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# IMPACTS OF FOREST DISTURBANCE ON COMPOSITION, STRUCTURE AND FLORISTICS OF TROPICAL EVERGREEN FOREST, MON STATE, MYANMAR

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## ABSTRACT
This paper presents the composition, structure, and floristics of vegetation in four types of disturbed forests: 1) shifting cultivation areas, 2) landslide-affected areas, 3) selective logging areas, and 4) human interfered forest, as well as a old growth forest for reference in a tropical evergreen forest of the Kyaik Htee Yoe Reserve Forest, Mon State, Myanmar. Sixty $30 \times 30$ m plots were arbitrarily established in each disturbed forest, and in the old growth forest. All trees $\geq 3$ cm diameter at breast height (DBH) were measured in all plots. A total of 119 species belonging to 57 families were identified in the sample plots. The old growth site showed the highest basal area (26.01 $m^2$/ha), volume (535.42 $m^3$/ha), and stand density (2187 trees/ha). We found that the community composition, species composition, and structural pattern varied significantly according to disturbance type. The old growth forest had high species diversity. Although species diversity in the disturbed areas was higher than in the human interfered forest, the stand densities of those areas were lower than in the human interfered forest. For all disturbance sites, the community composition similarity index was lower when compared to that of the old growth forest.

**KEYWORDS:** Shifting cultivation, landslide, selective logging, human-interfered forest, old growth forest.

## INTRODUCTION
Although tropical forests cover less than 10% of global land areas, they likely harbor more than half of all species on Earth (Riccardo 2008). In tropical regions, deforestation and forest degradation are among the main causes of species loss in biodiversity hotspots (Mayers 2000; Pimm and Raven 2000; Stork et al. 2010). Tropical deforestation has become a major concern globally. Whole regions in South and Central America, Africa, and Southeast Asia have completely lost their forests, or are expected to become deforested in the near future (Jepson et al. 2001; Laurence et al. 2001). The loss of tropical forests comes at a time when our knowledge of their structure and dynamics is severely deficient (Stephen 1992). The contrast between the rich natural environment and severe human poverty has resulted in challenges for conservation, development, and livelihood security (Ferraro 2002). Disturbances can change the biological organization of ecosystems (Moral and Waller 2007), often leading to primary or secondary succession depending on whether the disturbance involves species changes on substrates with little or no biological legacy (primary succession), or if the succession begins with some biological legacy (secondary succession) (Walker 2013).
The structure of a forest stand can provide a valuable indicator of impacts of disturbances, because measures such as forest basal area and stem density can index responses to disturbances (Ingram, Whittaker, & Dawson, 2005). Species richness and abundance data are critical for assessing the impacts of disturbances on biodiversity, and for conservation priority setting and long-term monitoring (Ingram et al., 2005). Scientists and researchers have observed significant relationships between species diversity and forest structural features that respond to disturbances, such as stand density, stem diameter, and stem size class distributions (Feroz et al. 2015). Due to population growth, illegal logging, and high demand from neighboring countries, Myanmar's forests were previously under high pressure from increased resource utilization, mainly between 1990 and 2000 (Mon et al. 2012). Consequently, there have been spatial and temporal changes in species richness, composition, and stand structure. Nevertheless, due to the limited information and evidence concerning variations in the stand structure and species composition in Myanmar, it is difficult to gauge the prospects of biodiversity conservation in both the short and long term.
Knowledge of forest structure, composition, and diversity according to different levels of human disturbance would facilitate the creation and implementation of more effective conservation measures (Htun et al. 2011). A clear understanding of forest dynamics could assist in optimizing silvicultural operations and provide the information necessary for conservation and management operations. The present study area suffered natural and anthropogenic disturbances over 30 years ago, and some of the area is still facing minor disturbances due to the extraction of non-wood forest products. The lack of any alternative measures for those encroachment activities is a major barrier to sustainable conservation. The present study focuses on tree composition, structure, and floristic

diversity status, as well as the community characteristics of forest stands and tree population. The specific objectives are to: 1) determine the species composition, diversity, and distribution in the study area, and 2) investigate the impacts of natural and anthropogenic disturbances on vegetation structure.

## MATERIALS AND METHODS

### Study site

The study site, Kyaik Htee Yoe Reserve Forest (KTY), is located in the Kyaik Hto Township of Mon State, Myanmar (Fig. 1). The area was legally classed as a forest reserve in 2001. KTY covers an area of ~156 km$^2$. The elevation ranges from ~283 to 931 mamsl. The entire reserve forest is occupied by tropical evergreen forest. The temperature in the Kyaik Hto Township ranges between 25.6 and 29.4°C. The average rainfall in the study area is more than 5500 mm per year.

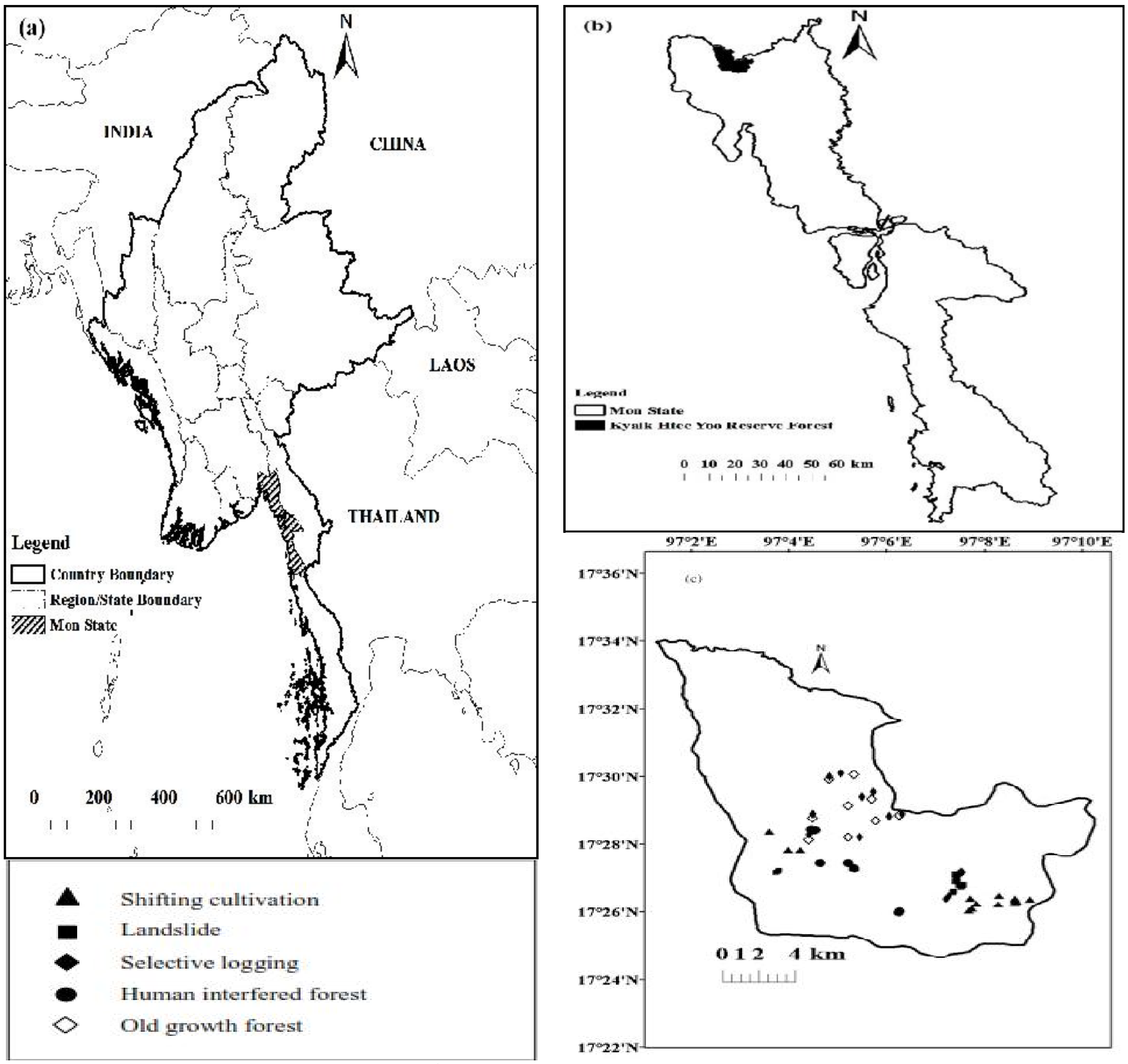



**FIGURE 1:** Maps of (a) Myanmar, (b) Mon State, and (c) Study plot

### Natural and anthropogenic disturbance types

The present study examined the composition, structure, and floristics of forest vegetation in KTY according to four disturbance types: shifting cultivation, landslides, selective logging, and human-interfered forest, as well as a old growth forest with no disturbance history. To obtain records and evidence of the natural and human disturbance types, official records kept by the township's forest department were accessed and in-depth interviews were conducted with locals during the preliminary survey carried out in 2015.

As recently as 1970, the entire study area was covered with natural forest that had not been disturbed by natural or anthropogenic factors. Parts of the study area were affected by landslides 26 years ago and we included plots in those areas. Shifting cultivation is referred to as "Shwe Pyaung Taungya" in Burmese, which means "moving hill-farm" (S. Win & others, 2005). Normally, shifting cultivation is practiced by the Kachin, Kayah, Kayin, Chin, and Shan tribes in Myanmar. Our study plots were in hilly regions mostly occupied by the Kayin ethnic group. Over the years, shifting cultivation was practiced in some of the study areas by the local Kayin people. After clearing the forest, they cultivated upland rice and several seasonal crops for 1 year, followed by a 15-year fallow period. In our study, we chose areas that had been fallow for more than 15 years.

Since 1856, the Myanmar Selection System (MSS) has been in practice for timber harvesting in Myanmar. Under the MSS, the felling cycle is 30 years, and marketable trees meeting exploitable diameter at breast height (DBH) limits (73 cm in moist teak forests and 63 cm in dry teak forests) are selected and cut. The DBH limits for other hardwoods vary according to species, and timber extraction is mostly carried out using elephants (Win et al. 2009). The selective logging site in our study was cut more than 30 years ago.

We selected old growth forest areas as reference sites, as these areas had not suffered any disturbances during the past 80 years according to official records and interviews. During the preliminary survey, we found that some of the locals enter the old growth sites to collect various fruits and other non-wood forest products. Footpaths, trails, and clearance of bushes and shrubs were evidence of human encroachment into those areas, which are human-accessible and thus referred to as human-interfered forest. The remaining old growth forest sites were strictly conserved by a Buddhist monk and have experienced no major or minor disturbances over the past 80 years; these areas are referred to herein as old growth forest.

**Vegetation survey**

Vegetation surveys were conducted in 2015 and 2016 and 30 × 30 m sample plots were randomly selected and established within the study area. Altogether, we sampled 60 plots (15 shifting cultivation plots, 15 landslide-affected plots, 10 selectively logged plots, 10 human-interfered forest plots, and 10 old growth forest plots). All recorded trees were identified to the species level by the Botany Department, University of Forestry, Yezin, Myanmar.

**Data analysis**

We estimated Shannon-Wiener diversity index, to examine the impacts of disturbances on forest diversity (Shannon, 2001),as follows:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

where, H' is the Shannon-Wiener diversity, S is the total number of species in the community, $p_i$ is the proportion of individuals belonging to the $i^{th}$ species, and ln is the natural logarithm.

Simpson's diversity index was used to examine species evenness. Values range from 0 to 1, with 1 representing perfect evenness (all species are present in equal numbers) (Simpson 1949). Evenness was calculated by the following formula:

$$D = 1 - \{\sum (n_i - 1) | N (N - 1)\}$$

Where, $n_i$ is the number of individuals of species "i" and $N$ is the total number of individuals of all species.

To determine ecological importance, the importance value index (IVI) values (the product of the relative abundance and relative frequency) were computed at the species and family levels; values range from 0 (no indication) to 100 (perfect indication) (Curits 1951) and were calculated as follows:

IVI = RDo + RD + RF

where, RDo is the relative dominance, RD is the relative density, and RF is the relative frequency.

RDo = (total basal area of a species/total basal area of all species) × 100

RD = (number of individuals of a species /total number of individuals) × 100

RF = (frequency of a species/sum frequency of all species) × 100

The quantitative indices of Jaccard and Sørensen were calculated to assess differences in tree community composition and relative abundances of shared species among the different sites (Heltshe & Forrester, 1983) (Magurran 1988). Differences in vegetation properties (diameter, basal area, height, volume, and stand density) among the different sites were tested using analysis of variance (ANOVA). A least significant difference (LSD) post hoc test was performed to detect significant pairwise differences in the means of dependent variables ($P \leq 0.05$).

To visualize variation in patterns of vegetation among the five different forest types, ordination by non-metric multidimensional scaling (NMDS) using the basal area was performed (McCune 2006). This is a nonparametric method of ordination that requires no assumptions concerning species distribution or the relationships between species occurrence and environmental variables. NMDS graphically shows patterns of ecological communities by maximizing the rank-order correlation between distance measures and distances in reduced ordination space (Clarke 1993). NMDS was accomplished using Sørensen's index of arcsine transformed cover data (Zar 1999). We calculated correlations between each variable and the ordination axes using the SPSS statistics package (ver. 23.0; SPSS Inc., Chicago, IL, USA) and PC-ORD (ver. 5.10, MjM Software Design). Species area values and standard deviations were calculated using PC-ORD to construct species area curves in Microsoft Excel (Microsoft Corp., Redmond, WA, USA).

## RESULTS

**Community similarity and forest heterogeneity**

We used a two-dimensional solution for vegetation assemblage based on the stress value (19.081, $P < 0.01$). The two axes accounted for 56% of the variance in vegetation communities (axis 1 = 34%, axis = 22%) (Fig. 2). Ordination analysis of basal area values yielded four main site types: old growth forest, human-interfered forest, and selective logging areas formed three separate groups, while shifting cultivation and landslide-affected areas were grouped together. Based on the NMDS results, it was clearly indicated that species composition in the old growth forest was different from other disturbed forests.

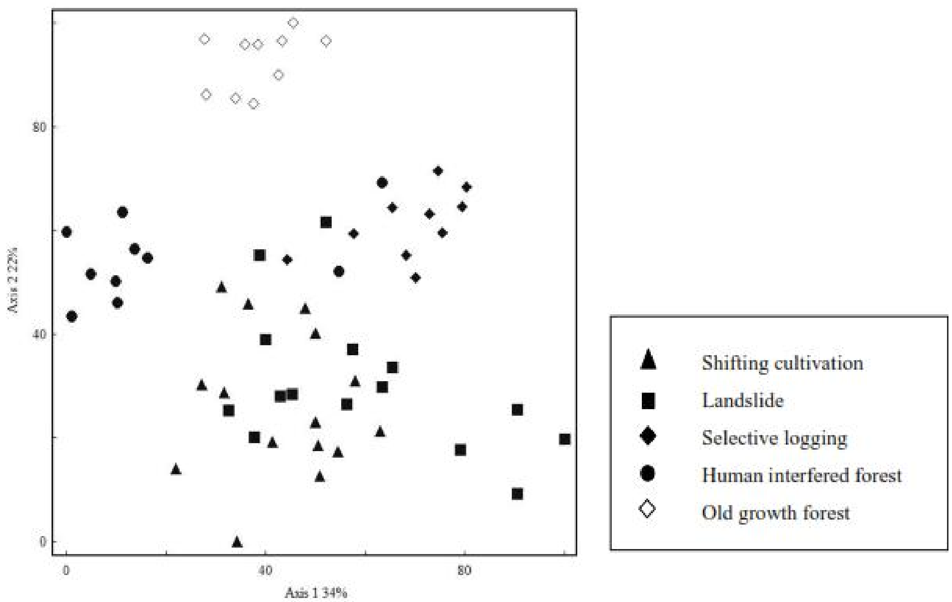



**FIGURE 2.** Nonmetric multidimensional scaling (NMDS) analysis of the basal area of all tree species: shifting cultivation > 15 years ago, landslide > 26 years ago, selective logging > 30 years ago, human interfered forest, and old growth forest.

To assess the degree of floristic similarity among sites, the indices of Sørensen and Jaccard were analyzed at the species level (Table 1). In this case, we intended to explore only the composition pattern of the study area, so we used species-level (presence and absence) data.

**TABLE 1.** Floristic similarity of disturbance and old growth forest areas at the species level

(a) Sorencen's index (%)

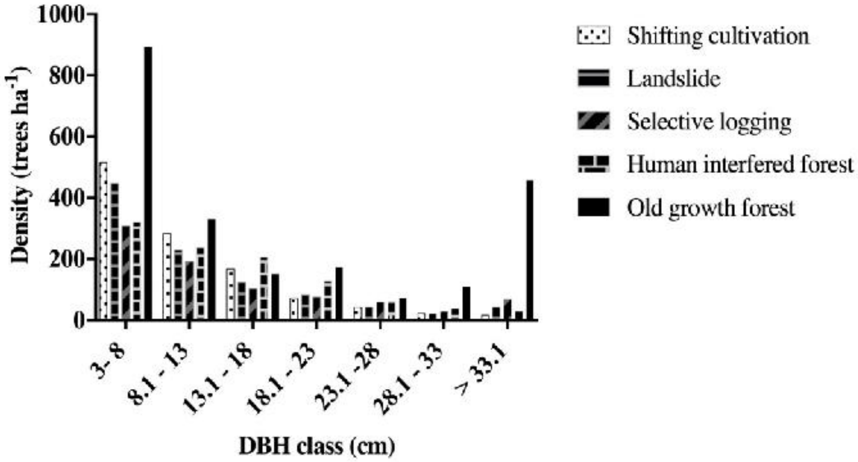
| | Shifting cultivation | Landslide | Selective logging | Human interfered forest | Old growth |
|---|---|---|---|---|---|
| Shifting cultivation | 100 | | | | |
| Landslide | 72 | 100 | | | |
| Selective logging | 56 | 56 | 100 | | |
| Human interfered forest | 49 | 54 | 54 | 100 | |
| Old growth | 52 | 46 | 54 | 54 | 100 |

(b) Jaccard index (%)

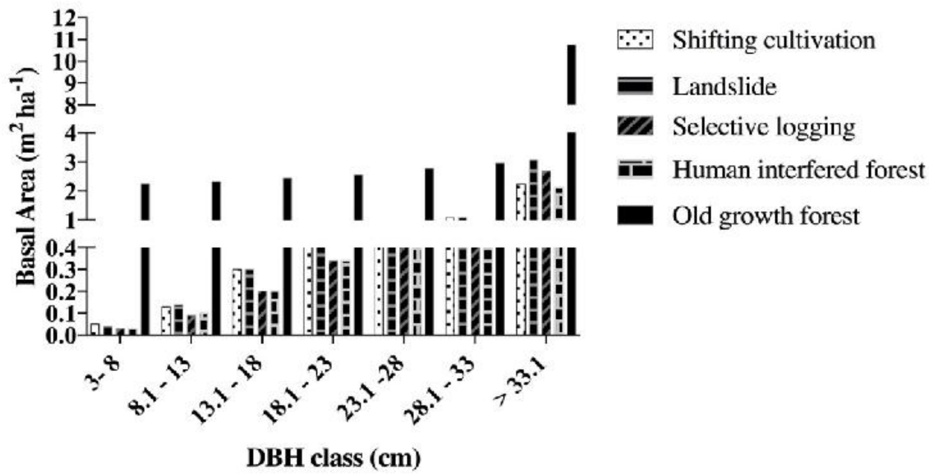
| | Shifting cultivation | Landslide | Selective logging | Human interfered forest | Old growth |
|---|---|---|---|---|---|
| Shifting cultivation | 100 | | | | |
| Landslide | 56 | 100 | | | |
| Selective logging | 39 | 39 | 100 | | |
| Human interfered forest | 33 | 37 | 37 | 100 | |
| Old growth | 35 | 30 | 37 | 37 | 100 |

For both the Sørensen and Jaccard indices, the species composition coefficients of similarity between the shifting cultivation and landslide-affected areas had the highest values. When compared to the old growth forest, both the selective logging and human-interfered forest areas showed highly similar species compositions.

Several structural differences were observed among the sites (Fig. 3). Tree density at all sites showed a reverse J shape in every size class. The tree density of the 3–8 cm size class was the highest. In the old growth forest, while the 3–8-cm size class showed the highest tree density, the second-highest tree density was observed for the ≥ 33.1 cm DBH class. In the selective logging and landslide-affected sites, tree density gradually decreased, but increased for the ≥ 33.1 cm DBH size class. The basal area of the old growth forest was the highest among all sites. All basal area values were highest in the ≥ 33.1 cm size class. The basal area of the shifting cultivation site was greatest in the 3-8 cm DBH class. We estimated the number of tree species using a rarefaction curve. Although Lamprecht (1989) suggested that a stock with DBH > 10 cm is generally adequate to draw species-area curves, our curve was drawn based on trees with height ≥ 1.3 m and DBH ≥ 3 cm. We included smaller diameter trees because the secondary forest in our study was ~30 years old. The total area surveyed in this study was 5.4 ha. Species richness was highest in the shifting cultivation area, followed by the landslide-affected area, and lowest in the selective logging sites (Fig. 4).




**(a)**




**(B)**

**FIGURE 3 (a)** Tree density and (b) basal area according to girth class distribution

**TABLE 2.** Characteristics of the different disturbance type forest areas (Mean value ± SE)

| | Shifting cultivation | Landslide | Selective logging | Human interfered forest | Old growth forest |
|---|---|---|---|---|---|
| Mean Diameter (cm) | 12.28 ± 0.92 [a] | 13.68 ± 0.91 [a] | 16.03 ± 0.71 [a] | 14.04 ± 0.70 [a] | 29.28 ± 3.27 [b] |
| Basal Area ($m^2$/ha) | 5.05 ± 0.03 [a] | 5.95 ± 0.04 [a] | 4.62 ± 0.05 [a] | 4.02 ± 0.04 [a] | 26.01 ± 0.55 [b] |
| Mean Height (m) | 9.66 ± 0.70 [ab] | 9.00 ± 0.43 [a] | 10.92 ± 0.74 [ab] | 11.92 ± 1.00 [b] | 10.20 ± 1.86 [ab] |
| Volume ($m^3$/ha) | 18.79 ± 0.33 [a] | 23.37 ± 0.33 [a] | 34.21 ± 1.05 [a] | 23.54 ± 0.94 [a] | 535.42 ± 22.72 [b] |
| Stand Density (trees/ha) | 1121 ± 113 [a] | 995 ± 93 [a] | 831 ± 64 [a] | 1018 ± 90 [a] | 2187 ± 217 [b] |
| Shannon | 2.35 ± 0.08 [a] | 2.35 ± 0.07 [a] | 2.35 ± 0.08 [ab] | 2.14 ± 0.11 [a] | 2.59 ± 0.06 [b] |
| Simpson | 0.86 ± 0.01 [ab] | 0.85 ± 0.01 [ab] | 0.87 ± 0.01 [a] | 0.82 ± 0.02 [b] | 0.89 ± 0.01 [a] |
| Total no of Species | 80 | 68 | 42 | 54 | 56 |
| No of Species (Jackknife estimate) | 111 | 86 | 65 | 76 | 80 |
| Total no of families | 45 | 38 | 25 | 34 | 36 |

* Difference between means is significant at 5 % alpha level.
Different letters in a row denote significant differences between disturbance types.

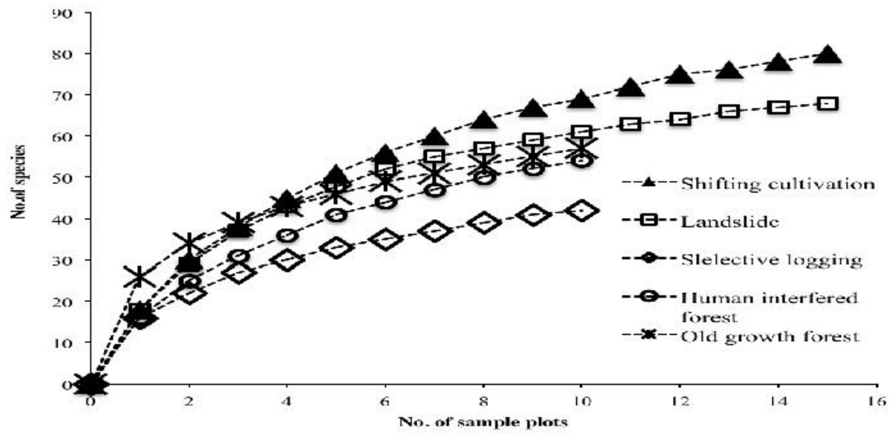



**FIGURE 4:** Species area curves

**Species richness and diversity**

Tree species richness and evenness were highest in the old growth forest (Shannon value = 2.59, Simpson value = 0.89) and varied according to disturbance type (Table 2). The species richness and evenness were lowest (Shannon value = 2.14, Simpson value = 0.82) in the human-interfered old growth forest but there was no significant difference. The shifting cultivation, landslide-affected, and selective logging disturbance areas shared similar species richness and evenness values. The old growth forest showed the largest mean diameter (29.28 cm), the highest basal area (26.01 $m^2$/ha), and the highest volume (535.42 $m^3$/ha). The smallest mean diameter (12.28 cm), basal area (5.05 $m^2$/ha), and volume (18.79 $m^3$/ha) were observed in the shifting cultivation area. The stand density was highest in the old growth forest (2,187 trees/ha) and lowest in the selective logging area (831 trees/ha).

**Floristic composition**

The IVI was used to assess the species composition and stand structure. Among the shifting cultivation plots, *Microcos paniculata* was the most dominant species, followed by *Heterophragma adenophylla* and *Archidendron jiringa* (Table 3). In the landslide-affected area plots, *Microcos paniculata, Ficus glomerata,* and *Abarema bigemina* had the highest IVI values. *Abarema bigemina*, *Cedrela serrata*, and *Anisoptera scaphula* dominated the selective logging area plots. *Ilex sulcata*, *Styrax serrulatum*, and *Glochidion glaucifolium* were the most dominant species in the human interfered forest. In the old growth forest, the most abundant species were *Anisoptera scaphula*, *Eugenia bracteata*, and *Styrax serrulatum.*

**TABLE 3.** Top 10 most abundant species based on IVI values for each disturbed forest and old growth forest

**(a) Shifting cultivation**

| | | BA ($m^2$/ha) | Vol ($m^3$/ha) | SD (Trees/ha) | RBA (%) | RD (%) | RF (%) | IVI (%) |
|---|---|---|---|---|---|---|---|---|
| *Microcos paniculata* | Malvaceae | 1.29 | 1.34 | 246 | 0.26 | 0.16 | 0.05 | 16 |
| *Heterophragma adenophylla* | Bignoniaceae | 0.23 | 0.77 | 134 | 0.05 | 0.09 | 0.04 | 6 |
| *Archidendron jiringa* | Fabaceae | 0.25 | 1.46 | 88 | 0.05 | 0.06 | 0.04 | 5 |
| *Styrax serrulatum* | Styraceae | 0.12 | 0.63 | 109 | 0.02 | 0.07 | 0.04 | 5 |
| *Aporusa roxburghii* | Euphorbiaceae | 0.12 | 0.39 | 104 | 0.02 | 0.07 | 0.03 | 4 |
| *Abarema bigemina* | Fabaceae | 0.12 | 0.47 | 77 | 0.02 | 0.05 | 0.04 | 4 |
| *Cryteronia paniculata* | Lauraceae | 0.12 | 0.55 | 56 | 0.02 | 0.04 | 0.04 | 4 |
| *Pterospermum semisagittatum* | Sterculiaceae | 0.07 | 0.21 | 92 | 0.01 | 0.06 | 0.01 | 3 |
| *Barringtonia angusta* | Lecythidaceae | 0.07 | 0.26 | 41 | 0.01 | 0.03 | 0.03 | 2 |
| *Bridelia retusa* | Euphorbiaceae | 0.04 | 0.08 | 38 | 0.01 | 0.03 | 0.04 | 2 |
| | Others | 2.61 | 12.63 | 136 | 0.52 | 0.35 | 0.62 | 49 |
| | Total | 5.05 | 18.79 | 1121 | 100 | 100 | 100 | 100 |

**(b) Landslide**

| | | BA ($m^2$/ha) | Vol ($m^3$/ha) | SD (Trees/ha) | RBA (%) | RD (%) | RF (%) | IVI (%) |
|---|---|---|---|---|---|---|---|---|
| *Microcos paniculata* | Malvaceae | 0.89 | 2.66 | 189 | 0.15 | 0.14 | 0.05 | 15 |
| *Fiscus glomerata* | Moraceae | 0.21 | 0.75 | 148 | 0.04 | 0.11 | 0.04 | 4 |
| *Abarema bigemina* | Fabaceae | 0.33 | 1.65 | 82 | 0.06 | 0.06 | 0.04 | 6 |
| *Styrax serrulatum* | Styraceae | 0.14 | 0.82 | 60 | 0.02 | 0.04 | 0.04 | 2 |
| *Scaphium scaphigerum* | Sterculiaceae | 0.11 | 0.44 | 71 | 0.02 | 0.05 | 0.03 | 2 |
| *Anthocephalus morindaefolius* | Rubiaceae | 0.22 | 1.18 | 29 | 0.04 | 0.02 | 0.02 | 4 |
| *Archidendron jiringa* | Fabaceae | 0.15 | 0.80 | 31 | 0.03 | 0.02 | 0.03 | 3 |
| *Cedrela serrata* | Meliaceae | 0.06 | 0.32 | 42 | 0.01 | 0.03 | 0.04 | 1 |
| *Lagerstroemia tomentosa* | Lythraceae | 0.14 | 0.69 | 22 | 0.02 | 0.02 | 0.02 | 2 |
| *Dalbergia obtusifolia* | Fabaceae | 0.07 | 0.33 | 41 | 0.01 | 0.03 | 0.02 | 1 |
| | Others | 3.63 | 13.71 | 280 | 0.61 | 0.47 | 0.66 | 61 |
| | Total | 5.95 | 23.37 | 995 | 100 | 100 | 100 | 100 |

**(c) Selective logging area**

| | | BA ($m^2$/ha) | Vol ($m^3$/ha) | SD (Trees/ha) | RBA (%) | RD (%) | RF (%) | IVI (%) |
|---|---|---|---|---|---|---|---|---|
| *Abarema bigemina* | Fabaceae | 0.61 | 5.04 | 105 | 0.13 | 0.14 | 0.06 | 11 |
| *Cedrela serrata* | Meliaceae | 0.41 | 2.19 | 76 | 0.09 | 0.10 | 0.06 | 8 |
| *Anisoptera scaphula* | Dipterocarpaceae | 0.25 | 1.96 | 75 | 0.06 | 0.10 | 0.06 | 7 |
| *Dipterocarpus alatus* | Dipterocarpaceae | 0.32 | 2.04 | 53 | 0.07 | 0.07 | 0.04 | 6 |
| *Barringtonia angusta* | Lecythidaceae | 0.27 | 1.48 | 43 | 0.06 | 0.06 | 0.06 | 6 |
| *Bouea burmanica* | Anacardiaceae | 0.14 | 0.68 | 63 | 0.03 | 0.08 | 0.05 | 5 |
| *Gynocardia odorata* | Achariaceae | 0.26 | 1.99 | 46 | 0.06 | 0.06 | 0.04 | 5 |
| *Styrax serrulatum* | Styraceae | 0.18 | 0.84 | 39 | 0.04 | 0.05 | 0.06 | 5 |
| *Neolitsea lanuginosa* | Lauraceae | 0.20 | 1.20 | 25 | 0.04 | 0.03 | 0.05 | 4 |
| *Antiaris toxicaria* | Moraceae | 0.44 | 8.37 | 4 | 0.09 | 0.01 | 0.02 | 4 |
| | Others | 1.54 | 8.41 | 302 | 0.33 | 0.29 | 0.49 | 37 |
| | Total | 4.62 | 34.21 | 831 | 100 | 100 | 100 | 100 |

**(d) Human interfered forest**

| | | BA ($m^2$/ha) | Vol ($m^3$/ha) | SD (Trees/ha) | RBA (%) | RD (%) | RF (%) | IVI (%) |
|---|---|---|---|---|---|---|---|---|
| *Ilex sulcata* | Aquifoliaceae | 1.18 | 4.46 | 248 | 0.29 | 0.27 | 0.06 | 21 |
| *Styrax serrulatum* | Styraceae | 0.69 | 4.52 | 168 | 0.17 | 0.18 | 0.06 | 14 |
| *Glochidion glaucifolium* | Euphorbiaceae | 0.25 | 1.38 | 67 | 0.06 | 0.07 | 0.04 | 6 |
| *Ziziphus incurva* | Rhamnaceae | 0.35 | 6.39 | 12 | 0.09 | 0.01 | 0.03 | 4 |
| *Eurya japonica* | Pentaphylacaceae | 0.17 | 1.18 | 47 | 0.04 | 0.05 | 0.04 | 4 |
| *Eugenia bracteolata* | Myrtaceae | 0.16 | 1.00 | 28 | 0.04 | 0.03 | 0.06 | 4 |
| *Abarema bigemina* | Fabaceae | 0.17 | 1.96 | 38 | 0.04 | 0.04 | 0.04 | 4 |
| *Dillenia pentagyna* | Dilleniaceae | 0.14 | 0.92 | 35 | 0.03 | 0.04 | 0.05 | 4 |
| *Michelia champaca* | Magnoliaceae | 0.08 | 0.60 | 44 | 0.02 | 0.05 | 0.04 | 4 |
| *Lannea coromandelica* | Annarcardiaceae | 0.06 | 0.48 | 19 | 0.01 | 0.02 | 0.04 | 2 |
| | Others | 3.96 | 23.06 | 999 | 0.99 | 0.98 | 0.96 | 32 |
| | Total | 4.02 | 23.54 | 1018 | 100 | 100 | 100 | 100 |

**(e) Old growth forest**

| | | BA ($m^2$/ha) | Vol ($m^3$/ha) | SD (Trees/ha) | RBA (%) | RD (%) | RF (%) | IVI (%) |
|---|---|---|---|---|---|---|---|---|
| *Anisoptera scaphula* | Dipterocarpaceae | 3.77 | 120.00 | 310 | 0.14 | 0.15 | 0.04 | 11 |
| *Eugenia bracteolata* | Myrtaceae | 2.91 | 41.59 | 236 | 0.11 | 0.12 | 0.04 | 9 |
| *Styrax serrulatum* | Styraceae | 1.14 | 12.61 | 295 | 0.04 | 0.15 | 0.04 | 8 |
| *Dipterocarpus alatus* | Dipterocarpaceae | 4.14 | 80.53 | 39 | 0.16 | 0.02 | 0.03 | 7 |
| *Dimocarpus longan* | Sapindaceae | 0.89 | 13.66 | 185 | 0.03 | 0.09 | 0.04 | 6 |
| *Lithocarpus wrayi* | Fegaceae | 1.79 | 22.82 | 96 | 0.07 | 0.05 | 0.03 | 5 |
| *Abarema bigemina* | Fabaceae | 1.03 | 14.41 | 133 | 0.04 | 0.07 | 0.04 | 5 |
| *Myristica amygdalina* | Myristicaceae | 0.73 | 8.68 | 97 | 0.03 | 0.05 | 0.04 | 4 |
| *Syzygium thumra* | Myrtaceae | 1.69 | 26.58 | 21 | 0.06 | 0.01 | 0.03 | 3 |
| *Cedrela serrata* | Meliaceae | 1.31 | 25.11 | 37 | 0.05 | 0.02 | 0.03 | 3 |
| | Others | 6.60 | 169.43 | 738 | 0.25 | 0.28 | 0.64 | 39 |
| | Total | 26.01 | 535.42 | 2187 | 100 | 100 | 100 | 100 |

BA = basal area, Vol = volume, SD = stand density, RBA = relative basal area, RD = relative density, RF = relative frequency, IVI = important value index

No single species was found as a common in all disturbance type forest areas, although there were some overlapping species among the different disturbance areas. *Microcos paniculata* of the family Malvaceae, and *Archidendron jiringa* of the family Fabaceae, occurred in both the shifting cultivation and landslide-affected areas. In both the shifting cultivation and selective logging areas, *Barringtonia angusta* of the Lecythidaceae family was commonly found. *Cedrela serrata* of the family Meliaceae was present in landslide-affected, selective logging, and old growth forest. *Anisoptera scaphula* and *Dipterocarpus alatus*, members of the Dipterocarpaceae family, were found in both the selective logging and old growth forest areas. *Eugenia bracteolata* of the Myrtaceae family was found in both the human-interfered old growth forest and the old growth forest.

Among all disturbed forests and old growth forest, *Illex sulcata* was the most frequently occurring species, with the highest stand density (2,756 trees/ha) and the highest IVI value (18%). The second-highest IVI value, of 15%, was for *S. serrulatum*. *Microcos paniculata* had the second-highest stand density (2,733 trees/ha), occurring in the shifting cultivation area. The family Fabaceae was common among all disturbance type forest areas. Malvaceae, Fabaceae, Aquifoliaceae, and Dipterocarpaceae had the highest IVI values in all disturbance type forest areas.

## DISCUSSION

### Impact of disturbances on species composition

In plant ecology and forestry, species diversity is a meaningful and valuable tool for comparing the composition of different species. Neumann 2001 and Padalia (2004) noted that tree species diversity in tropical forests differs significantly from location to location, mainly due to variations in biogeography, habitat, and disturbance type. In this study, we compared changes in plant diversity after natural and anthropogenic disturbances. The old growth forest had high species diversity (Table 2): the species richness and diversity indices were highest in the old growth forest. These results agree with many previous studies, such as Jigme (2016) and Shauna (2010). Although all plots in our study were located in the same region, a Buddhist monk strictly conserved the old growth forest area over many years. Historically and at present, any disturbance activities engaged in by the villagers and people in the surrounding area, such as collection of fuel wood and non-timber forest products, are prohibited. This is the main reason that the forest in the study area was not subjected to any anthropogenic disturbances.

The significant decrease of species diversity was found in selective logging area (Table 2, Fig. 4). This may be one of the reasons of encountered disturbance during harvesting operations. The main species harvested in the study area are Dipterocarpaceae, which are very common and remain dominant in selective logging and human-interfered forest areas. The non targeted and non commercial species of *Abarema bigemina* and *Cedrela serrata* showed the highest IVI values in the selective logging area.

Although species diversity in the shifting cultivation, landslide-affected, and selective logging areas was higher than in the human-interfered forest, the stand densities of those areas were lower than in the human-interfered forest. The species diversity after shifting cultivation and selective logging showed similar recovery rates in this study. This is contrary to the findings of Deng (2016) who indicated that species diversity after shifting cultivation increased but only a little changed after selective logging in Diaoluoshan Nature Reserves, Hainan Island, China. These findings demonstrate that the type of disturbance can influence the recovery rate of species richness. In young and middle-aged forests with intermediate levels of disturbance, pioneer species with high sprouting ability rapidly colonize abandoned disturbed areas (McNamara 2012).

**Community composition patterns according to disturbance type**

We have shown that some regrown forests can reach a tree species density and basal area similar to a human-interfered forest within three decades (Table 2). However, even the human-interfered forest areas had a different composition from the old growth forest, because those areas suffered from small-scale disturbances. According to the similarity index, the present community composition reflects historical natural disturbances.

Our current study of the effects of different types of disturbance on tropical evergreen forest suggests that the tree floristic compositions associated with two disturbance types (shifting cultivation and selective logging) and human-interfered forest area were reached half stage of old growth forest (Table 1). The shifting cultivation occurred over 15 years ago and all sample plots had no repeated fallows cycles. The longer a cultivated area had been abandoned, the greater the similarity of its vegetation structure and community composition to that of the old growth forest (Auemporn 2014). This is in accordance with the findings of Lawrence (2004) that community composition failed to recover after as little as one cycle of shifting cultivation, and that the diversity of the forest decreased progressively with more cycles of shifting cultivation.

Our analysis uncovered similar community composition patterns between shifting cultivation and landslide-affected areas; the most common species were the same in both of these area types, namely *Microcos paniculata*, *Archidendron jiringa*, *Styrax serrulatum*, and *Abarema bigemina*. (Fig. 2, Table 3). Those two communities together accounted for 72% of Sørensen's index. The composition of the old growth forest was clearly differentiated from that of the disturbed areas (Fig. 2). The community composition of the landslide-affected area showed the lowest similarity to the old growth forest (Table 1). It is assumed that many tree stands collapsed, possibly because a key factor in recovery processes is the presence or absence of residuals, defined as individual organisms (or their propagules) that survive a disturbance event (Turner, Baker, Peterson, & Peet, 1998). For all disturbance sites, including the human-interfered old growth forest, the community composition similarity index was lower when compared to that of the old growth forest.

**Structural effects**

Tree diameter distribution is often used to represent the forest population structure. A higher tree density in the smallest DBH class is indicative of sufficient young trees to replace mature trees. We have shown that disturbances, whether natural or anthropogenic, create new vegetation structural patterns. Our results demonstrate that different degrees of forest disturbance have different influences and effects on forest structure and composition. Both natural and anthropogenic disturbances had the same effect on structural factors (tree diameter, basal area, volume, and stand density) (Table 2). After three decades, abandoned cultivation areas, abandoned selective logging areas, and landslide-affected areas resembled a human-interfered forest with no significant disturbance records in terms of tree diameter, basal area, volume, and stand density. Surprisingly, these three disturbance types were comparable to the human-interfered forest in terms of structural effects. This demonstrates that human interference in the old growth forest caused a disturbance effect that persisted over several decades.

The J-shaped distribution of the basal area observed in the selective logging sites was similar to the shape of the old growth forest, with larger trees comprising the highest proportion of basal area. This is indicative of the consistency in the growth rate of individuals in different DBH classes, and of a stable stand condition (Bhat et al., 2011). Both basal area and stem density tended to increase significantly with tree diameter in the selective logging area (Fig. 3). This finding is in accordance with Ferry et al. (2002). Differences in basal area among the study plots may be due to differences in altitude, species composition, tree age, disturbance extent, and successional strategies of the trees.

The evidence of the stand density decreases from small DBH size to large DBH in all disturbance types, including the human-interfered forest, may be an effect of competition. In the selective logging area, the finding of lowest tree density in the youngest stage indicated that road and ground disturbances during logging operations had unfavorable effects on younger generations. In Kibale National Park, Uganda, reduced sapling densities and tree growth rates were still observed more than 25 years after logging, possibly due to a high amount of elephant activity

(Chapman 1997). In the present study, in every tree diameter class the old growth forest had high basal area and density values. (Van Gemerden, Olff, Parren, & Bongers, 2003) noted that disturbances may be inferred from the diameter distribution of trees. Letcher (2009) found that disturbed forests recovered, in terms of basal area and species richness, but not all tropical secondary forests show the same level of recovery (Ding, Zang, Liu, He, & Letcher, 2012).

**Implications for the maintenance of ecosystem processes**

Assessment of biodiversity is necessary because biodiversity affects key ecological processes. Woody plant species are major components of the forest ecosystem; they are responsible for forest architecture and influence the overall composition of forest communities. Therefore, documentation of tree diversity and distribution patterns can provide data that are useful for management. Tree density, basal area, diversity, and composition are the key of forest structure recovery assessment indicators after disturbances of old growth and primary forests (Guariguata & Ostertag, 2001). Disturbance history and type were better predictors of changes in species composition and diversity than environmental factors. Soil nutrient availability was a good predictor of species composition, diversity (species richness and Shannon index values), and density (Ding et al., 2012). Some studies have directly compared forest recovery following anthropogenic and natural disturbances within the same region and time period (Chazdon, 2003). Our study indicates the importance of old growth forests in maintaining and conserving high plant diversity.

We found that the community composition, species composition, and structural pattern varied significantly according to disturbance type. Based on our results, the human-interfered forest resembled the other disturbance types in terms of community composition and structural pattern. Due to the basic livelihood requirements of locals and merchants located around Kyaik Htee Yoe Pagoda, non-wood forest products like honey, medicinal plants, and wildlife products are always in high demand. Though other disturbed forest areas had been abandoned several decades ago, human interfered forest is still suffering some kind of minor disturbances such as fuel wood collection, extraction of non-wood forest products, etc in a continuous pattern. According to our results, the forest area with repeated minor disturbances in a continuous action has more impacts on vegetation composition pattern than other disturbed areas like shifting cultivation and selective logging.

The number of sample plots should be increased in future studies to obtain a precise assessment of the impacts of different disturbance types in comparison to old growth forest. However, our results and findings revealed important preliminary information and will be beneficial when assessing tropical evergreen forests in Myanmar. This will facilitate the development of sound strategies for the conservation and sustainable management of reserve forests in Myanmar.

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