a

The Republic of the Union of Myanmar

Ministry of Environmental Conservation and Forestry

Forest Department

Assessment on Plant Diversity of the Popa Mountain Park

in Myanmar

Mu Mu Aung, Assistant Research Officer
Dr. Thaung Naing Oo, Director
Aung Zaw Moe, Assistant Research Officer
Forest Research Institute

December, 2015

ပုပ္ပါးတောင်ဉယျာဉ်၏ အပင်ဇီဝမျိုးစုံမျိုးကွဲများအား ဆန်းစစ်အကဲဖြတ်လေ့လာခြင်း

မူမူအောင်၊ လက်ထောက်သုတေသနအရာရှိ

ဒေါက်တာသောင်းနိုင်ဦး၊ ညွှန်ကြားရေးမှူး

အောင်ဇော်မိုး၊ လက်ထောက်သုတေသနအရာရှိ

စာတမ်းအကျဉ်း

ပုပ္ပါးတောင်သည် မြန်မာပြည်အလယ်ပိုင်းရှိ အပူပိုင်းဒေသတွင် တည်ရှိနေ သော်လည်း ရေမြေ သဘာဝအရ ရာသီဉတုမတူညီဘဲ တမူထူးခြား၍ စိမ်းလန်းစိုပြေသော သစ်ပင်မျိုးစုံ ပေါက်ရောက်လျက်ရှိသည့် မီးတောင်ဟောင်း တစ်ခု ဖြစ်ပါသည်။ ပင်လယ်ရေ မျက်နှာပြင် အထက်အမြင့်ပေ (၄၉၈၁)ပေအထိ မြင့်မားသော ပုပ္ပါးတောင်တွင် သစ်တောအမျိုးအစား အမျိုးမျိုးကိုလည်း တွေ့ရှိရပါသည်။ အပင်ဇီဝမျိုး စုံမျိုးကွဲများစုံလင်လှသော ပုပ္ပါးတောင်မှ အပင်များ၏ ပေါက်ရောက်ပုံ ပေါက်ရောက်နည်း၊ အပင်ဂေဟဗေဒစနစ် ဖွဲ့စည်းတည်ရှိပုံ၊ အပင်မျိုးစိတ်များ တည်ရှိမှုပမာဏ၊ ပုပ္ပါးတောင် ပတ်ဝန်းကျင်တွင် မှီခိုနေထိုင်ကြသော ကျေးရွာများမှ ဒေသခံပြည်သူများ၏ လူမှုစီးပွားရေးနှင့် ရိုးရာဓလေ့ ထုံးစံတို့ကို သိရှိနိုင်ရန် သုတေသနပြု လေ့လာဆန်းစစ် အကဲဖြတ်ထားသော စာတမ်းဖြစ်ပါသည်။ ပင်လယ်ရေ မျက်နှာ ပြင်အထက် အမြင့်ပေအလိုက် အပင်မျိုးစိတ်များ၏ ပေါက်ရောက်ပုံပေါက်ရောက်နည်း၊ အပင် ဂေဟဗေဒဆိုင်ရာ နီးနွယ်ဆက်စပ်မှု၊ ရှားပါးလာသော မျိုးစိတ်များနှင့် မျိုးသုဉ်းပျောက်ကွယ် တော့မည့် အပင်မျိုးစိတ်များအား သိရှိနိုင် မည့်အပြင် မျိုးစိတ်များ၏ တူညီမှု ကွဲပြားခြားနားမှု၊ တစ်ခုနှင့်တစ်ခုဆက်စပ်မှု၊ တည်ရှိမှုပမာဏ၊ တော၏ ဖွဲ့စည်းမှုနှင့်ပြောင်းလဲမှုကို လေ့လာတင်ပြ ထားသည့်အပြင် အပင်ဇီဝမျိုး စုံမျိုးကွဲ များကြွယ်ဝမှုကို တိုင်းတာညွှန်ပြသည့် အတိုင်အတာ များဖြစ်သည့် Species richness, eveness, species frequency, abundancy, species density and Importance Value Index (IVI) တို့ကို အသေးစိတ် တင်ပြ ထားပါသည်။ အပင်ဇီဝမျိုး စုံမျိုးကွဲများကြွယ်ဝမှုကို Simpson and Shannon Diversity Indices အညွှန်းကိန်းများဖြင့်လည်း တင်ပြထားပါသည်။ ဤလေ့လာ တွေ့ရှိချက်များကို အခြေခံ၍အပင်ဇီဝမျိုးစုံ မျိုးကွဲများကို စဉ်ဆက်မပြတ် ထိန်းသိမ်း ကာကွယ်နိုင်ရန် သင့်ဝင်တော်သောနည်းလမ်းများကို လေ့လာတင်ပြ ထားခြင်းဖြစ်ပါသည်။

Assessment on Plant Diversity of the Popa Mountain Park in Myanmar

Mu Mu Aung, Assistant Research Officer

Dr. Thaung Naing Oo, Director

Aung Zaw Moe, Assistant Research Officer

Forest Research Institute, Yezin.

Abstract

Assessment of plant diversity of the Popa Mountain Park (PMP) and prioritization of communities for conservation has been giving much attention. Therefore, the study has been conducted in a biodiversity rich PMP between 500-1500m to analyse the structure, composition of the forest communities including richness of economically important, native, endemic and rare-endangered species, and prioritize communities for conservation. The research activities were carried out in two parts i.e., western and eastern part of the core zone of the park during 2011 and 2012. Plant species identification and specimen collection were carried out through forest inventory and systematic botanical studies. The ecological linkage between and among the plant species, quantitative estimate of plant species diversity, stand structure and stand dynamic of the park were also investigated. The quantitative estimate of plant species diversity and ecological linkage between and among species are presented by using diversity indices (i.e. Simpson and Shannon Diversity Indices) and main parameters of vegetation study such as species richness, evenness, number of individuals or density (abundance), frequency and Importance Value Index (IVI). Social aspects of the National Park are also presented in order to realize and highlight the importance role of forests for the livelihoods of the rural people living around the PMP. Based on overall results of the different research activities, appropriate means and ways and recommendations for sustainable conservation of plant species diversity of the Popa Mountain Park (PMP) as well as a protected area system are presented.

iii

Contents

.

Assessment on Plant Diversity of the Popa Mountain Park in Myanmar

1. Introduction

Myanmar is one of the biodiversity hotspots in the world, and its PAs play a crucial role in conserving the country's rich biodiversity (Myers et al. 2000). During the last 10 years the number of protected areas in Myanmar has increased from 20 to 42, covering 6.67% of total land area of the country (Forestry in Myanmar 2011). The Nature and Wildlife Conservation Division (NWCD) of the Forest Department, Ministry of Forestry, is mainly responsible for PA management in Myanmar. Generally, PAs in Myanmar can be categorized into National park, Marine Park, Wildlife sanctuary, Nature reserved, and Zoo Park. Although Myanmar's PAs do not fully conform to PA categories of the International Union of Conservation of Nature (IUCN), they are most similar to IUCN category IV (Aung 2007).

Myanmar's PA management rules and regulations prohibit local people from using resources within PAs. Conflicts arise as local people often have no other source of resource than the PA. Rao, Rabinowitz, and Khaing (2002) reported that nontimber forest products were extracted from 85% and fuelwood was collected from more than 50% of PAs in Myanmar. The mean annual population growth rate is 2.1% (Central Statistics Organisation 2006) and is highest in rural areas where most Myanmar PAs are located. Population increase is linked to an increase in the number of people seeking land for grazing, collecting fuelwood, and extracting timber and other forest products. The rapid growth of PAs and the huge pressures placed on them by the increasing human population are a great challenge for sustainable PA management.

Popa Mountain Park (PMP) possesses a diverse forest ecosystem in central Myanmar where most forests have already disappeared. PMP was selected for the present study for two reasons: (1) a historic relationship between PMP and local communities and (2) high people's pressure on the park resulting from the high population density together with resource scarcity in the surrounding area (N. Z. Htun *et.al* 2012). The Forest Department has had great success in the

reforestation of Popa Mountain, which is a high priority for forest conservation. It is important to understand local people's perceptions and attitudes toward PMP for its sustainability.

2. Rationale of the study

The Popa Mountain Park (PMP) is very well known throughout the globe due to its representative, unique, natural, and socio-economically important flora and fauna (Myers *et al*. 2000). Due to this peculiar feature, the Indo-Myanmar has been identifies one of the biodiversity Hot Spots (van Dijk *et al* 2004). This rich biodiversity is being utilized by the inhabitants of the region for medicine, as wild edible (food), fodder, fuel, timber, in making agriculture tools, religious and various other purposes. With the increasing human population, the demand of the economically important biodiversity is increasing fast. Collection of medicinal plants, fodder and fuel species from the park has been identified one of the chronic problems in the PMP for the degradation of forest. The anthropogenic pressures including heavy grazing coupled with the natural calamities have lead the degradation of natural habitats of many species to a great extent. This loss of biodiversity and changing pattern of vegetation has necessitated assess the biodiversity of the region and prioritize habitats, communities and species for conservation. In general, structural and functional diversity of the some parts of the PMP have been evaluated by various scientists. Among others, the floristic compositions, plant community types, natural regeneration potential of the forests as well as population structure are very limited studied and documented. Given the Park's multifarious roles and the requisite to manage it for these ends, there is a need to measure the extent of a given natural resource against the demand for its use. Hence, the main purpose of this research work is to contribute filling these gaps. Therefore, the attempt has been made to; (i) describe the floristic composition and plant community types of PMP; (ii) study the species diversity of PMP along gradient of altitude; (iii) study the species similarities between western and eastern part of PMP; (iv) collect the baseline information on the vegetation parameters of the study area for subsequent environmental monitoring.

3. Materials and methods

3.1 Study Area

The Popa Mountain Park (PMP) is an extinct volcano in middle Myanmar. It is located between 20° 56' N and 95° 12' E in Kyaukpadaung Township of Mandaly Region that, at 1,518P m altitude, stands topographically isolated within the dry zone lowland savanah of central Myanmar (Fig. 1). The mountain receives an annual average rainfall of c. 1,040 mm concentrated in the period June to October, demarcating strong wet-dry seasonality. Due to its elevation and the concentration of small natural springs, PMP exhibits great plant diversity, and a riches of vegetation types that have developed since the last eruption about 320,000 years ago (Yin Yin Kyi 1992). PMP was established in 1982 to protect the dry zone ecosystem, conserve the watershed area of Kyetmauk Taung reservoir, conserve medicinal plant species of Popa Mountain, to conduct public education and research, and to promote ecotorusim. PMP supports forest vegetation types that has been classified into six types, namely (with increasing altitude) dry forest (Than-Dahat), low *Indiang* dipterocarp forest, dry hill forest, moist upper mixed deciduous forests, dry upper mixed deciduous forests, evergreen forests (Yin Yin Kyi 1999, Yin Yin Kyi & Aung Zaw Moe 1997) and savanah-type grassland around the 1,518 m summit (Tanaka *et al.* 2007). A core area of 128.5 km^2 to the foot of the mountain has been enlisted as a PMP since 1982, and is encircled y a 103.6 km^2 buffer zone. Medicinal plants of Popa Mountain are famous all over Myanmar. Many globally threatened species of mammals are recorded in the area (Eld's Deer, Dusky Langur, Capped Langur, and Dhole).
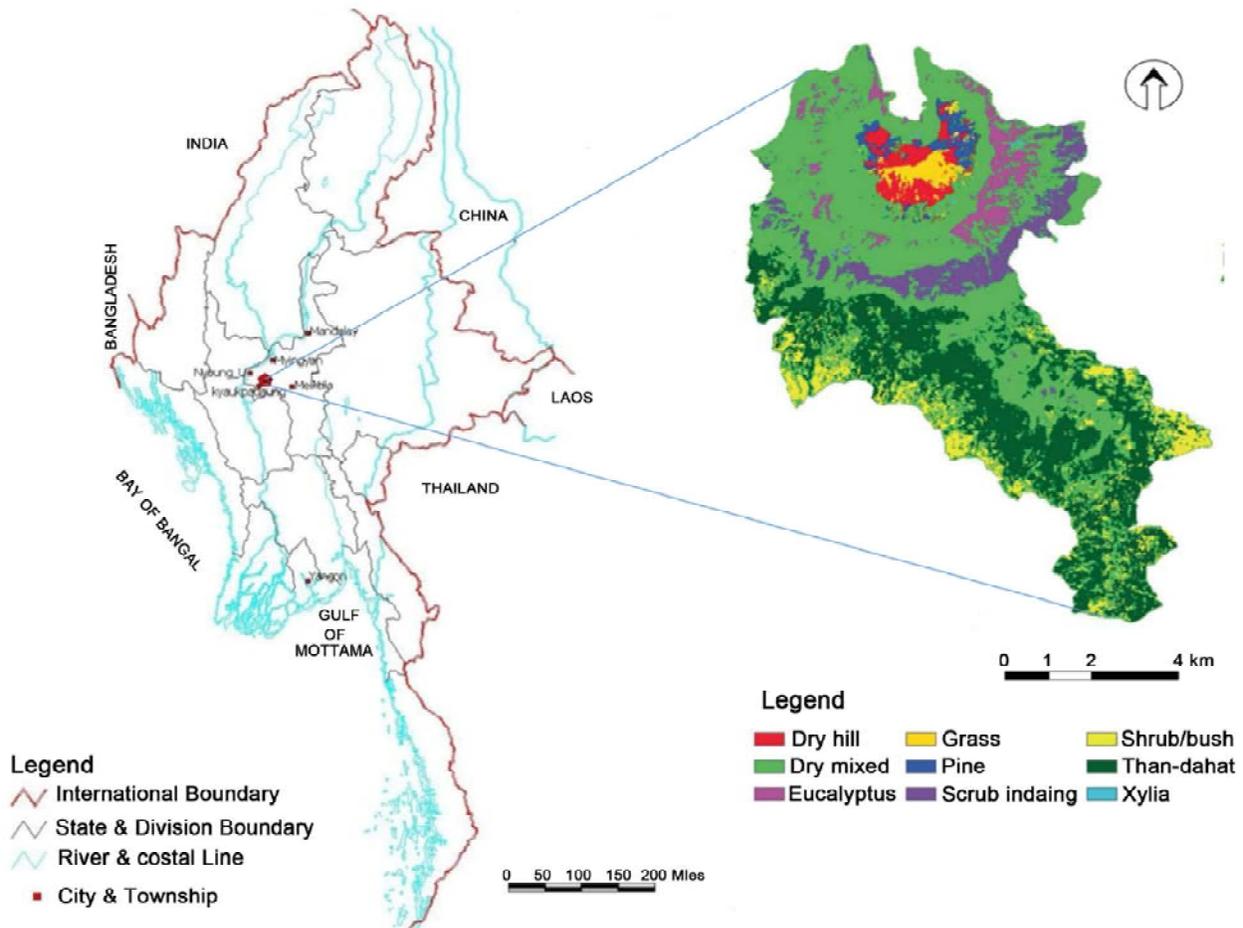
Source: Y.Y. Aye *et al* 2014

Fig. 1 Location map of Study Area

The park is richly endowed with diverse flora, which contributes habitats for wildlife such as leopard, barking deer, bear, jungle goat, mountain goat, wild boar, jungle cat and many kinds of birds (Ministry of Forestry, 2000). According to the ancient legend, the slopes of the hill were wholly covered with many flowering plants and trees and thus the hill was given the name of "Popa" which in Sanskrit, "Puppha" means "Flower". Thus, to the early Myanmar, it was recognized as the mountains of flowers (Yin Yin Kyi, 1997). Popa Mountain Park is very well known National Park in Myanmar because of its diverse florisitic composition and ample sources of habitats for wild animals. It also plays an important role in Myanmar religious belief. The scenery of the park attracts people for recreation and the diverse forest flora and fauna provide substantial opportunities for ecotourism development. Management actions include weekly

patrolling and annual biodiversity surveys. Special conservation actions target the dusky leaf monkey population inhabiting the old crater. The establishment of banana and mango plantations have supported the development of the villagers located in the buffer zone, although further assistance is needed.

Popa Mountain is a famous ecotourism site of Myanmar and many local and foreign tourists visit Popa throughout the year due to its good location on the way to or from famous ancient Bagan pagodas. Thirty-two villages of varying size are located within or close to the boundary of the buffer zone. Consently, PMP is of great social significance in providing a variety of services ranging from the religious (e.g. natural and mammade sites used for Buddish worship) to the commercial (e.g. a developing ecotourist trade), in addition to the vast array of subsistence and environmental benefit it embodies in term of clamitic regulation, the facilitation of agriculture and provision of shelter, fresh water, food, medicines and other material resources.

3.2 Vegetation Sampling

A systematic sampling design was used to collect data on vegetation of different growth forms (Kent and Coker 1992; McCune and Grace, 2002; Mueller-Dombois and Ellenberg, 2002). Vegetation information was collected in sample plots of 20 x 20 meters. The plots were distributed along transects that ranges from 1 km to 1.6 km which were laid parallel to the slope. The distance between adjacent transects was 500 m while 150 m between consecutive plots. In total 74 samples plots, 32 from East and 32 from West of PMP were set up. Within each main plots four small plots of size 5 m X 2 m were laid; two at the corners (Fig. 2)
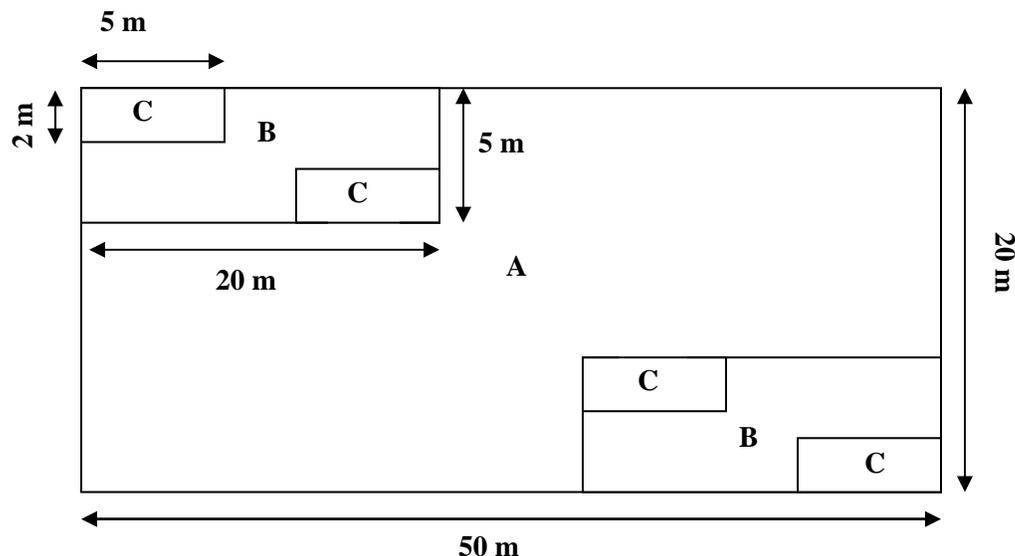
Fig. 2 Layout of sample plots

Sub-plot A : 0.1 ha (50 m x 20 m) - record all trees with DBH ≥ 10 cm.

Sub-plot B : 0.01 ha (20 m x 5 m) - record of shrubs and saplings <10 cm dbh and > 130 cm in
   height.

Sub-plot C : 0.001 ha (5 m x 2 m) - count herbs, climbers and seedlings between 30 cm and 130
   cm in height.

3.3 Diversity analysis

Diversity measures

Species richness is a biologically appropriate measure of alpha (α) diversity and is
usually expressed as number of species per sample unit (Whittaker 1972). The Shannon diversity
(H ') and evenness (E') indices are calculated as a measure to incorporate both species richness
and species evenness (Magurran, 1988). The Simpson index (D) and Shannon diversity index
(H') were calculated using the following equation.

Simpson's Diversity Index

$$D = \sum_{i=1}^{s} \frac{(n_i(n_i-1))}{(N(N-1))} \qquad (4)$$

where, D = Simpson's index of diversity

n_i = number of individuals of species "i" in the sample

s = number of species in the sample

N = total number of species in the sample

Shannon Diversity Index

$$H' = \sum_{i=1}^{s} P_i \ln (P_i)$$

where, H' = index of species diversity

S = number of species in the sample

Pi = proportion of total sample belonging to "i^{th}" species

ln = the theoretical maximum value of diversity by a given number of total species (S) found in the sample.

The values of Shannon diversity index is usually found to fall between 1.5 and 3.5 and only rarely surpasses 4.5 (Magurran, 1988). To test whether Shannon indices of East and West Park are statistically significant independent t test was used. Since Shannon index is approximately normaly distributed, making comparison with paramrtric tests is feasible (Magurran, 2004).

Evenness ('E) was calculated from the ratio of observed diversity to maximum diversity (Magurran, 1988) using the following equation.

Evenness

$$E(\%) = 100.H'/\ln H_{max}$$

where, E   = Shannon's Evenness (evenness measure, range 0-1)

H'   = Shannon-Wiener function

H_{max} = ln (S); the theoretical maximum value of diversity by a given number of total species (S) found in the sample.

Magurran (1988) explained that E ' ranges normally between 0 and 1, where 1 representing a situation in which all the species are equally abundant.

❑ **Jackknife estimate of species richness**

$$\hat{s} = s + \left(\frac{n-1}{n} \right)^k$$

Where, $\hat{s}$ = Jackknife estimate of species richness

s   = observed total number of species in "n" sample plots

n   = Total number of plots sampled

k   = number of unique species

The variance of the Jackknife estimate of species richness is

$$Var\,(\hat{s}) = \left(\frac{n-1}{n} \right) \left(\sum_{j=1}^{s} (j^2 . f_j) - \frac{k^2}{n} \right)$$

Where, Var (ŝ)   = variance of Jackknife estimate of species richness

n   = total number of plots sampled

k   = number of unique species

f_j = number of plots containing "j" unique species (j = 1,2,3,…,s)

The variance can be used to obtain confidence limits for the Jackknife estimator as follows;

$$\hat{s} \pm t_\alpha \sqrt{var(\hat{s})}$$

where, tα = Student's value for (n-1) degrees of freedom for the appropriate value of "α" .

(In this study, 95 % confidence tα = 2.26).

4. Results and discussion

4.1. Floristics Composition

Including those plants that were found out of the study plots, totally 321 species from 92 families and 243 genera were identified in this study (Table 1). When the number of species, families and genera from the two forests analysed separately, western part has higher share in all aspect. As shown in Table 1 the number of families, species and genera which were recorded in western part are higher than that of eastern part. Eighty two and 67 families were identified in western and eastern parts, respectively. The number of genera decreased from 201 to 155 when we go from western to eastern part of PMP.

Table 1. Number of families, genera and species of tree species occurred in East and West Park

No.	Categories	Western part of the core zone			Eastern part of the core zone		
		Family	Genera	Species	Family	Genera	Species
1	Trees*	40	125	153	27	73	91
2	Shrubs	17	22	38	11	20	32
3	Climbers	12	20	25	10	15	20
4	Herbs	7	11	10	12	10	13

| 5 | Bamboos | 1 | 3 | 5 | 1 | 3 | 5 |

*Trees with DBH≥5 cm

Out of the total 321, only 271 of the species were recorded in the study plots. From these 271 species only 211 of them comprising 77 families and 171 genera were recorded in western part while in eastern portion only 161 species from 61 families and 121 genera were recorded in the plots. Out of the 92 families recorded, 63% of them (58 families) occurred in both portions. Twenty four families (26.1% of the total families) were recorded only in west portion while the rest 10.9% (10 families) were recorded only in east portion.

When the whole data set is considered together, the species richest family of PMP is Dipterocarpaceae, represented by 24 species and 19 genera, followed by Rubiaceae which is represented by 21 species and 16 genera. The third species rich family is Fabaceae which is represented by 15 species and 12 genera. Orchidaceae and Malvaceae are represented by 12 species each while Acanthaceae consists of 11 species. Myrtaceae, Magnoliaceae and Moraceae are represented by 10 species each.

In western part of PMP, Dipterocarpaceae is the richest family being represented by 12 species and 11 genera. The second richest family is Fabaceae with 11 species and 11 genera followed by Euphorbiaceae consisting of 10 families and nine genera. Orchidaceae, Malvaceae, Fabaceae, Solanaceae, Acanthaceae, Asparagaceae and Aspleniaceae are other species rich families in eastern part which are represented by 5 or more species.

In both forests the first ten species rich families comprises considerable number of species. In western part of PMP, 42.7 % (108 species) of the recorded species belongs to the top ten families. However, 37 of the families recorded (45.1 %) in this forest were represented only by one specie. The same is true for eastern part of PMP, where, 42.5 % (77 species) of the total species were from top ten species rich families and 44.8 % (30 families) of the families were represented only by a single species.

4.2 Species-area relationship (species area curve)

As indicated in Figure 2, species accumulation curves (rarefaction) were plotted for the vascular plants recorded in western and eastern part of PMP. This graph was plotted for the cumulative number of species recoded as a function of sampling effort i.e. the number of samples pooled.
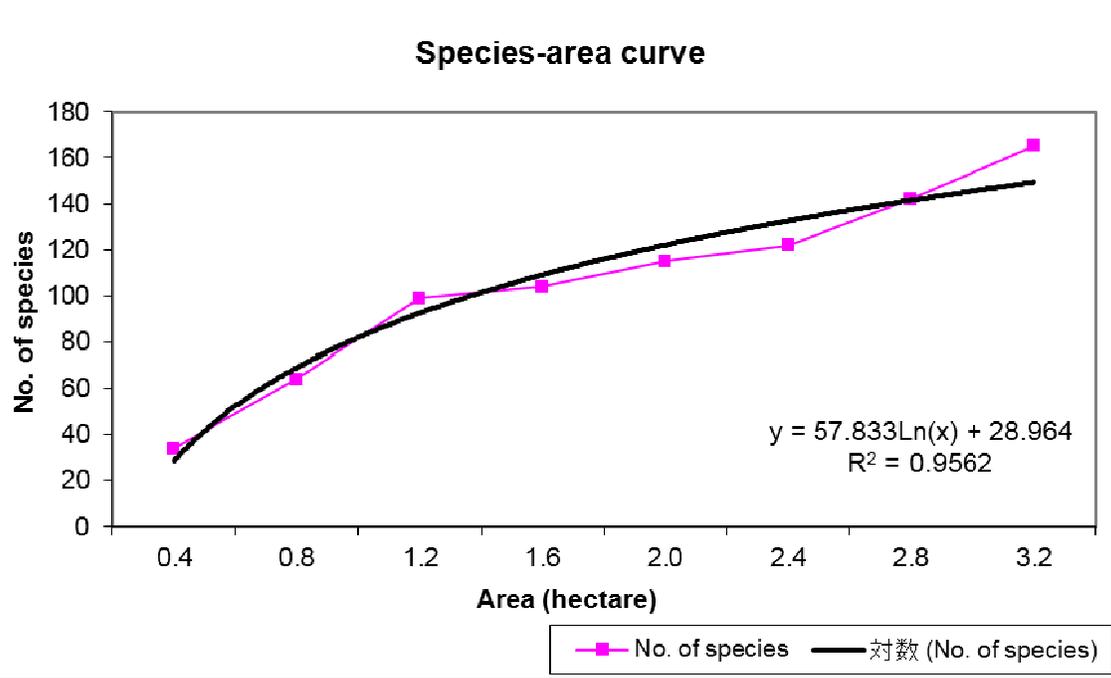

Figure 2. Species area curves of west and east portions for trees dbh ≥5 cm

The species area curves indicate species diversity in relation to increasing size of area. Both curves for all trees with diameter at breast height equal and greater than 5 cm ($\geq$ 5 cm DBH) show a higher number of species per unit area. According to the curves, the number of species in the west portion of the core zone is relatively higher than that of the east portion.

4.3. Species richness estimation

As it was described totaly 321 vascular plant species (including those found out side of the study plots) were recorded in PMP. However, these are not the only species that are found in this ecosystem. For various reasons especially those which are rare might not be included in sampling process. Hence, it is valid to estimate the total number of species. Based on different species richness estimators, the total number of species in PMP was estimated to be between the range of 286.54 and 358.85. The lowest estimate (i.e. 286.54) was given by Chao1, while the highest estimate was obtained using Jackknife 2 (i.e. 358.85). Based on these different estimations, in this study 75.25 to 94.56 % of the estimated species were recorded.

As indicated in Table 2 using different methods, species richness (number of species) of both part of PMP was separately estimated. All the species richness estimators used in this study resulted in higher species richness than the observed number of species (Sobs). In both forests the highest species richness estimation (283.45 for weatern and 208.52 for eastern PMP) was obtained by second order Jackknife estimator. While the smallest estimate for western part (219.55) was given by Chao 1 estimator. In this study 76.76-92% of the species estimated by various estimators for eastern as well as 74.4-96% for that of western PMP were recorded.

Table 2. Number of samples, individuals, observed species and estimated species richeness (based on different methods) of western and eastern part of PMP

Characteristics	PMP
Number of samples	74
Number of individuals	42055
Number of species	321
Sobs	271
Chao 1	286.54 ±7.56
Chao 2	325.58 ±18.62
Jackknief estimate of species richness (S)	330.21 ±7.86
Species collection degree	75.52-94.57 %

4.4 Floristic similarities

As indicated in both incidence and abundance based similarity indices resulted in very low similarty indices for western and eastern PMP. Incidence based Sørensen similarity index was 0.39 and that of incidence based Jaccard was 0.25. Almost identical values were obtained for the corresponding abundance based similarty indices. Chao-Sørensen similarty index resulted in 0.38 and that of Chao-Jaccard index gave 0.25, which is very low in both cases.

Species diversity is a function of the number of species present (species richness or number of species) and the evenness with which the individuals are distributed among these species (species evenness, species equitability, or abundance of each species) (Margalef 1958; Lloyd and Ghelardi 1964; Pielou 1966; Spellerberg 1991). One method has been to construct mathematical indices broadly known as diversity indices and the other involves comparing observed patterns of species abundance to theoretical species abundance models. Species diversity indices take two aspects of a community into account, namely species richness and evenness or equitability (the distribution of abundance among the species) (Hamilton, 2005). In this study Shannon diversity index is computed to evaluate the species diversity of the study sites.

In fact it is difficult to compare the species richness of one area with others directly as there might be difference in forest size, data collection methodology and objectives of the studies. However, species richness can show the overall diversity of a given forest. In this regard PMP are not poor in species richness though the number of species is less when compared to other PAs. The integrated conservation of forest ecosystems serve as a reservoir of continually evolving tree species and population and fulfill the basic needs of the people. Thus, special measures need to be planned and undertaken in order to conserve, if possible, each species or habitat or biological diversity. Forest resources in PAS also need to be assigned consumptive and non-consumptive values so that the conservation of forest resources can be linked to the sustainable socio-economic development of the local people.

5. Conclusions

Biodiversity is part of daily lives and livelihoods of human being and constitutes the resource upon which families, communities, nations and future generation depend. Every gene, species or ecosystem lost represents the loss of an available option to adapt to local and global change. The problem of biodiversity conservation has become a global issue (Thaung Naing Oo, Lwin Ko Oo & Yin Yin Kyi 2006). The present study provides comprehensive information on site characteristic, habitats, community diversity, vegetation distribution pattern and forest composition of the species including richness of economically important, native, endemic and rare endangered species, prioritization of communities for conservation. Based on the results, it can be concluded that the area has high potential in terms of number of species and communities. The occurrence of high number of native, endemic, economically important and rare-endangered species enhance the conservation as well as socio-economic values of the PMP. The day to day need of forest resources particularly fuel and fodder species has increase the pressure on forest trees and shrubs to a great extent. Furthermore, the over-exploitation of species for fuel, fodder, medicine, food (wild edibles), and house building may lead to the extirpation of these species from the area. Therefore, there is a need to develop adequate strategy and action plan for the

conservation and management of habitats, species, and communities, so that sustainable utilization of the species could be ensured.

6. References

Aung, U. M. 2007. Policy and practice in Myanmar's protected area system. J. Environ. Manage. 84:188–203.

Aye, Y.Y., Pampasit, S., Umponstira, C., Thanacharoenchanaphas, K. and Sasaki, N. (2014) Floristic Composition, Diversity and Stand Structure of Tropical Forests in Popa Mountain Park. *Journal of Environmental Protection*, **5**, 1588-1602. http://dx.doi.org/10.4236/jep.2014.517150

Central Statistics Organisation. 2006. Statistical year book of Myanmar 2005. Yangon, Myanmar:
Central Statistics Organization.

Chao, A., Chazdon, R. L., Colwell, R. K., and Shen, T. 2005. A new statistical approach for assessing similarity of species composition with incidence and abundance data. *Ecology letters* 8:148-159

Chao, A., Chazdon, R. L., Colwell, R. K., and Shen, T. 2006. Abundance-based Similarity indices and their estimation when there are unseen species in samples. *Biometrics* 62:361-371.

Heltshe and Forrester, 1983. Estimating specie richness using Jackknife Procedure.

Htun, N.Z., Mizoue, N. and Yoshida, S. (2012) Determinants of Local Peoples's Perceptions and Attitudes Toward a Protected Area and Its Management: A Case Study From Popa Mountain Park, Central Myanmar. Society & Natural Resources: An International Journal, 25:8, 743-758. http://dx.doi.org/10.1080/08941920.2011.620597

Htun, N.Z., Mizoue, N. and Yoshida, S. (2011) Classifying Tropical Deciduous Vegetation: A Comparison of Multiple Approaches in Popa Mountain Park, Myanmar. *International Journal of Remote Sensing*, **32**, 8935-8948.
http://dx.doi.org/10.1080/01431161.2010.531779

Kershaw, Kenneth A. 1964: Quantitative and Dynamic Plant Ecology. Second edition. Edward Arnold Limited-London.

Kress, W. J., R. A. DeFilipps, E. Farr and D. Y. Y. Kyi. 2003. A checklist of the trees, shrubs, herbs, and climbers of Myanmar. Contributions from the United States
National Herbarium **45**: 118–124

Magurran; Anne, E. 1988. Ecological Diversity and Its Measurement.Princeton University Press, New Jersey.

Mostafa K. Tolba, Osama A. El-Kholy et al, 1992. The world environment 1972 – 1992: Two decades of challenge. Published by Chapman & Hall on behalf of UNEP, Nairobi, Kenya.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853–858.

Nature and Wildlife Conservation Division. 2008. Protected areas in Myanmar. Nay Pyi Taw, Manmar: Forest Department

Neuman, W.L., 2000. Social Research Method-Qualitative and Quantitative Approaches. Allyn and Bacon, USA.

Pandey, A.K, 1995. Taxonomy and Biodiversity. CBS Publishers & Distributors 4596/1A, 11 Daryaganj New Delhi - 110 002.

P.C. Kotwal and Suijoy Banerjee et., al. 2000. Biodiversity conservation in managed forests and protected areas. Agrobis, India.

Pei Shengji and Percy Sajise et. al., 1995. Regional Study on Biodiversity: Concepts, Frameworks, and Methods. Yunnan University Press, Kuming- China.

Rao, M., A. Rabinowitz, and S. T. Khaing. 2002. Status review of the protected-area system in Myanmar, with recommendations for conservation planning. Conserv. Biol. 16:360–368.

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

Simpson, G. G. 1964. Species density of North American recent mammals. *Systematic Zoology* 13:57–73

Soberon, J. M. and Llorente, J. B. 1993. The use of species accumulation functions for the prediction of species richness. *Conservation Biology* 7:480–488.

Hamilton, A. J. 2005. Species diversity or biodiversity? *Journal of Environmental Management* 75:89–92

Tanaka, N. 2005. The Flowering Plants of Mt. Popa, Central Myanmar. Makinoa New Ser. No. 5: 1-102

Tanaka, N. 2007. Ethnomedical Flora of Mt. Popa, Central Myanmar. Makinoa New Ser. No. 6: 63-93

Thaung Naing Oo, Lwin Ko Oo & Yin Yin Kyi (2006) Assessment of Plant Diversity of the Alaungdaw Kathapha National Park in Myanmar. Forest Research Institute, Forest Department, Myanmar.

Van Dijk, P.P., A. W. Tordoff, J. Fellowes, M. Lau and M. Jinshuang. (2004). Indo-Burma. Pp 323-330 in R. A. Mittermeier, P. Robles Gil, M. Hoffmann, J. Pilgrim, T. Brooks, C. G. Mittermeier, J. Lamoreaux and G. A. B. da Fonseca (ed.s) Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions. CEMEX, Agrupacion Sierra Madre, Mexico.

Yin Yin Kyi (1992) Preliminary Report on Vegetation and Flora of Mount Popa. Forest Research Institute, Forest Department, Myanmar,

Yin Yin Kyi and Aung Zaw Moe (1997) Plant Biodiversity of Mount Popa (Part I). Forest Research Institute, Forest Department, Myanmar