007	
12	*Protohermes* sp.		Neuroptera	Corydalidae	SNP_8584	
13	*Aretaon* nr *asperimus*	Redtenbacher	Phasmida	Heteropterygidae	SNP_8417	Endemic

Socio-economic evaluation and community's perception on forest conservation: a case study of the community adjacent to Mount Silam in Lahad Datu, Sabah

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Abstract. This study was conducted in four study sites, namely Kampung Teluk Soaiun, Kampung Tampenau, Kampung Bumiputra and Kampung Sri Aman which are located near Mount Silam. The villages were all located within the Sapagaya Virgin Jungle Reserve (Class 6) and Sepagaya Forest Reserve (Class 1) in Lahad Datu. The objectives of the study were to evaluate the socio-economic condition of the community, their perception on conservation efforts in the forest reserves and their level of dependency on forest resources. The methodology utilized to conduct this study included focus group discussion, household survey, key informant interview and literature review. A total number of 40 respondents were surveyed for the purpose of the study. The study findings will assist related stakeholders in understanding the livelihood condition of the communities, the issues and concerns that the community are facing and their current socio-economic status and these can further improve the design and planning of projects related to the community.

Keywords: socio-economic, focus group discussion, household survey, local community, Mount Silam, Sepagaya Forest Reserve.

INTRODUCTION

The World Bank (2002) stated that approximately 1.6 billion people globally were substantially dependent on forests to sustain their livelihood. Forest is important and essential for the provision of basic necessity, act as safety nets and cash savings (Shackleton *et al.* 2007). Forest has been the source of employment, medicine, energy and other subsistence needs for the local communities (Bahuguna 2000). Mc Elwee (2010) informed that some people were highly dependent on forest as their only source of subsistence and had even surpassed other source of livelihood, such as agriculture. Although forest contributes to livelihoods, the level of dependency of human on forests is a multifaceted phenomenon (Beckley 1998). It is different geographically, over time and across communities (Babulo *et al.* 2008). Household's socio-economic is one of the various factors that influences the community's forest dependency (Panta *et al.* 2009). This study aims to evaluate the socio-economic condition of the community, their perception on conservation efforts in the forest reserve and their level of dependency on the forest resources. This study was conducted during the Mount Silam Scientific Expedition on 13th January until 18th January 2020, organised by the Forest Research Centre, Sabah Forestry Department. All of the chosen study sites were located near Mount Silam in which the mountain is

located within two different forest reserves, namely Sapagaya Virgin Jungle Reserve (Class 6) and Sepagaya Forest Reserve (Class 1) in Lahad Datu. The research team were able to obtain a total number of 40 respondents for the study due to the limited time available during the expedition.

METHODOLOGY

Site Description

There are four study sites chosen for this study, namely Kampung Teluk Soaiun, Kampung Bumiputra, Kampung Sri Aman and Kampung Tampenau (Figure 1). All the villages surveyed were within Sapagaya Forest Reserve and Sepagaya Forest Reserve. The community in the four study sites were mainly planters of oil palm plantation, planting of fruit trees and home gardening.

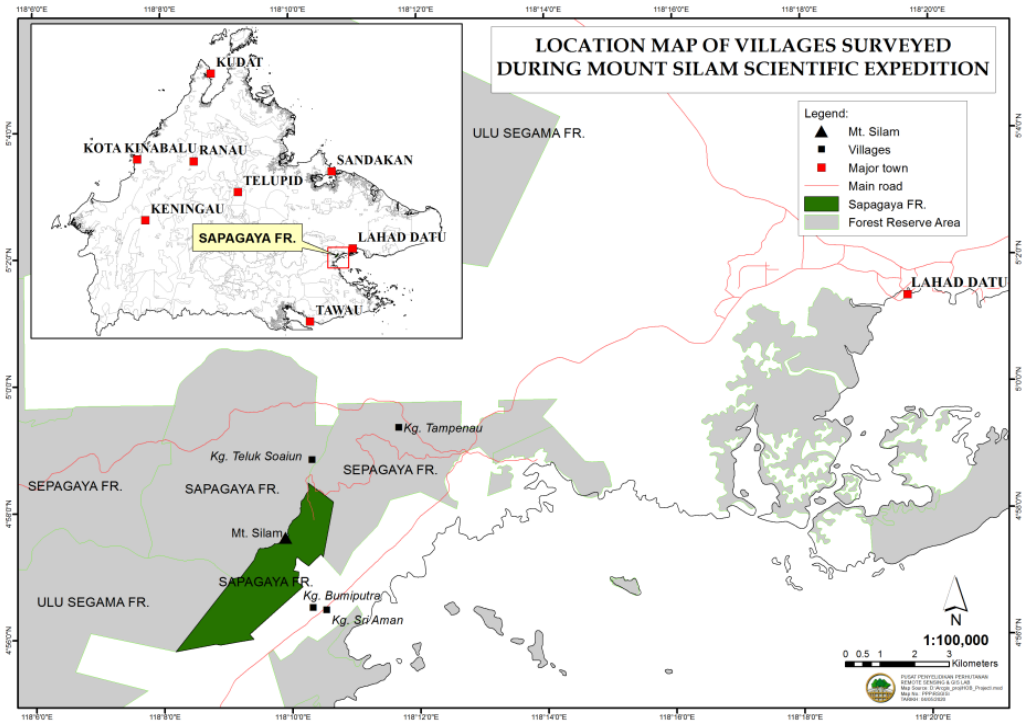

Figure 1. Location map of all villages surveyed.

Survey methods

This study utilized four types of method which included Household Survey, Focus Group Discussion (FGD), Key Informant Interview, and literature review. The Household Survey was conducted using a questionnaire consisting of information, such as socio-economic information, awareness and importance of forest reserve, dependency on forest resources, perception on conservation effort, community involvement in decision making processes, women's involvement in conservation activity, factors influencing women's involvement in forestry, relationship between community and forest management team, impact of forest reserve establishment on the community and suggestions. The respondents for the household survey were selected using random and purposive sampling. A fair representation of both men and

women were taken into account in the sampling. In the FGD, participants were divided into two main groups, which was the man and woman groups. FGD was conducted in only three villages which was Kampung Teluk Soaiun, Kampung Tampenau and Kampung Bumiputra. The community from Kampung Sri Aman had participated in the FGD with Kampung Bumiputra as the distance between both the villages was very near. While on the other hand, the key informant interview was conducted using a semi-structured interview of experts to obtain in-depth information. Literature review was mostly referring to past reports and records of information related to the study sites. Data recorded was compiled using Microsoft Excel and was analyzed using Statistical Package for Social Sciences (SPSS) version 26.

RESULTS

Socio-demographic background

The total number of respondents surveyed for this study was 40 respondents. 20 of the respondents were male and the remaining 20 of the respondents were females. As mentioned earlier, a fair representation of both men and women were taken into account in the sampling. Majority of the respondents was 41 to 51 years old with 30.9%, followed by 52 to 62 years old with 25.7% and the third highest was over 63 years old with 20.7%. A total of 87.5% of the respondents were married and 12.5% were widow. Majority of the respondents were Bajau with 47.5%, followed by Dusun with 15% and Suluk with 12.8%. Others include Brunei, Bisaya, Bugis, Idahan, Tidung, Banjar and Kadazan with small percentages. The highest level of education achieved by the respondents was Sijil Pelajaran Malaysia (SPM) with 37.5%. followed by Penilaian Menengah Rendah (PMR) with 30% and the third highest were no formal education with 17.5%. Other levels of education of the respondents include Ujian Penilaian Sekolah Rendah (UPSR), Sijil Tinggi Pelajaran Malaysia (STPM) and university degree with smaller percentages. From the survey data analysis, it was also recorded that the highest number of respondents in terms of income were ranging from RM 501 to RM 1000 with 25%, followed by income range of less than RM 500 with 24.2% and the third highest was income range of RM 1501 to RM 2000 with 7.5%. In terms of occupation, majority of the respondents were self employed with 40%. They were mostly cultivating oil palm in their area. This was followed by unemployed respondents with 17.5%. The third highest value for occupation were farmers with 15%. The farmers mostly plant and sell fruit trees and establish home gardens.

Table 1. Socio-demographic information of the community.

Socio-demographic background	**SILAM**			
	Number of respondent (n=40)	Percentage of respondent (%)	Mean	Standard deviation
Gender				
Male	20	50.0	1.50	0.51
Female	20	50.0		

Age				
≤18 years old	N/A	N/A		
19-29 years old	2	5.1		
30-40 years old	7	18.1	50.77	12.31
41-51 years old	12	30.9		
52-62 years old	10	25.7		
≥63 years old	8	20.7		
Marital status				
Single	N/A	N/A		
Married	35	87.5	2.13	0.34
Widow/widower	5	12.5		
Occupation				
Business	2	5.0		
Gardener	6	15.0		
Government sector	3	7.5	5.90	2.27
Private sector	5	12.5		
Self-employed	16	40.0		
Head village	1	2.5		
Not working	7	17.5		
Household roles				
Father	20	50.0	1.55	0.64
Mother	19	47.5		
Other	1	2.5		
Race				
Dusun	6	15.0		
Kadazan dusun	1	2.5		
Brunei	1	2.5		
Bajau	19	47.5		
Bugis	3	7.7	6.90	2.98
Suluk	5	12.8		
Bisayah	1	2.5		
Idahan	2	5.0		
Tidung	1	2.5		
Banjar	1	2.5		
Education level				
UPSR/Related certificate	2	5.0		
PMR/Related certificate	12	30.0		
SPM/Related certificate	15	37.5	3.33	1.59
STPM/Related certificate	2	5.0		
Degree	2	5.0		
No formal education	7	17.5		
Total income				
≤RM500	8	24.2		
RM501 - RM1000	10	25.0	1406.06	1331.57
RM1001 - RM1500	7	17.5		
RM1501 - RM2000	3	7.5		
≥RM2001	5	12.5		

Notes: N/A refers to Not Available

Dependency on forest resources

Figure 2 shows the respondents' dependency on forest resources. Results show that 40% of the respondents were still depending on the forest resources while 60% of

the respondents were no longer depending on forest resources. The respondents surveyed mentioned that they had other alternatives to obtain food and not relying too much on forest resources. They bought their daily food from the nearby market which includes rice, cooking oil, meat, vegetables and other types of groceries and daily necessities. They mentioned that it was easier to obtain it from the market and that it is difficult to enter the forest now compared to the past. To test the difference between the level of dependency, Mann-Whitney U test were used. The analysis shows that there is a significant difference between the dependency of the community towards forest resources as the value of $p = 0.008$.

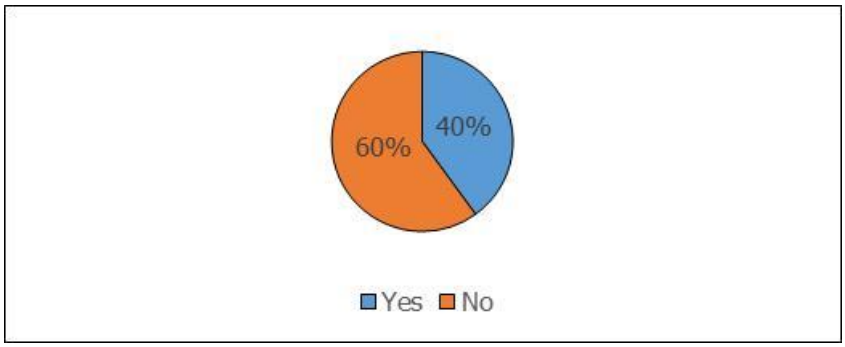

Figure 2. Community's dependency on forest resources.

Based on respondents, they have collected several types of non-timber forest products, such as fruits and vegetables for their own consumption and as one of their food resources. The community also collected medicinal herbs. Table 2 summarizes the non-timber forest products collected by the community.

Table 2. List of forest resources collected by the community in Silam.

No.	Local name	Scientific name	Function
1.	Coconut	*Cocos nucifera*	Used as skin healer and taken as a food ingredient
2.	Durian	*Durio* spp.	Food
3.	*Rambutan*	*Nephelium lappaceum*	Food
4.	Mango	*Mangifera indica*	Food
5.	*Jantung pisang*	*Musa paradisiaca*	Cooked as vegetables
6.	*Daun pisang*	*Musa acuminata*	Food packaging
7.	Lemongrass	*Cymbopogon nardus*	Used to cure headache

Source: Interview with informants (2020).

Figure 3 shows the respondents' frequency of entering the forest to collect forest resources. Based on the survey analysis, 35% of the respondents enter the forest only when in need, followed by 25% of the respondents, only enter the forest 1-3 times per month and 11% respondents rarely enter the forest.

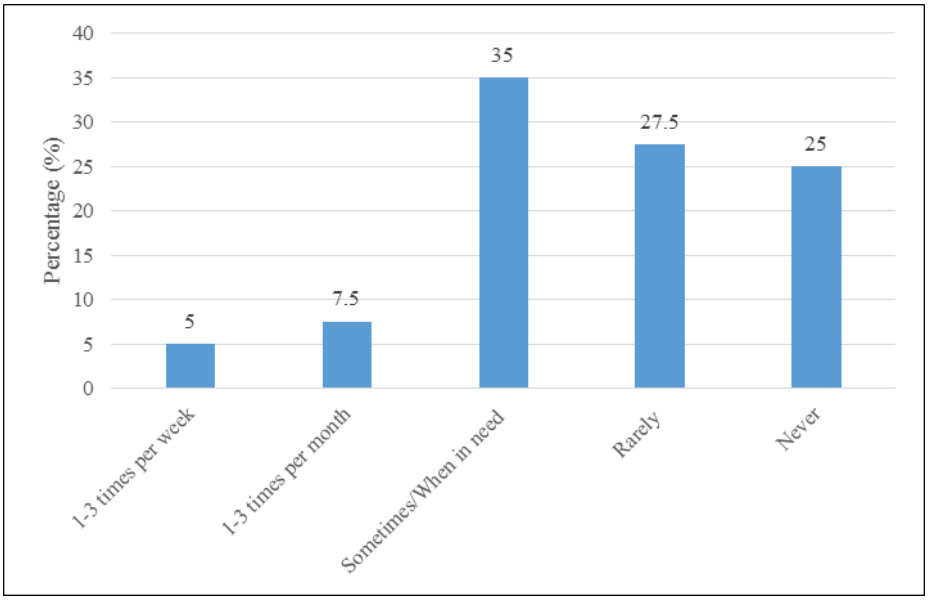

Figure 3. Frequency of entering the forest.

Community's involvement in decision making processes

Based on Figure 4 below, communities are getting involved in decision making processes related to the surrounding area of their respective village which includes forest reserve area. Results show that 80% of the communities will report to the Sabah Forestry Department if there were any problems or issues related to the nearby forest reserve, followed by the communities will always informed others about the final decision of the meeting that they attended with 65.0% and the third highest is that the communities will always be present in the meeting with the Sabah Forestry Department with 62.5%. The analysis also shows that 22.5% of the respondents surveyed hold a position in the committee attending meetings with Sabah Forestry Department.

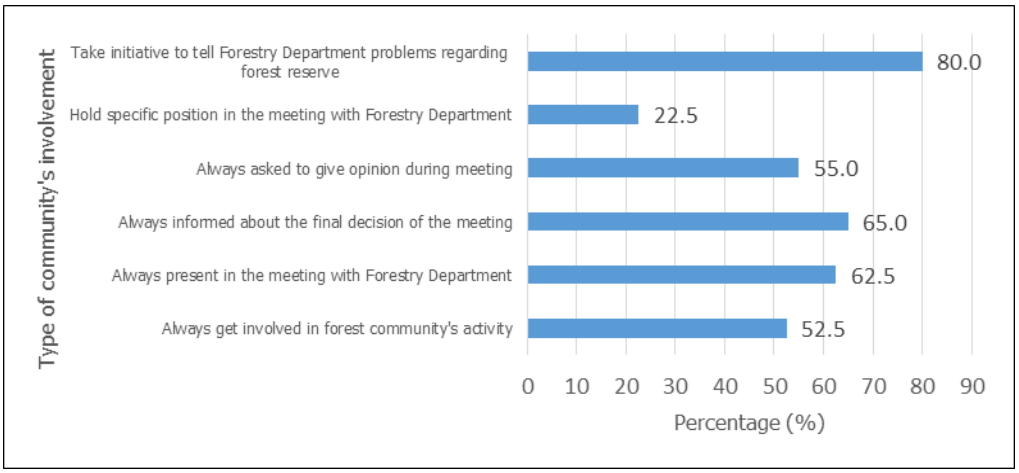

Figure 4. Percentage of community's involvement in decision making processes.

Woman's Participation in Restoration Activity

Figure 5 shows the woman's participation in the restoration activity conducted in the nearby forest reserve. Among 20 female respondents that were interviewed,

only 20% of the respondents were actively involved in the restoration activity and 80% were not actively involved in the restoration activity. The types of restoration activity are further explained in Figure 6.

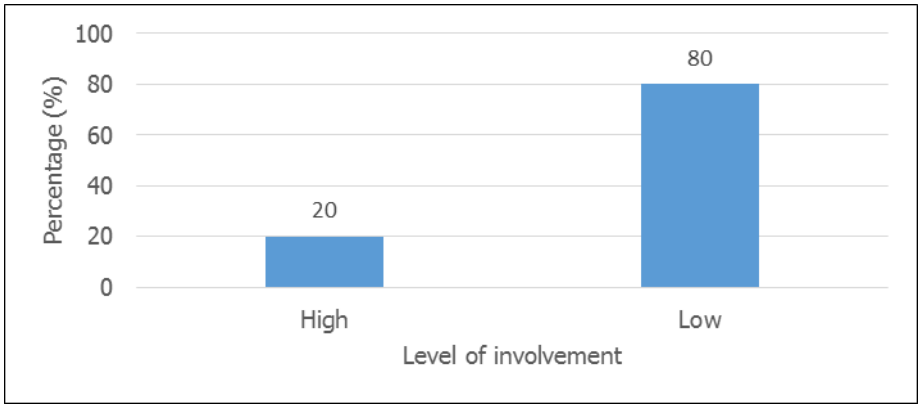

Figure 5. Percentage level of woman's involvement in restoration activities.

Figure 6 shows the woman's participation in three types of restoration activities which include replanting of fruit trees, replanting of forest trees and replanting of rubber trees.

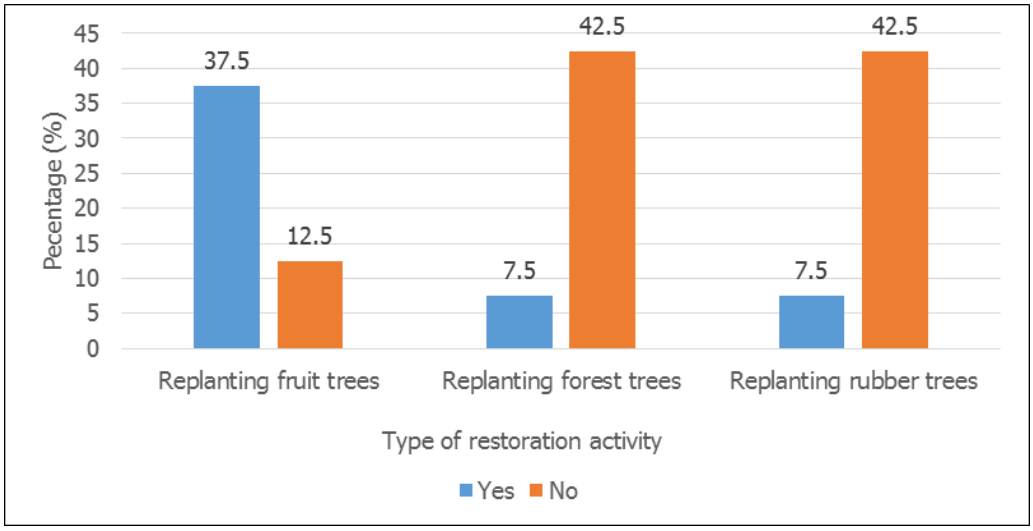

Figure 6. Woman's participation in three types of restoration activities.

Community's perception on conservation efforts

Figure 7 shows the perception of the community on the conservation efforts in the nearby forest reserve. Based on the result, majority of the respondent perceived that the conservation efforts in the nearby forest reserve is needed with 95% and 5% of the respondents mentioned that conservation efforts is not needed and is not important.

The respondents that did not agree on the need of conservation efforts mentioned that the area needs to be more focus on developing and improving the livelihood condition of the community living nearby the forest reserve and not put too much focus on conservation efforts of the forest. One of the issues raised was that there might be human-animal conflict, where the crops that they planted were

destroyed by the wildlife from the nearby forest. Majority of the respondents that agreed on the need of conservation of the forest mentioned that maintaining the health and conserving the forest would bring a lot of benefits. Among the benefits mentioned were clean source of water supply, protection of unique species of flora and fauna in the forest, clean supply of air and control the surrounding temperature.

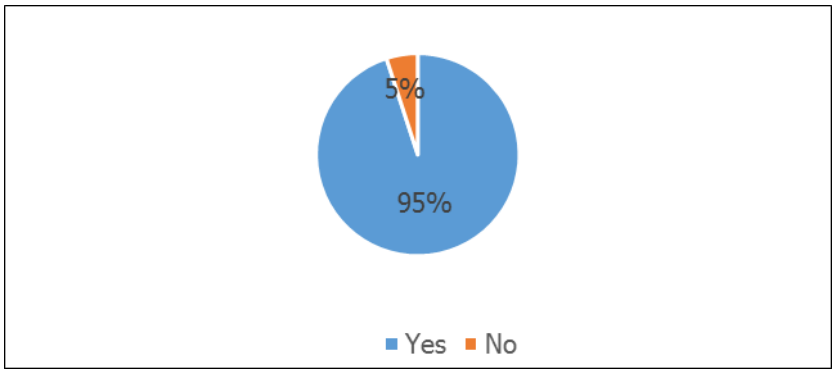

Figure 7. Respondents' perception on the need for forest conservation.

DISCUSSION

The surveyed study sites were all located within the forest reserve. One of the main issues and concerns raised repeatedly was on the status of their land. The community actively voiced out their demands and hoping for their village to be excised out of the forest reserve. During the interviews, the community mentioned that they are in good terms with the staff working in the Sabah Forestry Department. However, they hoped that frequent visits will be conducted at their respective villages to have active and open discussions. From our survey, it was also found that the community was not dependent on the forest resources. They do not hunt or collect firewood. They only occasionally collected medicinal herbs and vegetables from the forest. They preferred to buy from the market in town. The town is located quite near to the villages. In Kampung Bumiputra, the community planted oil palm around the area surrounding their houses. The area that they planted was part of the forest reserve. The size of the area planted with oil palm is quite large. The community mostly obtain their income from the revenue gained from the sales of their oil palm fruit bunches. The amount of income obtained from the sales of oil palm could reach more than RM 3000 per month depending on the size of their plantation area. When interviewed, the community were aware that the area is a forest reserve area and they were not allowed to plant in a forest reserve area, but they mentioned it was the only way for them to survive. They expressed their concern that the area could be taken away any time. One of the respondents mentioned that in the past, there were incidences where the area was burnt down by the Forestry Department. This statement was further verified by the staff of the Forestry Department. It was also informed that the price of oil palm dropped and had affected their income. There were also other problems mentioned by the community. The weather was very hot in their area, and they mentioned that it is much cooler in the forested area. Apart from that, they mentioned that they obtain their source of water from the forested area. However, due to drought, their water source was affected. Most of the community interviewed do not have legal identification card and mentioned that they were not originally from the place and moved there from their place of origin. In the past, Kampung Sri Aman was part of

Kampung Bumiputra but separated. This is to ease the division of government aids to the village. The communities had also complained about noise pollution. There is a quarry very near to their village and it is actively working. Multiple explosions occured in the quarry area and had caused damage on houses and nearby buildings, causing air pollution due to dust from the explosion and noise pollution as well. Toh and Grace (2006) stated that in 2003, approximately 87% of the total land cultivated in Sabah was oil palm area. This was further supported by a statement from Wahid (2010) whereby oil palm covered 1.36 million ha in Sabah at the end of the first decade of the year 2000s. Sabah is the biggest palm oil producer in Malaysia and had produced some 31% of the national output (POIC 2010). Clearing of forest area for oil palm plantation has significant consequences to the biodiversity (Koh 2007) but played a significant role in alleviating poverty among smallholders and the rural population in Malaysia (Arif & Tengku Mohd Ariff 2001).

The community in Kampung Teluk Soaiun highlighted that their village was a logging camp in the past. The community living in the village were locals that came from different places all around Sabah and from other countries, such as Phillipines and Indonesia. All of the respondents were former staff of the logging company and their family members. The area was issued with an Occupation Permit (OP) under Yayasan Sabah. The community in Teluk Soaiun had lived there for many years and mentioned that they wanted to settle down permanently in the area. The houses that they lived in were staff quarters. From our observation, the houses are very old and dilapidating. The community informed that they did not build new houses or do any major repair on their existing houses due to the status of the area which is a forest reserve area. They wanted the area to be gazetted as a village. The community mentioned that there were many sightings of wildlife at the nearby forest reserve. Kampung Tampenau was named Tampenau because of the origin of the community living in the village. They came from Tambunan, Penampang and Ranau and thus the name Tam-pe-nau. Some of the respondents surveyed were actually retirees and former staff of the Sabah Forestry Department. The community were active in forest restoration activities. They participated and helped in the tree planting activity held by the Sabah Forestry Department and were paid by the department to prepare seedlings for planting. It was observed that the distance between the houses in Kampung Tampenau are quite far compared to the other study sites. The village was also surrounded by forest and far from the main road and town. The Lahad Datu District Forestry Office had conducted many activities involving the local communities. One of the activities conducted was restoration with tree planting activities. Other than that, the local community received visits from other government agencies and institutions as well, which include health talks and religious activities.

CONCLUSION

The community in the study sites are no longer dependent on forest resources and mostly focus on oil palm plantation, planting of fruit trees and establishing home gardens to sustain their livelihood. The income generated from the oil palm plantation was very high but the main issue is that the oil palm plantation area is within the forest reserve area. The number of community living inside the forest reserve is quite large and it will be challenging in settling this issue. The number of people in a family is increasing and may lead to the need of a larger area to sustain the whole family. A

common ground needs to be accepted and agreed upon by the community and the stakeholder involved. The community understands the importance of the forest. Their source of water came from gravity pipes and rivers from the forest. They acknowledged that the forest needs to be conserved.

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REFERENCES

Arif, S. & Tengku Mohd Ariff, T.A. (2001). The case study on the Malaysian palm oil. Paper prepared for the UNCTAD/ESCAP Regional Workshop on Commodity Export Diversification and Poverty Reduction in South and South-East Asia, Bangkok, 3-5 April.

Babulo, B., Muys, B., Neg,a F., Tollens, E., Nyssen, J., Deckers, J. & Mathijs, E. (2008). Household livelihood strategies and forest dependence in the high lands of Tigray, Northern Ethiopia. *Agric. Syst.* 98 (2): 147-155.

Bahuguna, V.K. (2000). Forests in the economy of the rural poor: an estimation of the dependency level. *AMBIO: A Journal of the Human Environment* 29 (3): 126 – 129.

Beckley, T.M. (1998). The nestedness of forest dependence: a conceptual framework and empirical exploration. *Soc. Nat. Resou.r* 11 (2): 101–120.

Koh, L.P. (2007). Potential habitat and biodiversity losses from intensified bio-diesel feed stock production. *Conservation Biology* 21 (5): 1373-1375.

McElwee, P.D. (2010). Resource use among rural agricultural households near protected areas in Vietnam: the social costs of conservation and implications for enforcement. *Environ. Manag.* 45 (1): 113-131.

Panta, M., Kim, K. & Lee, C. (2009). Household's characteristics, forest resources dependency and forest availability in central Terai of Nepal. *Journal of Korean Forest Society* 98 (5): 548 – 557.

POIC (Palm Oil Industry Cluster - Sabah) (2010). POIC Sabah Sdn. Bhd. http://www.poic.com.my/Index.asp (22 February 2012) .

Shackleton, C.M., Shackleton, S.E., Buiten, E. & Bird, N. (2007). The importance of dry wood lands and forests in rural livelihoods and poverty alleviation in South Africa. *Forest Policy Econ*. 9 (5): 558 – 577.

Toh, S.M. & Grace, K.T. (2006). Case study: Sabah forest ownership. In: *Understanding forest tenure in South and Southeast Asia. Forestry policy and institutions.* Working Paper 14. Food and Agriculture Organization of the United Nations, Rome, Italy. Ftf://ftp.fao.org/docrep/fao/009/j8167e/j8167e10.pdf (22 February 2012)

Wahid, M.B. (2010). Overview of the Malaysian oil palm industry 2009. Malaysian Palm Oil Board, [Selangor, Malaysia].
http://econ.mpob.gov.my/economy/overview_2009.pdf (2 May 2010).

World Bank (2002). *A revised forest strategy for the World Bank Group*. The World Bank, Washington.


Plate 1. Picture taken during FGD with the men's group at Kampung Teluk Soaiun (Left) and picture taken during FGD with women's group at Kampung Bumiputra and Kampung Sri Aman.

Plate 2. Picture taken during Key Informant Interview and discussion with Mr. Azman Said, the Lahad Datu District Forestry Officer and his staff at the Lahad Datu Forestry Department Office.


Plate 3. Picture taken during Household Survey with the community at the study sites.

Potential tourism attractions in Mount Silam, Lahad Datu, Sabah

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Abstract. This paper aims to compile the main findings from a scientific expedition of the Mount Silam, Lahad Datu, Sabah, which was conducted from 13th to 18th January, 2020. A fieldwork was carried out to survey the potential attractions of the area, including the natural landscapes, which can be developed for ecotourism purposes. Findings from SWOT analysis identified the strength in flora and fauna diversity, as well as the stewardship of conserving the natural resources by the management. Forest encroachment is one of the identified weaknesses that needs regular monitoring. Developing Mount Silam as an ecotourism site is an opportunity that is beneficial to the local community and the surrounding areas. On the other hand, threats from human activities cannot be eliminated, but proactive measures can reduce the impact.

Keywords: tourism, ecotourism, attraction, activity, Mount Silam

INTRODUCTION

In general, the tourism sector in an area was developed for various reasons, such as to generate economic benefits, to provide job opportunities for the local residents who live in the area. Next, tourism may help in preservation of the environment and cultural heritage. From the social perspective, tourism provides facilities and trading services as well as recreation for tourists and local residents which cannot be developed without the tourism itself (Inskeep 1996).

Mount Silam is located within the Sapagaya Forest Reserve (Class I – Protection), about 10 km from Lahad Datu town in eastern Sabah. It is easily accessible by road on the Lahad Datu-Tawau highway. It is an ultramafic coastal mountain facing the Darvel Bay, rising from sea level to 884 m a.s.l. making it the highest point in the Lahad Datu district. In addition, the adjacent forest reserve, namely Sepagaya Forest Reserve, also being survey in this study, due to its location nearby to the Mount Silam.

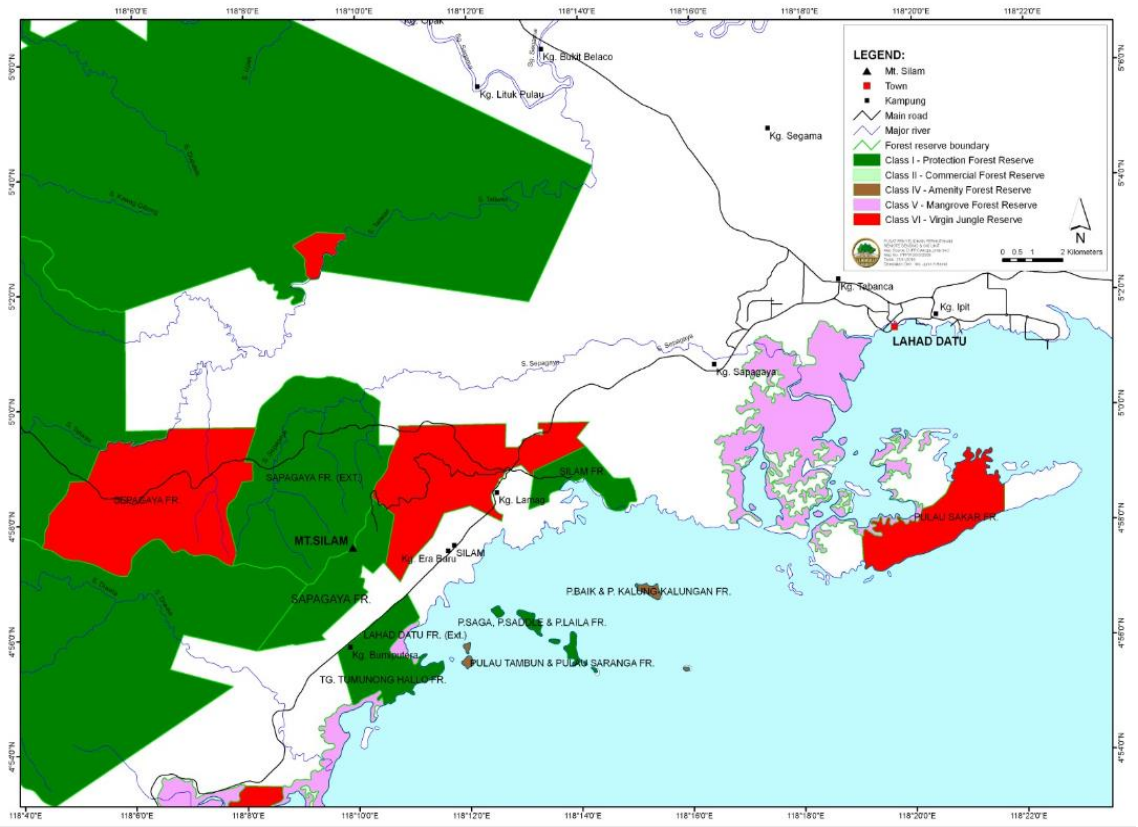

Figure 1: Location of Mount Silam in Lahad Datu, Sabah.

Sabah Forestry Department policy for ecotourism development

The planning to develop ecotourism site in or around the forest reserve is in line with Sabah Forest Policy 2018, Thrust 4: Economic well-being, objective 5: To promote forest recreation and nature-based tourism.

Strategy: to optimize revenue generation from forest recreation and nature-based tourism.

Action plan:

(a) to identify and develop potential sites for forest recreation and nature-based tourism consistent with the state tourism development policy;
(b) to encourage private sector participation in the development of forest recreation and nature based tourism;
(c) to promote local community participation in forest recreation and nature-based tourism;
(d) to intensify marketing promotion for forest recreation and nature based tourism product; and
(e) to provide accessibility to key forest recreation and nature-based tourism areas.

(SFD 2018)

Purpose of the study

The study was conducted to investigate tourism attractions that can be developed into tourism products in Mount Silam, Lahad Datu. In addition, the survey, also evaluated the current situation in Mount Silam, so that advantages and disadvantages on tourism activities in this area can be identified.

MATERIALS & METHODS

The subjects for survey include natural beauty, cultural values, interesting and significant flora, fauna, landscapes, caves, waterfalls, man made structures, communities' tradition and lifestyles, which eventually can be incorporated as tourist attractions. The method used in this study was basically by 'hands on', which means the investigator will explore the potential area in order to get the current information. Cameras were used to capture photos for reporting. Besides surveying the forest reserve area, interesting elements surrounding the forest reserve, were also being observed to get more information of the area on the perspective of ecotourism. To get first-hand information about the site, representatives from the nearby villages were interviewed as to get information on interesting elements of the area. Strengths, Weaknesses, Opportunities and Threats (SWOT) of the ecotourism development of the forest reserve, have also been listed.

RESULTS AND DISCUSSION

Sources that have the potential to be introduced as tourism products

The definition of tourism products consists of all the elements which influence the experience of a person to the destination that has been visited. Tourism products do not only consist of tourist attractions but it is also consisted of facilities and infrastructure which support the systems of tourism (Mohamed & Nordin 2007). Tourism attractions in Mount Silam Lahad Datu, are listed in the following sub-heading. However, there should be a proper inventory in the area to get complete data of the availability of tourism sources.

Tourism attractions in Mount Silam, Lahad Datu

Tower of Heaven

Tower of Heaven at Mount Silam is an observation tower, rises to 30 metres high, officially open in 2012. Visitors are able to get a scenic bird's eye view of the Darvel Bay Islands and some part of the Lahad Datu area. The tower also offers visitor, good views of the forest and birds of Mount Silam.

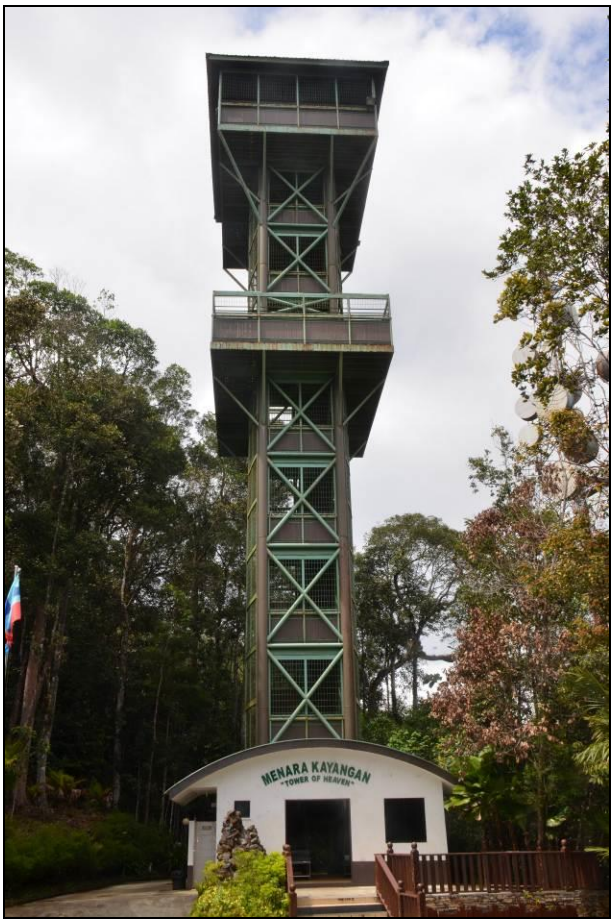

Figure 2: Tower of Heaven, Mount Silam, Lahad Datu.

Flora

Mount Silam, has a forest area with abundant of flora species that can be an attraction to tourists.

Figure 3: A variety of tree species found in Mount Silam.

Fauna

The quality of these Sabah wildlife attractions is of international standard. The images of Sabah wildlife are very strong features of the public and private sector's tourism marketing images, both in Sabah and Malaysia (Ministry of Tourism and Environmental Development 1996). There is a rich presence of wildlife in Mount Silam. Some of the wildlife species that can be found in Mount Silam (Suis *et al* 2020), is shown in table 1.

Table 1: List of fauna that has been captured by the camera trap, night survey by car and spotted via recce walk by Wildlife Research Unit, Forest Research Centre, Sabah Forestry Department.

No.	Mammals species	Saintific Name	Survey Methods		
			Camera Traps	Night survey by car	Recce walk transect
1	Bearded pig	*Sus barbatus*	19		66
2	Bornean gibbon	*Hylobates muellerii*			7
3	Bornean-necklaced partridge	*Arborophila graydoni*	1		
4	Bornean-red muntjac	*Muntiacus muntjac*			1
5	Common-palm civet	*Paradoxurus hermaphroditus*		2	1
6	Gaint squirrel	*Ratufa affinis*			1
7	Greater-mouse deer	*Tragulus napu*	2		
8	Jentink's-flying squirrel	*Hylopetes platyurus*		1	
9	Large treeshrew	*Tupaia tana*	1		2
10	Lesser-mouse deer	*Tragulus javanicus*			1
11	Long-tailed macaque	*Macaca fascicularis*			5
12	Malay civet	*Vevera tangalunga*	1		
13	Pangolin	*Manis javanica*			1
14	Pig-tailed macaque	*Macaca namestrina*	16		10
15	Plantain squirrel	*callosciurus notatus*			4
16	Prevost squirrel	*Callosciurus prevostii*			2
17	Red-leaf monkey	*Presbytes rubicunda*			3
18	Red-spiny rat	*Maxomys surifer*	2		
19	Sambar deer	*Cervus unicolor*	1		6
20	Short-tailed mongoose	*Urvah brachyurus*			2
21	Sun bear	*Helarctos malayanus*			1
22	Tufted-ground squirrel	*Rheithrosciurus macrotis*			1

Birds

Interesting bird species that are found in Mount Silam, such as Bornean Banded Pitta (*Hydrornis schwaneri*), Bornean Brown Barbet (*Caloramphus fuliginosus*) (Joeman *et al.* 2020), and Chesnut-naped forktail (*Enicurus ruficapillus*), can be an attraction for tourists to do birdwatching activities.

Figure 4: A Bornean banded pitta (*Hydrornis schwaneri*), endemic to the island of Borneo, found at Mount Silam, picture from Vivian Rudolf.

Forest trails

Trails are provided for visitors to explore more on the forest, in Mount Silam, there are forest trails that can be use by the visitors, namely Trail Kayangan, Trail Kalung-kalungan, Trail Kubu Jepun, Trail Syurga Haiwan, Trail Kubang Badak, Trail Mata Air Silam, and Trail Air Terjun Lompat-Lompat. Visitors can to hike to the Mount Silam summit, by using the Trail Kayangan or Trail Kalung-kalungan.

Rivers and waterfalls

Rivers and waterfalls in Sepagaya Forest Reserve, offers a site to relax and enjoy for tourists.

Figure 5: A waterfall at the Sepagaya Forest Reserve.

Panoramic views

Mount Silam (884 meter a.s.l.), is the highest point in the Lahad Datu District. This allows visitors to view the Darvel Bay and some parts of Lahad Datu area.

Figure 6: Majestic view of the Darvel bay from the Mount Silam viewing platform.

Wildlife wallow

A wildlife wallow that is found at the Trail Kubang Badak, Mount Silam can be developed as an interpretation spot for tourist visitation and for environmental education.

Figure 7: A wildlife wallow in Mount Silam, Lahad Datu.

Other interesting findings

Interesting findings by the other researchers in their respective field, can also be introduced as a tourism attraction for Mount Silam, such as insects and frogs.

Table 2. Bornean endemic insect species that can be found in Mount Silam forest (Chung *et al.* 2020).

No.	Species	Author	Order	Family
1	*Lilioceris sandakana*	Achard	Coleoptera	Chrysomelidae
2	*Amata prepuncta*	Holloway	Lepidoptera	Erebidae
3	*Calliteara box*	Holloway	Lepidoptera	Erebidae
4	*Lygniodes schoenbergi*	Guenee	Lepidoptera	Erebidae
5	*Nishada syntomioides*	Walker	Lepidoptera	Erebidae
6	*Herochroma clariscipta*	Holloway	Lepidoptera	Geometridae
7	*Lassaba vinacea*	Prout	Lepidoptera	Geometridae
8	*Spaniocentra apatelloides*	Holloway	Lepidoptera	Geometridae
9	*Spaniocentra lobata*	Holloway	Lepidoptera	Geometridae
10	*Eooxylides etias*	Druce	Lepidoptera	Lycaenidae
11	*Calymera* nr *vinacea*	Holloway	Lepidoptera	Nolidae
12	*Antheraea alleni*	Holloway	Lepidoptera	Saturniidae
13	*Libellago phaeton*	Laidlaw	Odonata	Chlorocyphidae
14	*Coeliccia nigrohamata*	Laidlaw	Odonata	Platycnemididae
15	*Aretaon* nr *asperimus*	Redtenbacher	Phasmida	Heteropterygidae

Tourism activities that can be explored in Mount Silam

Enjoying the view

View of the Darvel Bay and some parts of Lahad Datu area can be seen by the visitors from the Mount Silam viewing platform.

Jungle trekking

Tourists who are more into adventurous activities can go for jungle trekking in the jungle area. Interesting permanent trails can be developed and maintained as the jungle trekking trails for tourists. Developing a well managed and marketed trekking trip in Sabah would provide additional opportunities for activity-based tourists, and could bring significant benefits to rural communities (Ministry of Tourism and

Environmental Development 1996). Interesting Jungle trekking trail can be explored in Mount Silam forest.

Night walk

The trail for jungle trekking can also be used as trails for night walking activity and tourists can experience the night atmosphere in the forest.

Bird watching

Bird watching activity can be organized by taking the tourists to the locations that have the potential to watch birds of different species, especially at the areas where they have fruit trees because it is the main source of food for the birds. Besides as a hobby, bird watching can build up greater awareness and appreciation of the broader natural world (Unwin 2008).

Nature photography

The sceneries and interesting nature in the forest reserve would catch the attention of tourists who love nature photography. Photography will help the tourists to enjoy the beauty of nature. Nature photography can also educate the community to appreciate and protect nature. This makes photography a useful and beneficial activity (Bakar 2012).

Picnicking

The Sepagaya FR waterfall, adjacent to Mt. Silam forest is a suitable place for picnicking and family outing.

SWOT analysis

Managing the marketing function begins with analysis of the company's situation. The marketer should conduct a SWOT analysis, by which it evaluates the company Strengths, Weaknesses, Opportunities and Threats in running their business (Kotler *et al.* 2010).

i. Strengths: Internal capabilities that may help a company reach its objectives.
ii. Weaknesses: Internal limitation that may interfere with a company's ability to achieve its objectives.
iii. Opportunities: external factors that the company may be able to exploit to its advantage.
iv. Threats: Current and emerging external factors that may challenge the company's performance.

SWOT analysis for tourism development in Mount Silam, Lahad Datu

Strengths

- Managed by Sabah Forestry Department. This factor provides a good management base for the development of this area.

- Sapagaya Forest has been gazzeted as a forest reserve, which means Mount Silam is free from logging and plantation operation.
- Abundance of natural resources.
- Wildlife habitat.
- The presence of various species of birds.
- Beautiful surrounding view
- Located near to the Lahad Datu Township, about 10 km.
- Easy accessibility, connected with the main road from Lahad Datu to Tawau and vice versa.
- Research activities can be an added value for tourism.
- Sabah Forestry Department can get information on Mount Silam, from the scientific exploration and research conducted in the area.
- Telecommunication signal available, but doesn't cover all areas.
- Fresh air around the viewing platform up to the summit of Mount Silam.
- Relatively cheap admission fee, Malaysian: Adult RM5, Children RM2, Non Malaysian: Adult RM15, Children RM7.
- Stopover place for tourists going to Lembah Danum and Borneo Rainforest Lodge.

Weaknesses

- Not a top tourism destination yet.
- No iconic wildlife such as Orang utan, Pygmy elephant and Clouded leopard.
- Limited manpower to entertain visitors and to do maintanence work.
- Only one access road from the main road to the viewing platform of Mount Silam, if it disconnected, there will no other optional road to reach the viewing platform.
- The plateau area of the viewing platform of Mount Silam is relatively narrow.
- The road to the viewing platform of Mount Silam is narrow and steep.
- Telecommunication towers limited other tourism facilities.
- If it is raining, limited activities can be done.
- If it is misty, limited views can be seen.
- Some of the trails area are steep and slippery, there should be stairs and railing for user's convenience.
- The cemented trails to the summit are very slippery, more so during and after the rain (this is a very serious problem!).
- Gazebos not been built at the trails for user's convenience.
- Limited washroom for visitors.
- Limited parking space.
- Lack of basic facilities eg. Interpretation signboards, handrails, maps, dustbin, etc,
- Limited publicity of the area.
- Can be encroached from many directions.
- No souvenir shop.
- Limited camping area.
- Limited accommodation, only can cater up to 10 person / day.
- The road going up to Mount Silam viewing platform not suitable for big busses that have more then 20 seats.
- No official website for Mount Silam.
- Close at night.

- Limited facilities for handicapped people.
- Not easy to reach by visitor who walk or using bicycle from Lahad Datu Town.

Opportunities

- Can be the icon for Lahad Datu tourism.
- Potential birding spot.
- Potential wilderness camp.
- Environmental education site.
- Forestry research area.
- Forest recreation area.
- Night safari for wildlife viewing.
- Cooperation with private sector.
- Site for paragliding activity.
- Organizing sports event such as Mount Silam Run.
- Publishing Mount Silam documentary.
- Publishing Book on Mount Silam.

Threats

- Change in government policy on land use.
- Development of this area can be a nuisance for the wildlife.
- Forest encroachment.
- Illegal hunting.
- Human – Wildlife conflict.
- Forest Fire.
- Drought.
- Pollution.
- Soil erosion.
- Diseases, such as malaria, leptospirosis.
- Development of new ecotourism site at nearby area can be a competition.
- Distruption from tourists / researchers, such as throwing garbage and damaging plants.
- Deforestration.
- Funding limitation for development and maintainence.

CONCLUSION

From the study that had been conducted, Mount Silam in Lahad Datu has the potential to be developed as a nature-based ecotourism attraction. A well-organized planning system must be established with resources that can be potentially developed for tourist attractions. The tourism development process should be monitored thoroughly and various aspects should be taken into account.

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REFERENCES

Bakar, A.R. (2012). Nature Photography – Panduan merakam foto alam semulajadi. Pts Netmedia. Sdn. Bhd, Batu Caves, Selangor, Malaysia. Pp 1.

Chung, A.Y.C., Japir, R., Damit, D.F.A, Binti, M., & Yukang, J.L. (2020). Insect diversity of Mount Silam forest in Lahad Datu, Sabah. Forest Research Centre, Sabah Forestry Department.

Inskeep, E. (1996). Penterjermah: Che Elainee Che Hassan, Norlida Abd. Halim. Perancangan Pelancongan, pendekatan pembangunan bersepadu dan berkekalan. Dewan Bahasa dan Pustaka, Kuala Lumpur. Pp. 3-24.

Joeman, B.D., Petol, G.H., Lolin. L., Rudolf, V., Tingkoi, L. (2020). Avifaunal survey of Mt. Silam and surrounding areas in the district of Lahad Datu, Sabah, Malaysia.
SFD (2018). Sabah Forest Policy 2018. Sabah Forestry Department, Sandakan.

Kotler, P., Bowen, J.T. & Makens, J. C. (2010). Marketing for Hospitality and Tourism. Pearson Education, Inc., Upper Saddle River, New Jersey, U.S.A. Pp. 71-72.

M.A.F. Suis., J. Miun., L. Tingkoi & R. Nilus (2020). Additions to the current checklist of mammal in Mount Silam, Lahad Datu, Forest Research Centre, Sabah Forestry Department.

Ministry of Tourism and Environmental Development (1996). Sabah Tourism Masterplan. Institute for Development Studies (Sabah), Kota Kinabalu, Sabah, Malaysia. Pp 177, 194.

Mohamed, B. & Nordin, N.A. (2007). Perancangan pelancongan. Dewan Bahasa dan Pustaka, Kuala Lumpur. 147 pp.

Joeman, B.D., Petol, G.H., Lolin. L., Rudolf, V., Tingkoi, L. (2020). Avifaunal survey of Mt. Silam and surrounding areas in the district of Lahad Datu, Sabah, Malaysia.

SFD (2018). Sabah Forest Policy 2018. Sabah Forestry Department, Sandakan, Sabah. 55 pp.

Unwin, M. (2008). RSPB guide to birdwatching, a step-by-step approach. A & C Black Publishers Ltd, 36 Soho Square, London, Pp. 6-8

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