ASSESSMENT OF TREE DIVERSITY AND DISTRIBUTION PATTERN IN LENGTENG WILDLIFE SANCTUARY OF MIZORAM, INDIA

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IN
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BY

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DECLARATION

I, Ms. Grace Lalawmpuii Sailo, hereby declare that the subject matter of this thesis entitled, “Assessment of Tree Diversity and Distribution pattern in Lengteng Wildlife Sanctuary of Mizoram, India” is the research done by me under the supervision and guidance of Prof. H. Lalramnghinglova, Department of Environmental Science, Mizoram University, Aizawl. The content of this thesis did not form the basis of any previously awarded degree to me or to the best of my knowledge to anybody else.This thesis has not been submitted by me for anyresearch degree in any other university or institute.

This thesis is being submitted to the Mizoram University, Aizawl for the award of the Degree of Doctor of Philosophy in Environmental Science.

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CERTIFICATE

This is to certify that the thesis entitled, "Assessment of Tree Diversity and distribution pattern in Lengteng Wildlife Sanctuary of Mizoram, India" submitted by Grace Lalawmpuii Sailo, a research scholar in the Department of Environmental Science, Mizoram University, Aizawl embodied the record of original investigation under the supervision. It is further certified that the scholar's bonafide researches and the research findings have not been submitted for the award of any degree in this or any other university or institute.

She is now allowed to submit the thesis for examination for the award of the Degree of Philosophy in Environmental Science.

(PROF. H. LALRAMNGHINGLOVA)

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CHAPTER 1

INTRODUCTION

1.1. The basics of biodiversity

The first man who used the biological diversity is Raymon F. Dashman in 1968 (Dashman, 1986) to present a combination of two related concepts, genetic diversity (the amount of genetic variability within species) and ecological diversity (the number of species in a community of organisms). The term biological diversity was abridged as "biodiversity" apparently by W.G. Rosen in 1985 for the first planning meeting of the "National Forum on Biodiversity" held in Washington D.C. in September 1986 (Anon., 1995). The concept of Biodiversity was introduced by Lovejoy (Lovejoy, 1980) for the expression of number of species. Biodiversity encompasses all life forms, ecosystems and ecological processes and acknowledges the hierarchy at genetic, taxon and ecosystem levels (McNeely, *et al.,* 1990) and in short, reflects the totality of genes, species and ecosystems in region.

According to the Convention on Biological Diversity 1992, biodiversity is defined as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (Hawksworth, 1996). The India's Biological Diversity Act 2002 defines it as, "The variability among living organisms from all sources and the ecological complexes of which they are part and includes diversity within species or between species and of ecosystems" (Anon., 2002).

Biodiversity is a vast and complex concept and its ramifications extend deep into all spheres of human life and activity (Krishnamurthy, 2004). Diversity addresses two distinct aspects *i.e.,* species richness and evenness. Species Richness refers to the number of species per unit area, and evenness refers to their abundance, dominance, or spatial distribution. The focus of biodiversity measurement is typically the species, because they are easily observed and mostly used in the studies of forest ecosystems (Barnes, *et al.,* 1998).

Biodiversity provides to humankind enormous direct economic benefits, an array of indirect essential services through natural ecosystems, and plays a prominent role in modulating ecosystem function and stability. Biodiversity is not uniformly distributed on the earth, and could comprise 5 to more than 50 million species. Biodiversity is the very basis of human survival and economic well-being, and encompasses all life forms, ecosystem and ecological processes, acknowledging the hierarchy at genetic, taxon and ecosystem levels. Biodiversity is responsible for the essential ecosystem services, including regulation of the atmospheric gaseous composition, climate, disturbance and water, soil formation and maintenance of soil fertility, processing and acquisition of nutrient, wastes assimilation, pollination, biological control, pollution control, recreation.

It provides us direct benefits to the humankind in the form of timber, food, fibre, medicines, industrial enzymes, food, flavors, fragrances, cosmetics, emulsifiers, dyes, plant growth regulators, and pesticides. Studies indicate a prominent role of the composition and quantity of biodiversity in controlling ecosystem functions and ecosystem stability. Higher diversity allows greater access to available resources and hence increased net primary production and decrease nutrient losses. A grassland field experiment indicated that the reduction of diversity occurring globally may reduce the capacity of ecosystems to capture additional C under conditions of rising atmospheric

CO_2 concentrations and N deposition levels. However, relating biodiversity of ecosystems functions has remained and intractable problem in ecology and the subject of hot debate among ecologists.

It is estimated that there exist 5-50 million species of living organisms on the earth. Only 1.6 million have been identified so far. According to McNeely, *et al.* (1990) less than 5% of the biological diversity of the rain forest is known to Science. The report based on the studies carried out by the Food and Agriculture 1974 found that the tropical forest is shrinking at the rate of 0.8% each year. If the current rate continues, estimated rate of extinction will be 5-10% roughly with the next 30 years (Agarwal, 2002).

1.2. Levels of biodiversity

The scientific characterization of biodiversity of an area or region involves observation and characterization of the main units of variation *i.e.*, genes, species, and ecosystems and quantification of variation within and between them. In reality they are part of the same process, their analysis defines unity and at the same time characterize their variation (Bibsby and Coddington *in* Heywood, 1995). Various authors have proposed specific and detailed elaborations of biodiversity, Gatson and Spicer proposed a three-fold definition of "biodiversity:- ecological diversity, genetic diversity, and organismal diversity- while others documented as genetic diversity, species or taxonomic diversity and ecosystem diversity (Mc Allister, 1991; Solbring, 1991; Groombridge, 1992; Heywood, 1994).

The types of biodiversity are as below:

a) Genetic Diversity (Diversity within species): It refers to the variation of genes within species. This constitutes distinct population of the same species or genetic variation within population or varieties within a species (Agrawal, 2002). Genetic diversity, at its most elementary level, is represented by differences in the sequences of four nucleotides, which form the DNA within the chromosomes in the cells of organisms.

Genetic diversity serves as a way for populations to adapt to changing environments. With more variation, it is more likely that some individuals in a population will possess variations of alleles that are suited for the environment. Those individuals are more likely to survive to produce offspring bearing that allele. The population will continue for more generations because of the success of these individuals. Genetic diversity exists: within a single individual, between different individual of a single species, between different species (species diversity) Laverty, *et al.*, (2008).

b) Species Diversity (Diversity between species): It refers to the variety of species within a region. It can be defined as a group of inter-breeding or potentially inter-breeding natural populations that are reproductively isolated from other such groups. It is also referred to as Taxonomic or Organismal Diversity (Agarwal, 2002). Species diversity is the building block for the diversity of higher taxa and for the diversity of ecological association such as communities and biomes (Kiester, 2001).

The effective number of species refers to the number of equally abundant species needed to obtain the same mean proportional species abundance as that observed in the dataset of interest (where all species may not be equally abundant). Species diversity consists of two components: Species richness and Species evenness. Species richness is a simple count of species, whereas species evenness quantifies how equal the abundancesof the species are. Species diversity consists of two components.

Species richness is the number of different species represented in an ecological community, landscape or region. Species richness is simply a count of species, and it does not take into account the abundance of the species or theirrelative abundance distribution. Species diversity takes into account both species richness and species evenness.

Species evenness refers to how close in numbers each species in an environment is. Mathematically it is defined as a diversity index, a measure of biodiversity which quantifies how equal the community is numerically.

c) Ecosystem diversity: An ecosystem is a community plus the physical environment that it occupies at a given time (Laverty, *et al.*, 2008). The ecosystem is the first unit in the molecule to ecosphere hierarchy that is complete, that is, it has all the components, biological and physical, necessary for survival. It is diversity at a higher level of organization, the ecosystem.

There are three levels of pattern and levels of species diversity:

i) *Alpha (α) Diversity*- It is the species diversity within a community or habitat.

ii) *Beta (β) Diversity*- It is the inter-community diversity expressing the rate of species turnover per unit change in habitat.

iii) *Gamma (¥) Diversity*- It is the overall diversity at landscape level and includes both α and β diversities.

$$¥ = \alpha + \beta + Q$$

Where,
Q= total no. of habitats or community
α = average value of α diversity
β = average value of β diversity

1.3 Loss of biodiversity

India is a vast country with varied types of soil and climate and topography, its geographical situation has made it a biological bonanza, although tree environment cannot be dealt with in isolation. There are 17 identified mega diversity countries in the world which encompasses 60-70% of all global biodiversity (Mittermeier and Mittermeier, 1997). India ranks 9th position in terms of plant diversity and endemism in these mega diversity countries.

Norman Myers identified ten tropical forest *hotspots* based on plant endemism and threat in 1988, and his method was later adopted by Conservation International (CI) in 1989. The method of selecting hotspot has been refined since then. *A terrestrial biodiversity hotspot* is now defined quantitatively as an area that has at least 0.5%, or 1,500 of the world's 300,00 species of green plants, and that has lost at least 70% of its primary vegetation. Today, Conservation International (CI) recognizes 34 hotspots (Mittermeier, *et al.,* 2005) including 9 new hotspots in the great range of Himalayas and the island nation of Japan (Holsinger, 2005). These hotspots covered 15.7% of the planet but already 86% of the hotspots have been destroyed and they now cover just 2.3% of the planet. The global biodiversity hotspots are as shown below:

I. AFRICA

1. Cape Floristic Region
2. Coastal Forests of E. Asia
3. Easter Afro-montane
4. Guinean forests of W.Asia
5. Horn Africa
6. Madagascar & Indian Ocean Island
7. Maputland-Pondoland Albany
8. Succalent Karoo

II. ASIA PACIFIC

9. East Malaysia Islands
10. Himalaya

11. Indo Burma
12. Japan
13. S.W China
14. New Caledonia
15. New Zealand
16. Philippines
17. Polynesia-Microlesia
18. SW Australia
19. Sunderland
20. Wallace
21. Western-Ghats and Sri Lanka

III. EUROPE/CENTRAL ASIA

22. Caucasus
23. Irano-Atlantalian
24. Mediteranean Basin
25. Mountain of Central Asia
26. California Floristic Province
27. Caribbean Island
28. Madrean Pine-Oak Woodland
29. Meso-america

IV. SOUTH AMERICA

30. Atlantic Forest
31. Verrado
32. Chilean Winter Rainfall-Valdivian Forests
33. Tumes-Choco-Magdalena
34. Tropical Ande

The loss of biological diversity is a global crisis. There is hardly any region on the Earth that is not facing ecological catastrophes. Of the 1.7 million species known to inhabit the earth, one fourth to one third is likely to extinct within the next few decades (Spellberg, 1991). According to Myers (1979), these exponential species extinction rates have increased dramatically in the last 50,000 years from one extinction per 1,000 years to about 1,000 extinctions per year and may reach 40,000 per year until the end of this century, so that one species will be lost every hour. Although habitat loss may be greatest threat to most species, overharvesting, non sustainable use, and the illegal trade in some species are threatening not only their continued survival but also that of ecosystems and the livelihoods of communities and local economics that depend upon them (Eldredge, 2002).

There has been a great of worry regarding the loss of biodiversity because it represents the potential source of wealth in the form of the loss of biodiversity. Current extinction rates caused by human activities are orders of magnitude higher than natural background levels. The over-exploration of ecosystems is evident at local to global scales with profound negative impacts on biological diversity and livelihood opportunities of the people. Habitat destruction, pollution, overpopulation and species introduction are the major causes of biodiversity loss (Singh, *et al.*, 2010). The loss of biological diversity is having impacts on the local rights of people along with their cultural diversity.

1.4 Concept of Forest:

There are numbers of definitions of the term "forest." These definitions were differs based on the emphases or concerns of different people. Forest is a dense growth of trees, together with other plants, covering a large area of land. The science concerned with the study, preservation, and management of forests is forestry. A forest is an ecosystem—a community of plants and animals interacting with one another and with the physical environment. The forests of the world are classified in three general types, or formations, which are primarily expressions of the climate in which the vegetation grows.

The value of forests to the world’s human population is becoming increasingly evident. The importance of their role in our planet’s functioning is clearly reflected in multilateral environmental agreements such as the United Nations Framework Convention on Climate Change and the Convention on Biological Diversity. Yet demographic, economic and social changes around the world continue to exert considerable pressure on forest cover and condition. Tropical forests, although covering less than 10% of the land area represent the largest terrestrial reservoir of biological diversity, from the gene to the habitat level.

Tropical forests suffer from rapid land use changes (Achard, *et al.,* 2002). Agricultural expansion, commercial logging, plantation development, mining, industry, urbanization and road building are all using deforestation in tropical regions (Geist and Lambin, 2002). Recent studies (Sala, *et al.,* 2000) have suggested that land use changes are likely to have a greater impact on biodiversity reduction than climate change, nitrogen deposition, biotic exchange or increased carbon dioxide concentrations. The extensive forest resources of northeastern India are under intensive exploitation for timber and conversation to agriculture (Mayaux, *et al.,* 2005).

The value of forests to the world's human population is becoming increasingly evident. The importance of their role in our planet's functioning is clearly reflected in multilateral environmental agreements such as the United Nations Framework Convention on Climate Change and the Convention on Biological Diversity. Yet demographic, economic and social changes around the world continue to exert considerable pressure on forest cover and condition. Tropical forests, although covering less than 10% of the land area represent the largest terrestrial reservoir of biological diversity, from the gene to the habitat level. For example, more than 50% of known plant species grow in tropical forests (*Ibid,* 2005).

Forest stratification simply refers to the different layers within the community. Sometimes the stratification is very complex where community possesses a number of vertical layers of species each made up of a characteristic growth form. It refers to the different layers of plants in a forest. In older, mature forests there are typically several distinct layers of vegetation spread out from the forest floor to the tree canopy. Young forests may not show clear separations between layers. Once the forest ages and trees grow to create a tall canopy, layering becomes visible. A very common usage for “layer” or “stratum” is to indicate a plant-life form group, for example, tree, shrub and herb layers (Hussain, *et al.*, 1994), or an age class, such as the tree, and seedling layers (Craig, 1993), that tend to exist at a characteristic height. Sometimes the relative coverage of these different forms is used described stands (Cain and Castro, 1959). The use of profile diagram has been continued by some, who argue that thoughtfully prepared illustrations are more valuable than random sampling, given the current poor knowledge of canopy structure (Kuiper, 1988). Though somewhat laborious, it has proved a valuable method of recording and comparing the structure of tropical forest communities. The nature of stratification of forest determines the microclimate of that area, which has pronounced effect on seed germinations and growth (Richardson, 1958).

1.4.1 Trees

Trees are nature’s master-pieces of creation. Trees according to pragmatic definition of a forester are perennial woody erect plants that reach a minimum height of 3 to 4 metres, have a well formed crown of foliage and attain a diameter of 7.5cm at 1.35 meters from ground level. A tree is born, it grows, and it dies (Chaudhuri, 1993).

Trees that constitute forests are of our amazing heritage that contributes to a large extent to the prosperity of a nation. Trees with a rough, coriaceous and sticky leaf surface collect soot and oil and reduce environmental pollution. When trees grow in association, a forest is born; an environment is created and thus a plant succession along with animal succession is initiated and in years they are in perfect balance with each other.

Trees have played an important role in the evolution of humanity; they are the greatest benefactors, friends, teachers and preceptors. Trees are lined up with our existence from cradle to grave. Trees have created our aesthetic sense and provided us with faculties for love, service, sacrifice and harmony. They are indispensable to human life and we must ensure their preservation. Trees belong to the basic elements of our World and have been present with man from his beginnings - trees powerful symbolic figures, ever personalities.

A forest is a highly complex community of trees, shrubs and ground plants, mammals, birds, insects and soil fauna dominated by trees which shield them all beneath them from the impact of sun, wind and rain. The trees may be evergreen, deciduous or both in mixtures.

Six important vegetation types of forest are found in the North Eastern Region harboring 80000 out of 15,000 species of flowering plants, 40 out of 54 species of gymnosperms, 500 out of 1012 species of Pteridophytes, 825 out of 1145 species of orchids, 80 out of 90 species of Rhododendrons, 60 out of 110 species of bamboo 25 out of 56 species of canes. All these species belong to about 200 plant families out of 315 recorded from North East India (Anon., 1990). Some of the families Nepanthaceae, Illiciaceae and Clethraceae are unique in the world. According to the Indian Red Data Book, 10 % of the total flowering plants are endangered. Of the 1500 species, 800 are reported from North East India.

1.4.2 Patterns of tree distribution

The forest Type of Lengteng Sanctuary is Montane sub tropical forest. A number of studies suggest that there are zones or belts of vegetation on tropical mountains in which there is elevation-related discontinuous variation in floristic composition or structure. With increase elevation, there is a change in trees present in the areas. The variation of climate such as rainfall pattern and temperature has a large influence on the distribution pattern of trees in an area.

The forest or vegetation covers of North-East India has been discussed by many eminent botanists and forest officers such as Hooker (1872-1897), Champion and Seth (1968), Singh, *et al.* (2002) classified the forests of Mizoram, based mainly on the altitude, rainfall and dominant species composition.

1.5 Concept of Protected Area

Protected area is a broad term given primarily to Biosphere Reserves, National Parks and Wildlife Sanctuaries meant for affording protection to wild animals and their habitat. They also include game reserves and biosphere reserves. Protected areas have been set up all over the world with specific aim of protecting and conserving animal plants.

A network of 668 Protected Areas (PAs) has been established, extending over 1,61,221.57 sq. km (4.90% of total geographic area), comprising 102 National Parks, 515 Wildlife Sanctuaries, 47 Conservation Reserves and 4 Community Reserves (http://www.moef.nic.in/downloads/public-information/protected-area-network.pdf).

Many protected areas have been created after the enactment of Wildlife Protection Act of 1972 (Anon., 1972). The state governments are empowered to constitute National Parks and Wildlife Sanctuaries. The Central Government has been armed with more powers under the forty-second constitutional amendment with regard to forests and wildlife. In Mizoram, the total protected area covers 1,241 sq. km which constitute 5.89% of the state's geographical area (Anon., 2011).

1.5.1 Biosphere Reserve

Biosphere Reserves are the major vegetation protected against disturbance, to act as a reference area for natural vegetation. Biosphere Reserves are areas of terrestrial and coastal ecosystems promoting solutions to reconcile the conservation of biodiversity with its sustainable use. Each Biosphere Reserve is intended to fulfill three basic functions: a) *Conservation function* - to contribute to the conservation of landscapes, ecosystems, species and genetic variation; b) *Development function* - to foster economic and human development which is socio-culturally and ecologically sustainable; c) *Logistic function* - to provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development. The management component consists of – a) Core zone, b) Buffer zone and c) Transitional zone

1.5.2 National Park

According to Wildlife Protection Act, 1972 (Anon., 1972), National Park means 'an area declared, whether under section 35 or section 38, deemed, under sub-section (3) of section 66, to be declared, as a National Park.

National Parks help in conservation of endangered species of animals, as well as plants. India's first national park (an IUCN category II protected area) was established in

1935 as *Hailey National Park*, now known as Jim Corbett National Park. There are 2 National Parks notified so far in Mizoram *viz*., Murlen National Park (100 km^2) and Phawngpui National Park (50 km^2).

1.5.3 Wildlife Sanctuary

According to Wildlife Protection Act, 1972, Sanctuary means 'an area declared, whether under section 1[26A] or section 38, deemed, under sub-section (3) of section 66, to be declared, as wildlife sanctuary' (Anon., 1972). There are over 500 wildlife sanctuaries in India of which 7 sanctuaries notified so far in Mizoram. Mizoram has two National Parks (Murlen National Park, 100 sq. km and Phawngpui National Park, 50 sq. km), seven wildlife sanctuaries (Nengpui Wildlife Sanctuary, 100 sq. km; Khawnglung Wildlife Sanctuary, 41 sq. km; Lengteng Wildlife Sanctuary, 60sq. km; Tawi Wildlife Sanctuary, 35.75 sq. km; Thorang Tlang Wildlife Sanctuary, 50 sq. km), and one Tiger Reserve (Dampa Tiger Reserve, 500sq. km.) covering 1,241 sq. km. which constitute 5.89% of the state's geographical area (Anon., 2011).

The Sanctuary declared under Section 18 of the Wildlife Protection Act, 1972 has an area with adequate ecological, faunal, floral, geomorphological, natural or zoological significance. For the purpose of protection, propagation or development of wildlife or its environment, certain rights of people living inside the Sanctuary could be permitted. Further, during the settlement of claims, before finally notifying the Sanctuary, the Collector may, in consultation with the Chief Wildlife Warden, allow the continuation of any right of any person in or over any land within the limits of the Sanctuary.

1.6 Scope and Objectives of the research

1.6.1 Scope of research

Of the ten protected areas in Mizoram, so far basic research work had been carried out in Tawi Wildlife Sanctuary (Lallawmkimi, 2010), Phawngpui National Park (Malsawmsanga, 2011), Murlen National Park (Lalramnghinglova, 2011) and Thorang Tlang Sanctuary (Lalbiaknunga, 2012). Proper scientific investigation has not yet been carried out in Lengteng Sanctuary. So this research can be used as the first information report, and it will help a great deal in wildlife management as well. Study of tree diversity within this area will aid in further identification, conservation and management of these trees and can be of great assistance in finding out their uses of timbers, fuel wood, fruit, fodder, many traditional and medicinal values.

1.6.2 Objectives

The research work is focused on the following objectives:

i) To assess the composition and distribution pattern of tree species.

ii) To analyze phytosociological characteristics of tree community.

iii) To document uses of timber, fuel-wood, fodder, charcoal, food, fruit and medicinal importance.

iv) To suggest conservation measures for better management of the sanctuary.

CHAPTER 2

REVIEW OF LITERATURE

The components of the forest structure include density, diameter size, and size distribution attributes, and the patterns of these relationships are multiple and gradient-dependent (Huang, *et al.*, 2003). The density-diameter (d-d) distribution of the stems has been used repeatedly to represent the population structure of the forests (Anon., 1978). The population structure of a species in a forest can convey its regeneration behavior (Saxena, *et al.*, 1984).

Assessment of the diversity and distribution of trees and shrubs in a disturbed plot in the Takamanda Rainforest was done by Ndah and his co-workers (Ndah, *et al.*, 2013). Studies on floristic diversity, dominance and abundance to frequency ratio of tree, sapling, seedling, shrub and herb species were studied in two different forest sites of a tropical foot hill region of Garhwal Himalaya and reveals that the distribution pattern of most the species on the site was contagiously distributed (Kumar and Bhatt, 2006). An extensive sampling was conducted for vegetational analysis in different forest sites between 1600 m and 2600 m a.s.l. in Kumaun Himalaya, the abundance-frequency ratio in the present study showed contagious distribution pattern in tree, shrub and herb species (Kharkwal and Singh, 2010).

The species may be distributed in clumped, uniform or randomly manner in the community. Contagious distribution is by far the most wide spread and it is due to small but significant variation in the environment while regular distribution occurs due to severe competition between the individuals (Odum, 1971). According to Kershaw (1973) regular distribution is most likely to occur where there is high density of individuals within the uniform area. In the natural forest stands contagious distribution also reflects magnitude of biotic interference such as grazing and lopping (Odum, 1971). The preponderance of contagious distribution of species in the communities has been reported by several workers (Greig-Smith, 1957; Kershaw, 1973; Singh and Yadav, 1974).

The floristic composition and distribution pattern of the different tree species with reference to density, IVI, diversity index and the structural characteristics of tree communities in a moist temperate forest study was conducted in Pithoragarh of Kumaun Himalayas along an elevation gradient of 1554-1969 m a.s.l. (Bhatt and Bankoti, 2016). Altitude is one of the major environmental variables influencing the distribution of tree taxa around the world, and can be a useful parameter for the development of conservation strategies (Rezende, *et al.*, 2015).

Altitude is an important factor that determines species composition and structure of plant communities. Diversity in the floristic pattern occurs due to altitudinal variation, and rainfall (Arora, 1995). The change in altitude is readily reflected in change in floristic composition and community setup (Sakya and Baina, 1998). The variation in plant diversity and species distribution may also be due to the differences in micro-environment condition Chandra (Chandra, *et al.*, 2010), Ellu and Obua (2005) have suggested that altitude and slope influence species richness and dispersion behavior of tree species.

2.1 Global level

The introduction of the term biodiversity is not new, which roses some twenty years ago (McNeely, *et al.* 1990), but the origins of the concept go far back in time. According to Magurran (2003) the earliest reference of biological diversity was attempted by Gerbilskii and Petrunkevitch (1955) in the context of inter-species variation in behavior and life history, and followed by Lovejoy (1980), Norse and Mac Manus (1980), Wilson (1988). Biodiversity hotspots are areas with a significant reservoir of endemics that is under threat from humans. The British biologist Norman Myers coined the term “biodiversity hotspot” as a bio-geographic region characterized both by exceptional levels of plants endemism and by serious levels of habitat loss (Myers, 1988).

Man has made remarkable advancements in many fields of science but when it comes to recording and scientifically describing different kinds of plants, animals and microorganisms, there remains much more explored and recorded than they are known. The known described number of species of all organisms on the earth is between 1.7 to 1.8 million, which is fewer than 15% of the actual number. Studies on plant diversity were conducted by Hubbell and Foster (1983, 1992) in Panama. The structure and tree species composition in sub-tropical dry forest in Dominican Republic has been studied and compared with a dry forest of Puerto Rico (Hare, *et al.*, 1997). Kumar, *et al.* (2006) have found out that trees forms the major structural and functional basis of tropical forest ecosystems and can serve as robust indicators of changes and stressors at landscape. Anthropogenic disturbance influences regional pattern of local diversity of trees (Stapanian, *et al.,* 1997).

Tropical forests comprise of 7% of the earth's land surface, but they contain more than half of the world's species. About 50% of the biological diversity of the rain forest is known to Science (McNeely, *et al.,* 1990). Scientists have said that about 7% of the land surface is covered with species and occurs in moist tropical forest which accounts for more than half of the species of earth. However many tropical forest are under great anthropogenic pressure and require management intervention to maintain the overall biodiversity, productivity and sustainability.

According to the IUCN Red List of Threatened Plants (Walter and Gillet, 1998), there are an estimated 2,70,000 known species of vascular plants, which include ferns, fern allies, gymnosperms (including conifers and cycads) and flowering plants. Of these species assessed, 33,798 species, or at least 12.5 per cent of all known vascular plants, are threatened with extinction on a global level. These plants are found in 369 families, and are scattered throughout 200 countries around the globe. Of these, 91 per cent are limited to a single country- which links their potential for extinction to national economic and social conditions.

The highest tree species richness in Amazon is reported from western portion where Gentry (1988) and Valencia, *et al.* (1994) recorded 283 and 307 species respectively. According to Proctor, *et al.* (1983) and Whitmore (1984), in tropical rainforests, the range of tree species count per ha is from about 20 to a maximum of 223. A phytosociological study was carried out in four 1-ha forest plots in the Sierra Maigualida region, Venezuelan Guayana (Zent and Zent, 2004). The structure of forest, composition and tree species diversity of eight plots in an environmental matrix of four altitudes on Mount Kinabalu, Borneo was studied by Aiba and Kitanya (1999). Studies on mixed coniferous-broadleaf forest in the Changbai Mountains, northeastern China shows that some of these species exhibited closely clustered distributions at fine distances. As spatial distance increased, a random or even regular distribution gradually appeared (Zhang, *et al.*, 2015), Study was conducted by Sobuj and Rahman (2011) in the Khadimnagor National Park of Bangladesh and 26 tree species were recorded.

2.2 National level

India is endowed with forest resources rich in diverse flora and fauna. The forest types vary from Tropical Rain Forest in north-eastern India. Western Ghats and Andaman and Nicobar Islands to Desert and Thorn Forests in Gujarat and Rajasthan, Rich mangrove Forests in West Bengal, Orissa, Andhra Pradesh and Andaman and Nicobar Islands to Dry Alpine Forests in Western Himalayas. India has approximately 7% of total mangrove forests of the world.

India is one of the richest countries in the world in terms of biodiversity. This natural variation in life is also reflected in the demography of the land. Although the causes behind biodiversity and demographic diversity are different, the human population of the land has depended on the biodiversity in many ways for a long time. At the same time, today, the excessive human population of India is leading to a survival pressure on biodiversity.

The vegetation and forest types of India were analyzed by Champion and Seth (1968). The country has over 1,15,000 species of plants and animals already identified and described, out of 45,000 species of the flora, 15,000 species are flowering plants, of which 33% are endemic and located in 26 endemics centers (Singh *et al.,* 2002).

The composition of vegetation along altitudinal gradient was studied in Khajjiar Wildlife Sanctuary in Chamba district, Himachal Pradesh (Verma and Kapoor, 2016). A total of 55 plant species comprising of five trees, 21 shrubs and 29 herb species have been recorded from Kinnaur District, Himachal Pradesh (Singh, *et al.,* 2016). Mathur and Joshi (2015) recorded 57 important tree species from Kumaun, Uttarakhand. A floristic survey was conducted in the Great Himalayan National Park (GHNP), Himachal Pradesh resulted in the addition of 66 species of Angiosperms belonging to 55 genera under 32 families (Singh, *et al.*, 2015). Floristic diversity of Shimla Water Catchment Sanctuary of Himachal Pradesh was carried out by Rana and Kapoor (2015).

Plants as the integrated part of an ecosystem and forms the basis of food directly or indirectly to the fauna of the ecosystem. The diversity of plants actually reflects the carrying capacity of the ecosystem. A total of 417 species comprising of 89 families were recorded from Tiruchirapalli forest, Tamil Nadu (Kumaraguru, *et al.*, 2016). The total forest cover of the country, as per 14th assessment made by Forest Survey of India is 701,673 sq. km which constitute 21.34% of geographical area of the country. Madhya Pradesh has largest forest cover (77,462 sq. km) in the country followed by Arunachal Pradesh (67,248 sq. km). Mizoram has the highest percentage of forest cover with 88.93% followed by Lakshadweep 84.56% of their total geographical area. The overall change in forest cover as compared to the previous assessment of 2013 results in increase of 3,775 sq. km (Anon., 2015). India has more than 1700 tree species of various sizes, crown shapes and forms. In India, the vegetation classification was first done by H. G. Champion in 1936 which is later modified by G. S. Puri and his co-workers in 1990 (Puri, *et al.*, 1990). The most acceptable classification of India vegetation to date is Champion and Seth's classification of the forest types of India, 1968.

Tree species richness, and composition and diversity of riparian forests across forest and agro-ecosystem landscape observed along the river Cauvery of southern India was studied by Sunil, *et al.*, (2016.) The more disturbed evergreen forest has low diversity compared to the less disturbed forests, and there are variations in the class structure in the more and less disturbed forests (Murthy, *et al.*, 2016) studies were also conducted by Ravindranath, *et al.* (2006) and Chaturvedi, *et al.* (2011) in this region. Research study on the impact of climate change on floral and faunal diversity was conducted by Kumar, *et al.* (2015) in Punjab. The illegal cutting and lopping of a few dominant species, grazing of understory plant species, the loss of ecological sites, habitat fragmentation, thinning of population etc., are responsible for the spatial and temporal variation in species diversity at local and regional scales (Swamy, *et al.*, 2000).

2.3 Northeastern level

The North-Eastern Region of the country comprising eight States namely, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura is endowed with rich forest resources. The region, which constitutes only 7.98% of the geographical area of the country, accounts for nearly fourth of its forest cover. Because of its biodiversity richness, the region has been identified as one of the 18 biodiversity hotspots of the world. One distinct feature of land use is the prevalence of shifting cultivation in hilly parts of almost all the States of this region. Shifting cultivation has traditionally been to socio-cultural life of tribal people.

The ecosystem varies from tropical wet evergreen, moist deciduous sub-alpine, alpine forest and grasslands to the swamps and marshy wetlands. A number of sacred groves have been reported from Meghalaya and Manipur. Takhtajan (1969) considered northeast India as "The *cradle of ancient angiosperms*" due to the presence of a large number of primitive and ancient flowering plant in the region. Phytosociological characteristics and diversity patterns of tropical forest tree species in Garo Hills, western Meghalaya, Northeast India was analyzed by Kumar, *et al.* (2006) for the purpose of forest managers in conservation planning of the tropical forest ecosystem of Northeast India.

Further studies on forest ecosystem of North East India were carried out by Rao and Verma (1982), Rao, *et al*. (1990), Mishra and Jeeva (2008), Reddy (2011). Deb, *et al.* (1987) studied tree diversity and population structure of Eastern Himalaya, India. Analysis of vegetation, soil and microbial biomass in Northeast India was studied by Deb, *et al*. (1987). Barik, *et al.* (1992) studied the species diversity in the sub-tropical forest of Meghalaya. The vegetation of Meghalaya has been classified by Kanjilal, *et al.* (1934-1940), Champion and Seth (1968), Haridasan and Rao (1985), Chauhan and Singh

(1992). In tropical forest lands, shifting cultivation or slash and burn agriculture is practiced widely that affects forest structure and species composition and subsequent abandonment results in the creation of mosaic forest patches of different ages (Ramakhrishnan, 1985).

As per the present assessment, the total forest cover in the region is 171,964 sq. km., which is 65.59% of its geographical area in comparison to the national forest cover of 21.34%. Very dense, moderately dense and open forests constitute 14.81%, 43.85% and 41.34% respectively. The current assessment shows an actual decrease of forest cover to the extent of 628 sq. km in the North-Eastern region. The main reason for this decrease is attributed to the biotic pressure and shifting cultivation in the region (Anon., 2015). Study the floristic diversity of *Dipterocarpus tuberculatus* dominated forest of Manipur situated along the Indo-Myanmar Border, north-eastern India was conducted and total of 123 species belonging to 48 families were recorded by Devi and Yadava (2006).

The ecosystem of Northeast India varies from tropical wet evergreen, moist deciduous sub-alpine, alpine forests and grasslands to the numerous freshwater lakes, rivers, swamps and marshy wetlands. A number of sacred groves have been reported from Meghalaya and Manipur States. Hattar *in* Kotwal & Benerjee (2002) has described the faunal wealth of N.E India. The region is also highly endemic, and the endemism is reported by Chaudhuri and Sarkar (2003). The previous studies have depicted that the forests of northeast India, especially sacred force forests are very rich in plant diversity, and mild disturbance supports maximum species richness (Mishra, *et al.*, 2004).

The northeast India is a treasure house of plant resources. Varied physiographic, climatic conditions mainly temperature and rainfall has resulted in a wide range of vegetation from tropical to alpine. This part of the country is an extension of the eastern

Himalayan complex and a hotspot of biodiversity. About 50% of the Indian flora is confined to this region only (Rao and Hajra, 1986). However, the rich biodiversity of India is under severe threat owing to habitat destruction (Agarwal, 2002).

The region is considered as the primary and secondary centers of origin and diversity of about 50 crop plants and about 190 wild relatives. Important crop plants originated in this zone include Citrus, banana and plantain, mango, rice and several species of legumes, cucurbits, orchids, bamboos and medicinal an aromatic plants (Anon., 2009).

2.4 Local Level

The geographical area of Mizoram is 21, 081 sq. km of which 88.93% is recorded to be forest cover of the state; 138 sq. km of very dense forest, 5,858 sq. km of moderately dense forest and 12,752 sq. km open forest (Anon., 2015). The State has 2 National Parks and 8 Wildlife Sanctuaries covering an area of 5.88% of the total geographical area of the state.

The existing literature indicates that the plant diversity of Mizoram is not adequately studied as compared to other states of North-East India. The first collection of Mizoram plants was made by Col. A.T. Gage in the year of 1899 and recorded 317 species including 26 species of Cryptogams. The plant collection of the state have been also made by some previous workers such as, Gage (1899), Kanjilal, *et al.* (1934-1940), Parry (1932) and recent workers include Sawmliana (2003), Lalramnghinglova (1997 and 2003), Singh, *et al.*(2002). Lalramnghinglova (1997) published a book, "Handbook of Common Trees of Mizoram" and carried out Ethno-botanically important plants in different forest area and published a book on, "Ethno-Medicinal Plants of Mizoram" in 2003. Sawmliana (2003) recorded about 966 plant species from Mizoram.

Lalramnghinglova (1997) and Lalnunmawia (2003) identified 20 species of bamboos Lalnuntluanga (2007) identified 12 species of canes from Mizoram. Lalramnghinglova and Lalchhuanawma (2010) published a book on Plants of Mizoram University Campus, Aizawl and Lalramnghinglova and Lalnunmawia (2011) edited a book on Forest Resources of Mizoram. Saithantluangi Zote recorded 202 orchid species of Mizoram (Zote, 2010) and Lalnuntluanga Vanchhawng recorded 52 species of Zingiberaceae in Mizoram (Vanchhawng, 2016).

Some species of edges and grasses were worked out for the state by some workers (Rao and Verma, 1982; Shukla 1995). Parry (1932) also made some collection between 1924 and 1929 from Lunglei district. Most of her collections were sent to Royal Botanical Garden, Kew and to Indian Botanic Garden, Calcutta. Fischer (1938) published "The Flora of the Lushai Hills". He recorded 1360 species, including 6 species of Gymnosperms and 155 species of Cryptogams. Singh, *et al.* (1990) recorded 244 species of orchids under 74 genera from the state (Singh, *et al.* 2002)

Studies on plant diversity of protected areas in Mizoram were done by some workers *viz.*, Lallawmkimi (2010), Malsawmsanga (2011), Lalbiaknunga (2012), Lalramnghinglova (2011).

CHAPTER 3

STUDY AREA

3.1 Brief background of Mizoram

Mizoram (land of the hill people) is located within the Indo–Burma biodiversity hotspot at the far end of the Himalayan mountain range. Roughly 91% of the area is under forest cover. It lies between 92°15' and 93°26'E longitude and 21°58' and 24°35'N latitude, with an altitudinal range of 2,100 – 2,157 m a.s.l. The climate of the area is moist tropical to sub–tropical. The temperature ranges between 20°and 30°C and between 7°and 18°C during summer and winter, respectively, and it receives an annual rainfall of 2,000 mm – 3,200 mm (Barbhuiya *et al.*, 2016). The state is characterized by hills with sparse to dense forest throughout. Mizoram shares international borders on three sides, with Myanmar in the East and South (*ca* 404km) and Bangladesh in the West *(ca* 306km). It is surrounded in the North by Cachar District of Assam, in the East- and South-East by Myanmar and the West by Chittagong Hill Tracts of Bangladesh **(Fig. 1)**

The State comprises of eight districts, namely- Aizawl, Champhai, Kolasib, Lawngtlai, Lunglei, Mamit, Saiha and Serchhip. In terms of geographical area, Lunglei District covers the largest area with 4,536 sq. km. While Kolasib district is the smallest with the area of 1.382 sq. Km. Aizawl, the capital city of Mizoram has an area of 3,575 sq. km. Mara Autonomous District Council lies within Saiha District, Lai and Chakma Autonomous District Council lies within Lawngtlai District having their respective jurisdiction. The total population of Mizoram according to 2011 census is 1,091,014 out of which 5,52,339 are male and 5,38,675 are female. The literary rate is 91.58% as per 2011 population census and statistic collected by Economics & Statistics Department, Government of Mizoram (Anon., 2011). The main occupation of the people is agriculture.

According to State Forest Report, The total geographical area of Mizoram is 21,081 sq. km in which 88.93% of the total geographical area is under forest cover, 138 sq. km of very dense forest, 5,858 sq. km of moderately dense forest and 12,752 sq. km open forest. There is a reduction of 306 sq. km of forest cover with respect to State Forest Report 2013 attributable to shifting cultivation and other biotic pressure on forest lands (Anon., 2015).

Table 1: Protected Areas of Mizoram

Sl. No.	Name of Protected Areas	Area in sq.km.	District	Notification No. & Date
1	Dampa Tiger Reserve	500	Mamit	No.B.11011/14/90-FST of 07.12.1994
2	Murlen National Park	100	Champhai	No.B.12012/5/99-FST of 24.01.2003
3	Phawngpui National Park	50	Lawngtlai	No.B.12011/5/91-FST o f22.07.1997
4	Ngengpui Wildlife Sanctuary	110	Lawngtlai	No.B.12012/4/91-FST of 22.07.1997
5	Khawnglung Wildlife Sanctuary	35.75	Lunglei	No.B.12012/10/96-FST of 12.10.2000
6	Lengteng Wildlife Sanctuary	60	Champhai	No.B.12012/15/94-FST of 31.05.2002
7	Tawi Wildlife Sanctuary	35	Aizawl	No.B.12012/1/91-FST of 16.11.2001
8	Thorangtlang Wildlife Sanctuary	50	Lunglei	No.B.12012/17/2001-FST of 23.04.2002
9	Pualreng Wildlife Sanctuary	50	Kolasib	No.B.12012/19/01-FST of 29.07.2004
10	Tokalo Wildlife Sanctuary	250	Saiha	No.MADC 68/E&F/2006-2007/63 of 01.10.2007
	TOTAL :	**1240.75**		**5.88% of the geographical area of the State**

Forest Types/ vegetation cover

The forest or vegetation cover of North-east India has been discussed by many eminent botanists and forest officers such as Hooker (1872-1897), Kanjilal, *et al.* (1934-40), Champion and Seth (1968), Rao and Panigrahi (1961). However, studies pertaining to forest types of Mizoram (Deb and Dutta, 1987; Singh, 1997; Lalramnghinglova and Jha, 1997) are scanty. Based on these fragmentary studies as well as from the observations and collections made in the field, Singh, *et al.* (2002) classified the forests of Mizoram into the following types:

1. Tropical Wet Evergreen Forest
2. Montane sub-tropical Forest
3. Temperate Forests
4. Bamboo Forests
5. Quercus Forests
6. Jhumland.

1. Tropical wet evergreen and semi-evergreen forests:

These forests usually occur below an altitude of 900 m and form one of the major forest types of the State with rich species diversity. Patches of these forests can be seen usually on the steep slopes, rocky and steady river banks and areas not suitable for shifting cultivation. The exact distinction between the evergreen and semi-evergreen forests is difficult as they occur in the areas of similar characteristics where rainfall averages between 2,000 mm - 2,500 mm annually and temperature varies between 20^{o}C to 22^{o}C. Tropical wet evergreen forests are met usually in southern and western part of Mizoram, while semi-evergreen forests occur in northern, north-western and central part of the State.

The tropical wet evergreen forests exhibit clear zonation or canopies consisting of a mixture of numerous species with dense and impenetrable herbaceous undergrowth.

Most of the species of the top canopy are evergreen trees with tall boles. Cauliflory is rather common. The middle and lower canopies are dense, evergreen and diverse. Epiphytes and parasites are few. Tree ferns, aroides, palms, ferns, orchids, bryophytes and lichens are fairly common. Lianas are frequent and conspicious, sedges and grasses are common in humid places or along the banks of rivers and rivulets. Species of *Musa* are also common along the streams on hilly slopes.

In exposed and drier areas, having a thin of soil, deciduous elements along with some evergreen trees are found. Sometimes these are grouped as distinct type, referred as tropical moist deciduous forests. The distinction between the tropical evergreen forests and tropical moist deciduous forests is difficult as they are found in the small hill ranges.

The third storey of canopy consists of smaller trees and shrubs with maximum floristic diversity.

2. **Montane sub-tropical forests:**

These forests are usually found between 900 m to 1,500 m altitude in the eastern fringes bordering Chin Hills of Myanmar, and places which are cooler and have less precipitation. Sub-tropical vegetation shows mixed pine forests. The common species of these forests are *Castanopsis purpurella Duabanga grandiflora, Myristica* spp.*, Phoebe goalparensis, Pinus kesiya, Podocarpus neriifolia, Prunus cerasoides, Quercus acutissima, Quercus semiserrata*, *Schima wallichii,* etc.

3. Temperate forests:

These forests usually occur above the elevation of 1,600 m in areas like Lengteng, Naunuarzo, Pharpak, Thaltlang, Phawngpui reserve forests and display impenetrable virgin primary forests. These forests are not typical temperate forests as found elsewhere in eastern Himalaya. The predominant arboreal elements in the forests are *Pinus kesiya, Actinodaphne microptera, Betula alnoides, Exbucklandia populnea, Elaeocarpus serratus, Dillenia pentagya, Michelia doltsopa, M. Champaca, Garcinia anomala, Schisandra neglecta, Photinia intergrifolia, Litsea salicifolia, Myrica esculenta, Lithocarpus dealbata, Rhododendron arboreum,* etc.

4. Bamboo forests:

Bamboos usually grow as an under-storey to the tree species in tropical evergreen and sub-tropical mixed-deciduous forests, whereas *Melocanna baccifera* forms dense or pure forests in certain areas in the State. Large tracts of bamboos are seen throughout Mizoram but their distribution is somewhat restricted to about 1,600 m and below. They occur mostly between 40 m and 1,520 m in tropical and sub-tropical areas. Few species occur in temperature areas in Blue Mountain and Mount Chalfilh. It appears that bamboos have resulted from jhumming system of cultivation (Deb and Dutta, 1987). For practicing jhum cultivation the forests are burnt and tree species are destroyed but the bamboo rhizomes throw out new culms as soon as favourable temperature and seasonal monsoon arrive. Therefore, in abandoned jhumland they are the first colonizer and grow rapidly. Some important associates found growing along with bamboos are *Emblica officinalis, Litsea monopetala, Pterospermum acerifolium, Terminalia myriocarpa, Caryota mitis, Artocartus chama, Duabanga grandiflora, Albizia procera, Gmelina arborea, Syzygium species* (Singh, *et al.*, 2002).

5. Quercus forests:

These forests are mostly found intermingled in sub-tropical and temperate areas. Pure patches or predominate *Quercus griffithiana* is present near Champhai-Biate hill ranges and its distribution is restricted to other small areas in the eastern part of Mizoram. *Lithocarpus dealbata* is other main species (Singh, *et al.*, 2002).

6. Jhumland:

Jhumlands are very common in Mizoram. They are classified variously as current jhumland, old jhumland and abandoned jhumland. Jhumlands are more prevalent in eastern Mizoram where extensive and intensive jhumming is practiced. Similarly, the areas in western side in Lunglei district towards Bangladesh have also Jhumlands.

3.2 Lengteng Wildlife Sanctuary

The area of Lengteng sanctuary is 60 sq. km. The word Lengteng is derived from Paihte. 'Leng' means, Cicada (Rengchal/Thereng) and 'Teng' means 'to dwell, to live or to exist' and so, the word 'Lengteng' may be defined as 'The place where cicada (Thereng) dwell or exsist'. In olden days in this particular plain area there used to live Rhinoceros and so it was called Samakzawl. There is another place called Naunuarzo tlang at the highest point of Lengteng Wildlife Sanctuary peak, this point is 2141 m also the second highest peaks next to Phawngpui Blue Mountain (2175 m) in Mizoram. In western part of Lengteng Wildlife Sanctuary, there is a wide cave called 'Vamur puk' (Swallow cave) since swallow birds can be sighted every time inside this cave.

3.2.1 Location: The sanctuary is located in the eastern part from Aizawl in Champhai district, 198 km from Aizawl taking Ngopa road (12 km from Ngopa village). It lies between 23^{o}42' N Latitude and 93^{o} 10'E Longitude.

3.2.2 Surrounding villages: The area is surrounded by seven (7) villages *viz.*, Ngopa, Kawlbem, Lamzawl, Selam, Lungphunlian, Pamchung and Tualcheng **(Fig. 2)**.

3.2.3 Notification: Lengteng wildlife sanctuary is notified under notification No.B.12012/15/94-FST on 3^{rd} May, 2002.

3.2.4 Description of the Boundary: The boundary of Lengteng Wildlife Sanctuary will be as follows:-

North: The north boundary starts from R.Chhimchhawnglui. It goes North Eastern direction up to the place called Kawrkhaikhuai and then goes upto the source of R. Pharsihlui it cross Diphulmual thence turn to southward to meet Hmunphal and proceed to the foot cliff of Naunuarzo.

East: From Nauzuar it goes upto R.Leiva. It follows R. Leiva up hill upto the point where Samaklui (stream) meets R Leiva. It then follows Samaklui upstream till the point where Pharlui (stream) meets Samaklui. It then goes upto the source of Pharlui and then crossing the saddle (Tlangkhan) upto the river called Zoluipui. It follows R. Zoluipui downstream meeting Pu Rochhunga road and it follows Pu Rochhunga road till it crosses R.Ailianlui. It follows R.Ailianlui downstream till it meets R.Dimphailui.

South: It then follows R.Dimphailui up streams upto its main source and then it goes upto the addle (Khankawn). From the saddle it goes to the source of R.Zamuanglui and it follows R.Zamuanglui streams. From R.Zamuanglui before reaching R.Tuimailui it goes along the foot hills towards North through Sasawbawk kawn upto Ngalhih. Then it crosses the exstream source of R.Zawngeklui meeting to Bawktlang kawn along Phunchawngzawl and then upto the source of Thingkhuanglui.

West: From the source of R.Thingkhuailui it goes towards North along the foothills of Lengteng cliff till it meets R.Tuiluailui. From R.Tuiluailui it goes along the foothills of Lengteng cliff till Leiawngkawn and then upto Chhimchhawnglui the starting point of North Boundary.

3.2.5 Forest vegetation (Fig. 3)

The forest types include Sub-Montane forests, Tropical Evergreen and Semi-evergreen forest. The major species include *Quercus spp, Schima wallichi, Michelia champaca, Rodhodendron spp., Artocarpus spp., Tetrameles nudiflora, Toona ciliata, Gmelina arborea, Callophyllum polyantum, Dysoxylum alliaria, etc.*

3.2.6 Climate

Mizoram enjoys a moderate climate owing to its tropical location. It is neither very hot nor too cold throughout the year. The region falls under the direct influence of the south-west monsoon. As such, the region receives an adequate amount of rainfall. The climate is humid tropical, characterized by long summer with heavy rainfall. Temperature falls between 20 ^{o}C-28 ^{o}C during summer and 10 ^{o}C -20 ^{o}C during winter season, rainfall covers 2000 mm-3000 mm per annum.

3.2.7 Drainage system

The drainage pattern is virtually shaped by its physiography and the geological structures. The rivers and streams within this area are- R.Chhimchhawnglui, R.Pharsihlui, R.Leiva, Samaklui (stream), Pharlui (stream), R.Zoluipui, R.Ailianlui, R.Dimphailui, R.Zamuanglui, R.Tuimailui, R.Zawngeklui , R.Thingkhuanglui, R.Tuiluailui.

3.2.8 Rainfall:

An automatic rain gauge was set up at Kawlbem village. It is an instrument used to gather and measure the amount of precipitation over a set period of time. The recording chart on an autographic rain gauge is mounted on a drum which is driven by clockwork and typically rotates round a vertical axis once per day. The rainwater in a collector displaces a float so that a marking pen attached to the float makes a continuous trace on a graph paper.

Rainfall data was recorded for three years (2013-2015). A School teacher named Mr Laldingliana was entrusted to take year-wise rainfall data, for which the technique of handling and recording the rainfall was taken in a Rainfall Diary.

3.2.9 Management of the sanctuary

Lengteng Sanctuary is under the management of Divisional Forest Officer, Khawzawl in Champhai district. A Ranger's headquarters was set up at Lamzawl to look after the Sanctuary.As per mentioned earlier,there are seven villages in the vicinity of the sanctuary *viz.* Lamzawl, Ngopa, Kawlbem, Selam, Lungphunlian, Tualcheng and Pamchung. From these villages, Beat Officer, Forest Guard and Wildlife Guard were located to take care of this area.

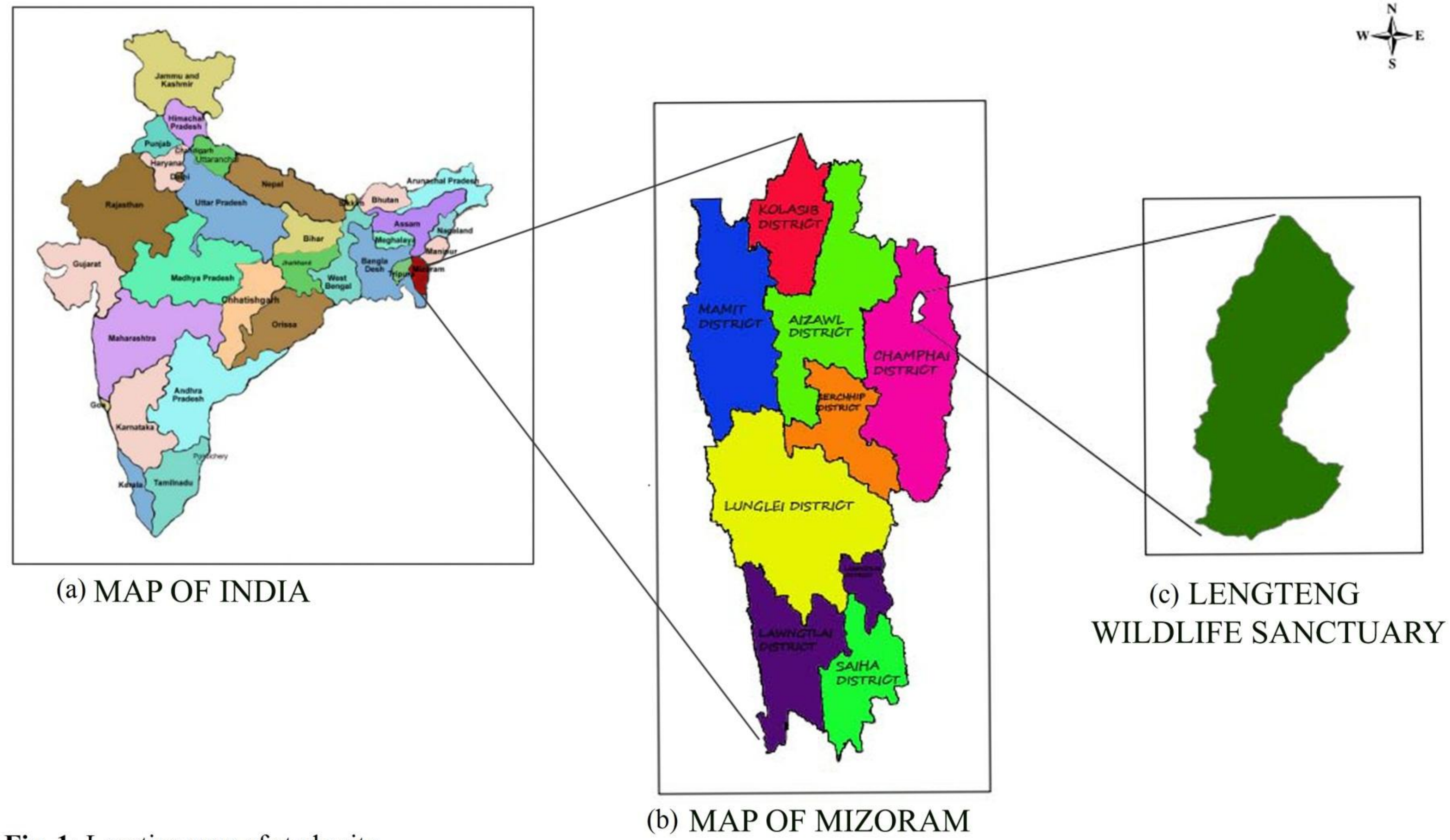


Fig. 1: Location map of study site.

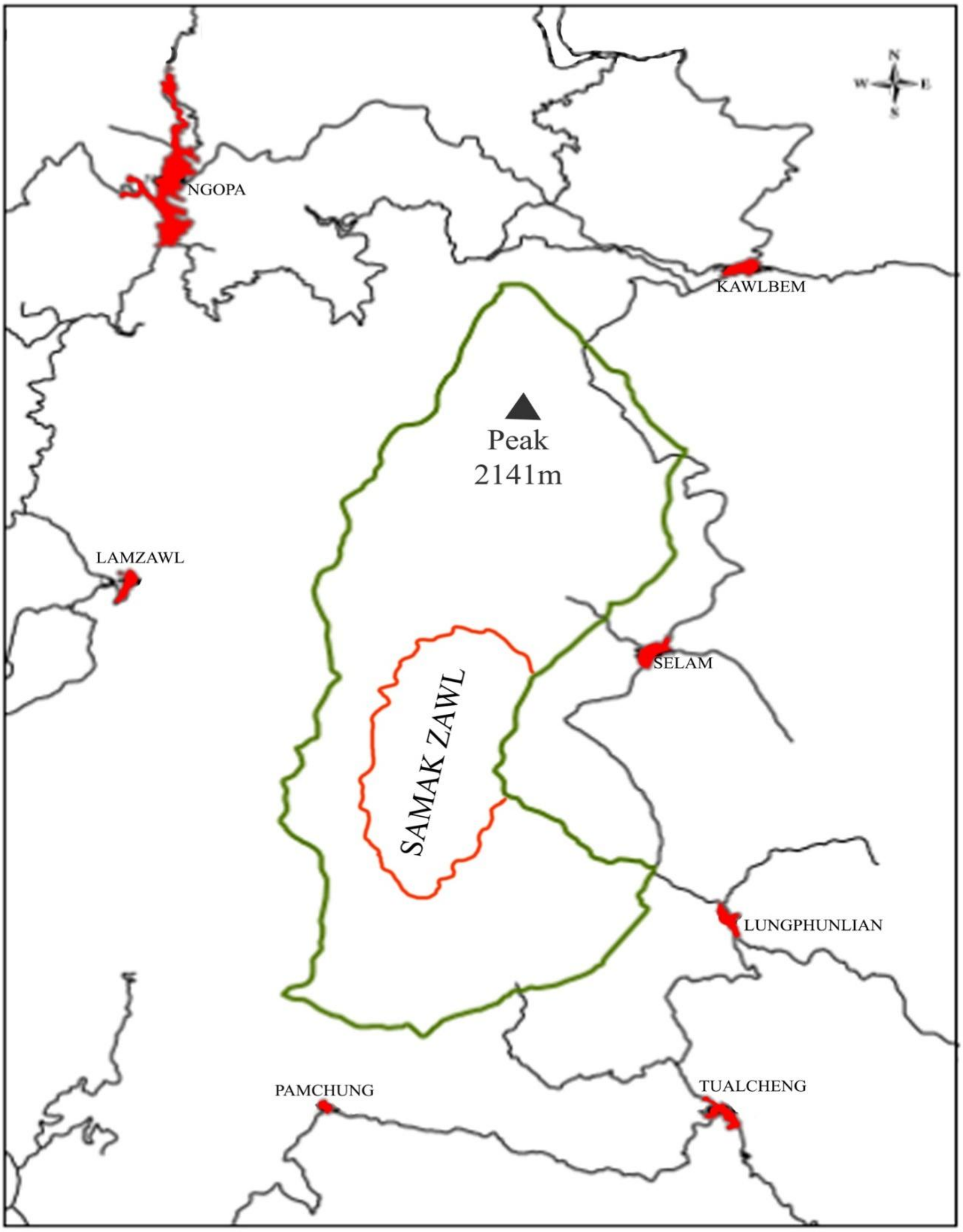


Fig. 2: Map of Lengteng Wildlife Sanctuary and its surrounding villages

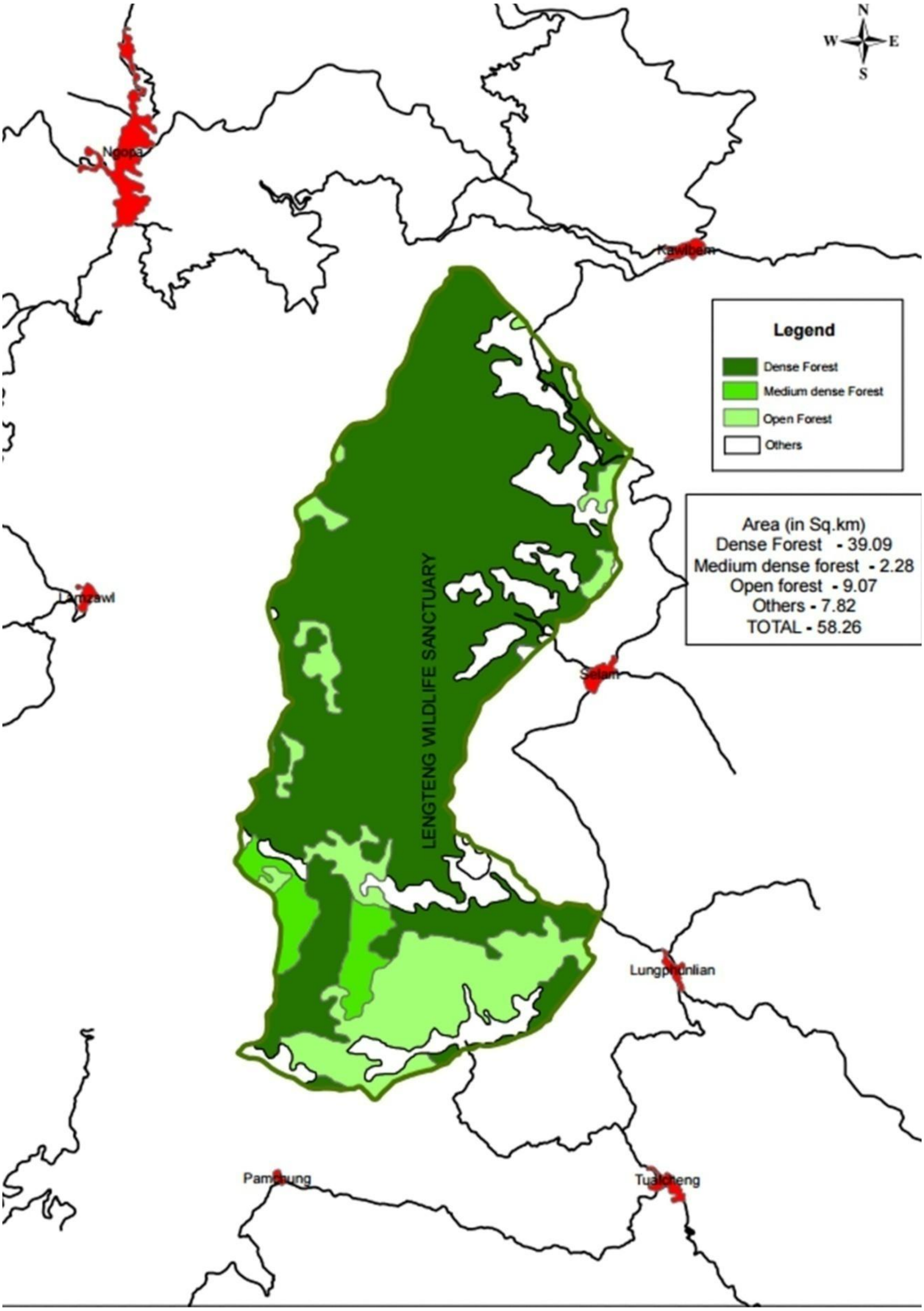


Fig. 3: Map of forest density cover of Lengteng Wildlife Sanctuary.

CHAPTER 4

METHODOLOGY

The following methodologies were employed in the present study.

4.1 Survey of the study area

Preliminary survey of the area was done during 2013 to study its climate, landscape pattern and topographic features and demarcate the area into different region. ***viz***..Site-1, Site-2 and Site-3 respectively with corresponding altitudinal levels. Site-1 has the lowest region (1500 m.a.s.l to 1700 m.a.s.l.) the middle region, Site-2 lies between 1700 m.a.s.l. to 1900 m.a.s.l. Site-3 is the uppermost region ranging from 1900 m to the highest peak which is 2141 m.a.s.l.

4.2 Random systematic sampling methods

As indicated above, the study area was divided into three sites ***viz.,*** Site-1, Site-2 and Site-3 respectively at different altitudes by diving the area into six transect belts of 1ha size each. Inside each transect belt, five quadrates of 20 m x 50 m. In each quadrats laid down, another five quadrats of 10 m x 10 m were selected randomly (Fig. 4)

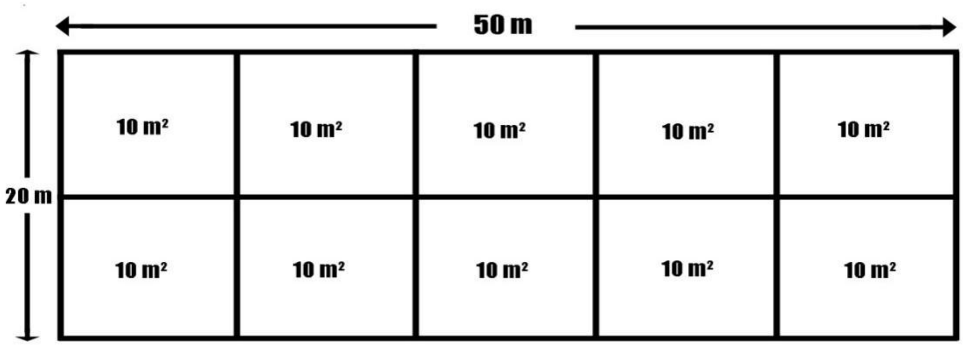


Fig 4: Quadrat layout

4.3 Vegetation Analysis

Vegetation analysis was done during 2013 and 2014. Plant species present in each quadrats were counted, measured and recorded. Girth was measured at breast height (DBH 1.3 m) using a girth tape. In the case of buttressed trees, the measurements were made above the buttress.

4.3.1 Phytosociological analysis of tree species:

The field data collected was taken into consideration for determining quantitative analysis such as frequency, density and abundance of tree species as per Curtis and McIntosh (1950). The formula for computing frequency, density and abundance were given below:

a) Frequency (%): It refers to the degree of dispersion of individual species in an area and expressed in terms of percentage. It was studies by sampling the study area randomly at several places and recording the name of the species that occured in each sampling unit or quadrat, it is calculated by the equation.

$$\textit{Frequency (\%)} = \frac{\text{No. of quadrates in which the species occur}}{\text{Total no. of quadrates studied}}$$

b) **Density** (trees/saplings/poles-^{1}ha): Density is the numerical strength of a species where the total number of individuals of each species in all the quadrats is divided by the total number of quadrats studied. It is calculated by the equation.

$$\textit{Density} = \frac{\text{Total no. of individuals of the species in all the quadrates}}{\text{Total no. of quadrates studied}}$$

c) Dominance (m^2 ha^{-1}): It is the total basal area of species per hectare.

$$Dominance = \frac{\text{Basal cover of the species}}{\text{Total based cover of all the species}}$$

d) Abundance: Abundance is the study of the number of individuals of different species in which the number of individuals of each species was summed up for all the quadrats divided by the total number of quadrats in which the species occurred. It is represented by the equations:

$$\text{Abundance} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats in which the species occured}}$$

4.3.2. Importance Value Index (IVI)

All the tree species recorded were used for calculating dominance of a species. In order to express the dominance and ecological success of any species, with a single value the concept of Imporance Value Index was used. The index utilized three characters *viz.* relative frequency, relative density and relative dominance (Misra, 1968). The importance value index is defined as 'the sum of relative dominance, relative density and relative frequency of a species' (Mueller-Dombois and Ellenberg, 1974).

e) Relative Density (%): It is the study of numerical strength of a species in relation to the total number of individuals of all species. Relative density is calculated as:

$$Relative\ Density\ (\%) = \frac{\text{Density of a species}}{\text{Total no.of density of all species}} \text{X } 100$$

f) **Relative Frequency (%):** It is the degree of dispersion o individual species in an area in relation to the number of all the species occurred. Relative frequency is calculated as follows:

$$\textit{Relative Frequency (\%)} = \frac{\text{Frequency of a species}}{\text{Total no.of all species}} \text{X100}$$

g) **Relative Dominance (%):** Dominance of a species is determined by the value of the basal cover. Relative dominance is the coverage value of a species with respect to the sum of coverage of the rest of the species in the area. Relative dominance is calculated using the formula:

$$\textit{Relative Dominance (\%)} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all species}} \text{X100}$$

Basal area = $\pi r^2 D$

Where, r = Radius

D= Density

The IVI was computed by using the formula given by Phillips (1959) as follows:

IVI = Relative Frequency + Relative Density + Relative Dominance

4.4 Analysis of tree diversity:

The study of diversity of plants of the sanctuary was done by using the following diversity indices:

a) **Shannon-Wiener (Shannon-Wiener, 1963) diversity Index (H'):** One of the most commonly used measures of species diversity is the Shannon- Wiener diversity index. It combines two quantifiable measures; (1) the species richness (the number of species in the community), and (2) species equitability (how even are the numbers of individuals of each species). The higher the number, the higher is the species diversity. The Shannon- Wiener index for diversity was calculated using the formula:

$$H' = -\sum (ni/N)\ln(ni/N)$$

Where, N = the total abundance

ni = abundance of the i^{th}species

b) Margalef's Diversity Index (D_{Mg}) – This index is given by Clifford and Stephenson in 1975 (Clifford and Stephenson, 1975), the equation is given as follows;

$$D_{Mg} = (S-1)/\ln N$$

Where, S = number of species recorded

N = total number of individuals

Ln = natural logarithm

c) Simpson (Simpson, 1949) Index of Dominance (D): The Simpson index is a dominance index because it gives more weight to common or dominant species. In this case, a few rare species with only a few representatives will not affect the diversity. This index will be calculated using the following formula:

$$D = \sum ni(ni-1)/N(N-1)$$

Where, ni = no. of individuals of the i^{th} species

N= total no. of individuals

d) Evenness Index (Pielou's index, 1969)

The equation is as follows:

$$\mathbf{J'} = H'/H_{max} \text{ or } J' = H'/LnS$$

Where, H' = Shannon's index value

S =Total Number of species

H_{max} = Maximum diversity

e) Sorensen's index of similarity:

Indices of similarity were calculated by using formulae as per Misra (1968) and Sorensen (1948) as follows:

$$S = \frac{C}{\frac{1}{2}(A+B)}$$

Where,

A = number of species at Site-A

B = number of species at Site-B

C = number of species common to two sites *i.e.*, Site-A and Site-B

4.5 Characterization of tree distribution pattern:

The distribution pattern of trees species in the area were studied based on the following parameters.

4.5.1 Change of vegetation according to altitudinal variations in different aspects:

The distribution of vegetation tends to change based on the altitudinal variation, rainfall pattern and other climatic factors. The change of vegetation also depends on the pattern of landscape. The members of vegetation of each group having a similar function in a community as a whole and similar relationship to their physical and biotic environment. Pattern of tree distribution in different altitudinal variations and aspects were recorded.

4.5.2 Abundance frequency ratio (A/F)

The spatial distribution of trees was determined following Whitford (1949).

WI = abundance/frequency (A/F Ratio). This ratio has indicated regular (<0.025), random (0.025-0.05) and contagious (>0.05) distribution patterns (Whitford, 1949).

4.5.3 Density-diameter distribution pattern

The height, size and density of trees maybe different at different locations were estimated with the help of measuring their girth (diameter breast height) at 1.3 m. Different trees were separated into different DBH classes of saplings, poles and trees [<10 cm (saplings), 10-30 cm (Poles), 31-50 cm, 51-70 cm, 71-90cm, >90cm (Trees)] (Whitford,1949; Curtis and Cottam, 1956; Sukumar, *et al.*,1992).

4.6 Canopy stratification:

Forest stratification simply refers to the different layers within the community. Sometimes the stratification is very complex where community possesses a number of vertical layers of species each made up of a characteristic growth form. A size of 1 m x 100 m was plotted at various distributional pattern and/or aspects to study the stratification. A graph was plotted against the stratification.

4.7 Taxonomic analysis:

The plant specimens collected during the research work were identified with the help of various regional floras upto family, genera and species.

4.8 PRA techniques for uses of tree species:

Participatory Rural Appraisal (PRA) is a methodology for interacting with villagers, understanding them and learning from them. It involves a set of principles, a process of communication and a menu of methods for seeking villagers' participation in putting forward their points of view about issue and enabling them to do their own analysis with the view to make use of such learning (Mukherjee, 2003).

Information for use of timber, fuel-wood, charcoal, food, fruit, and medicinal uses through personal interview from women, men and children from the surrounding villages were collected by using Participatory Rural Appraisal technique. A PRA technique is a useful methodology to focus attention on people, their livelihoods and their inter-relationship with socio-economic and ecological factors (*Ibid.*, 2003). The PRA techniques adopted in the present study is personal interview. During 2014-2015, the president and members of village council, leaders of the Young Mizo Association, and several local people of the adjacent villages of the study area were interviewed to know about the socio-economic conditions of their respective villagers.

4.9 Herbarium

A herbarium is a store-house of plant specimens collected from far and wide, mounted on appropriate sheets, arranged according to some known system of classification, and kept in pigeon-holes of steel or wooden cupboards, usually specially designed for the purpose (Jain and Rao, 1977; Lalramnghinglova, 2016).

It is a collection of dried plants specimens mounted on a standard sheet of paper, identified by experts and labeled by their proper scientific name, together with other information. These specimens are filled in case according to families, genera and species, available for ready reference. The plant materials collected in the field are spread flat in old newspapers or white or grey sheet, and sun-dried in plant press between the blotters or absorbers. The dried specimens are mounted on a white board and labeled with essential data such as collection no., date, locality, distribution, altitude, habit and habitat, and placed in a specially designed herbarium storage system.

4.9.1 Methods of plant collection

There are various types of plant collections or field collection or field trip. Different methodologies are briefly given:

1) A herbarium specimen or botanical specimen is a whole plant or plants, or portion of a plant with roots, stem, leaves, and flowers and if possible, fruits, depending upon the size or form of plants.
2) If the plants are shrubs or trees, reproductive twigs with leaves (at least 9" long) were collected and pressed flat and fitted onto a white mounting board (28 cm x 42 cm).
3) Each specimen is entered and recorded in the field note book with its morphological characters.
4) The specimens were pressed flat and sun-dried. Three to four numbers of twigs of the same species were collected with an identical field numbers tagged in each specimens.
5) The duplicates (replicates) were kept for identification purpose and herbarium specimens and necessary loaning.

4.9.2 Field notebook / Field diary

Early botanists recorded only scanty data or no data at all along with the collections. Modern botanists keep records of plants in the field notebook. Filed notebooks may be of different sizes and designs in which collector's name, collection number, place of collection, date of collection and features of the plant not shown by the dried specimens are recorded.

Professional collectors usually use a printed field notebook in which space is provided for the information to be recorded. The parameters given in the field book may vary from one herbarium to the other according to the choice of the collectors or botanists.

4.9.4 Chemical preservatives

Avoidance of fungal or bacteria decay in the specimens is the objectives of the collection. The effective preservatives such as formaldehyde (H_2CO) Ethyl alcohol (C_2H_2OH) and Paraformaldehyde (H.CHO) for preservation of plant specimens.

4.9.5 Poisoning of specimens

Specimen poisoning was done by dipping the dried materials into **Kew Mixture** (115g of Mercuric Chloride $HgCl_2$ dissolved in 4.5L of ethyl alcohol or rectified spirit or methylated spirit) are used against the attack of pests and insects.

4.9.6 Mounting

Mounting is the process whereby the specimen and accompanying labels are attached permanently to a sheet of paper (mounting board) for permanent filling in the herbarium (Womerseley, 1981) It is perhaps the most costly operation in a herbarium order than the basic one of collection of the specimens. It should be fair quick-drying. Attachment of the specimens to the card or board can be achieved by several methods, of which were done with the help of Fevicol and stiching of recalcicant twigs of plants.

4.9.7 Labelling

Labels (12 cm x 9 cm) are pasted on the lower right-hand corner of the voucher specimens. The labels contained the following data.

i. Collection No. and Date
ii. Name of the family
iii. Name of the genus
iv. Name of the species
v. Locality
vi. Notes
vii. Collector’s name and number.

4.9.8 Plant identification

The mounted specimens processed in the laboratory were identified with the help of regional floras, references and journals including the books of “Flora of British India Vol. 1-7” (Hooker 1892-1897), “Flora of Assam” Vol. 1-5 (Kanjilal, *et al.* 1934-1940), “Flora of Mizoram Vol. 1” (Singh *et al.,* 2002), “A handbook of common trees of Mizoram” (Lalramnghinglova, 1997), “Ethno medicinal plants of Mizoram” (Lalramnghinglova, 2003) and Book of Mizoram plants” (Sawmliana, 2003). Unidentified specimens were taken to Botanical Survey of India, Eastern circle, Shillong and Central National Herbarium, Botanical Garden, Howrah, Kolkata for proper identification and matching of the specimens. Identified specimens were deposited in the Herbarium of Mizoram University, Aizawl.

4.10 Analysis of data

All the data collected were analyzed statistically and represented using Microsoft EXCEL 2010. With the help of MS Excel, all the necessary calculations were done using MS Excel.

CHAPTER 5

RESULTS AND DISCUSSION

5.1. Tree species composition

Statistical analysis shows that a total of 127 tree species belonging to 89 genera and 52 families were recorded from the study area. Most of the tree species (13) belong to the family of Fagaceae followed by Lauraceae (11 species), Moraceae (6 species), Fabaceae and Verbenaceae and Rosaceae (5 species each). The total numbers of 25 families were recorded represented by single genera with a single species **(Table 2, Fig. 5).**

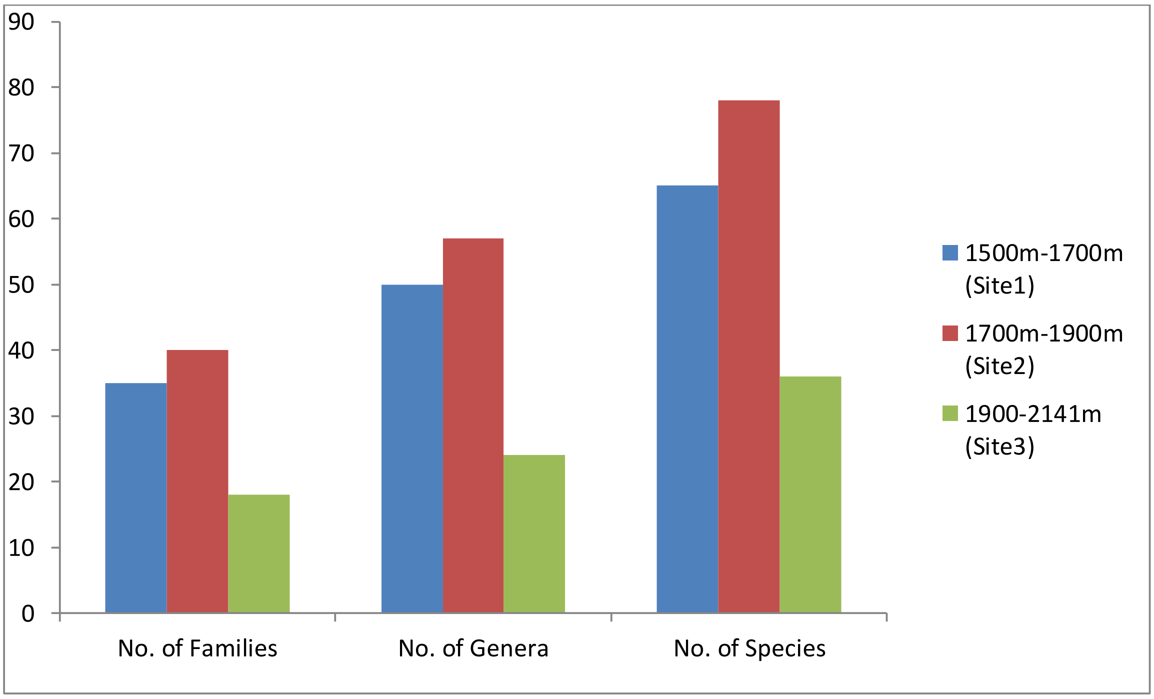


Fig. 5: Comparison for number of Families, Genera and Species from the three study sites.

From **Site-1** (1500 m.a.s.l.-1700 m.a.s.l.), 65 tree species were recorded from 50 genus belonging to 35 families. Most of the tree species belong to Fagaceae (7 species), Lauraceae contribute 5 species; Fabaceae, Euphorbiaceae, Phyllanthaceae, Rosaceae, Theaceae, Tiliaceae contribute 3 species each. Anacardiaceae, Asteraceae, Ebenaceae, Elaeocarpaceae, Moraceae, Oleaceae, Proteaceae and Verbenaceae contribute 2 species each. There are 19 families contributing a single species each. **(Table 3a)**.

In **Site-2**, (1700 m.a.s.l - 1900 m.a.s.l.), 78 tree species were recorded from 58 genera belonging to 40 families. Highest number of tree species were recorded from Fagaceae (9 species), followed by Lauraceae (7 species). (**Table 3b)**

From **Site-3**, (1900 m.a.s.l - 2141 m.a.s.l) 36 tree species were recorded from 24 genera belonging to 18 families. Ten species were recorded from Lauraceae, followed by Fagaceae (7 species) while Ericaceae, Myrtaceae and Theaceae contribute 2 species each; and one species each from Caesalpinoidae, Cornaceae, Ebenaceae, Juglandaceae, Meliaceae, Moraceae, Phyllanthaceae, Pittosporaceae, Podocerpaceae, Proteaceae and Urticaceae respectively **(Table 3c).**

Total of 2096 individual tree species were recorded from **Site-1**, basal area cover measures 54.71 m^2 ha^{-1}. The basal area ranged from 0.0002-11.51 m^2 ha^{-1} for different species in the study area. Trees cover 27.21 m^2 (49.73% of the total basal cover) of the study area, where as saplings cover 2.6 m^2 (4.76% of the total basal cover) and 24.89 m^2 (45.5% of the total basal cover) respectively. The highest basal area of 11.51 m^2 ha^{-1} was observed with *Schima wallichi* Choisy (11.11 m^2 ha^{-1}), closely followed by *Quercus spicata* Sm The lowest basal area of 0.0001 m^2 ha^{-1} was noted with *Celtis timorensis* Span. **(Table 4a).**

Total basal area cover for Site-2 is 1007.38 m^2 ha^{-1}. Trees cover the area of 992.79 m^2 ha^{-1} (98.55% of the total basal cover), saplings cover 1.22 m^2 ha^{-1}(0.12%) and poles 13.37 m^2 ha^{-1} (1.33%). The highest basal area of 297.92 m^2 ha^{-1} was observed with *Dysoxylum mollissimum* Blume, the lowest basal area of 0.00064 cm^2 ha^{-1} was noted with *Messua ferrae* Linn. Total number of individuals recorded is 1778. **(Table 4b)**

Total basal area cover for Site-3 is 54.77 m^2 ha^{-1}. Saplings cover 0.63 m^2 ha^{-1} (1.14%), poles 7.77 m^2 ha^{-1} (14.19 %) and trees 46.37 m^2 ha^{-1} (84.66%) of the total basal cover. Lowest basal area cover of 0.003 m^2 ha^{-1} was recorded for *Syzygium claviflorum* Roxb. The highest basal area of 7.54 m^2 ha^{-1} was observed with *Pitosporum floribundum* followed by *Phoebe angustifolia* Meisn. (6.4 $m^2 ha^{-1}$) **(Table 4c).**

The results of present study is lower than record of 917 species from seasonally dry tropical forest (Trejo and Dirzo, 2002), 660 species in a 50 ha plot of Pasoh forest reserve, Malaysia (Kochummen, *et al.* 1990), 229 species in a 50 ha Barro Colorado Island, Panama (Condit, *et al.* 1996); 153 species in a 30 ha plot at Varagalaiar, Anamalais, Western Ghat, India (Ayyapan and Parthasarathy 2001), 164 species in a 25 ha plot of Sinharaja Biosphere reserve, Sri Lanka (Condit, *et al.*, 2000). It is higher than 71 species reported from Namdapha National Park, North east India (Nath, *et al.*,2005), 123 woody species in 1ha area of the two sacred grooves in Meghalaya, northeast India (Upadhaya, *et al.*, 2002).

Tropical forests are structurally complex plant communities (Condit, *et al.*, 1996). In the tropical rainforest, tree species count per hectare ranged about 20 – 223 (Whitmore, 1984). In a word, the altitudinal gradient is an important factor affecting species composition and structure (Whittaker, 1972). With the altitude increasing, needle-leaf trees replace broad-leaf trees and become dominant tree in communities, the number of shrubs under trees declines and finally disappears, and the durable-shade herbs appear (Gao, *et al.*, 2006). The changes in species composition among the forests may be due to altitude and edaphic factors. The altitudinal variation might be due to variation in temperature, relative humidity, radiation values, wind movements and edaphic factors (Nakashizuka, *et al.*, 1992), but the variation in species composition along an altitude is very difficult to explain (Proctor, *et al.*, 1988).

Information on the species composition of a forest is essential for its wise management in terms of economic value, regeneration potential (Wyatt-Smith, 1987) and ultimately may be leading to conservation of biological diversity (Verma, *et al.*, 1999). Natural regeneration potential is an important indicator for any forest ecosystems.

Tree density was recorded to be 464 trees ha^{-1} and basal area was 426.21 m^2ha^{-1}in Sal dominated forest; and 336 trees ha^{-1} and 11.42 m^2ha^{-1} in *Schima* dominated forest (Majumdar, 2012). Basal area is recorded to be 104.60 m^2ha^{-1}, 51.75 m^2ha^{-1} and 18.60 43.23 m^2ha^{-1} for disturbed, mildly disturbed and highly disturbed forest respectively in wet evergreen forest in Arunachal Pradesh, Eastern Himalayas, India (Bhuyan, 2003). The above mentioned record were higher than the present study record of Site-3 and lower than Site-2 and Site-3.28.350 m^2ha^{-1} , 67.400 m^2ha^{-1} , 64.260 m^2ha^{-1} for low-elevation forests, evergreen forest and high-elevation forest respectively in tropical forest in Tamil Nadu, India (Swamy, *et al.*, 2000).

5.2 Quantitative analysis of plant species

5.2.1 Shannon-Wiener diversity index of plant species in the study area

Shannon diversity index was calculated on the basis of the important values. The diversity (H') was highest in middle altitude (Site-2) with a value of 3.13 and lowest in the higher altitude (2.56) **(Table 5a, Fig. 6a)**.

Generally, measurement of biodiversity typically concentrates on the species level and species diversity is one of the most important indices which are used for the evaluation of ecosystems at different scales (Ardakani, 2004). The diversity index is generally higher in the tropical forests, where it has been reported to vary between 3.6 and 5.40 for tree species (Knight, 1975). A rich ecosystem with high species diversity has a large value of H’, while an ecosystem with little diversity has a low H’. In the study site, Shannon-Wiener diversity index range from 2.56 - 3.16. The values reported in present study are quite high compare to 2.20–2.65 for the tropical forests of Kodayar in the Western Ghats of southern India (Sundarapandian and Swamy, 2000). It is lower than values reported from the evergreen forest of Western Ghats, Pascal (1988) who has reported values ranging from 3.2 – 4.8. More comparable values were reported from Sitapahar natural forest of Chittagong (South) forest division of Bangladesh with diversity value of 2.98 (Nath and Alam., 2000), in Khadimnagar National Park the value is 7.76 (Sobuj and Rahman, 2011), a diversity value ranging from 2.9 to 3.36 is reported by Malsawmsanga (2011) from Phawngpui National Park.

As elevation increases, the isolation of slopes from pathways of migration increases linearly. With a reduction in the channels available for immigration, there is a reduction in the number of species that occupy high elevation sites. Human activities, such as changes in land-use, have a long lasting and direct impact on species richness in mountain environments. A study conducted by Curtin (1995) in southwest Colorado demonstrated that species diversity in the subalpine at elevations between 3000 m - 3200 m could be affected by human land use up to 110 years after the departure of the inhabitants. This study also showed that plant communities in high elevations are very sensitive to human disturbance.

5.2.2 Margalef's index of species richness:

The species richness of the study area was calculated by using Margalef's index of species richness. The value is found to be highest in Site-2 (23.98) followed by Site-1 (19.27) and lowest in Site-3 (12.33) **(Table 5a, Fig. 6a).**

With the altitude increasing, Margalef index presents the same fluctuation with Shannon-Wiener index. The value reported is found to be higher compare to 9-19 for Badoli forest reported by Bhatt and Bankoti (2016), 4.44 – 9.88 for Phawngpui National Park (Malsawmsanga, 2011), 4.3 – 14.73 reported by Sagar and Singh (2004) from tropical dry deciduous forest of northern India. The result is comparable to the value of 12.2 – 20.1 reported from The Swer sacred grove, Meghalaya (Mishra, *et al.*, 2004).

Several hypotheses have been put forward to explain elevation patterns of species richness. For example, optimum humidity conditions at mid-elevations (Rahbek, 1995, 1997) and the high productivity in the mid-elevation region which resulted by optimal combination resource availability (Rosenzweig, 1995). This observed hump-shaped species richness patterns of spermatophyte in Hubei province is in accordance with the hypothesis of productivity and optimum resource combination in the intermediate portion of the elevation gradient. The mid-elevation ranges with an optimal combination of environmental resource were more preferable for many species to coexist (Lomolino 2001; Brown, 2001). The major decline in species richness with increase elevation could be due in part to ecophysiological constrains, such a reduced growing season, low temperature and low ecosystem productivity in high elevation (Körner, 1998). In addition, the boundary effect could also influence the species richness at high elevation (Colwell and Lees, 2000; Grytnes and Vetaas, 2002).

Mild climatic conditions at mid-elevation (high humidity, moderate temperatures) permit co-existence of taxa which otherwise have high, mid or low elevation centers distribution **(**Becker, *et al.,* 1988), high productivity in the mid-elevation region which is resulted by optimal combination resource availability (Rosenzweig, 1995) and found that the decline in tree diversity with elevation on mountains may be related to elevational declines in the rates of plant growth and forest turn-over. The decrease in species richness at a higher elevation may be due to harsh environment at a higher elevation, reduced growing season, low productivity (Korner, 1998).

5.2.3 Simpson's Index of dominance

The Index of dominance was calculated by using Simpson's index (Simpson, 1949) for a finite community. The highest dominance (D) was observed in Site-3 (0.13) and is found to be similar in lower and middle altitude (Site-1 and Site-2) with a value of 0.08. **(Table 5a, Fig. 6a)**.

The Simpson's index (Simpson, 1949) is a measure of the probability that two randomly sampled individuals belongs to different species. It provides a measure of dominance because it weights towards the most common species in the system. Simpson's index is useful because of its ability to produce unbiased estimations from a sample of reasonable size, its predictable dependence on sample size/sampling effort (which permits accurate extrapolations), and its ability to measure similarity between communities (Lande, *et al.,* 2000).

The value of reported dominance value of present study area is higher compare to the average value of 0.06 reported by Knight (1975) and Malsawmsanga (2011) from Phawngpui National Park (0.85 – 0.93), value of 0.03-0.07 reported by Rahman, *et al.,* (Rahman, 2010) from Khadimnagar National Park (KNP) and Tilagaor Eco-Park

(TGEP). However the reported value is found to be lower compare to those reported by Whittaker and Niering (1965), Ralhan, *et al.,* (1982) and Singhal, *et al.,*(1986) from temperate forests (0.10 – 0.9).

A result of high species diversity and low dominance in species rich communities was reported by Whittaker and Niering (1975) and the lower value of dominance index is mainly due to sharing of dominance by many plant species.

5.2.4 Pielou's Index of evenness

The evenness index of the community was calculated by adopting Pielou's index (1969). The value was almost equals in the three study sites, with a value of 0.72, 0.73 and 0.71 in Site-1, Site-2 and Site-3 respectively **(Table 5a, Fig. 6a)**.

Pielou's evenness index is a measure that how evenly distributed abundance is among the species that exist in a community. The present study showed little difference among the groups, and no significant differences were found among all of the groups for overstory, understory and herbaceous layer species **(Table 5a, Fig. 6a)**. These results suggested that the species distribution was even for every layer in the secondary forest stands.

Pielou's evenness index tended to decline at uppermost altitude. The value of present study is comparable to the result of 0.5836 to 0.8982 reported from of tropical mountain cloud forest in the Yunnan, South Western China (Shi and Zhu, 2007). And 0.6 – 0.8 reported by Zhang, *et al.* (2015).

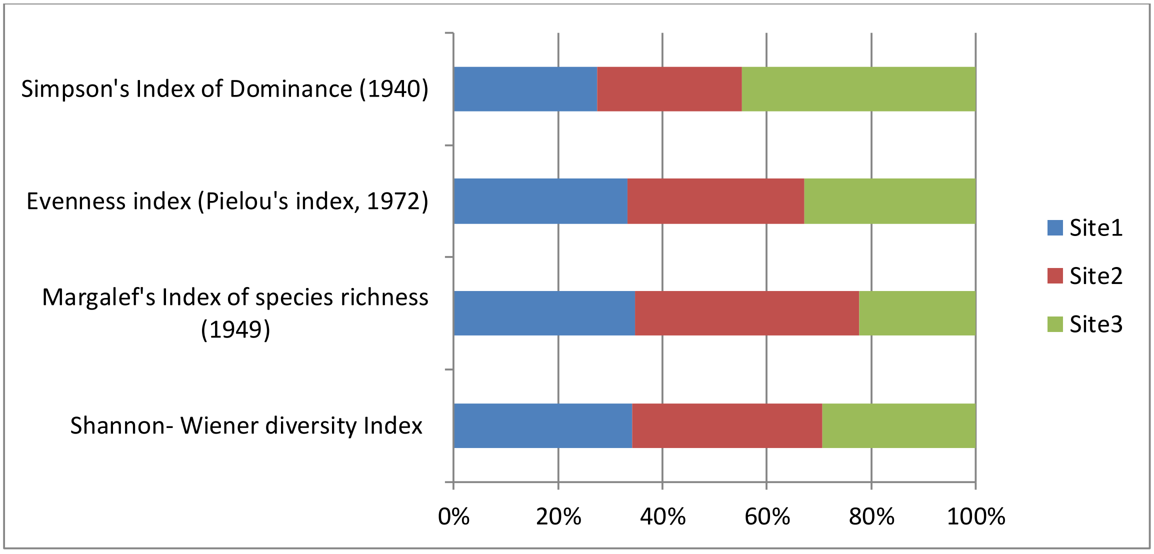


Fig 6a: Graphical representation of the plant diversity indices of different study sites of the sanctuary

5.2.5 Sorensen's Index of similarity

Sorensen's index of similarity (**S**) in the three sites was not too high. The value of similarity was found to be almost similar between Site-1 and Site-2; and between Site-1 and Site-3 (0.36), lowest between Site-2 and Site-3 (0.28) **(Table 5b, Fig. 6b)**.

The reported value of present study is lower than the value of 0.8 reported by Sambaré, *et al.* (2011) from riparian forest.Similarity of tree species wasalso evaluated by Kumar and Bhatt (2006) in sub-tropical forest of Garhwal Himalayas. The result is comparable to 0.3-0.4 value of similarity reported in natural forest (Correia, *et al.*, 2010).

Sorensen's index characterizes the variation of plant species across the different study sites or altitudinal gradient in the study area. The Sorensen's index of similarity of plant species was found to be lower and middle altitude (Site-1 and Site-3). The reported values of the present study is quite low for each sites reflecting that the similarity between the neighbouring sites of the study area was not high and may explain the transitional position from the base lower altitude to vertical higher altitude as reported by Jiang, *et al*. (2007).

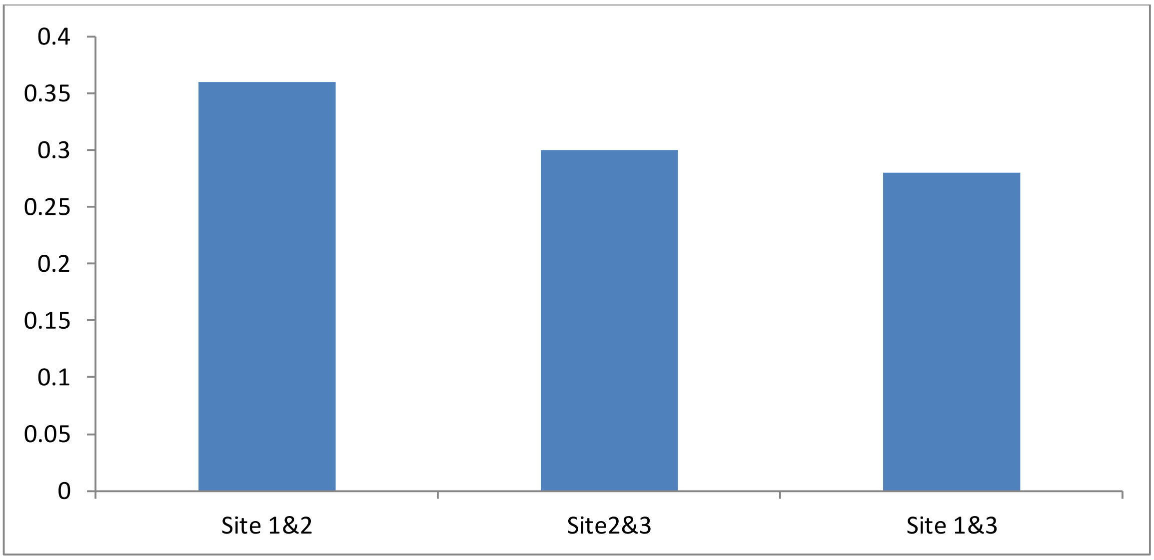


Fig 6b: Graphical representation of Sorensen's index of the plant diversity index of different study sites of the sanctuary.

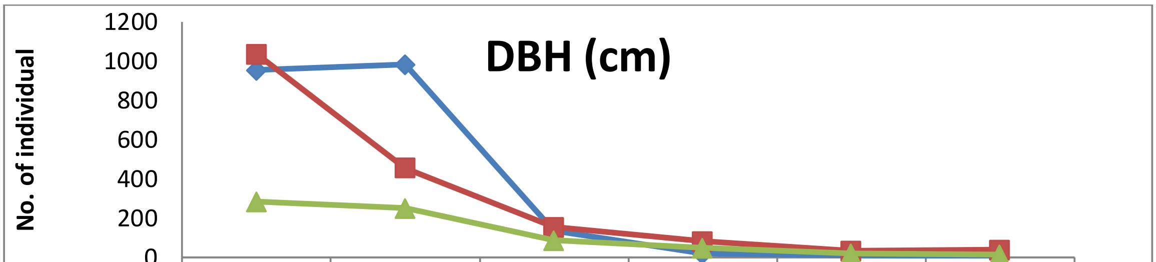
5.3Distribution of tree species

5.3.1 A/F Ratio: Statistical analysis was done on the distribution pattern of each species by calculating its Abundance/Frequency ratio. The result shows that the abundance/frequency ratio analysis of distribution pattern of tree species exhibited contagious pattern of distribution. The abundance/frequency ratio of tree species on each sites were >0.05 showing clumped or contagious distribution for each species **(Table 6a, 6b &6c)** and none of the species showed regular and random patterns of distribution.

A clumped or contagious distribution have been observed by Kumar and Bhatt (2006), Ndah, *et al.* (2013), Bhatt and Bankoti (2016), Zent and Zent (2004). Hubbell (1979), in dry tropical forest observed that all species were either clumped or randomly dispersed, with a rare species more clumped than common species. Plant populations exhibit three patterns of spatial distribution, *viz*. contagious or clumped, and random, regular or uniform. Patchiness, or the degree to which individuals are aggregated or dispersed, is crucial to the understanding of how species uses resources, and how it is used as a resource. Besides, the distribution pattern of species population is often related to its productive biology. Webb, *et al*. (1967), Ashton (1972) and Austin, *et al*. (1972) indicated that in the absence of major disturbance, soil and water conditions play major roles in controlling species distribution pattern. The contagious distribution pattern of species indicates the mosaicness of the forest stand. The contagious of the species suggests the increase in fragmentation and patchiness of the natural vegetation due to mining.

5.3.2Altitudinal gradient:

A total of 954 trees (<10 cm) were recorded along 1500 m.a.s.l. to 1700 m.a.s.l. (Site-1) altitudinal gradient. They have taxonomic variation comprising of 52 species, 44 genera and 29 families, maximum of 1034 and minimum of 282 individuals were recorded in 1700 m.a.s.l. to 1900 m.a.s.l. (Site-2) and 1900 m.a.s.l. to 2141 m.a.s.l. respectively. In dbh class of 10 cm-30 cm, it was found to be highest in lower altitudinal region (Site-1) with 982 individuals followed by 450 individuals in the middle altitude. **(Table 7c, Fig. 7a)**.



	<10 cm	11 cm - 30 cm	31 cm - 50 cm	51 cm - 70 cm	71 cm - 90 cm	>90 cm
Site - 1	954	982	132	19	8	1
Site - 2	1034	454	151	79	32	37
Site - 3	282	248	85	45	19	11

Fig. 7a: Comparison for DBH from the three study sites

A total of 2096 individuals (46.57% of the total individual species) were classified under saplings in Site-1, 982 (45.99%) as poles and only 8 individuals (0.38%) were classified under 71-90 m DBH class. Drastic decreases in number of trees with higher DBH classes are highly attributable to illegal felling of timbers in the area. With the altitude increasing, the DBH of the trees firstly increase and then decline. The maximum DBH of the trees were found in the middle altitude of 1700-1900 m (Site-2), 1034 (57.86 of total population) were recorded as saplings, 454 (25.40%) as poles (**Fig. 7b, 7c, 7d**).

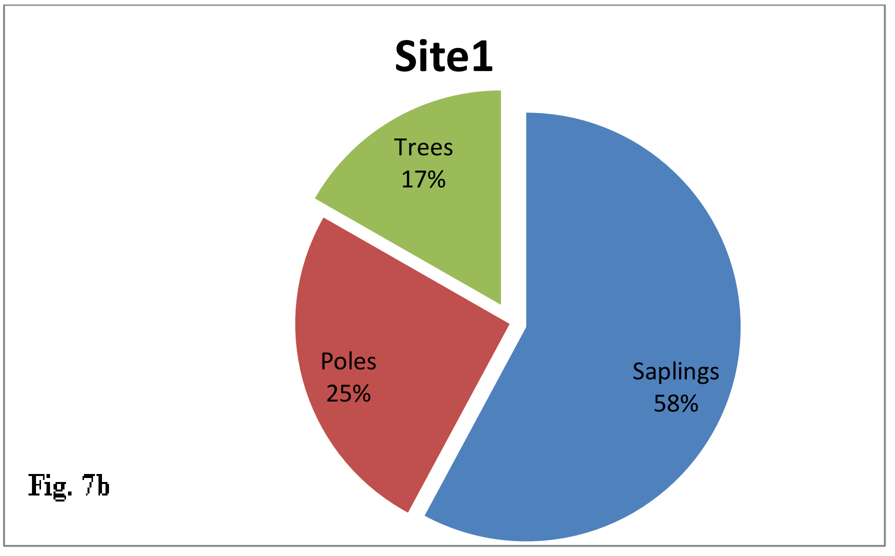


Fig. 7b

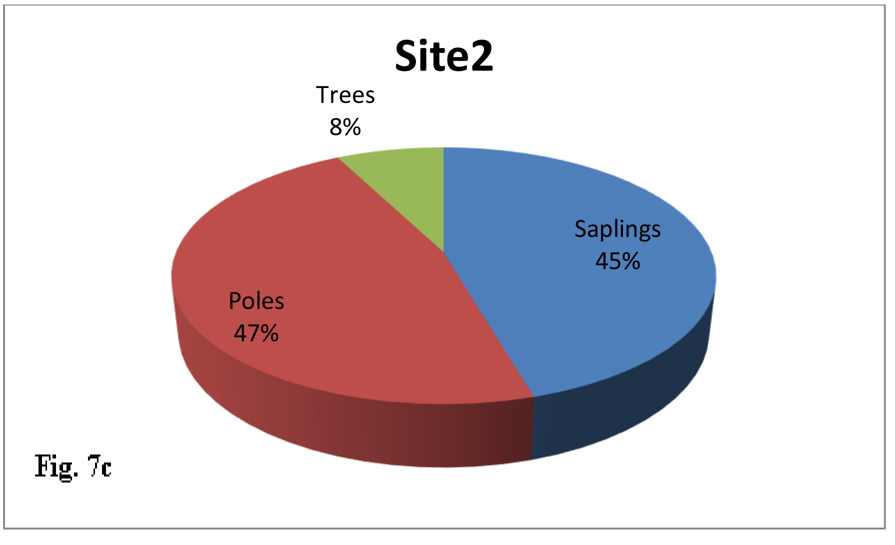


Fig. 7c

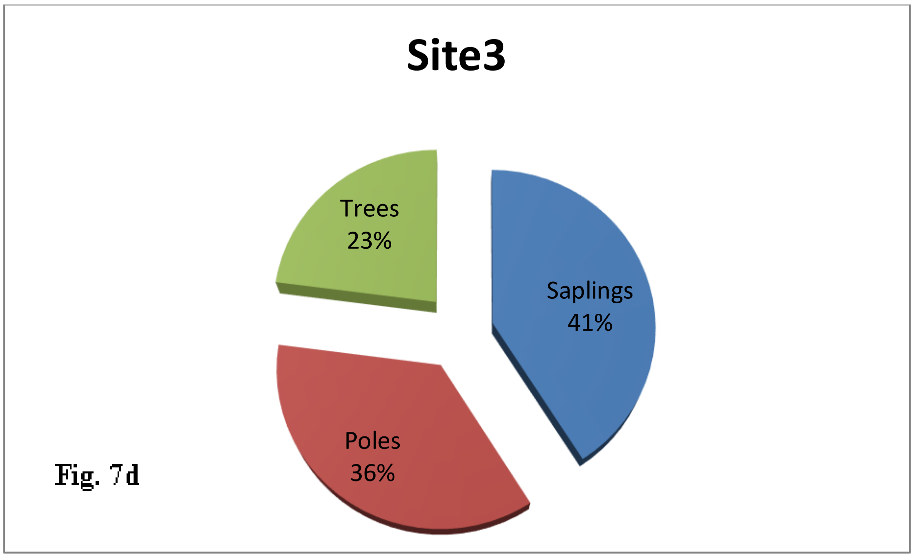


Fig. 7a, 7b & 7c: Graph showing composition of saplings, poles and trees in Site-1 (**Fig.7b**), Site-2 (**Fig.7c**) and Site-3 (**Fig.7d**).

The order of DBH along different altitudinal gradient is as follows: Site-2 ＞Site-1＞Site-3. *Wendlandia grandis* (Hook. F.) Cowan, *Betula alnoides* Buch.-Ham ex D.Don, *Columbia flagocarpa* (C.B Clarke) Craib, *Litocarpus pachyphyllus* (Kurz) Rehder, *Quercus spicata* Sm., *Quercus xylocarpus* (Kurz.) Markgr., and *Schima wallichi* Choisy etc., live in low altitudinal communities with strong human disturbances (the altitude of 1500 m.a.s.l. – 1700 m.a.s.l.). *Albizia chinensis* (Osb.), *Eurya acuminata* DC., *Persea glaucescens* (Nees) D.G. Long, *Persea odoratissima* (Nees) Kostern., *Phoebe angustifolia* Meisn. and *Quercus xylocarpus* (Kurz.) Markgr. etc., inhabit the middle altitudinal communities with relatively little human disturbances (the altitude of 1700 m.a.s.l. –1900 m.a.s.l.). Moreover, in Site-3 (1900 m.a.s.l. -2141 m.a.s.l.) DBH are minimal, because of the rigorous condition, especially the strong wind. With the altitude increasing, DBH of trees firstly increase and then decrease, with a peak in the communities at the altitude of 1900 m.a.s.l. - 2141 m.a.s.l. 282 (40.98%) saplings, 248 (36.02%) poles and 158 (22.96%) trees were recorded in the highest altitude.

In the low altitudinal communities, human disturbances are chief factors affecting growths of trees, and impair advantages of water and heat. In the middle altitudinal communities, the quantities of water and heat are adequate and human disturbances lessen obviously, thus the maximal height and DBH of trees are maximal in the communities. In contrast, the maximal height and DBH of trees in the high altitudinal communities are minimal because of rigorous environmental conditions. In a word, the changes of the tree height and DBH are related to the altitude, community composition, and the feature of trees as well as human disturbances.

The distributional pattern of genera and families seem to follow the species distribution pattern along gradient (**Fig. 5**). A maximum of 78-genera and 57-families were observed in middle elevation, whereas minimum of 24-genera and 18-families were observed in 1900 m.a.s.l. - 2141 m.a.s.l. **(Table 7c)**. The distribution of plant species first increases and then decline as we move up to higher altitude showing hump shapes distribution curve in the study area (**Fig. 10**). A humped shaped distribution pattern of plant species richness in relation to alttitude have been observed by various works such as Whittaker (1960), Janzen (1960), Tilman (1982), Schmida and Wilson (1985), Rahbek (1997), Grytnes and Vetaas (2002), Oomen and Shanker (2005), Kharkwal, *et al.,* (2005), Jiang,*et al.,* (2007), Gairola *et al.,* (2008) and Aneykulu (2008).

The variation of tree species at any sites along the altitudinal gradients indicates that the species have their own distributional limits. The large variation of species between the quadrats in each step support the individualistic hypothesis of community organization (Gleason, 1926) that posits the distribution of each species is determined by its own ability to survive, compete and produce successfully in different environments, resulting in each species having its own distinctive distribution, and in community composition changing more or less continuously along ecological and altitudinal gradients. In a word, the changes of the tree height and DBH are related to the altitude, community composition, and the feature of trees as well as human disturbances (Gao and Zhang, 2006).

5.4 Stratification of the forest

The stratification of the forest was studied by drawing a profile diagram along belt transect (1m thickness X 100 m length) in each sites. **(Fig. 8a, 8b & 8c).**

Site-1 (1500 m.a.s.l. to 1700 m.a.s.l.): From the profile diagram of Site-1, the forest could be stratified into three layers ***viz.,*** the top layer layers were above 20 m high, the middle layers were between 8 m to 20 m high and the ground vegetation. The top canopy species include *Duabanga grandiflora, Quercus spicata, Helicia excelsa, Castanopsis tribuloides, Quercus helferiana, Quercus xylocarpus, Helicia robusta, Engelhardtia spicata, Quercus lineata*, *Phoebe angustifolia*, *Betula alnoides Elaeocarpus rugosus, Dysoxylum hamiltoni*, *Lithocarpus pachyphyllus* and *Pittosporum floribundum* and *Choreospondias axilaris, Olea salicifolia* and *Laurocerasus jenkinsii*. The middle layer consists of *Schima wallichii, Columbia floribunda, Glochidion lanceolarium, Litsea salicifolia , Bauhinia variegata, Zizyphus incurva, , Leucomeris decora, Wendlendia grandis, Vitex canescens, Derris pseudorobusta, Rhus chinensis, Macaranga denticulata, Colombia floribunda, Lisea monopetala, Elaecarpus lanceofolius* and *Derris robusta*.
The ground vegetation consists of *Oroxylum indica, Ammomum daelbatum, Gynura bicolour, Eupatorium odoratissima, Curculigo crassifolia* **(Fig. 8a).**

Site-2 (1700 m.a.s.l. to 1900 m.a.s.l.): The profile diagram of Site-2 of the study area showed that the forest could be stratified into three layers ***viz.,*** the top layer were above

15 m high, the middle layer were between 6 m and 15 m high and the ground vegetation. The top canopy species are *Toona ciliata, Persea odoratissima, Betula alnoides, Quercus xylocarpus, Phobe angustifolia, Diospyros lanceifolia, Garcinia xanthochymus, Clausena heptaphylla, Phoebe hainesiana, Phoebe lanceolata, Cephalotaxus griffithi, Dysoxylum mollissimum, Michelia champaca, Castopsis tribuloides, Syzygium claviflorum, Heteropanax oreophyllum, Podocarpus nerifolius, Lobelia pyramidalis, Pitosporum floribundum, and Choreospondias axilaris.* The middle layer consists of *Elaeocarpus lanceifolius, Castanopsis echinocarpa Boehmeria rugulosa, Eugenia jambolana, Citrus latipes, Citrus indica, Schima wallichii, Persea glaucescens, Holboellia latifolia, Olea dioca, Messua ferrae, Melia dubia, Derris robusta, Eurya acuminate, Bursera serrata* and *Cinnamomum obtusifolia.* with large amount of *Arudinaria callosa* The ground vegetation consists of *Ammomum dealbatum, Blumea alata, Gynura bicolour, Osbeckia sikkimensis, Calamus erectus, Calamus gracilis* **(Fig. 8b)**.

Site-3 (1900 m.a.s.l. to 2141 m.a.s.l.) : The profile diagram of Site-3 shows that the forest could be stratified into three layers ***viz.,*** the top canopy layer which were above 10 m high, the middle layer which were between 2 m to 10 m high and the group vegetation. The top canopy species are *Pittosporum floribundum, Engelhardtia spicata, Quercus helferiana, Ficus subulata,Acrocarpus fraxinifolious Podocarpus nerifolius, Cephalotaxus grifithii, Cinnamomum obtusifolium, Phoebe lanceolata, Nyssa javanica* and *Helicia excelsa*. The middle layer consists of *Phoebe angustifolia*, *Castanopsis echinocarpa, Quercus xylocarpus, Castanopsis tribuloides, Persea odoratissima, Persea minutiflora, Persea glaucescens, Boehmeria rugulosa, Schima khasiana, Litsea salicifolia, Litsea monopetala, Glochidion lanceolarium, Rhododendron formosum, Rhododendron arboretum.* The ground vegetation is composed by *Calamus gracilis,* *Osbeckia sikkimemsis, Osbeckia chinensis, Ardisia macrocarpa, Curculigo crassifolia* **(Fig. 8c).**

From the profile diagrams of each sites of the study area, we could stratify the forest of the study area into three layers such as the top canopy layer which were above 15 m high, the middle layer consists of a wide range from 2 m to 15 m high, then the ground vegetation below 2 m. From the profile diagram it is clear that trees in the lower altitude (Site-1) are higher than the tree in the higher altitude (Site-3) which shows that vertical growth of trees is controlled by altitude and climate conditions. Description of forest using profile diagram have been done by various workers such as Davis and Richards (1934) in the forest of Guyana, Brown (1919) of the Phillipine *Dipterocarp* forest and Beard (1946) of Mora associations of Trinidad.

Fig. 8a **Profile diagram of Site-1:** 1. Duabanga grandiflora, 2. Helicia excelsa, 3. Quercus spicata, 4. Castanopsis tribuloides, 5. Quercus helferiana, 6. Quercus xylocarpus, 7. Helicia robusta, 8. Engelhardtia spicata, 9. Quercus lineata, 10. Phoebe angustifolia, 11. Betula alnoides, 12. Elaeocarpus rugosus, 13. Columbia floribunda, 14. Dysoxylum hamiltoni, 15. Lithocarpus pachyphyllus, 16. Pittosporum floribundum, 17. Choreospondias axilaris, 18. Olea salicifolia 19. Laurocerasus jenkinsii, 20. Schima wallichii, 21. Glochidion lanceolarium, 22. Litsea salicifolia , 23. Bauhinia variagata, 24. Zizyphus incurva, , 25. Leucomeris decora, 26. Rhus chinensis, 27. Wendlendia grandis,, 28. Derris pseudorobusta, 29. Vitex canescens, 30. Macaranga denticulata, 31. Colombia floribunda, 32. Derris robusta, 33. Lisea monopetala, 34. Elaecarpus lanceofolius.

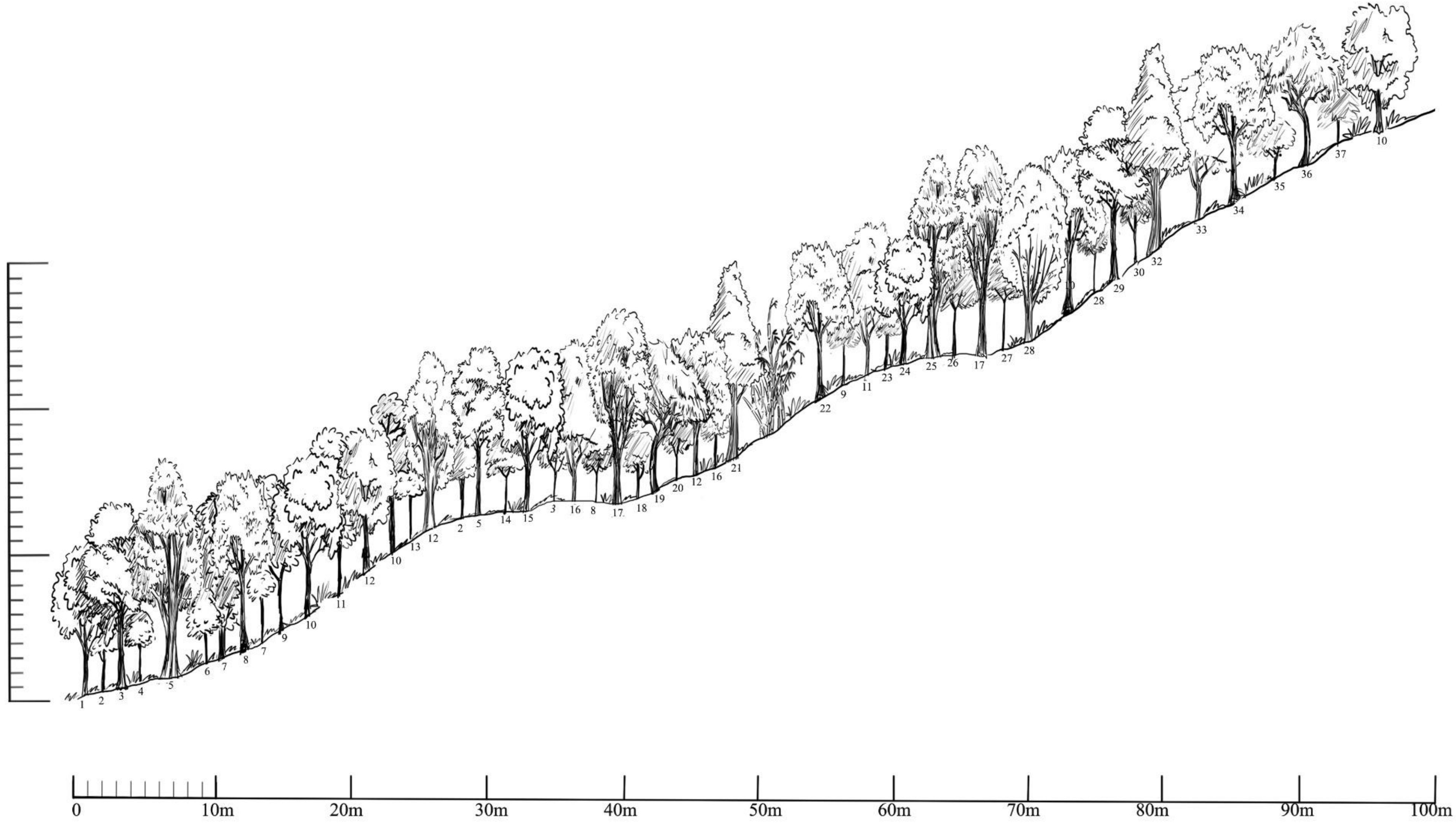


Fig. 8b : Profille diagram of Site-2: 1. *Toona ciliata*, 2. *Persea odoratissima*, 3. *Phoebe angustifolia*, 4. *Betula alnoides*, 5. *Phoebe hainesiana*, 6. *Betula alnoides*, 7. *Quercus xylocarpus*, 8. *Diospyros lanceifolia*, 9. *Garcinia xanthochymus*, 10. *Cephalotaxus griffithi*, 11. *Phoebe lanceolata*, 12.*Dysoxylum mollissimum*, 13. *Bursera serrata*, 14. *Cinnamomum obtusifolia*, 15. *Michelia champaca* 16. *Castanopsis tribuloides*, 17. *Podocarpus nerifolius*, 18. *Syzygium claviflorum*, 19. *Mesua ferrae*, 20. *Heteropanax oreophyllum*, 21. *Persea glaucescens*, 22. *Derris robusta*, 23. *Lobelia pyramidalis*, 24. *Pittosporum floribundum* , 25. *Choreospondias axilaris*, 26. *Elaeocarpus lanceifolius*, 27. *Clausena heptaphylla*, 28. *Castanopsis echinocarpa*, 29. *Boehmeria rugulosa*, 30. *Eugenia jambolana*, 31. *Citrus latipes*, 32. *Citrus indica*, 33. *Schima wallichii*,34. *Hoboellia latifolia*, 35. *Olea dioica*, 36. *Melia dubia*, 37. *Eurya acuminata* ,

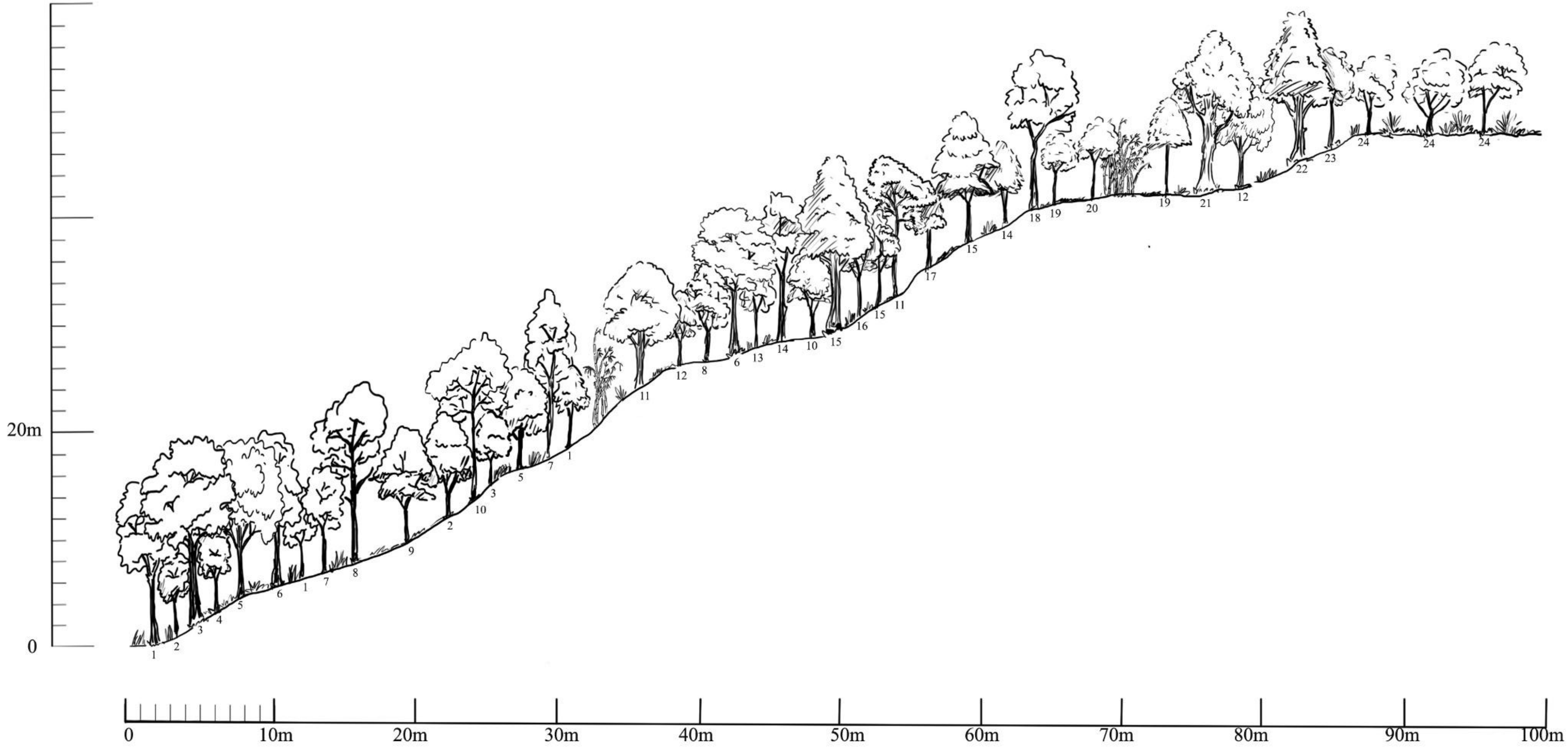


Fig. 8c Profile diagram of Site-3: 1. *Quercus helferiana*, 2. *Castanopsis echinocarpa*, 3. *Pittosporum floribundum*, 4. *Engelhardtia spicata*, 5. *Ficus subulata*, 6. *Acrocarpus fraxinifolious* 7. *Podocarpus nerifolius*, 8. *Cephalotaxus grifithii*, 9. *Cinnamomum obtusifolium*, 10. *Phoebe lanceolata*, 11. *Nyssa javanica* , 12. *Helicia excelsa*, 13. *Phoebe angustifolia*, 14. *Quercus xylocarpus*, 15. *Castanopsis tribuloides*, 16. *Persea odoratissima*, 17. *Persea minutiflora*, 18. *Schima khasiana*, 19. *Persea glaucescens*, 20. *Boehmeria rugulosa*, 21. *Litsea salicifolia*, 22. *Litsea monopetala*, 23. *Glochidion lanceolarium*, 24. *Rhododendron arboretum*, 25. *Rhododendron formosum*.

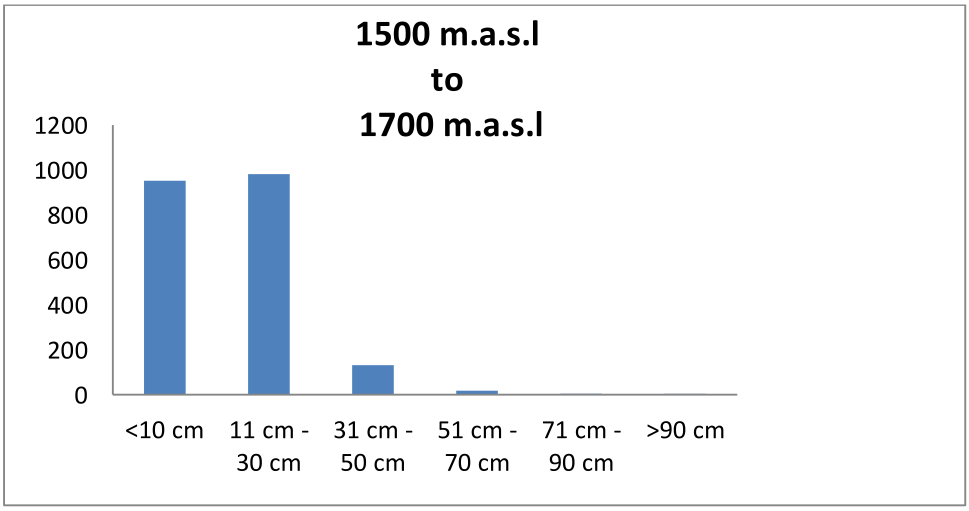
5.5 Phytosociological analysis of tree community

In Site-1, *Quercus spicata* Sm. (4.76) has highest density followed by *Quercus xylocarpus* (Kurz.) Markgr. (4.33). *Quercus spicata* Sm. has the highest value of IVI (48.13) followed by *Schima wallichi* Choisy (39.14). In Site-2, *Persea odoratissima* (Nees) Kostern.has highest value of IVI 41.81 followed by *Dysoxylum hamiltonii* Hiern (37.64). Highest density is recorded with *Persea odoratissima* (Nees) Kostern (4.9). In Site-3, *Pitosporum floribundum* Wight. & Arn. (51.29) has highest IVI value and *Castanopsis echinocarpa* Miq. (2.1) has highest density **(Table 9a, 9b and 9c)**.

5.6 Population structure

The diameter classes of tree species recorded were used to study the population structure of the study area.

Site-1: Highest density of species was observed in diameter class less than 10 cm (954 individuals per hectare) forming 46.57% of the total population which is followed by trees having a diameter class of 10 cm – 30 cm (982 individuals per hectare), and only one individual is recorded in dbh class higher than 90 cm. (**Fig. 9a**)



9a: Population structure - tree species of Site-1 in Lengteng wildlife sanctuary.

Site-2: Highest density was observed in diameter class smaller than 10 cm constituting 57.86% of the total population. 25.40% of recorded trees falls under a diameter class of 12 cm-30cm. Trees having diameter class 70 cm - 90 cm having 32 individuals. (**Fig. 9b**)

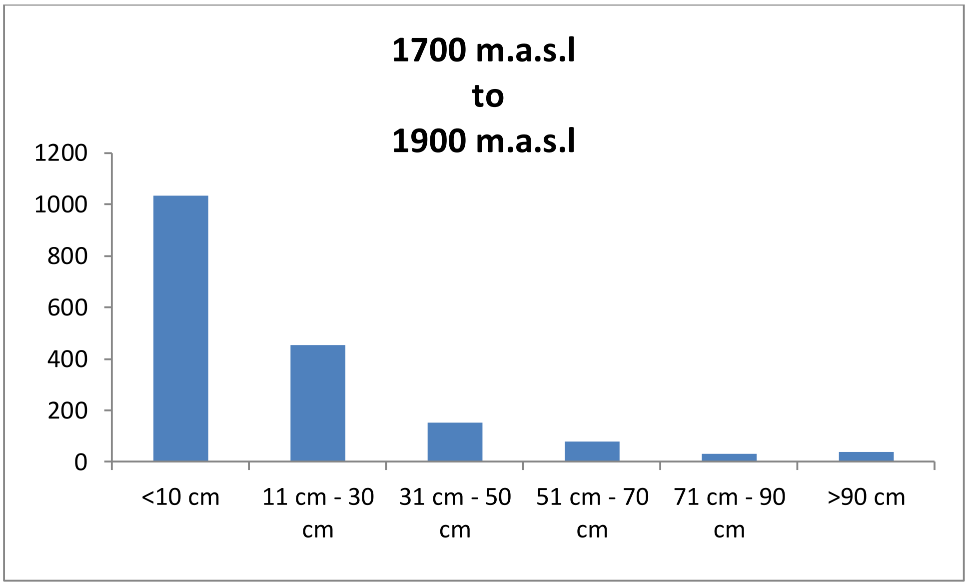


Fig. 9b: Population structure tree species Site-2 in Lengteng wildlife sanctuary.

Site-3: The highest species density was recorded in dbh class less than 10cm having 282 individuals per hectare, followed by 10 cm - 30 cm dbh class (248) and lowest in diameter class higher than 90 cm **(Fig.9c)**.

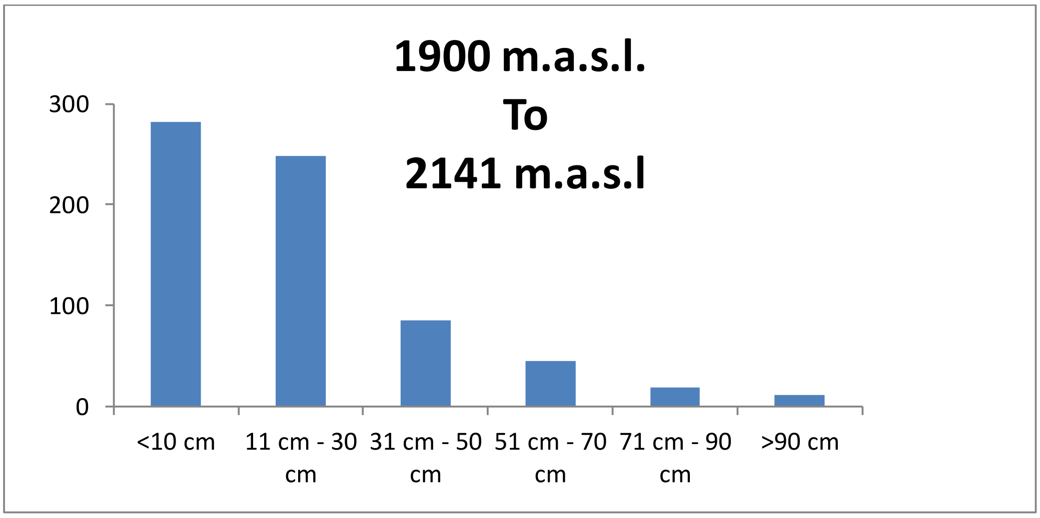


Fig. 9c: Population structure of tree species of Site-3 in Lengteng wildlife sanctuary.

The total population of trees with respect to their diameter class shows that trees having a diameter class less than 10 cm (2270 individuals) dominate the forest followed by trees having 10 cm-30 cm diameter class with 1684 individuals. Trees having a diameter class greater than 90 cm are the least with 49 individuals. **(Fig.9d, Table 8a)**.

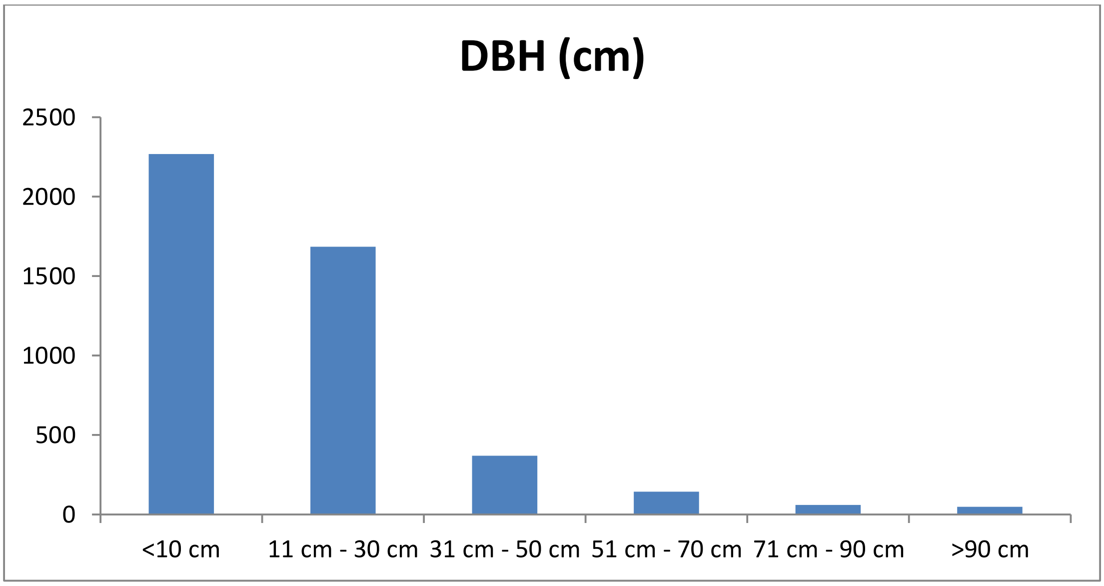


Fig. 9d: Overall Population structure of tree speciesin Lengteng wildlife sanctuary.

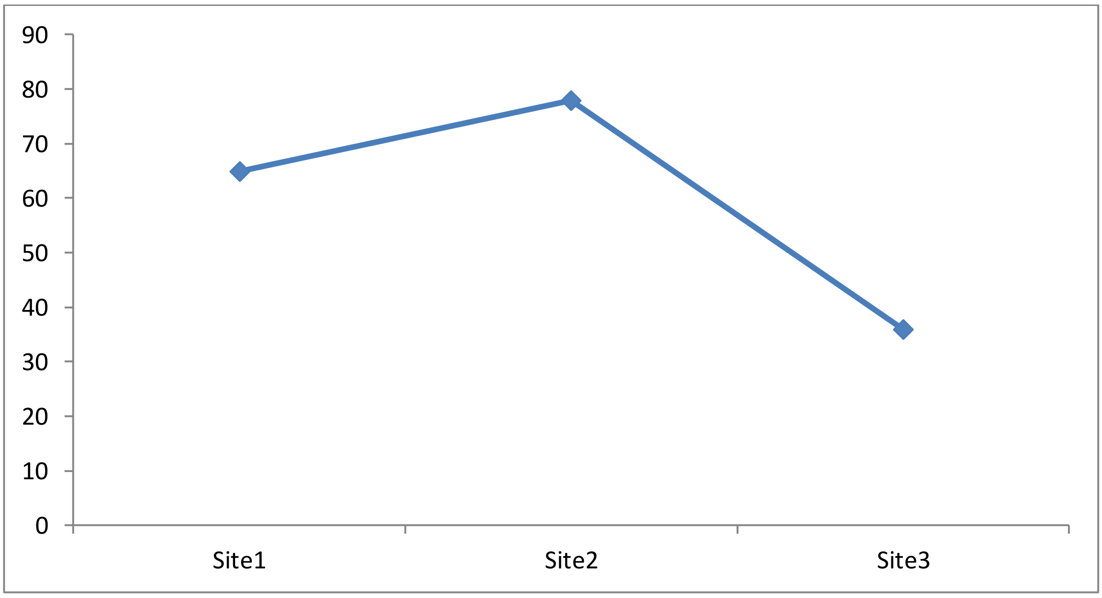


Fig 10: Hump-shaped distribution pattern of tree species

The results shows that tree diversity of Lengteng Wildlife Sanctuary follow a hump shaped pattern **(Fig. 10)**. This falls within the general pattern of initial increases in species richness with elevation followed by a peak in the middle and then decline with further increases in elevation. This pattern is typical of many mountain system, and is similar to those vegetation found in Oregon and California (Whittaker, 1960), along a steppe Tundra gradient in Alaska (Edwards and Ambruser, 1989), along an elevational gradient in Israel (Schmida and Wilson, 1985), Himalayan woody plants (Oomen and Shanker, 2005), in the Eastern Escarpment of the Rift Valley of Northern Ethiopia (Aynekulu, 2008),

The hump-shaped model of Grime (1973 a, b, 1979) has been a valuable tool from the perspectives of both basic research and conservation. However, it is now clear that the generality of the hump-shaped model should not be overstated (Waide, *et al.*, 1999). Even across community types, the scale at which the hump-shaped relationship is most common, a majority of published studies fail to find a hump-shaped relationship (*ibid., et al.* 1999). Furthermore, productivity often limits species richness rather than controlling it tightly, creating a hump or triangle which may be 'filled in' to varying degrees (Grace 1999). There are also crucial differences in the location of the peak in species richness between forests and herbaceous vegetation.

The reasons for the low number of species observed in some families could be attributed to diseases and browsing by herbivores which resulted in poor growth and establishment and perhaps seeds need scarification treatment before germination. Similar results were reported by Coley and Barone (1996) on herbivory and plant defenses on herbivores. The low number of species could also be attributed to anthropogenic activities which affected species growth and production. Similar findings have been reported by Sumina (1994) on plant communities on anthropogenically disturbed sites in Chukotka Peninsula, in the Qilian mountain which peaked at 2400 m-2800 m (Wang, *et al.*, 2003), The distribution of species richness along elevation gradients is governed by a series of interacting biological, climatic and historical factors (Colwell and Lees, 2000). Further, elevation represents a complex gradient along which many environmental variables change simultaneously (Austin, *et al.*, 1996).

Several hypotheses have been put forward to explain elevation patterns of species richness. For example, optimum humidity conditions at mid-elevations (Rahbek, 1995, 1997) and the high productivity in the mid-elevation region which resulted by optimal combination resource availability (Rosenzwieg, 1995). This observed hump-shaped species richness patterns of spermatophyte in Hubei province is in accordance with the hypothesis of productivity and optimum resource combination in the intermediate portion of the elevation gradient. The mid-elevation ranges with an optimal combination of environmental resource were more preferable for many species to coexist (Lomolino 2001; Brown, 2001). The major decline in species richness with increase elevation could be due in part to ecophysiological constrains, such a reduced growing season, low temperature and low ecosystem productivity in high elevation (Körner, 1998). In addition, the boundary effect could also influence the species richness at high elevation (Colwell and lees, 2000; Grytnes and Vetaas, 2002).

As elevation increases, the isolation of slopes from pathways of migration increases linearly. With a reduction in the channels available for immigration, there is a reduction in the number of species that occupy high elevation sites. Human activities, such as changes in land-use, have a long lasting and direct impact on species richness in mountain environments. A study conducted by Curtin (1995) in southwest Colorado demonstrated that species diversity in the subalpine at elevations between 3000 m - 3200 m could be affected by human land use up to 110 years after the departure of the inhabitants. This study also showed that plant communities in high elevations are very sensitive to human disturbance.

5.7 Rainfall data:

Rainfall data was recorded for three years (2013-2015). An automatic rain gauge was fixed up at Kawlbem village. A School teacher named Mr Laldingliana was entrusted to take year-wise rainfall data, for which the technique of handling and recording the rainfall was taken in a Rainfall Diary. It is recorded that rainfall was highest in the month of August and lowest or totally absent in January. Generally, absence of rainfall during December-January is more or less the normal phenomenoa in Mizoram (**Fig. 11**).

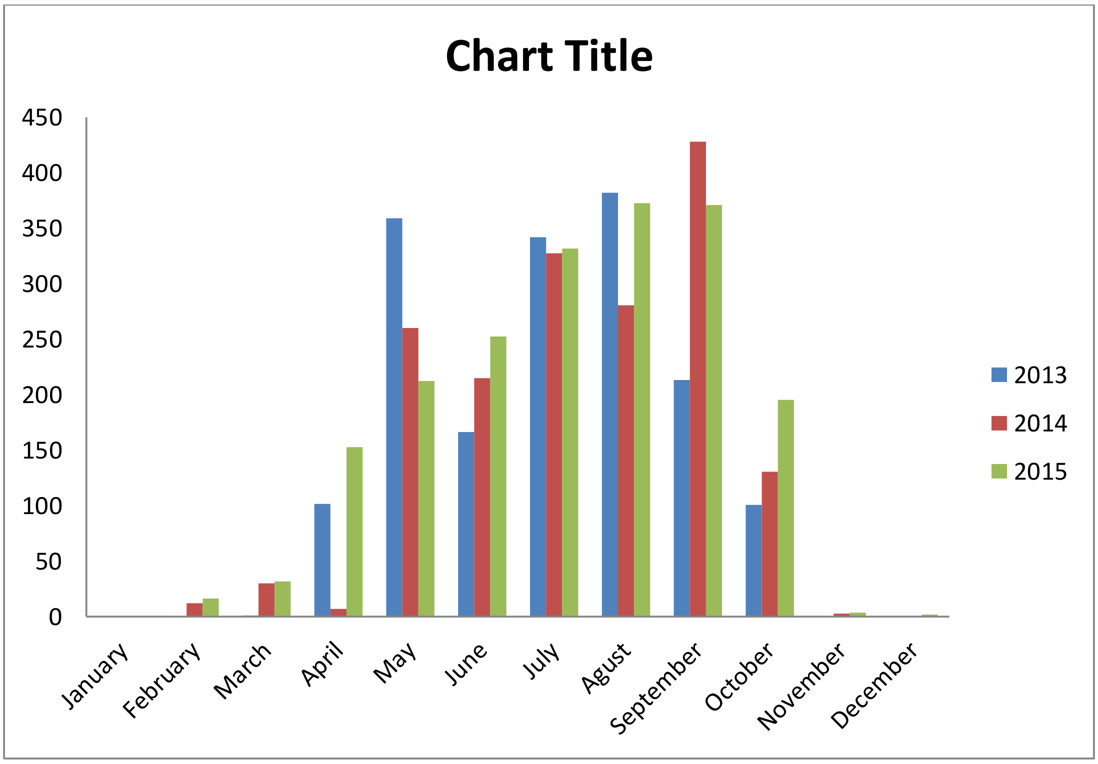


Fig. 11: Comparison of Rainfall (mm) from 2013-2015

Table 2: Tree species composition

Sl no.	Family	Genus	Botanical Name	IUCN Status	Site-1	Site-2	Site-3
1	2	3	4	5	6	7	8
1	Anacardiaceae	*Choreospondias*	*Choreospondias axilaris* Roxb.	NA	✓	✓	
		Drimycarpus	*Drimycarpus racemosus* (Roxb.) Hook. f. ex Marchand.	NA		✓	
		Mangifera	*Mangifera sp*	NA		✓	
		Rhus	*Rhus chinensis* Mill.	LC	✓		
2	Annonaceae	*Alphonsea*	*Alphonsea ventricosa* (Roxb.) Hk. f. & Th.	NA		✓	
3	Apocyanaceae	*Alstonia*	*Alstonia scholaris* R. Br.	LC	✓		
4	Aquifoliaceae	*Ilex*	*Ilex godajam* Colebr. ex Hook.f.	NA	✓		
5	Araliaceae	*Heteropanax*	*Heteropanax oreophyllum*	NA		✓	
6	Asteraceae	*Leucomeris*	*Leucomeris decora Kurz*	DD	✓		
		Vernonia	*Vernonia volkamerifolia* DC.	LC	✓		
7	Betulaceae	*Betula*	*Betula alnoides* Buch.-Ham ex D.Don	LC	✓	✓	
8	Bignoniaceae	*Sterospermum*	*Sterospermum chelonoides* (L. fil) DC.	NA	✓		
9	Burseraceae	*Bursera*	*Bursera serrata* Wall. ex Colebr.	NA		✓	
10	Caesalpiniaceae	*Bauhinia*	*Bauhinia variegata* L.	LC	✓		
		Acrocarpus	*Acrocarpus fraxinifolious* Wight ex Arn.	NA			✓
11	Campanulaceae	*Lobelia*	*Lobelia pyramidalis* Wall.	NA		✓	
12	Cephalotaxaceae	*Cephalotaxus*	*Cephalotaxus griffithi* Hook.f.	VU		✓	✓
13	Clusiaceae	*Calophyllum*	*Calophyllum polyanthum* Wall. ex Planch. & Triana	LC		✓	
		Garcinia	*Garcinia xanthochymus* Hook. f.	NA		✓	
		Messua	*Messua ferrae* Linn.	NA		✓	
14	Combretaceae	*Terminalia*	*Terminalia chebula* Retz.	NA		✓	
15	Cornaceae	*Nyssa*	*Nyssa javanica* (Blume) Wangerin	NA			✓
16	Ebenaceae	*Diospyros*	*Diospyros glandulosa* Lace.	NA	✓		
			Diospyros lanceifolia Roxb.	NT	✓	✓	✓
			Diospyros pilosiuscula G.Don	NA		✓	

Table 2 contd.

1	2	3	4	5	6	7	8
17	Elaeocaroaceae	*Elaeocarpus*	*Elaeocarpus lanceifolius* Roxb.	NA	✓	✓	
			Elaeocarpus prunifolius Wall. ex Muell. Berol.	VU		✓	
			Elaeocarpus rugosus Roxb. ex G.Don.	VU	✓	✓	
18	Ericaceae	*Rhododendron*	*Rhododendron arboreum* Sm.	LC			✓
			Rhododendron formosum Wall.	NA			✓
19	Euphorbiaceae	*Antidesma*	*Antidesma bunius* (L.) Spreng.	NA		✓	
		Aporosa	*Aporosa oblonga* Muell. Arg. *A. octandra* (Buch.-Ham ex D.Don) Vickery	NA	✓		
		Macaranga	*Macaranga denticulata* (Bl.) Mueller	NA	✓		
		Sapium	*Sapium sp*	NA		✓	
20	Fabaceae	*Claoryton*	*Claoryton longipetiolatum*	NA	✓		
		Dalbergia	*Dalbergia lanceolaria* L.f.	LC		✓	
		Derris	*Derris pseudorobusta* Thoth.	NA	✓		
			Derris robusta (DC.) Benth.	NA	✓	✓	
		Erythrina	*Erythrina stricta* Roxb.	NA		✓	
21	Fagaceae	*Castanopsis*	*Castanopsis echinocarpa* Miq.	NA	✓	✓	✓
			Castanopsis indica (Roxb. ex Lindl.) A. DC.	NA		✓	✓
			Castanopsis tribuloides (Sm). A. DC.	NA	✓	✓	✓
		Lithocarpus	*Lithocarpus obscurus* C.C.Huang & Y.T Chang	NA	✓		✓
			Litocarpus pachyphyllus (Kurz) Rehder	NA	✓		
		Quercus	*Quercus spicata* Sm.	NA	✓		
			Quercus glauca Thunb.	LC	✓	✓	
			*Quercus helferiana*A. DC.	LC	✓	✓	✓
			Quercus lineata Blume	NA	✓		
			Quercus semiserrata Roxb.	NA		✓	
			Quercus serrata Murray	NA		✓	
			Quercus sp	NA		✓	✓
			Quercus xylocarpus (Kurz.) Markgr.	NA	✓	✓	✓
22	Juglandaceae	*Engelhardtia*	*Engelhardtia spicata* Lechen ex Blume	LC	✓	✓	✓
		Juglans	*Juglans regia* Linn.	LC		✓	
23	Laedizabalaceae	*Holboellia*	*Holboellia latifolia* Wall.	NA	✓	✓	

Table 2 contd.							
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
24	Lamiaceae	*Callicarpa*	*Callicarpa arborea* Roxb.	NA		✓	
		Vitex	*Vitex canescens* Kurz	NA	✓		
			Vitex glabrata R.Br.	NA		✓	
			Vitex peduncularis Wall. ex Schauer	NA		✓	
			Vitex quinata Lour. (F.N.)Williams	NA		✓	
25	Lauraceae	*Alseodaphne*	*Alseodaphne petiolaris* Hook. f.	NA		✓	
		Cinnamomum	*Cinnamomum obtusifolium* (Roxb.) Nees	NA		✓	✓
		Litsea	*Litsea monopetala* (Roxb.) Pers.	NA	✓		✓
			Litsea salilicifolia (Roxb. ex Nees)	NA	✓		✓
		Machillus	*Machillus sp*	NA			✓
		Persea	*Persea glaucescens* (Nees) D.G. Long	NA		✓	✓
			Persea minutiflora Kostern *Machilus parviflora* Meissn.	NA			✓
			Persea odoratissima (Nees) Kostern. *Machilus odoratissima* Nees	NA	✓	✓	✓
		Phoebe	*Phoebe angustifolia* Meisn.	NA	✓	✓	✓
			Phoebe hainesiana Brandis	NA		✓	✓
			Phoebe lanceolata (Nees) Nees	NA	✓	✓	✓
26	Magnoliaceae	*Magnolia*	*Magnolia ballonii* Pierre *Talauma phellocarpa* King	NA		✓	
		Michelia	*Michelia champaca* KL.	LC	✓	✓	
27	Meliaceae	*Dysoxylum*	*Dysoxylum mollissimum* Blume *Dysoxylum hamiltonii* Hiern	NA	✓	✓	✓
		Melia	*Melia dubia* Cav.	NA		✓	
		Toona	*Toona ciliata* M. Roem	LC		✓	
28	Mimosaceae	*Albizia*	*Albizia chinensis* (Osb.) Merr.	NA		✓	
			Albizzia odoratissima (L.f.) Benth.	NA		✓	
29	Moraceae	*Artocarpus*	*Artocarpus sp.*	NA	✓		
			Artocarpus lakoocha Roxb.	NA	✓		
		Ficus	*Ficus prostrata* (Wall ex Miq.) Buch.-Ham. ex Miq.	NA		✓	
			Ficus religiosa L.	NA		✓	
			Ficus semicordata Buch.-Ham ex Sm.	NA		✓	
			Ficus subulata Linn.	NA			✓
30	Myricaceae	*Eugenia*	*Eugenia jambolana* Lam.	NA	✓	✓	
31	Myrsinaceae	*Maesa*	*Maesa indica* (Roxb.) A. DC.	NA		✓	

Table 2 contd.

1	2	3	4	5	6	7	8
32	Myrtaceae	*Syzygium*	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	NA		✓	✓
			Syzygium cuminii (L.) Skeels	NA	✓		
			Syzygium macrocarpum Bahadur & R.C. Gaur	NA			✓
33	Oleaceae	*Olea*	*Olea dioca* Roxb.	NA	✓	✓	
			*Olea salicifolia*Wall. ex. G.Don	NA	✓		
34	Oxalidaceae	*Averrhoa*	*Averrhoa corambola* L.	NA	✓	✓	
35	Phyllanthaceae	*Bischofia*	*Bischofia javanica* Blume	LC	✓		
		Glochidion	*Glochidion lanceolarium* Muell. Arg.	NA	✓		✓
		Phyllanthus	*Phyllanthus emblica* L. *Emblica officinalis* Gaertn.	NA	✓		
36	Pittosporaceae	*Pitosporum*	*Pitosporum floribundum* Wight. &Arn. Syn. *Pittosporum naupalense* (DC.) Reher & E.H Wilson	NA	✓	✓	✓
37	Podocarpaceae	*Podocarpus*	*Podocarpus nerifolius* D.Don.	NA		✓	✓
38	Proteaceae	*Helicia*	*Helicia excelsa* (Roxb.) Blume	NA	✓	✓	✓
			Helicia robusta (Roxb.) R. Br.	NA	✓		
39	Rhamnaceae	*Ziziphus*	*Ziziphus incurva* Roxb.	NA	✓		
40	Rhizophoraceae	*Caralia*	*Caralia brachiata* (Lour.) Merr.	NA		✓	
41	Rosaceae	*Cerasus*	*Cerasus cerasoides* (Buch.-Ham. Ex D.Don) S.Y Sokolov	LC	✓		
		Eriobotrya	*Eriobotrya bengalensis* (Roxb.) Hook. f.	LC	✓		
		Laurocerasus	*Laurocerasus jenkinsii (Hook. f. & Thomson)* Browicz	NA	✓	✓	
			Laurocerasus undulata (D.Don)	NA		✓	
		Pyrus	*Pyrus sp.*	NA			✓
42	Rubiaceae	*Breonia*	*Breonia chinensis* (Lam.) Capuron	LC		✓	
		Wendlandia	*Wendlandia grandis* (Hook. F.) Cowan	NA	✓		
43	Rutaceae	*Citrus*	*Citrus indica* Yu. Tanaka	NA		✓	
			Citrus latipes (Swingle) Yu. Tanka	NA		✓	
		Clausena	*Clausena heptaphylla* (Roxb.) Wight & Arn.	NA		✓	
		Lindera	*Lindera sp*	NA	✓		

Table 2 contd.							
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
44	Sonneratiaceae	*Duabanga*	*Duabanga grandiflora* (DC.) Walp. *Duabanga sonneratioides* Buch.-Ham.	NA	✓		
45	Styraceae	*Styrax*	*Styrax serulatum* Roxb.	NA		✓	
46	Theaceae	*Eurya*	*Eurya acuminata* DC.	NA	✓	✓	
			*Eurya japonica*Thunb.	NA	✓	✓	
		Schima	*Schima khasiana* Dyer	NA			✓
			Schima wallichi Choisy	LC	✓	✓	✓
47	Thymeleaceae	*Aquilaria*	*Aquilaria sp*	NA		✓	
48	Tiliaceae	*Colona*	*Colona floribunda* (Kurz.) Craib	NA	✓		
		Columbia	*Columbia flagocarpa* (C.B Clarke) Craib	NA	✓		
		Grewia	*Grewia sclerophylla* Roxb. ex G.Don	NA	✓		
49	Ulmaceae	*Celtis*	*Celtis timorensis* Span	NA	✓		
50	Urticaceae	*Boehmeria*	*Boehmeria rugulosa* Wedd.	NA		✓	✓
51	Vaccinaceae	*Vaccinium*	*Vaccinium dodianum*	NA		✓	
52	Verbenaceae	*Gmelina*	*Gmelina arborea* Roxb. ex Sm.	NA	✓		
			Gmelina oblongifolia Roxb.	NA	✓		

NA= Not Available; LC= Least Concern; VU= Vulnerable, NT= Near Threatened; DD= Data Deficient

Table 3a: Tree species composition in Site-1			
Sl no.	**Botanical Name**	**Genus**	**Family**
1	**2**	**2**	**3**
1	*Choreospondias axilaris* Roxb.	*Choreospondias*	Anacardiaceae
2	*Rhus chinensis* Mill.	*Rhus*	
3	*Alstonia scholaris* R. Br.	*Alstonia*	Apocyanaceae
4	*Ilex godajam* Colebr. ex Hook.f.	*Ilex*	Aquifoliaceae
5	*Leucomeris decora* Kurz	*Leucomeris*	Asteraceae
6	*Vernonia volkamerifolia* DC.	*Vernonia*	
7	*Betula alnoides*Buch.-Ham ex D.Don	*Betula*	Betulaceae
8	*Sterospermum chelonoides* (L. fil) DC.	*Sterospermum*	Bignoniaceae
9	*Bauhinia variegata* L	*Bauhinia*	Caesalpiniaceae
10	*Diospyros glandulosa* Lace.	*Diospyros*	Ebenaceae
11	*Diospyros lanceifolia* Roxb.		
12	*Elaeocarpus lanceifolius* Roxb.	*Elaeocarpus*	Elaeocaroaceae
13	*Elaeocarpus rugosus* Roxb. ex G.Don.		
14	*Aporosa oblonga* Muell. Arg. *A. octandra* (Buch.-Ham ex D.Don) Vickery	*Aporosa*	Euphorbiaceae
15	*Macaranga denticulata* (Bl.) Mueller	*Macaranga*	
16	*Claoryton longipetiolatum*	*Claoryton*	Fabaceae
17	*Derris pseudorobusta* Thoth.	*Derris*	
18	*Derris robusta* (DC.) Benth.		
19	*Castanopsis echinocarpa* Miq.	*Castanopsis*	Fagaceae
20	*Castanopsis tribuloides* (Sm). A. DC.		
21	*Lithocarpus obscurus* C.C.Huang & Y.T Chang	*Lithocarpus*	
22	*Litocarpus pachyphyllus* (Kurz) Rehder		
23	*Quercus spicata* Sm.	*Quercus*	
24	*Quercus glauca* Thunb.		
25	*Quercus helferiana*A. DC.		
26	*Quercus lineata* Blume		
27	*Quercus xylocarpus* (Kurz.) Markgr.		
28	*Engelhardtia spicata* Lechen ex Blume	*Engelhardtia*	Juglandaceae
29	*Holboellia latifolia* Wall.	*Holboellia*	Laedizabalaceae
30	*Vitex canescens* Kurz	*Vitex*	Lamiaceae
31	*Litsea monopetala* (Roxb.) Pers.	*Litsea*	Lauraceae
32	*Litsea salilicifolia* (Roxb. ex Nees)		

Table 3a contd.			
1	**2**	**3**	**4**
33	*Persea odoratissima* (Nees) Kostern. *Machilus odoratissima* Nees	*Persea*	Lauraceae
34	*Phoebe lanceolata* (Nees) Nees	*Phoebe*	
35	*Michelia champaca* KL.	*Michelia*	Magnoliaceae
36	*Dysoxylum mollissimum* Blume *Dysoxylum hamiltonii* Hiern	*Dysoxylum*	Meliaceae
37	*Artocarpus sp.*	*Artocarpus*	Moraceae
38	*Artocarpus lakoocha* Roxb.		
39	*Eugenia jambolana* Lam.	*Eugenia*	Myricaceae
40	*Syzygium cuminii* (L.) Skeels	*Syzygium*	Myrtaceae
41	*Olea dioca* Roxb.	*Olea*	Oleaceae
42	*Olea salicifolia* Wall. ex. G.Don		
43	*Averrhoa corambola* L.	*Averrhoa*	Oxalidaceae
44	*Bischofia javanica* Blume	*Bischofia*	Phyllanthaceae
45	*Glochidion lanceolarium* Muell. Arg.	*Glochidion*	
46	*Phyllanthus emblica* L. *Emblica officinalis* Gaertn.	*Phyllanthus*	
47	*Pitosporum floribundum* Wight. &Arn.	*Pitosporum*	Pittosporaceae
48	*Helicia excelsa* (Roxb.) Blume	*Helicia*	Proteaceae
49	*Helicia robusta* (Roxb.) R. Br.		
50	*Ziziphus incurva* Roxb.	*Ziziphus*	Rhamnaceae
51	*Cerasus cerasoides* (Buch.-Ham. Ex D.Don) S.Y Sokolov	*Cerasus*	Rosaceae
52	*Eriobotrya bengalensis* (Roxb.) Hook. f.	*Eriobotrya*	
53	*Laurocerasus jenkinsii* (Hook. f. & Thomson) Browicz	*Laurocerasus*	
54	*Wendlandia grandis* (Hook. F.) Cowan	*Wendlandia*	Rubiaceae
55	*Lindera sp*	*Lindera*	Rutaceae
56	*Duabanga grandiflora* (DC.) Walp.	*Duabanga*	Sonneratiaceae
57	*Eurya acuminata* DC.	*Eurya*	Theaceae
58	*Eurya japonica* Thunb.		
59	*Schima wallichi* Choisy	*Schima*	
60	*Colona floribunda* (Kurz.) Craib	*Colona*	Tiliaceae
61	*Columbia flagocarpa* (C.B Clarke) Craib	*Columbia*	
62	*Grewia sclerophylla* Roxb. Ex G.Don	*Grewia*	
63	*Celtis timorensis* Span	*Celtis*	Ulmaceae
64	*Gmelina arborea* Roxb. ex Sm.	*Gmelina*	Verbenaceae
65	*Gmelina oblongifolia* Roxb.		

Table3b: Tree species composition in Site-2

Sl no.	Botanical Name	Genus	Family
1	**2**	**3**	**4**
1	*Choreospondias axilaris* Roxb.	*Choreospondias*	Anacardiaceae
2	*Drimycarpus racemosus* (Roxb.) Hook. f. ex Marchand.	*Drimycarpu*	
3	*Mangifera sp*	*Mangifera*	
4	*Alphonsea ventricosa* (Roxb.) Hk. f. & Th.	*Alphonsea*	Annonaceae
5	*Heteropanax oreophyllum*	*Heteropanax*	Araliaceae
6	*Betula alnoides* Buch.-Ham ex D.Don	*Betula*	Betulaceae
7	*Bursera serrata* Wall. ex Colebr.	*Bursera*	Burseraceae
8	*Lobelia pyramidalis* Wall.	*Lobelia*	Campanulaceae
9	*Cephalotaxus griffithi* Hook.f.	*Cephalotaxus*	Cephalotaxaceae
10	*Calophyllum polyanthum*Wall. ex Planch. & Triana	*Calophyllum*	Clusiaceae
11	*Garcinia xanthochymus* Hook. f.	*Garcinia*	
12	*Messua ferrae* Linn.	*Messua*	
13	*Terminalia chebula* Retz.	*Terminalia*	Combretaceae
14	*Diospyros lanceifolia* Roxb.	*Diospyros*	Ebenaceae
15	*Diospyros pilosiuscula* G.Don		
16	*Elaeocarpus lanceifolius* Roxb.	*Elaeocarpus*	Elaeocaroaceae
17	*Elaeocarpus prunifolius* Wall. ex Muell. Berol.		
18	*Elaeocarpus rugosus* Roxb. ex G. Don.		
19	*Antidesma bunius* (L.) Spreng.	*Antidesma*	Euphorbiaceae
20	*Sapium* sp	*Sapium*	
21	*Dalbergia lanceolaria* L.f.	*Dalbergia*	Fabaceae
22	*Derris robusta* (DC.) Benth.	*Derris*	
23	*Erythrina stricta* Roxb.	*Erythrina*	
24	*Castanopsis echinocarpa* Miq.	*Castanopsis*	Fagaceae
25	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.		
26	*Castanopsis tribuloides* (Sm). A. DC.		
27	*Quercus glauca* Thunb.	*Quercus*	
28	*Quercus helferiana* A. DC.		
29	*Quercus semiserrata* Roxb.		
30	*Quercus serrata* Murray		
31	*Quercus sp*		
32	*Quercus xylocarpus* (Kurz.) Markgr.		
33	*Engelhardtia spicata* Lechen ex Blume	*Engelhardtia*	Juglandaceae
34	*Juglans regia* Linn.	*Juglans*	
35	*Holboellia latifolia* Wall.	*Holboellia*	Laedizabalaceae
36	*Callicarpa arborea* Roxb.	*Callicarpa*	Lamiaceae
37	*Vitex glabrata* R.Br.	*Vitex*	
38	*Vitex peduncularis* Wall. ex Schauer		
39	*Vitex quinata* (Lour.) F.N. Williams		

Table 3b Contd.			
1	**2**	**3**	**4**
40	*Alseodaphne petiolaris* Hook. f.	*Alseodaphne*	Lauraceae
41	*Cinnamomum obtusifolium* (Roxb.) Nees	*Cinnamomum*	
42	*Persea glaucescens* (Nees) D.G. Long	*Persea*	
43	*Persea odoratissima* (Nees) Kostern.		
44	*Phoebe angustifolia* Meisn.	*Phoebe*	
45	*Phoebe hainesiana* Brandis		
46	*Phoebe lanceolata* (Nees) Nees		
47	*Magnolia ballonii* Pierre	*Magnolia*	Magnoliaceae
48	*Michelia champaca* KL.	*Michelia*	
49	*Dysoxylum mollissimum* Blume	*Dysoxylum*	Meliaceae
50	*Melia dubia* Cav.	*Melia*	
51	*Toona ciliata* M. Roem	*Toona*	
52	*Albizia chinensis* (Osb.) Merr.	*Albizia*	Mimosaceae
53	*Albizzia odoratissima* (L.f.) Benth.		
54	*Ficus prostrata* (Wall ex Miq.) Buch. -Ham. ex Miq.	*Ficus*	Moraceae
55	*Ficus religiosa* L.		
56	*Ficus semicordata* Buch.-Ham ex Sm.		
57	*Eugenia jambolana* Lam.	*Eugenia*	Myricaceae
58	*Maesa indica* (Roxb.) A. DC.	*Maesa*	Myrsinaceae
59	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	*Syzygium*	Myrtaceae
60	*Olea dioca* Roxb.	*Olea*	Oleaceae
61	*Averrhoa corambola* L.	*Averrhoa*	Oxalidaceae
62	*Pitosporum floribundum* Wight. &Arn.	*Pitosporum*	Pittosporaceae
63	*Podocarpus nerifolius* D.Don.	*Podocarpus*	Podocarpaceae
64	*Helicia excelsa* (Roxb.) Blume	*Helicia*	Proteaceae
65	*Caralia brachiata* (Lour.) Merr.	*Caralia*	Rhizophoraceae
66	*Laurocerasus jenkinsii* (Hook. f. & Thomson) Browicz	*Laurocerasus*	Rosaceae
67	*Laurocerasus undulata* (D. Don)		
68	*Breonia chinensis*(Lam.) Capuron	*Breonia*	Rubiaceae
69	*Citrus indica* Yu. Tanaka	*Citrus*	Rutaceae
70	*Citrus latipes* (Swingle) Yu. Tanka	*Citrus*	
71	*Clausena heptaphylla* (Roxb.) Wight &Arn.	*Clausena*	
72	*Styrax serulatum* Roxb.	*Styrax*	Styraceae
73	*Eurya acuminata* DC.	*Eurya*	Theaceae
74	*Eurya japonica* Thunb.		
75	*Schima wallichi* Choisy	*Schima*	Theaceae
76	*Aquilaria sp*	*Aquilaria*	Thymeleaceae
77	*Boehmeria rugulosa* Wedd.	*Boehmeria*	Urticaceae
78	*Vaccinium dodianum*	*Vaccinium*	Vaccinaceae

Table3c: Tree species composition in Site-3			
Sl no	**Botanical Name**	**Genus**	**Family**
1	*Acrocarpus fraxinifolious* Wight ex Arn.	*Acrocarpus*	Caesalpiniaceae
2	*Cephalotaxus griffithi* Hook.f.	*Cephalotaxus*	Cephalotaxaceae
3	*Nyssa javanica* (Blume) Wangerin	*Nyssa*	Cornaceae
4	*Diospyros lanceifolia* Roxb.	*Diospyros*	Ebenaceae
5	*Rhododendron arboreum* Sm.	*Rhododendron*	Ericaceae
6	*Rhododendron formosum* Wall.		
7	*Castanopsis echinocarpa* Miq.	*Castanopsis*	Fagaceae
8	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.		
9	*Castanopsis tribuloides* (Sm). A. DC.		
10	*Lithocarpus obscurus* C.C.Huang & Y.T Chang	*Lithocarpus*	
11	*Quercus helferiana* A. DC.	*Quercus*	
12	*Quercus sp*		
13	*Quercus xylocarpus (*Kurz.) Markgr.		
14	*Engelhardtia spicata* Lechen ex Blume	*Engelhardtia*	Juglandaceae
15	*Cinnamomum obtusifolium* (Roxb.) Nees	*Cinnamomum*	Lauraceae
16	*Litsea monopetala* (Roxb.) Pers.	*Litsea*	
17	*Litsea salilicifolia* (Roxb. ex Nees)		
18	*Machillus sp*	*Machillus*	
19	*Persea glaucescens* (Nees) D.G. Long	*Persea*	
20	*Persea minutiflora* Kostern Machilus parviflora Meissn.		
21	*Persea odoratissima* (Nees) Kostern.		
22	*Phoebe angustifolia* Meisn.	*Phoebe*	
23	*Phoebe hainesiana* Brandis		
24	*Phoebe lanceolata* (Nees) Nees		
25	*Dysoxylum mollissimum* Blume *Dysoxylum hamiltonii* Hiern	*Dysoxylum*	Meliaceae
26	*Ficus subulata* Linn.	*Ficus*	Moraceae
27	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	*Syzygium*	Myrtaceae
28	*Syzygium macrocarpa*		
29	*Glochidion lanceolarium* Muell. Arg.	*Glochidion*	Phyllanthaceae
30	*Pitosporum floribundum* Wight. &Arn. Syn. *Pittosporum naupalense* (DC.) Reher & E.H Wilson	*Pitosporum*	Pittosporaceae
31	*Podocarpus nerifolius* D.Don.	*Podocarpus*	Podocarpaceae
32	*Helicia excelsa* (Roxb.)Blume	*Helicia*	Proteaceae
33	*Pyrus sp.*	*Pyrus*	Rosaceae
34	*Schima khasiana* Dyer	*Schima*	Theaceae
35	*Schima wallichi* Choisy		
36	*Boehmeria rugulosa* Wedd.	*Boehmeria*	Urticaceae

Table 4a: Basal area for Site-1

Sl. No.	Botanical Name	Seedlings	Poles	Trees	Total basal
1	2	3	4	5	6
1	*Alstonia scholaris* R. Br.	0.01	0.02	0	0.02
2	*Aporosa oblonga* Muell. Arg.	0.01	0.02	0	0.02
3	*Artocarpus*	0.02	0.02	0	0.03
4	*Artocarpus lakoocha* Roxb.	0.01	0.01	0	0.02
5	*Averrhoa corambola* L.	0	0.01	0	0.01
6	*Bauhinia variegata* L.	0.04	0.51	0.14	0.68
7	*Betula alnoides* Buch.-Ham ex D.Don	0.04	0.43	0.51	0.97
8	*Bischofia javanica* Blume	0	0.02	0	0.02
9	*Castanopsis echinocarpa* Miq.	0	0.03	0	0.03
10	*Castanopsis tribuloides* (Sm). A.DC.	0.07	0.33	2.27	2.66
11	*Celtis timorensis* Span	0.01	0	0	0.01
12	*Cerasus cerasoides* (Buch.-Ham. Ex D.Don) S.Y Sokolov	0.02	0.02	0	0.04
13	*Choreospondias axilaris* Roxb.	0.02	0.1	0.12	0.23
14	*Claoryton longipetiolatum*	0.01	0.04	0.1	0.14
15	*Colona floribunda* (Kurz.) Craib	0.08	0.78	0.27	1.12
16	*Columbia flagocarpa* (C.B Clarke) Craib	0.13	1.21	3.24	4.57
17	*Derris pseudorobusta* Thoth.	0.04	0.08	0.11	0.22
18	*Derris robusta* (DC.) Benth.	0.02	0.05	0	0.06
19	*Diospyros glandulosa* Lace.	0	0.07	0	0.07
20	Diospyros lanceifolia Roxb.	0.01	0	0	0.01
21	*Duabanga grandiflora* (DC.) Walp.	0.02	0.1	0	0.12
22	*Dysoxylum hamiltoni* Hiern.	0	0	0.46	0.46
23	*Elaeocarpus lanceifolius* Roxb.	0.02	0.18	0	0.19
24	*Elaeocarpus rugosus* Roxb. ex G.Don.	0.03	0.04	0	0.06
25	*Engelhardtia spicata* Lechen ex Blume	0.03	0.05	0	0.07
26	*Eriobotrya bengalensis* (Roxb.) Hook. f.	0.01	0.05	0	0.06
27	*Eugenia jambolana* Lam.	0.01	0.03	0	0.03
28	*Eurya acuminata* DC.	0.01	0.03	0	0.04
29	*Eurya japonica* Thunb.	0.02	0	0	0.02
30	*Glochidion lanceolarium* Muell. Arg.	0.15	0.16	0	0.3
31	*Gmelina arborea* Roxb. ex Sm.	0	0	0.16	0.16
32	*Gmelina oblongifolia* Roxb.	0	0.02	0	0.02

Table 4a Contd.					
1	**2**	**3**	**4**	**5**	**6**
33	*Grewia sclerophylla* Roxb. ex G.Don	0.01	0	0	0.01
34	*Helicia excelsa* (Roxb.) Blume	0.06	0.28	0.58	0.92
35	*Helicia robusta* (Roxb.) R. Br.	0.01	0.3	0	0.3
36	*Holboellia latifolia* Wall.	0.01	0.1	0.09	0.18
37	*Ilex godajam* Colebr. ex Hook. f.	0	0.06	0	0.06
38	*Laurocerasus jenkinsii* (Hook. f. & Thomson) Browicz	0.01	0.07	0.21	0.27
39	*Leucomeris decora* Kurz	0.05	0.1	0.11	0.25
40	*Lindera sp*	0.01	0	0	0.01
41	*Lithocarpus obscurus* C.C.Huang & Y.T Chang	0	0.12	0	0.12
42	*Litocarpus pachyphyllus* (Kurz) Rehder	0.15	3.31	3.05	6.49
43	*Litsea monopetala* (Roxb.) Pers.	0.01	0.17	0	0.17
44	*Litsea salilicifolia* (Roxb. ex Nees)	0.1	0.6	0.09	0.78
45	*Macaranga denticulata* (Bl.) Mueller	0.03	0.01	0	0.03
46	*Michelia champaca* KL.	0.01	0.02	0	0.03
47	*Olea dioca* Roxb.	0	0.01	0	0.01
48	*Olea salicifolia* Wall. ex. G.Don	0.01	0	0	0.01
49	*Persea odoratissima* (Nees) Kostern. *Machilus odoratissima* Nees	0.03	0.02	0	0.05
50	*Phoebe angustifolia* Meisn.	0.07	0.15	0.13	0.34
51	*Phoebe lanceolata*(Nees) Nees	0.01	0	0	0.01
52	*Phyllanthus emblica* L. *Emblica officinalis* Gaertn.	0.01	0.1	0	0.11
53	*Pitosporum floribundum* Wight. &Arn.	0.1	0.37	0	0.46
54	*Quercus helferiana* A. DC.	0.1	1.66	2.22	3.97
55	*Quercus lineata* Blume	0.03	0.48	0.08	0.58
56	*Quercus spicata* Sm.	0.32	6.35	4.86	11.52
57	Quercus xylocarpus (Kurz.) Markgr.	0.57	3.15	0.33	4.04
58	*Rhus chinensis* Mill.	0.05	0.05	0	0.09
59	*Schima wallichi* Choisy	0.19	2.85	8.09	11.12
60	*Sterospermum chelonoides* (L. fil) DC.	0	0	0.12	0.12
61	*Syzygium cuminii* (L.) Skeels	0.01	0	0	0.01
62	*Vernonia volkamerifolia* DC.	0.03	0.15	0	0.17
63	*Vitex canescens* Kurz	0.01	0.13	0	0.13
64	*Wendlandia grandis* (Hook. F.) Cowan	0.05	0.13	0	0.17
65	*Ziziphus incurva* Roxb.	0.03	0.02	0	0.05
TOTAL		2.61 4.76%	24.9 45.50%	27.22 49.73%	54.72

Table4b: Basal area for Site-2

Sl. No	Botanical Name	Seedlings	Poles	Trees	Total
1	**2**	**3**	**4**	**5**	**6**
1	*Albizia chinensis* (Osb.) Merr.	0.02	0.068	4.404	4.491
2	*Albizzia odoratissima* (L.f.) Benth.	0.009	0.241	0.719	0.969
3	*Alphonsea ventricosa* (Roxb.) Hk. f. & Th.	0.005	0.035	3.42	3.46
4	*Alseodaphne petiolaris* Hook. f.	0.01	0	0	0.01
5	*Antidesma bunius* (L.) Spreng.	0.007	0	0	0.007
6	*Aquilaria sp*	0.001	0.079	1.606	1.685
7	*Averrhoa corambola* L.	0.002	0	1.792	1.794
8	*Betula alnoides* Buch.-Ham ex D.Don	0.014	0.096	11.518	11.627
9	*Boehmeria rugulosa* Wedd.	0.013	0.04	0	0.053
10	*Breonia chinensis* (Lam.) Capuron	0.014	0	0	0.014
11	*Bursera serrata* Wall. ex Colebr.	0.023	0	0	0.023
12	*Callicarpa arborea* Roxb.	0	0.273	2.936	3.208
13	*Calophyllum polyanthum* Wall. ex Planch. & Triana	0.008	0	0	0.008
14	*Caralia brachiata* (Lour.) Merr.	0.007	0.013	0	0.02
15	*Castanopsis echinocarpa* Miq.	0.006	0.287	9.653	9.946
16	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.	0.009	0.024	0	0.033
17	*Castanopsis tribuloides* (Sm). A.DC.	0.008	0.262	7.835	8.103
18	*Cephalotaxus griffith*i Hook.f.	0.001	0.045	0.781	0.826
19	*Choreospondias axilaris* Roxb.	0.012	0.034	3.185	3.231
20	*Cinnamomum obtusifolium* (Roxb.) Nees	0.005	0.315	9.417	9.736
21	*Citrus indica* Yu. Tanaka	0.086	0.03	0	0.116
22	*Citrus latipes* (Swingle) Yu. Tanka	0.026	0.283	0	0.309
23	*Clausena heptaphylla* (Roxb.) Wight & Arn.	0.037	0.352	7.053	7.442
24	*Dalbergia lanceolaria* L.f.	0.005	0.054	0	0.059
25	*Derris robusta*	0.005	0.011	0	0.016
26	*Diospyros lanceifolia* Roxb.	0.001	0.348	8.512	8.86
27	*Diospyros pilosiuscula* G.Don	0.006	0	0.964	0.97
28	*Drimycarpus racemosus* (Roxb.) Hook. f. ex Marchand.	0.013	0	0	0.013
29	*Dysoxylum mollissimum* Blume *Dysoxylum hamiltonii*Hiern	0.01	0	297.909	297.919
30	*Elaeocarpus lanceifolius* Roxb.	0.001	0.035	6.247	6.281
31	*Elaeocarpus prunifolius* Wall. Ex Muell. Berol.	0.001	0.062	3.09	3.152
32	*Elaeocarpus rugosus* Roxb. ex G.Don.	0.033	0.011	0	0.044
33	*Engelhardtia spicata* Lechen ex Blume	0	0.14	23.363	23.503
34	*Erythrina stricta* Roxb.	0.019	0.273	2.58	2.872
35	*Eugenia jambolana* Lam.	0.001	0.191	11.411	11.601

Table 4b Contd.					
1	**2**	**3**	**4**	**5**	**6**
36	*Eurya acuminata* DC.	0	0.035	0	0.035
37	*Eurya japonica* Thunb.	0.001	0.01	0	0.01
38	*Ficus prostrata* (Wall ex Miq.) Buch.-Ham. ex Miq.	0	0.055	0	0.055
39	*Ficus religiosa* L.	0.001	0	10.205	10.206
40	*Ficus semicordata* Buch.-Ham ex Sm.	0.007	0.067	0	0.073
41	*Garcinia xanthochymus* Hook. f.	0.029	0.027	0	0.056
42	*Helicia excelsa* (Roxb.)Blume	0.036	0.485	0	0.521
43	*Heteropanax oreophyllum*	0.005	0.034	0	0.039
44	*Holboellia latifolia* Wall.	0	0	2.428	2.428
45	*Juglans regia* Linn.	0.023	0	0	0.023
46	*Laurocerasus jenkinsii* (Hook. f. & Thomson) Browicz	0.002	0	0.765	0.767
47	*Laurocerasus undulata* (D.Don)	0	0.392	0.797	1.189
48	*Lobelia pyramidalis* Wall.	0	0	6.422	6.422
49	*Maesa indica* (Roxb.) A. DC.	0.005	0.012	0	0.016
50	*Magnolia ballonii* Pierre	0.008	0.036	0	0.044
51	*Mangifera sp*	0.001	0.03	0	0.03
52	*Melia dubia* Cav.	0.002	0	2.785	2.787
53	*Messua ferrae* Linn.	0.007	0	0	0.007
54	*Michelia champaca* KL.	0	0.182	7.096	7.277
55	*Olea dioca* Roxb.	0.001	0.012	0	0.013
56	*Persea glaucescens* (Nees) D.G. Long	0.26	0.13	18.475	18.865
57	*Persea odoratissima* (Nees) Kostern.	0.04	2.997	98.811	101.848
58	*Phoebe angustifolia* Meisn.	0.002	1.211	181.8	183.013
59	*Phoebe hainesiana* Brandis	0.001	0.085	35.04	35.124
60	*Phoebe lanceolata* (Nees) Nees	0.172	0.011	13.779	13.961
61	*Pitosporum floribundum* Wight. &Arn.	0.002	1.907	10.907	12.815
62	*Podocarpus nerifolius* D.Don.	0.001	0.068	0	0.068
63	*Quercus glauca* Thunb.	0.017	0.021	0	0.037
64	*Quercus helferiana* A. DC.	0.071	0	0	0.071
65	*Quercus semiserrata* Roxb.	0.003	0.027	0	0.03
66	*Quercus serrata* Murray	0.005	0.024	0	0.029
67	*Quercus sp*	0.033	0.137	0	0.17
68	*Quercus xylocarpus* (Kurz.) Markgr.	0	1.318	141.76	143.078
69	*Sapium sp*	0.001	0.044	0	0.045
70	*Schima wallichi* Choisy	0.015	0	29.795	29.81
71	*Styrax serulatum* Roxb.	0.018	0	0	0.018
72	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	0	0.031	10.66	10.69
73	*Terminalia chebula* Retz.	0.008	0	0.797	0.804
74	*Toona ciliata* M. Roem	0.001	0.027	0	0.027
75	*Vaccinium dodianum*	0.002	0.218	0	0.22
76	*Vitex glabrata* R.Br.	0.029	0.128	2.09	2.247
77	*Vitex peduncularis* Wall. ex Schauer	0.01	0.025	0	0.035
78	*Vitex quinata* (Lour.) F.N. Williams	0	0.011	0	0.011
	TOTAL	1.22 0.12%	13.37 1.33%	992.79 98.55%	1007.37

Table 4c: Basal area for Site-3

Sl. No.	BotanicalName	Seedlings	Poles	Trees	Total
1	*Pitosporum floribundum* Wight. &Arn.	0.14	1.793	5.612	7.544
2	*Phoebe angustifolia* Meisn.	0.056	0.228	6.119	6.402
3	*Ficus subulata* Linn.	0	0	6.19	6.19
4	*Castanopsis echinocarpa* Miq.	0.247	1.553	3.279	5.078
5	*Persea odoratissima* (Nees) Kostern.	0.042	0.963	4.009	5.013
6	*Persea minutiflora* Kostern	0.004	0.05	3.621	3.674
7	*Castanopsis tribuloides* (Sm.) A.DC.	0.011	0.227	2.471	2.707
8	*Persea glaucescens* (Nees) D.G. Long	0.001	0	2.701	2.701
9	*Quercus xylocarpus* (Kurz.) Markgr.	0.016	0.436	2.224	2.675
10	*Quercus sp*	0.014	0.208	2.22	2.441
11	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.	0.003	0.097	1.435	1.534
12	*Nyssa javanica*(Blume) Wangerin	0.001	0.195	1.162	1.357
13	*Acrocarpus fraxinifolious* Wight ex Arn.	0.001	0	1.123	1.124
14	*Cinnamomum obtusifolium* (Roxb.) Nees	0.001	0.208	0.906	1.114
15	*Phoebe lanceolata* (Nees) Nees	0.001	1.01	0	1.01
16	*Dysoxylum mollissimum* Blume	0.001	0	0.93	0.93
17	*Schima khasiana* Dyer	0.001	0.036	0.409	0.445
18	*Phoebe hainesiana* Brandis	0.001	0.077	0.304	0.381
19	*Cephalotaxus griffithi* Hook.f.	0.008	0.08	0.277	0.365
20	*Podocarpus nerifolius* D.Don.	0.001	0.088	0.277	0.365
21	*Machillus sp*	0	0.009	0.31	0.318
22	*Rhododendron arboreum* Sm.	0.024	0.098	0.088	0.209
23	*Quercus helferiana* A. DC.	0	0	0.202	0.202
24	*Syzygium macrocarpa*	0	0.083	0.088	0.17
25	*Pyrus sp*	0.017	0.022	0.125	0.163
26	*Litsea monopetala* (Roxb.) Pers.	0.007	0.068	0.072	0.146
27	*Lithocarpus obscurus* C.C.Huang & Y.T Chang	0.001	0	0.129	0.129
28	*Engelhardtia spicata* Lechen ex Blume	0.004	0	0.1	0.104
29	*Diospyros lanceifolia* Roxb.	0.004	0.091	0	0.095
30	*Boehmeria rugulosa* Wedd.	0.016	0.056	0	0.071
31	*Helicia excelsa* (Roxb.) Blume	0	0.042	0	0.042
32	*Rhododendron formosum* Wall.	0.007	0.026	0	0.033
33	*Litsea salilicifolia*(Roxb. ex Nees)	0.004	0.025	0	0.029
34	*Glochidion lanceolarium* Muell. Arg.	0	0.02	0	0.02
35	*Schima wallichi* Choisy	0.006	0	0	0.006
36	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	0.003	0	0	0.003
	TOTAL	0.628 1.15%	7.774 14.19%	46.371 84.66%	54.772

Table 5a: Plant Diversity indices of different study sites of Lengteng Wildlife Sanctuary

Species Diversity Index	**Site1**	**Site2**	**Site3**
Shannon- Wiener diversity Index	2.99	3.17	2.56
Margalef's Index of species richness (1949)	19.27	23.98	12.33
Evenness index (Pielou's index, 1972)	0.72	0.73	0.71
Simpson's Index of Dominance (1940)	0.08	0.08	0.13

Table 5b: Sorensen's index of similarity

Site 1&2	0.36
Site2&3	0.3
Site 1&3	0.28

Table 6a: Site-1 Frequency (%), Abundance and A/F Ratio

Sl. No.	Botanical Name	Frequency	Abundance	A/F
1	**2**	**3**	**4**	**5**
1	*Quercus spicata* Sm.	88	5.41	0.07
2	*Schima wallichi* Choisy	78.67	3.5	0.05
3	Quercus xylocarpus (Kurz.) Markgr.	84	5.16	0.07
4	*Litocarpus pachyphyllus* (Kurz) Rehder	74.67	3.77	0.06
5	*Columbia flagocarpa* (C.B Clarke) Craib	54.67	2.71	0.05
6	*Quercus helferiana* A. DC.	38.67	3.63	0.1
7	*Castanopsis tribuloides* (Sm). A. DC.	33.34	1.96	0.06
8	*Colona floribunda* (Kurz.) Craib	34.67	2.35	0.07
9	*Glochidion lanceolarium* Muell. Arg.	41.34	1.75	0.05
10	*Litsea salilicifolia* (Roxb. ex Nees)	26.67	3.3	0.13
11	*Phoebe angustifolia* Meisn.	28	2.43	0.09
12	*Helicia excelsa* (Roxb.) Blume	17.34	2.93	0.17
13	*Bauhinia variegata* L.	20	2.4	0.12
14	*Pitosporum floribundum* Wight.& Arn.	14.67	3.91	0.27
15	*Quercus lineata* Blume	16	2.92	0.19
16	*Betula alnoides* Buch.-Ham ex D.Don	12	3.12	0.26
17	*Wendlandia grandis* (Hook. F.) Cowan	21.34	1.82	0.09
18	*Leucomeris decora* Kurz	13.34	3.7	0.28
19	*Derris pseudorobusta* Thoth.	12	1.89	0.16
20	*Vernonia volkamerifolia* DC.	10.67	2.25	0.22
21	*Rhus chinensis* Mill.	10.67	2.13	0.2
22	*Engelhardtia spicata* Lechen ex Blume	10.67	1.88	0.18
23	*Helicia robusta* (Roxb.) R. Br.	6.67	2.2	0.33
24	*Duabanga grandiflora* (DC.) Walp.	9.34	1.58	0.17
25	*Elaeocarpus rugosus* Roxb. ex G. Don.	8	2.67	0.34
26	*Choreospondias axilaris* Roxb.	6.67	1.6	0.24
27	*Litsea monopetala* (Roxb.) Pers.	5.34	2.25	0.43
28	*Elaeocarpus lanceifolius* Roxb.	4	3.34	0.84
29	*Laurocerasus jenkinsii* (Hook. f. & Thomson) Browicz	4	1.67	0.42
30	*Ziziphus incurva* Roxb.	5.34	2	0.38
31	*Phyllanthus emblica* L. *Emblica officinalis* Gaertn.	4	2.67	0.67
32	*Dysoxylum hamiltoni* Hiern.	1.34	1	0.75

Table 6a Contd.				
1	**2**	**3**	**4**	**5**
33	*Holboellia latifolia* Wall.	4	1.67	0.42
34	*Macaranga denticulata* (Bl.) Mueller	5.34	1.75	0.33
35	*Derris robusta* (DC.) Benth.	4	3	0.75
36	*Vitex canescens* Kurz	4	1.34	0.34
37	*Phoebe lanceolata* (Nees) Nees	5.34	1.25	0.24
38	*Persea odoratissima* (Nees) Kostern. *Machilus odoratissima* Nees	4	2	0.5
39	*Claoryton longipetiolatum*	2.67	2.5	0.94
40	*Cerasus cerasoides* (Buch.-Ham. Ex D.Don) S.Y Sokolov	4	1.67	0.42
41	*Eugenia jambolana* Lam.	4	1.67	0.42
42	*Eurya acuminata* DC.	4	1.34	0.34
43	*Diospyros lanceifolia* Roxb.	4	1.34	0.34
44	*Lithocarpus obscurus* C.C.Huang & Y.T Chang	2.67	1.5	0.57
45	*Eriobotrya bengalensis* (Roxb.) Hook. f.	2.67	2	0.75
46	*Michelia champaca* KL.	2.67	2	0.75
47	*Aporosa oblonga* Muell. Arg.	2.67	2	0.75
48	*Gmelina arborea* Roxb. ex Sm.	1.34	1	0.75
49	*Eurya japonica* Thunb.	2.67	1.5	0.57
50	*Artocarpus lakoocha* Roxb.	2.67	1	0.38
51	*Sterospermum chelonoides* (L. fil) DC.	1.34	1	0.75
52	*Syzygium cuminii* (L.) Skeels	2.67	1	0.38
53	*Ilex godajam* Colebr. ex Hook.f.	1.34	2	1.5
54	*Diospyros glandulosa* Lace.	1.34	1	0.75
55	*Castanopsis echinocarpa* Miq.	1.34	2	1.5
56	*Alstonia scholaris* R. Br.	2	2	1.5
57	*Olea salicifolia* Wall. ex. G.Don	1.34	2	1.5
58	*Artocarpus sp.*	1.34	1	0.75
59	*Bischofia javanica* Blume	1.34	1	0.75
60	*Averrhoa corambola* L.	1.34	1	0.75
61	*Gmelina oblongifolia* Roxb.	1.34	1	0.75
62	*Olea dioca* Roxb.	1.34	1	0.75
63	*Celtis timorensis* Span	1.34	1	0.75
64	*Grewia sclerophylla* Roxb. ex G.Don	1.34	1	0.75
65	*Lindera sp.*	1.34	1	0.75

Table 6b: Site-2- Frequency (%), Abundance and A/F ratio

Sl. No	Botanical Name	Frequency	Abundance	A/F
1	**2**	**3**	**4**	**5**
1	*Albizia chinensis* (Osb.) Merr.	14.67	1.82	0.13
2	*Albizzia odoratissima* (L.f.) Benth.	14.67	1.46	0.1
3	*Alphonsea ventricosa* (Roxb.) Hk. f. & Th.	1.34	2	1.5
4	*Alseodaphne petiolaris* Hook. f.	2.67	2	0.75
5	*Antidesma bunius* (L.) Spreng.	1.34	1	0.75
6	*Aquilaria sp.*	6.67	2.2	0.33
7	*Averrhoa corambola* L.	1.34	3	2.25
8	*Betula alnoides* Buch.-Ham ex D. Don	9.34	2.72	0.3
9	*Boehmeria rugulosa* Wedd.	9.34	1.58	0.17
10	*Breonia chinensis* (Lam.) Capuron	1.34	1	0.75
11	*Bursera serrata* Wall. ex Colebr.	2.67	2	0.75
12	*Callicarpa arborea* Roxb.	8	2	0.25
13	*Calophyllum polyanthum* Wall. ex Planch. & Triana	1.34	1	0.75
14	*Caralia brachiata* (Lour.) Merr.	1.34	1	0.75
15	*Castanopsis echinocarpa* Miq.	16	2.84	0.18
16	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.	4	2	0.5
17	*Castanopsis tribuloides* (Sm). A.DC.	13.34	2.8	0.21
18	*Cephalotaxus griffith*i Hook. f.	5.34	2.25	0.43
19	*Choreospondias axilaris* Roxb.	2.67	2	0.75
20	*Cinnamomum obtusifolium* (Roxb.) Nees	21.34	1.69	0.08
21	*Citrus indica* Yu. Tanaka	4	2.67	0.67
22	*Citrus latipes* (Swingle) Yu. Tanka	22.67	4.18	0.19
23	*Clausena heptaphylla* (Roxb.) Wight & Arn.	21.34	2.57	0.13
24	*Dalbergia lanceolaria* L.f.	4	1.34	0.34
25	*Derris robusta* (DC.) Benth.	1.34	2	1.5
26	*Diospyros lanceifolia* Roxb.	25.34	2.43	0.1
27	*Diospyros pilosiuscula* G.Don	1.34	3	2.25
28	*Drimycarpus racemosus* (Roxb.) Hook. f. ex Marchand.	1.34	1	0.75
29	*Dysoxylum mollissimum* Blume Dysoxylum hamiltoniiHiern	33.34	2.6	0.08
30	*Elaeocarpus lanceifolius* Roxb.	9.34	2.86	0.31
31	*Elaeocarpus prunifolius*Wall. ex Muell. Berol.	2.67	2	0.75
32	*Elaeocarpus rugosus* Roxb. ex G.Don.	1.34	2	1.5
33	*Engelhardtia spicata*Lechen ex Blume	16	2.67	0.17
34	*Erythrina stricta* Roxb.	8	1.5	0.19
35	*Eugenia jambolana* Lam.	20	3.14	0.16
36	*Eurya acuminata* DC.	1.34	2	1.5

Table 6b Contd.				
1	**2**	**3**	**4**	**5**
37	*Eurya japonica* Thunb.	1.34	1	0.75
38	*Ficus prostrate* (Wall ex Miq.) Buch.-Ham. ex Miq.	6.67	1.8	0.27
39	*Ficus religiosa* L.	1.34	1	0.75
40	*Ficus semicordata* Buch.-Ham ex Sm.	4	1.34	0.34
41	*Garcinia xanthochymus* Hook. f.	1.34	3	2.25
42	*Helicia excelsa (*Roxb.) Blume	16	3	0.19
43	*Heteropanax oreophyllum*	1.34	1	0.75
44	*Holboellia latifolia* Wall.	2.67	4	1.5
45	*Juglans regia* Linn.	1.34	1	0.75
46	*Laurocerasus jenkinsii* (Hook. f. & Thomson) Browicz	1.34	1	0.75
47	*Laurocerasus undulata* (D.Don)	12	2.56	0.22
48	*Lobelia pyramidalis* Wall.	1.34	1	0.75
49	*Maesa indica* (Roxb.) A. DC.	4	2.67	0.67
50	*Magnolia ballonii* Pierre	1.34	1	0.75
51	*Mangifera sp*	1.34	3	2.25
52	*Melia dubia* Cav.	1.34	3	2.25
53	*Messua ferrae* Linn.	1.34	1	0.75
54	*Michelia champaca* KL.	10.67	2.88	0.27
55	*Olea dioca* Roxb.	1.34	1	0.75
56	*Persea glaucescens* (Nees) D.G. Long	13.34	2.1	0.16
57	*Persea odoratissima* (Nees) Kostern. *Machilus odoratissima* Nees	82.67	5.97	0.08
58	*Phoebe angustifolia* Meisn.	65.34	3.7	0.06
59	*Phoebe hainesiana* Brandis	13.34	2	0.15
60	*Phoebe lanceolata* (Nees) Nees	2.67	2.5	0.94
61	*Pitosporum floribundum*Wight. &Arn.	52	4.9	0.1
62	*Podocarpus nerifolius* D.Don.	2.67	1	0.38
63	*Quercus glauca* Thunb.	2.67	2.5	0.94
64	*Quercus helferiana* A. DC.	1.34	1	0.75
65	*Quercus semiserrata* Roxb.	9.34	1.29	0.14
66	*Quercus serrata* Murray	2.67	2	0.75
67	*Quercus sp*	4	1.67	0.42
68	*Quercus xylocarpus* (Kurz.) Markgr.	65.34	3.68	0.06
69	*Sapium sp*	1.34	1	0.75
70	*Schima wallichi* Choisy	4	4.34	1.09
71	*Styrax serulatum* Roxb.	10.67	1.25	0.12
72	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	8	3.34	0.42
73	*Terminalia chebula* Retz.	1.34	1	0.75
74	*Toona ciliata* M. Roem	2.67	2.5	0.94
75	*Vaccinium dodianum*	8	1.84	0.23
76	*Vitex glabrata* R.Br.	4	1.67	0.42
77	*Vitex peduncularis* Wall. ex Schauer	6.67	2.8	0.42
78	*Vitex quinata* (Lour.) F.N. Williams	4	1.34	0.34

Table 6c: Site3- Frequency (%), Abundance and A/F ratio

Sl. No	Botanical Name	Frequency	Abundance	A/F
1	*Acrocarpus fraxinifolious* Wight ex Arn.	4	1.67	0.42
2	*Boehmeria rugulosa* Wedd.	8	1.84	0.23
3	*Castanopsis echinocarpa* Miq.	46.67	4.58	0.1
4	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.	6.67	1.2	0.18
5	*Castanopsis tribuloides* (Sm.) A.DC.	18.67	2.43	0.14
6	*Cephalotaxus griffithi* Hook.f.	5.34	1.25	0.24
7	*Cinnamomum obtusifolium* (Roxb.) Nees	12	1.67	0.14
8	Diospyros lanceifolia Roxb.	2.67	2	0.75
9	*Dysoxylum mollissimum* Blume *Dysoxylum hamiltonii* Hiern	2.67	1.5	0.57
10	*Engelhardtia spicata* Lechen ex Blume	4	1	0.25
11	*Ficus subulata* Linn.	4	1	0.25
12	*Glochidion lanceolarium* Muell. Arg.	1.34	1	0.75
13	*Helicia excelsa* (Roxb.) Blume	1.34	1.8	0.27
14	Lithocarpus obscurus C.C.Huang & Y.T Chang	1.34	1	0.75
15	*Litsea monopetala* (Roxb.) Pers.	5.34	2	1.5
16	*Litsea salilicifolia* (Roxb. ex Nees)	1.34	1	0.19
17	*Machillus sp*	4	3	2.25
18	*Nyssa javanica* (Blume) Wangerin	1.34	1	0.25
19	*Persea glaucescens* (Nees) D.G. Long	10.67	4	3
20	*Persea minutiflora* Kostern Machilus parviflora Meissn.	12	1.63	0.16
21	*Persea odoratissima* (Nees) Kostern. *Machilus odoratissima* Nees	44	1.34	0.12
22	*Phoebe angustifolia* Meisn.	44	2.28	0.06
23	*Phoebe hainesiana* Brandis	5.34	1.82	0.05
24	*Phoebe lanceolata* (Nees) Nees	2.67	1.75	0.33
25	*Pitosporum floribundum* Wight. &Arn. Syn. *Pittosporum naupalense* (DC.) Reher & E.H Wilson	60	1.5	0.57
26	*Podocarpus nerifolius* D.Don.	5.34	3.29	0.06
27	*Pyrus sp*	6.67	1.5	0.29
28	*Quercus helferiana* A. DC.	1.34	1	0.75
29	*Quercus sp*	20	1.6	0.08
30	*Quercus xylocarpus* (Kurz.) Markgr.	18.67	2.5	0.14
31	*Rhododendron arboreum* Sm.	1.34	11	8.25
32	*Rhododendron formosum* Wall.	1.34	4	3
33	*Schima khasiana* Dyer	5.34	1.75	0.33
34	*Schima wallichi* Choisy	1.34	1	0.75
35	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	1.34	1	0.75
36	*Syzygium macrocarpa*	2.67	2	0.75

Table 7a: DBH class distribution in Site-1 (1500 m to 1700 m)

Sl. No.	Botanical Name	Saplings	Poles	Trees				Total individual
		>10cm	10 cm - 30cm	31cm - 50cm	51 cm - 70cm	71 cm - 90cm	>90 cm	
1	2	3	4	5	6	7	8	9
1	*Alstonia scholaris* R. Br.	1	1					2
2	*Aporosa oblonga* Muell. Arg.	3	1					4
3	*Artocarpus sp*		1					1
4	*Artocarpus lakoocha* Roxb.	1	1					2
5	*Averrhoa corambola* L.		1					1
6	*Bauhinia variegata* L.	18	17	1				36
7	*Betula alnoides* Buch.-Ham ex D.Don	13	12	2	1			28
8	*Bischofia javanica* Blume		1					1
9	*Castanopsis echinocarpa* Miq.		2					2
10	*Castanopsis tribuloides* (Sm). A.DC.	24	17	2	4	2		49
11	*Celtis timorensis* Span	1						1
12	*Cerasus cerasoides* (Buch.-Ham. Ex D.Don) S.Y Sokolov	4	1					5
13	*Choreospondias axilaris* Roxb.	3	4	1				8
14	*Claoryton longipetiolatum*	2	2	1				5
16	*Colona floribunda* (Kurz.) Craib	22	37	2				61
25	*Columbia flagocarp*(C.B Clarke) Craib	53	43	11	1	3		111
17	*Derris pseudorobusta* Thoth.	11	5	1				17
18	*Derris robusta* (DC.) Benth.	7	2					9
19	*Diospyros glandulosa* Lace.		1					1
20	*Diospyros lanceifolia* Roxb.	4						4
21	*Duabanga grandiflora* (DC.) Walp.	4	7					11
22	*Dysoxylum hamiltoni* Hiern.					1		1
23	*Elaeocarpus lanceifolius* Roxb.	5	5					10
24	*Elaeocarpus rugosus* Roxb. ex G.Don.	14	2					16
25	*Engelhardtia spicata*Lechen ex Blume	12	3					15
26	*Eriobotrya bengalensis* (Roxb.) Hook. f.	3	1					4
27	*Eugenia jambolana* Lam.	4	1					5
28	*Eurya acuminata* DC.	3	1					4
29	*Eurya japonica*Thunb.	3						3
30	*Glochidion lanceolarium* Muell. Arg.	43	11					54
31	*Gmelina arborea* Roxb. ex Sm.			1				1
32	*Gmelina oblongifolia* Roxb.		1					1
33	*Grewia sclerophylla* Roxb. ex G.Don	1						1

Table 7a:DBH class distribution in Site-1 (1500 m to 1700 m)Contd.								
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
34	*Helicia excels* (Roxb.) Blume	22	12	3	1			38
35	*Helicia robusta* (Roxb.) R. Br.	10	1					11
36	*Holboellia latifolia* Wall.	1	3	1				5
37	*Ilex godajam* Colebr. ex Hook.f.		2					2
38	*Laurocerasus jenkinsii* (Hook. f. & Thomson) Browicz	1	3		1			5
39	*Leucomeris decora* Kurz	15	21	1				37
40	*Lindera sp*	1						1
41	*Lithocarpus obscurus* C.C.Huang & Y.T Chang		3					3
42	*Litocarpus pachyphyllus* (Kurz) Rehder	68	116	26	1			211
43	*Litsea monopetala* (Roxb.) Pers.	2	7					9
44	*Litsea salilicifolia* (Roxb. ex Nees)	36	29	1				66
45	*Macaranga denticulata* (Bl.) Mueller	6	1					7
46	*Michelia champaca* KL.	3	1					4
47	*Olea dioca* Roxb.		1					1
48	*Olea salicifolia* Wall. ex. G.Don	2						2
49	*Persea odoratissima* (Nees) Kostern. *Machilus odoratissima* Nees	5	1					6
50	*Phoebe angustifolia* Meisn.	42	8	1				51
51	*Phoebe lanceolata* (Nees) Nees	5						5
52	*Phyllanthus emblica* L. *Emblica officinalis* Gaertn.	5	3					8
53	*Pitosporum floribundum* Wight. &Arn.	29	14					43
54	*Quercus helferiana* A. DC.	33	55	15	2			105
55	*Quercus lineata* Blume	12	22	1				35
56	*Quercus spicata* Sm.	102	220	30	4	1		357
57	*Quercus xylocarpus* (Kurz.) Markgr.	167	155	3				325
58	*Rhus chinensis* Mill.	5	12					17
59	*Schima wallichi* Choisy	81	92	27	4	1	1	206
60	*Sterospermum chelonoides* (L. fil) DC.			1				1
61	*Syzygium cuminii* (L.) Skeels	2						2
62	*Vernonia volkamerifolia* DC.	9	9					18
63	*Vitex canescens* Kurz		4					4
64	*Wendlandia grandis* (Hook. F.) Cowan *syn.Wendlandia budleoides* Wall. ex Wight &Arn.	24	5					29
65	*Ziziphus incurva* Roxb.	7	1					8
TOTAL		954	982	132	19	8	1	2096

Table 7b: DBH class distribution in Site-2 (1700 m to 1900 m)

Sl. No.	Botanical Name	Saplings	Poles	Trees				Total
		<10cm	10 cm -30cm	31cm -50cm	51cm -70cm	71cm -90cm	>90cm	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	*Albizia chinensis* (Osb.) Merr.	13	4	2	1			20
2	*Albizzia odoratissima* (L.f.) Benth.	8	7	1				16
3	*Alphonsea ventricosa* (Roxb.) Hk. f. & Th.		1		1			2
4	*Alseodaphne petiolaris* Hook. f.	4						4
5	*Antidesma bunius* (L.) Spreng.	1						1
6	*Aquilaria sp*	6	4	1				11
7	*Averrhoa corambola* L.	2		1				3
8	*Betula alnoides* Buch.-Ham ex D.Don	10	2	4	3			19
9	*Boehmeria rugulosa* Wedd.	10	1					11
10	*Breonia chinensis* (Lam.) Capuron	1						1
11	*Bursera serrate* Wall. ex Colebr.	4						4
12	*Callicarpa arborea* Roxb.	4	7		1			12
13	*Calophyllum polyanthum Wall. ex Planch. & Triana*		1					1
14	*Caralia brachiata* (Lour.) Merr.	1						1
15	*Castanopsis echinocarpa* Miq.	21	8	2	3			34
16	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.	4	2					6
17	*Castanopsis tribuloides* (Sm). A.DC.	19	6	1	1	1		28
18	*Cephalotaxus griffithi* Hook.f.	7	1	1				9
19	*Choreospondias axilaris* Roxb.	2	1		1			4
20	*Cinnamomum obtusifolium* (Roxb.) Nees	15	9		2		1	27
21	*Citrus indica* Yu. Tanaka	5	3					8
22	*Citrus latipes* (Swingle) Yu. Tanka	52	19					71
23	*Clausena heptaphylla* (Roxb.) Wight & Arn.	23	13	5				41
24	*Dalbergia lanceolaria* L.f.	3	1					4
25	*Derris robusta* (DC.) Benth.	1	1					2
26	*Diospyros lanceifolia* Roxb.	30	12	2	1	1		46
27	*Diospyros pilosiuscula* G.Don	2		1				3
28	*Drimycarpus racemosus* (Roxb.) Hook. f. ex Marchand.	1						1
29	*Dysoxylum mollissimum* Blume *Dysoxylum hamiltonii* Hiern	37				10	18	65
30	*Elaeocarpus lanceifolius* Roxb.	13	2	5				20
31	*Elaeocarpus prunifolius* Wall. ex Muell. Berol.	2	1		1			4
32	*Elaeocarpus rugosus* Roxb. ex G. Don.	1	1					2
33	*Engelhardtia spicata* Lechen ex Blume	18	4	5	4	1		32
34	*Erythrina stricta* Roxb.	2	6		1			9
35	*Eugenia jambolana* Lam.	32	9	4	1	1		47
36	*Eurya acuminata* DC.	1	1					2

Table 7b DBH class distribution in Site-2 (1700m to 1900m) Contd.								
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
37	*Eurya japonica* Thunb.		1					1
38	*Ficus prostrata* (Wall ex Miq.) Buch.-Ham. ex Miq.	6	3					9
39	*Ficus religiosa* L.						1	1
40	*Ficus semicordata* Buch.-Ham ex Sm.	1	3					4
41	*Garcinia xanthochymus* Hook. f.	1	2					3
42	*Helicia excelsa* (Roxb.) Blume	21	15					36
43	*Heteropanax oreophyllum*		1					1
44	*Holboellia latifolia* Wall.	6		2				8
45	Juglans regia Linn.	1						1
46	*Laurocerasus jenkinsii* (Hook. f. & Thomson) Browicz			1				1
47	*Laurocerasus undulata* (D.Don)	10	12	1				23
48	*Lobelia pyramidalis* Wall.						1	1
49	*Maesa indica* (Roxb.) A. DC.	7	1					8
50	*Magnolia ballonii* Pierre		1					1
51	*Mangifera sp*	1	2					3
52	*Melia dubia* Cav.	2			1			3
53	*Messua ferrae* Linn.	1						1
54	*Michelia champaca* KL.	16	5		2			23
55	*Olea dioca* Roxb.		1					1
56	*Persea glaucescens* (Nees) D.G. Long	9	3	7	1	1		21
57	*Persea odoratissima* (Nees) Kostern.	205	103	45	14	3		370
58	*Phoebe angustifolia* Meisn.	91	34	27	21	2	6	181
59	*Phoebe hainesiana* Brandis	8	2	2	5	2	1	20
60	*Phoebe lanceolata* (Nees) Nees	3	1				1	5
61	*Pitosporum floribundum* Wight. &Arn.	119	63	8	1			191
62	*Podocarpus nerifolius* D.Don.	1	1					2
63	*Quercus glauca* Thunb.	3	2					5
64	*Quercus helferiana* A. DC.	1						1
65	*Quercus semiserrata* Roxb.	7	2					9
66	*Quercus serrata* Murray	2	2					4
67	*Quercus sp*	10	4					
68	*Quercus xylocarpus* (Kurz.) Markgr.	91	46	21	9	7	6	180
69	*Sapium* sp		1					1
70	*Schima wallichi* Choisy	8			1	2	2	13
71	*Styrax serulatum* Roxb.	10						10
72	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	15	1	1	2	1		20
73	*Terminalia chebula* Retz.			1				1
74	*Toona ciliata* M. Roem	3	2					5
75	*Vaccinium dodianum*	4	7					11
76	*Vitex glabrata* R.Br.	1	3		1			5
77	*Vitex peduncularis* Wall. ex Schauer	12	2					14
78	*Vitex quinata* (Lour.) F.N. Williams	3	1					4
TOTAL		1034	454	151	79	32	37	1787

Table 7c: DBH Class Distribution of plant species at Site-3 (1900m to 2141m

Sl. No.	BotanicalName	Saplings	Poles	Trees				Total
		<10cm	10cm -30cm	31cm - 50cm	51cm - 70cm	71cm - 90cm	>90cm	
1	*Acrocarpus fraxinifolious* Wight ex Arn.	2			2	1		5
2	*Boehmeria rugulosa* Wedd.	7	4					11
3	*Castanopsis echinocarpa* Miq.	77	63	14	6			160
4	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.	1	2		1	1	1	6
5	Castanopsis tribuloides (Sm.) A.DC.	20	6	2	4	1	1	34
6	*Cephalotaxus griffithi* Hook.f.	2	2	1				5
7	*Cinnamomum obtusifolium* (Roxb.) Nees	2	7	5		1		15
8	*Diospyros lanceifolia* Roxb.	1	3					4
9	*Dysoxylum mollissimum* Blume *Dysoxylum hamiltonii* Hiern	1				2		3
10	*Engelhardtia spicata* Lechen ex Blume	2	1					3
11	*Ficus subulata* Linn.					2	1	3
12	*Glochidion lanceolarium* Muell. Arg.		1					1
13	*Pyrus sp.*	7	1	1				9
14	*Helicia excelsa* (Roxb.) Blume	1						1
15	*Lithocarpus obscurus* C.C.Huang & Y.T Chang	1		1				2
16	*Litsea monopetala* (Roxb.) Pers.	1	2	1				4
17	*Litsea salilicifolia* (Roxb. ex Nees)	2	1					3
18	*Machillus sp.*	1		2				3
19	*Nyssa javanica* (Blume) Wangerin	3					1	4
20	*Persea glaucescens* (Nees) D.G. Long	1	4	2	3	2	1	13
21	*Persea minutiflora* Kostern *Machilus parviflora* Meissn.	5	2	1	1	1	2	12
22	*Persea odoratissima* (Nees) Kostern.	24	32	12	5	1	1	75
23	*Phoebe angustifolia* Meisn.	32	9	8	5	4	2	60
24	*Phoebe hainesiana* Brandis	3	2	1	1			7
25	*Phoebe lanceolata* (Nees) Nees	1	2					3
26	*Pitosporum floribundum* Wight.&Arn.	55	70	16	4	2	1	148
27	*Podocarpus nerifolius* D.Don.	1	3	2				6
28	*Quercus helferiana* A. DC.				1			1
29	*Quercus sp*	4	8	7	4	1		24
30	*Quercus xylocarpus* (Kurz.) *Markgr.*	11	13	6	5			35
31	*Rhododendron arboreum* Sm.	5	5	1				11
32	*Rhododendron formosum* Wall.	3	1					4
33	*Schima khasiana* Dyer	4	1	1	1			7
34	*Schima wallichi* Choisy	1						1
35	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	1						1
36	*Syzygium macrocarpa*		3	1				4
TOTAL		282	248	85	43	19	11	**688**

Table 8a: Overall Population structure of tree species in Lengteng wildlife sanctuary.

dbh	1500 m to 1700 m	1700 m to 1900 m	1900 m to 2141 m	Total
<10	954	1034	282	2270
11-30 m	982	454	248	1684
31-50m	132	151	85	368
51-70m	19	79	45	143
71-90 m	8	32	19	59
>90m	1	37	11	49
	2096	1787	690	4573

Table8b: Tree comparision

	Family	Genera	Species
Site-1	35	50	65
Site-2	40	58	78
Site-3	18	24	36

Table 9a: Site1- Frequency (%), Density, IVI and Abundance

Sl. No.	Botanical Name	Frequency	Density	IVI	Abundance
1	2	3	4	5	6
1	*Quercus spicata* Sm.	88	4.76	48.14	5.41
2	*Schima wallichi* Choisy	78.67	2.75	39.14	3.5
3	Quercus xylocarpus (Kurz.) Markgr.	84	4.34	32.48	5.16
4	*Litocarpus pachyphyllus*(Kurz) Rehder	74.67	2.82	30.47	3.77
5	*Columbia flagocarpa* (C.B Clarke) Craib	54.67	1.48	19.89	2.71
6	*Quercus helferiana* A. DC.	38.67	1.4	16.69	3.63
7	*Castanopsis tribuloides* (Sm). A. DC.	33.34	0.66	11	1.96
8	*Colona floribunda* (Kurz.) Craib	34.67	0.82	8.91	2.35
9	*Glochidion lanceolarium* Muell. Arg.	41.34	0.72	7.85	1.75
10	*Litsea salilicifolia* (Roxb. ex Nees)	26.67	0.88	7.61	3.3
11	*Phoebe angustifolia* Meisn.	28	0.68	6.24	2.43
12	*Helicia excelsa* (Roxb.) Blume	17.34	0.51	5.46	2.93
13	*Bauhinia variegata* L.	20	0.48	5.25	2.4
14	*Pitosporum floribundum* Wight. & Arn.	14.67	0.58	4.56	3.91
15	*Quercus lineata* Blume	16	0.47	4.56	2.92
16	*Betula alnoides*Buch.-Ham ex D.Don	12	0.38	4.47	3.12
17	*Wendlandia grandis* (Hook. F.) Cowan	21.34	0.39	4.13	1.82
18	*Leucomeris decora* Kurz	13.34	0.5	3.75	3.7
19	*Derris pseudorobusta* Thoth.	12	0.23	2.58	1.89
20	*Vernonia volkamerifolia* DC.	10.67	0.24	2.39	2.25
21	*Rhus chinensis* Mill.	10.67	0.23	2.2	2.13
22	*Engelhardtia spicata* Lechen ex Blume	10.67	0.2	2.07	1.88
23	*Helicia robusta* (Roxb.) R. Br.	6.67	0.15	1.84	2.2
24	*Duabanga grandiflora* (DC.) Walp.	9.34	0.15	1.8	1.58
25	*Elaeocarpus rugosus* Roxb. Ex G. Don.	8	0.22	1.78	2.67
26	*Choreospondias axilaris* Roxb.	6.67	0.11	1.57	1.6
27	*Litsea monopetala* (Roxb.) Pers.	5.34	0.12	1.35	2.25
28	*Elaeocarpus lanceifolius* Roxb.	4	0.14	1.29	3.34
29	*Laurocerasus jenkinsii* (Hook. F. & Thomson) Browicz	4	0.07	1.19	1.67
30	*Ziziphus iliate* Roxb.	5.34	0.11	1.07	2
31	*Phyllanthus emblica* L. *Emblica officinalis* Gaertn.	4	0.11	1.04	2.67
32	*Dysoxylum hamiltoni* Hiern.	1.34	0.02	1.03	1

Table 9a Site1- Frequency (%), Density, IVI and Abundance Contd.

1	2	3	4	5	6
33	*Holboellia latifolia* Wall.	4	0.07	1.02	1.67
34	*Macaranga denticulate* (Bl.) Mueller	5.34	0.1	1	1.75
35	*Derris robusta* (DC.) Benth.	4	0.12	0.99	3
36	*Vitex canescens* Kurz	4	0.06	0.88	1.34
37	*Phoebe lanceolata* (Nees) Nees	5.34	0.07	0.87	1.25
38	*Persea odoratissima* (Nees) Kostern. *Machilus odoratissima* Nees	4	0.08	0.82	2
39	*Claoryton longipetiolatum*	2.67	0.07	0.8	2.5
40	*Cerasus cerasoides* (Buch.-Ham. Ex D.Don) S.Y Sokolov	4	0.07	0.76	1.67
41	*Eugenia jambolana* Lam.	4	0.07	0.75	1.67
42	*Eurya acuminata* DC.	4	0.06	0.71	1.34
43	*Diospyros lanceifolia* Roxb.	4	0.06	0.66	1.34
44	*Lithocarpus obscurus* C.C.Huang & Y.T Chang	2.67	0.04	0.66	1.5
45	*Eriobotrya bengalensis* (Roxb.) Hook. F.	2.67	0.06	0.6	2
46	*Michelia champaca* KL.	2.67	0.06	0.54	2
47	*Aporosa oblonga* Muell. Arg.	2.67	0.06	0.53	2
48	*Gmelina arborea* Roxb. ex Sm.	1.34	0.02	0.49	1
49	*Eurya japonica* Thunb.	2.67	0.04	0.47	1.5
50	*Artocarpus lakoocha* Roxb.	2.67	0.03	0.43	1
51	*Sterospermum chelonoides* (L. fil) DC.	1.34	0.02	0.41	1
52	*Syzygium cuminii* (L.) Skeels	2.67	0.03	0.41	1
53	*Ilex godajam* Colebr. Ex Hook. f.	1.34	0.03	0.36	2
54	*Diospyros glandulosa* Lace.	1.34	0.02	0.33	1
55	*Castanopsis echinocarpa* Miq.	1.34	0.03	0.3	2
56	*Alstonia scholaris* R. Br.	2	0.03	0.28	2
57	*Olea salicifolia* Wall. Ex. G.Don	1.34	0.03	0.27	2
58	*Artocarpus sp.*	1.34	0.02	0.25	1
59	*Bischofia javanica* Blume	1.34	0.02	0.24	1
60	*Averrhoa corambola* L.	1.34	0.02	0.22	1
61	*Gmelina oblongifolia* Roxb. ex Sm.	1.34	0.02	0.22	1
62	*Olea dioca* Roxb.	1.34	0.02	0.22	1
63	*Celtis timorensis* Span	1.34	0.02	0.21	1
64	*Grewia sclerophylla* Roxb. Ex G.Don	1.34	0.02	0.21	1
65	*Lindera sp.*	1.34	0.02	0.21	1
	TOTAL	**880.9**	**28.21**	**300**	

Table 9b Site2- Frequency (%), Density, Abundance and IVI

Sl. No	Botanical Name	Frequency	Density	IVI	Abundance
1	2	3	4	5	6
1	*Albizia chinensis* (Osb.) Merr.	14.67	0.27	3.53	1.82
2	*Albizzia odoratissima* (L.f.) Benth.	14.67	0.22	2.95	1.46
3	*Alphonsea ventricosa* (Roxb.) Hk. F. & Th.	1.34	0.03	0.64	2
4	*Alseodaphne petiolaris* Hook. F.	2.67	0.06	0.59	2
5	*Antidesma bunius* (L.) Spreng.	1.34	0.02	0.24	1
6	*Aquilaria sp*	6.67	0.15	1.68	2.2
7	*Averrhoa corambola* L.	1.34	0.04	0.53	3
8	*Betula alnoides* Buch.-Ham ex D. Don	9.34	0.26	3.47	2.72
9	*Boehmeria rugulosa* Wedd.	9.34	0.15	1.87	1.58
10	*Breonia chinensis* (Lam.) Capuron	1.34	0.02	0.24	1
11	*Bursera serrata* Wall. Ex Colebr.	2.67	0.06	0.59	2
12	*Callicarpa arborea* Roxb.	8	0.16	2.06	2
13	*Calophyllum polyanthum* Wall. Ex Planch. & Triana	1.34	0.02	0.24	1
14	*Caralia brachiata* (Lour.) Merr.	1.34	0.02	0.24	1
15	*Castanopsis echinocarpa* Miq.	16	0.46	5.03	2.84
16	*Castanopsis indica* (Roxb. Ex Lindl.) A.DC.	4	0.08	0.88	2
17	*Castanopsis tribuloides* (Sm). A.DC.	13.34	0.38	4.16	2.8
18	*Cephalotaxus griffith*i Hook.f.	5.34	0.12	1.3	2.25
19	*Choreospondias axilaris* Roxb.	2.67	0.06	0.91	2
20	*Cinnamomum obtusifolium* (Roxb.) Nees	21.34	0.36	5.33	1.69
21	*Citrus indica* Yu. Tanaka	4	0.11	1	2.67
22	*Citrus latipes* (Swingle) Yu. Tanka	22.67	0.95	7.04	4.18
23	*Clausena heptaphylla* (Roxb.) Wight & Arn.	21.34	0.55	5.89	2.57
24	*Dalbergia lanceolaria* L.f.	4	0.06	0.77	1.34
25	*Derris robusta* (DC.) Benth.	1.34	0.03	0.3	2
26	*Diospyros lanceifolia* Roxb.	25.34	0.62	6.84	2.43
27	*Diospyros pilosiuscula* G.Don	1.34	0.04	0.45	3
28	*Drimycarpus racemosus* (Roxb.) Hook. F. ex Marchand.	1.34	0.02	0.24	1
29	*Dysoxylum mollissimum* Blume *Dysoxylum hamiltonii*Hiern	33.34	0.87	37.67	2.6
30	*Elaeocarpus lanceifolius* Roxb.	9.34	0.27	2.99	2.86
31	*Elaeocarpus prunifolius* Wall. Ex Muell. Berol.	2.67	0.06	0.9	2
32	*Elaeocarpus rugosus* Roxb. Ex G.Don.	1.34	0.03	0.3	2
33	*Engelhardtia spicata* Lechen ex Blume	16	0.43	6.27	2.67
34	*Erythrina stricta* Roxb.	8	0.12	1.86	1.5
35	*Eugenia jambolana* Lam.	20	0.63	6.46	3.14
36	*Eurya acuminata* DC.	1.34	0.03	0.3	2

Table 9b Site2- Frequency (%), Density, Abundance and IVI Contd.

1	2	3	4	5	6
37	*Eurya japonica*Thunb.	1.34	0.02	0.24	1
38	*Ficus prostrata* (Wall ex Miq.)Buch.-Ham. Ex Miq.	6.67	0.12	1.4	1.8
39	*Ficus religiosa* L.	1.34	0.02	1.25	1
40	*Ficus semicordata* Buch.-Ham ex Sm.	4	0.06	0.77	1.34
41	*Garcinia xanthochymus* Hook. F.	1.34	0.04	0.36	3
42	*Helicia excelsa (*Roxb.) Blume	16	0.48	4.21	3
43	*Heteropanax oreophyllum*	1.34	0.02	0.24	1
44	*Holboellia latifolia* Wall.	2.67	0.11	1.05	4
45	*Juglans regia* Linn.	1.34	0.02	0.24	1
46	*Laurocerasus jenkinsii* (Hook. F. & Thomson) Browicz	1.34	0.02	0.31	1
47	*Laurocerasus undulata (*D.Don)	12	0.31	3.01	2.56
48	*Lobelia pyramidalis* Wall.	1.34	0.02	0.88	1
49	*Maesa indica (*Roxb.) A. DC.	4	0.11	0.99	2.67
50	*Magnolia ballonii* Pierre	1.34	0.02	0.24	1
51	*Mangifera sp.*	1.34	0.04	0.35	3
52	*Melia dubia* Cav.	1.34	0.04	0.63	3
53	*Messua ferrae* Linn.	1.34	0.02	0.24	1
54	*Michelia champaca* KL.	10.67	0.31	3.44	2.88
55	*Olea dioca* Roxb.	1.34	0.02	0.24	1
56	*Persea glaucescens* (Nees) D.G. Long	13.34	0.28	4.83	2.1
57	*Persea odoratissima* (Nees) Kostern.	82.67	4.94	41.91	5.97
58	*Phoebe angustifolia* Meisn.	65.34	2.42	37.04	3.7
59	*Phoebe hainesiana* Brandis	13.34	0.27	6.39	2
60	*Phoebe lanceolata (*Nees) Nees	2.67	0.07	2.03	2.5
61	*Pitosporum floribundum* Wight. &Arn.	52	2.55	18.93	4.9
62	*Podocarpus nerifolius* D. Don.	2.67	0.03	0.48	1
63	*Quercus glauca* Thunb.	2.67	0.07	0.64	2.5
64	*Quercus helferiana* A. DC.	1.34	0.02	0.25	1
65	*Quercus semiserrata* Roxb.	9.34	0.12	1.76	1.29
66	*Quercus serrata* Murray	2.67	0.06	0.59	2
67	*Quercus sp*	4	0.07	0.83	1.67
68	*Quercus xylocarpus* (Kurz.) Markgr.	65.34	2.4	33.02	3.68
69	*Sapium sp*	1.34	0.02	0.24	1
70	*Schima wallichi* Choisy	4	0.18	4.23	4.34
71	*Styrax serulatum* Roxb.	10.67	0.14	1.99	1.25
72	*Syzygium claviflorum* (Roxb.) Wall. Ex A.M.Cowan & Cowan	8	0.27	3.25	3.34
73	*Terminalia chebula* Retz.	1.34	0.02	0.32	1
74	*Toona ciliate* M. Roem	2.67	0.07	0.64	2.5
75	*Vaccinium dodianum*	8	0.15	1.71	1.84
76	*Vitex glabrata* R.Br.	4	0.07	1.04	1.67
77	*Vitex peduncularis* Wall. Ex Schauer	6.67	0.19	1.68	2.8
78	*Vitex quinata* (Lour.) F.N. Williams	4	0.06	0.76	1.34
TOTAL		752	23.71	300	

Table 9C: Site-3 Frequency (%), Density, Abundance and IVI

Sl. No	Botanical Name	Frequency	Density	IVI	Abundance
1	*Acrocarpus fraxinifolious* Wight ex Arn.	4	0.07	3.85	1.67
2	*Boehmeria rugulosa* Wedd.	8	0.15	3.87	1.84
3	*Castanopsis echinocarpa* Miq.	46.67	2.14	44.99	4.58
4	*Castanopsis indica* (Roxb. Ex Lindl.) A. DC.	6.67	0.08	5.46	1.2
5	*Castanopsis tribuloides* (Sm.) A. DC.	18.67	0.46	14.87	2.43
6	*Cephalotaxus griffithi* Hook.f.	5.34	0.07	2.82	1.25
7	*Cinnamomum obtusifolium* (Roxb.) Nees	12	0.2	7.42	1.67
8	Diospyros lanceifolia Roxb.	2.67	0.06	1.47	2
9	*Dysoxylum mollissimum* Blume *Dysoxylum hamiltonii* Hiern	2.67	0.04	2.85	1.5
10	*Engelhardtia spicata* Lechen ex Blume	4	0.04	1.7	1
11	*Ficus subulata* Linn.	4	0.04	12.81	1
12	*Glochidion lanceolarium* Muell. Arg.	1.34	0.02	0.54	1
13	*Helicia excelsa* (Roxb.) Blume	1.34	0.02	0.58	1.8
14	*Lithocarpus obscurus* C.C.Huang & Y.T Chang	1.34	0.03	0.89	1
15	*Litsea monopetala* (Roxb.) Pers.	5.34	0.06	2.27	2
16	*Litsea salilicifolia* (Roxb. Ex Nees)	1.34	0.04	0.85	1
17	*Machillus sp*	4	0.04	2.09	3
18	*Nyssa javanica* (Blume) Wangerin	1.34	0.06	3.06	1
19	*Persea glaucescens* (Nees) D.G. Long	10.67	0.18	10.03	4
20	*Persea minutiflora* Kostern	12	0.16	11.66	1.63
21	*Persea odoratissima* (Nees) Kostern. *Machilus odoratissima* Nees	44	1	31.8	1.34
22	*Phoebe angustifolia* Meisn.	44	0.8	32.16	2.28
23	*Phoebe hainesiana* Brandis	5.34	0.1	3.14	1.82
24	*Phoebe lanceolata* (Nees) Nees	2.67	0.04	3	1.75
25	*Pitosporum floribundum* Wight. &Arn. Syn. *Pittosporum naupalense* (DC.) Reher & E.H Wilson	60	1.98	51.3	1.5
26	*Podocarpus nerifolius* D. Don.	5.34	0.08	2.97	3.29
27	*Pyrus sp.*	6.67	0.12	3.39	1.5
28	*Quercus helferiana*A. DC.	1.34	0.02	0.87	1
29	*Quercus sp*	20	0.32	13.29	1.6
30	*Quercus xylocarpus* (Kurz.) Markgr.	18.67	0.47	14.96	2.5
31	*Rhododendron arboreum* Sm.	1.34	0.15	2.35	11
32	*Rhododendron formosum* Wall.	1.34	0.06	1	4
33	*Schima khasiana* Dyer	5.34	0.1	3.26	1.75
34	*Schima wallichi* Choisy	1.34	0.02	0.52	1
35	*Syzygium claviflorum* (Roxb.) Wall. Ex A.M.Cowan & Cowan	1.34	0.02	0.51	1
36	*Syzygium macrocarpa*	2.67	0.06	1.61	2

5.8 Uses of plants:

Participatory Rural Appraisal (PRA) technique was used for collecting information from local people. Here, transect walk method is used. Different houses were visits, to observe their lifestyle, to obtain information from the village people. Twigs of plants having reproductive organs will be collected for botanical specimens. Each specimen is entered and recorded in the field note book. The collected voucher specimen are deposited in the herbarium of Mizoram University, Aizawl

From the information noted in the present research, 41 plant species having medicinal value, belonging to 29 families were recorded. Of these, 10 species were cultivated where as the rest are collected from wild habit and habitat. The result shows that root and bark are used in 9 ailments, leaves in 17 ailments, fruits in 8 ailments, whole plants in 5 ailments.

The IUCN statuses of medicinal plants were listed compared with IUCN Red data List and most of the recorded species were not included in the list. 55 fruits, 26 timber species, 17 fuel wood species, 8 plant species used for charcoal and 5 fodder species and 38 edible plantswere also recorded from the area **(Table 10a-10f).**

Table10a: TIMBER

Sl.No.	Botanical Name	Local Name	Family
1	*Phoebe hainesiana* Brandis	Bul-eng	Lauraceae
2	*Persea odoratissima* (Nees) Kostern. *Machilus odoratissima* Nees	Bul-fek	Lauraceae
3	*Persea glaucescens* (Nees) D.G. Long	Bul-pui	Lauraceae
4	*Terminalis myriocarpa* Van Heurck & Mull. Arg.	Char	Combretaceae
5	*Pinus kesiya* Royle ex Gordon	Far	Pinaceae
6	*Macaranga denticulata* (Bl.) Mueller	Hnah-khar	Euphorbiaceae
7	*Betula alnoides* Buch.-Ham ex D.Don	Hriang-pui	Betulaceae
8	*Juglans regia* Linn.	Khaw-kherh	Juglandaceae
9	*Schima wallichi* Choisy	Khiang	Theaceae
10	*Alseodaphne petiolaris* Hook. F.	Khuang-thulh	Lauraceae
11	*Bischofia javanica* Blume	Khuang-thli	Phyllanthaceae
12	*Prunus nepalensis* Ser.	Lum-lerh	Rosaceae
13	*Litsea monopetala* (Roxb.) Pers.	Nau-thak	Lauraceae
14	*Michelia champaca* KL.	Ngiau	Magnoliaceae
15	*Bombax insigne* Wall.	Pang	Bombacaceae
16	*Toona cilliata* M. Roem	Tei-pui	Meliaceae
17	*Quercus floribunda* Lindl. Ex A.Camus	Thal	Fagaceae
18	*Mangifera sp.*	Thei-hai	
19	*Dysoxylum mollissimum* Blume *Dysoxylum hamiltonii* Hiern	Thing-sa-phu	Meliaceae
20	*Balakata baccata* (Roxb.) Esser	Thing-vawkpui	Euphorbiaceae
21	*Gmelina arborea* Roxb. ex Sm.	Thlanv-awng	Verbenaceae
22	*Garuga floribunda* Decne. var. *gamblei* (King ex W.W.Sm.) Kalkman	Tuai-ram	Burseraceae
23	*Cephalotaxus griffithi* Hook.f.	Tu-far	Cephalotaxaceae
24	*Hovenia dulcis* Thunb.	Vautang-baawk	Rhamnaceae
25	*Duabanga grandiflora* (DC.) Walp. *Duabanga sonneratioides* Buch.-Ham.	Zuang	Sonneratiaceae
26	*Vitex quinata* (Lour.(F.N. Williams	Thleng-reng	Verbenaceae

Table 10b: FUEL WOOD

Sl No.	Botanical Name	Local Name	Family
1	*Wendlandia grandis* (Hook. F.) Cowan	Ba-tling	Rubiaceae
2	*Quercus spicata* Sm.	Fah	Euphorbiaceae
3	*Quercus helferiana* A. DC.	Hlai	Fagaceae
4	*Macaranga denticulata* (Bl.) Mueller	Hnah-khar	Euphorbiaceae
5	*Betula alnoides* Buch.-Ham ex D.Don	Hriang	Betulaceae
6	*Schima wallichi* Choisy	Khiang	Theaceae
7	*Quercus serrata* Murray	Sasua	Fagaceae
8	*Helicia excelsa* (Roxb.) Blume	Sial-hma	Proteaceae
9	*Vaccinium dodianum*	Sir-kam	Vaccinaceae
10	*Phyllanthus emblica* L. *Emblica officinalis* Gaertn.	Sun-hlu	Phyllanthaceae
11	*Quercus xylocarpus* (Kurz.) Markgr.	Then	Fagaceae
12	*Litocarpus pachyphyllus* (Kurz) Rehder	Thil	Fagaceae
13	*Derris robusta* (DC.) Benth.	Thing-kha	Fabaceae
14	*Glochidion lanceolarium* Muell. Arg.	Thing-pawn-chhia	Phyllanthaceae
15	*Castanopsis tribuloides* (Sm). A. DC.	Thing-sia	Fagaceae
16	*Leucomeris decora* Kurz	Tlang-ham	Asteraceae
17	*Albizia chinensis* (Osb.) Merr.	Vang	Mimosaceae

Table 10c: CHARCOAL

Sl. No.	Botanical Name	Local Name	Family
1	*Litocarpus pachyphyllus* (Kurz) Rehder	Thil	Fagaceae
2	*Quercus spicata* Sm.	Fah	Euphorbiaceae
3	*Castanopsis tribuloides* (Sm). A. DC.	Thing-sia	Fagaceae
4	*Quercus xylocarpus* (Kurz.) Markgr.	Then	Fagaceae
5	*Quercus helferiana* A. DC.	Hlai	Fagaceae
6	*Helicia excelsa* (Roxb.) Blume	Sial-hma	Proteaceae
7	*Macaranga denticulata* (Bl.) Mueller	Hnah-khar	Euphorbiaceae
8	*Glochidion lanceolarium* Muell. Arg.	Thing-pawn-chhia	Phyllanthaceae

Table 10d: FODDER

Sl No.	Botanical Name	Local Name	Family
1	*Trema orientalis* (L.) Blume	Bel-phuar	Ulmaceae
2	*Vernonia volkamerifolia* DC.	Khup-al	Asteraceae
3	*Ficus semicordata* Buch.-Ham ex Sm.	Thei-pui	Moraceae
4	*Ficus prostrata* (Wall ex Miq.) Buch.-Ham. ex Miq.	Thei-tit	Moraceae
5	*Morus alba* Linn.	Thing-thei-hmu	Moraceae

Table 10e: FRUITS

Sl. No.	Botanical Name	Local Name	Family
1	*Calamus tennuis* Roxb.	Hrui-pui	Arecaceae
2	*Bursera serrata* Wall. ex Colebr.	Bil-thei	Burseraceae
3	*Meliosma punnata* (Roxb.) Maxim.	Buang-thei	Sabiaceae
4	*Ficus sp*.	Bung-rah	Moraceae
5	*Pyrus pashia* Buch.-Ham. ex D.Don	Chal-thei	Rosaceae
6	*Garcinia lanceifolia* Roxb.	Cheng-kek	Clusiaceae
7	*Zizyphus incurva* Roxb.	Hel	Rhamnaceae
8	*Ficus sp*.	Hmawng	Moraceae
9	*Aganope thyrsiflora* (Benth.) Polhill.	Hulhu	Fabaceae
10	*Calamus gracilis* Roxb.	Kawr-tai rah	Arecaceae
11	*Myrica esculenta*Buch.-Ham ex. D.Don	Kei-fang	Myricaceae
12	*Laurocerasus jenkinsii* (Hook. f. & Thomson) Browicz	Kei-pui	Rosaceae
13	*Juglans regia* Linn.	Khaw-kherh	Juglandaceae
14	*Rhus chinensis* Mill.	Khawm-hma	Anacardiaceae
15	*Elaecoarpus tectorius* (Lour.) Poir.	Kum-khal	Elaeocarpaceae
16	*Syzygium cuminii* (L.) Skeels	Len-hmui	Myrtaceae
17	*Aglaia perviridis* Hiern.	Luak-thei	Meliaceae
18	*Boehmeria rugulosa* Wedd.	Lum-ler	Urticaceae
19	*Caryota mitis* Lour.	Mei-hle	Arecaceae
20	*Embelia ribes* Burm.f.	Nau-fa-dawntuai	Myrsinaceae
21	*Toddalia asiaica* (L.) Lam.	Nghar-dai	Rutaceae
22	*Tetrastigma obovatum* (M.A. Lawson) Gangnep.	Puar peng	Vitaceae
23	*Mangifera sylvatica* Roxb.	Ram thei-hai	Anacardiaceae
24	*Passiflora edulis* Sims	Sap-thei	Passifloraceae
25	*Elaeagnus pyriformis* Hoook.f.	Sar-zuk	Elaeagnaceae
26	*Phyllanthus emblica* L. *Emblica officinalis* Gaertn.	Sun-hlu	Phyllanthaceae
27	*Spondias pinnata* (L.f.) Kurz	Tawi-taw	Anacardiaceae
28	*Tamarindus indica* L.	Teng-te-re	Fabaceae/ Caesalpiniaceae
29	*Kadsura heteroclite*(Roxb.) Craib	Thei ar-bawm	Schisandraceae
30	*Laurocerasus undulata* (D.Don)	Thei ar-lung	Rosaceae
31	*Ficus auriculata* Lour.	Thei bal	Moraceae
32	*Choreospondias axilaris* Roxb.	Thei khuang-chawm	Anacardiaceae

Table 10e: FRUITS Contd.

Sl. No.	Botanical Name	Local Name	Family
33	*Artocarpus lakoocha* Roxb.	Thei-tat	Moraceae
34	*Syzygium grande* (Wight) Walp.	Thei-chhawl	Myrtaceae
35	*Haematocarpus validus* (Miers) Bakh. f. ex Forman	Thei-chhung-sen	Menispermaceae
36	*Dimocarpus longan* Lour.	Thei-fei-mung	Sapindaceae
37	*Elaeocarpus rugosus* Roxb. ex G.Don.	Thei-kel-ek	Elaeocarpaceae
38	*Stelmocrypton khasianum* (Kurz) Baill.	Thei-kel-ki	Asclepiadaceae
39	*Sarcosperma griffithii* Hook.f. ex C.B Clarke	Thei-khaw kham	Sapotaceae
40	*Choreospondias axilaris* Roxb.	Thei-khuang-chawm	Anacardiaceae
41	*Bruinsmia polysperma* (C.B Clarke) Steeins.	Thei-pa-ling-kawh	Styraceae
42	*Ficus semicordata* Buch.-Ham ex Sm.	Thei-pui	Moraceae
43	*Caralia brachiata* (Lour.) Merr.	Thei-ria	Rhizophoraceae
44	*Ficus prostrata* (Wall ex Miq.) Buch.-Ham. ex Miq.	Thei-tit	Moraceae
45	*Diospyros glandulosa*	Thei-vawk-mit	Ebenaceae
46	*Saurauia punduana* Wall.	Tiar	Actinidiaceae
47	*Saurauia naupalensis* DC.	Tiar-pui	Actinidiaceae
48	*Castanopsis tribuloides* (Sm). A.DC.	Ting-se-mim	Fagaceae
49	*Embelia vestita* Roxb.	Tling	Myrsinaceae
50	*Garcinia xanthochymus* Hook. f.	Tuai-ha-beh	Clusiaceae
51	*Garuga floribunda* Decne *var. gamblei* (King ex. W.W.Sm.)Kalkman *Garuga gamblei* King ex. W.W.Sm.	Tuai-ram	Burseraceae
52	*Antidesma bunius* (L.) Spreng.	Tuai-tit	Euphorbiaceae
53	*Ardisia macrocarpa* Wall.	Va-hrit a thei	Myrsinaceae
54	*Alphonsea sp*.	Zawng bal-hla	Annonaceae
55	*Pyrularia edulis* (Wall.) A. DC.	Zawng-biang	Santalaceae
56	*Lepisanthes senegalensis* (Poir.) Leenh. *Sapindus attenuata* Wall. ex. Hiern	zu til	Sapindaceae
57	*Baccauria ramiflora* Lour.	Pang-kai	Euphorbiaceae

Table10f: Medicinal Plants.

Sl. No.	Botanical Name	Local Name	Family	Part used	Uses	IUCN Status
1	2	3	4	5	6	7
1	*Dillenia pentagyna* Roxb.	Kaih-zawl	Dilleniaceae	Bark	Decoction of the bark used for Ulcer, cuts and wounds, pile problems	NA
2	*Curcuma longa* Linn.	Ai-eng	Zingiberaceae	Rhizome	1. Crushed rhizome applied on sprains and wounds 2. Decoction of rhizome used for stomach problem, blood purifier.	NA
3	*Curcuma caesia* Roxb.	Ai-lai-dum	Zingiberaceae	Rhizome	Decoction of rhizome used for Jaundice, food poisoning, stomach problems.	NA
4	*Platycerium walllichii* Hook.	Awm-vel/ sai-beng	Polypodiaceae	Leaves	Crushed leaves applied on lorrain (Awmvel)	NA
5	*Blumea lanceolaria* (Roxb.) Druce	Buar-ze	Asteraceae	Leaves	1. Leaves are used for Kidney problems, asthma, tooth ache 2. Juice of the leaves applied on skin diseases and dandruff.	NA
6	*Osbeckia stellata* Buch.-Ham ex Ker Gawl.	Bui-lukham /Khampa	Melastomataceae	Root bark	Cold infusion of root bark is used for stomach problems and kidney failure and to prevent miscarriage	NA

Table 10f: Medicinal plants Contd.

1	2	3	4	5	6	7
7	*Musa sp.*	Chakai/tum bu	Musaceae	Fruits, flower	Unripe fruits and flowers are cooked with crab and taken againnst jaundice	NA
8	*Sesamus indicum* L.	Chhawh-chhi/ chhi-bung	Pedaliaceae	Leaves	Leaves are applied on bee sting	NA
9	*Lobelia angulata* G.Frost.	Choak-a-thi	Campanulaceae	leaves and fruits	1. Juice of the crushed leaves are taken for stomach ulcer, diarrhoea and Tooth ache 2. pounded leaves and fruits are applied on placental problems	NA
10	*Erythrina stricta* Roxb.	Far-tuah	Fabaceae	Spines	1. Juice of the crushed leaves is taken for stomach ulcer, diarrhoea and Tooth ache 2. pounded leaves and fruits are applied on placental problems	NA
11	*Mikania micrantha* Kunth	Japan-hlo	Asteraceae	Leaves	1. Juice of leaves applied on fresh wounds 2. Fresh leaves taken orally against dysentery, diarrhoea.	NA

Table 10f: Medicinal plants Contd.

1	2	3	4	5	6	7
12	*Smilax glabra* Roxb.	Kai-tluang	Smilacaceae	Leaves and roots	1. Decoction of leaves taken with sweet rice beer (zufang) for scitica. 2. Crushed roots are takenagagainst rheumatism, diarrhea 3. Decoction of leaves used for tonsilitis.	NA
13	*Ipomea batatas* (L.) Lam.	Kawl-ba-hra	Convulaceae	Leaves	Leaves are eaten against diarrhoea, dysentery, digestion problems and food poisoning.	NA
14	*Psidium guajava* Linn.	Kawl-thei	Myrtaceae	leaves	Young leaves eaten against diarhoea, dysentery	NA
15	*Hedyotis scandens* Roxb.	Kel-hnam-tur	Rubiaceae	Whole plant	Stalk and leaves are boliled and taken against urinary problems and inflamation of kidney	NA
16	*Rhus chinensis* Mill.	Khawm-hma	Anacardiaceae	Fruits	Decoction of Young fruits used against chiken pox	LC
17	*Schima wallichi* Choisy	Khiang	Theaceae	Leaves, fruits and bark	1. Powder of the bark and fruits is applied on the bite of centipede, scorpion sting 2. Young juice of leaves are applied on fresh cuts	LC

Table 10f: Medicinal plants Contd.

1	2	3	4	5	6	7
18	*Gomphogyne cissiformis* Griff.	Lalruanga dawibur	Cucurbitaceae	Fruits	Empty fruit is filled with water and taken against stomach ache, fever.	NA
19	*Centella asiatica* (L.) Urban.	Lam-bak	Apiaceae	Whole plant	Whole plant is boiled and eaten against malaria, eye problems and kidney troubles	LC
20	*Benincasa hispida* (Thunb.) Cogn.	Mai-pawl	Cucurbitaceae	Whole plant	Boiled with sugar for cholera, beestung	NA
21	*Eucalyptus citriodora* Hook.	Nawalh-thing	Myrtaceae	Charcoal	Stomach problems	NA
22	*Helicia robusta* (Roxb.) R. Br.	Pasal-taka-za	Proteaceae	Root bark	Juice of the bark is boiled and used for sciatica, stomach problems and ulcers.	NA
23	*Clerodendron glandulosum* Lindl.	Phui-hnam	Verbenaceae	Leaves and shoots	Decoction of leaves and young shoots are taken against hypertension	NA
24	*Uncaria sp.*	Ral-sam-kuai	Rubiaceae	Leaves	Leaves are chewed against toothache	NA
25	*Artemisia vulgaris* L.	Sai	Asteraceae	Leaves, fruits	Decoction of the leaves/fruits taken against malaria, fever.	NA

Table 10f: Medicinal plants Contd.

1	2	3	4	5	6	7
26	*Flueggea virosa* (Roxb. ex. Willd.) Royle *Syn. Securinega virosa* (Roxb. ex. Willd.) Baill.	Sai-siak	Euphorbiaceae	Leaves	Decoction of the leaves used for taking bath in measles and chicken pox	NA
27	*Stemona tuberosa* Lour.	Sang	Stemonaceae	Roots	Roots eaten raw for stomach problem, typhoid, cancer	NA
28	*Cheilocostus speciosus* (J.Koning) C. Spetcht. Syn. *Costus speciosus (J.Koing) Sm.*	Sum-bul	Zingiberaceae	Root Bark	infusion of bark is taken against kidney problems	NA
29	*Phyllanthus emblica* L. *Emblica officinalis* Gaertn.	Sun-hlu	Phyllanthaceae	Fruits	Juice of the pounded fruits is taken for expelling the retained placenta after child birth.	NA
30	*Solanum torvum* Sw. *Solanum rudepannum* Dunal	Tawk-te	Solanaceae	Fruits	Decoction of fruits orunripe fruits is taken for hypertension	NA
31	*Tamarindus indica* L.	Teng-te-re	Caesalpiniacea e	Leaves and Seeds	1. Dried seeds are considered antidote for snake bite and bee sting 2. Juice of the leaves are taken against fever and ulcers	LC
32	*Dendrocnide sinuata* (Blume) Chew	Thak-pui	Urticaceae	Root	Decoction of the root is used for sciatica.	NA

Table 10f: Medicinal plants Contd.

1	2	3	4	5	6	7
33	*Lindernia ruelloides* (Colsm.) Pennell	Tha-suih	Scrophulariaceae	Whole plant	1. Herb is applied externally on skin problems 2. Whole plant is used for cramps, rheumatism, sciatica.	NA
34	*Diospyros glandulosa* Lace	Thei-vawk-mit	Ebenaceae	Bark	Decoction of the bark used for cut wounds and Stomach problems.	NA
35	*Vitex glabrata* R. Br.	Thing-khawi-lu	Verbenaceae	roots and bark	Decoction of leaves and bark used for measles.	NA
36	*Acer oblongum* Wall. ex Blume	Thing-phing-phi-hlip	Aceraceae	Bark and leaves	Decoction of the bark and leaves are used for talking bath as a remedy against Measels, chicken pox, skin problems.	CR
37	*Chromolaena orata* (L.) R.M.King & H.Rob.	Tlang-sam	Asteraceae	Whole plant	1. Juice of leaves applied on fresh cuts. 2. Juice of the entire plants is taken against ulcer, antiseptic, kidneyproblem.	NA
38	*Embelia vestita* Roxb.	Tling	Myrtaceae	Leaves	Decoction of leaves is used for taking bath as a remedy for chickenpox.	NA

Table 10f: Medicinal plants Contd.

1	2	3	4	5	6	7
39	*Mussaenda sp*	Va-kep	Rubiaceae	Leaves	Juice of the leave applied on bee sting	NA
40	*Paederia foetida* Linn.	Vawih-uih-hrui	Rubiaceae	Stem and leaves	1. Stem and leaves are chewed for curing toothache. 2. Juice of the crushed leaves is used for diarrhoea and dysentery.	NA
41	*Sterospermum chelonoides* (L. fil) DC.	Zih-nghal	Bignoniaceae	Leaves	Young leaves are boiled and used for taking bath as a remedy for fever.	NA

Table 10g: Edible plants

Sl. No.	Botanical Name	Local Name	Family	Parts used
1	2	3	4	5
1	*Calamus tennuis* Roxb.	Hruipui zik	Arecaceae	Pith of the stem cooked as vegetable
2	*Ammomum dealbatum* Roxb.	ai du	Zingiberaceae	Young buds eaten as vegetable
3	*Fagopyrum acutatum* (Lehm.) Mansf. ex K.Hammer	An bawng	Polygonaceae	Stalks and leaves cooked as vegetable
4	*Acmella oleraceae* (L.) R.K. Jansen	An sa pui	Asteraceae	Leaves are cooked as vegetable
5	*Acmella paniculata* (Wall ex DC.) R.K. Jansen	An salai	Asteraceae	Leaves are cooked as vegetable
6	*Solanum nigrum* Linn.	Anhling	Solanaceae	Young stalkand leaves cooked as vegetable
7	*Marsdenia formosana* Masam.	Ankhate	Asclepiadaceae	Leaves are cooked as vegetable

Table 10g: Edible plants contd.

1	2	3	4	5
8	*Oroxylum indicum* (L.) Kurz.	Ar changkawm	Bignoniaceae	Young leaves and pods cooked as vegetable
9	*Eryngium foetidum* Linn.	Bahkhawr	Apiaceae	Leaves used for salad
10	*Alocasia fornicata* (Roxb.) Schott	Baibing	Araceae	Spadix cooked as vegetable
11	*Wendlandia budleioides* Wall. ex. Wight &Arn	Batling	Rubiaceae	Flowers are cooked as vegetable
12	*Pteris vitata* Linn.	Chakawk	Pteridaceae	Young shoots and leaves cooked as vegetable
13	*Aralia foliosa* Seem. ex C.B. Clarke	Chim chawk	Araliaceae	Young shoots and leaves cooked as vegetable
14	*Calamus flagellum* Griff.	Hruipui	Arecaceae	Young shoots are eaten as vegetable
15	*Zalaca secunda* Griff.	Hruitung	Arecaceae	Young shoots are eaten as vegetable
16	*Tresesia palmata* (Roxb. ex Lindl.) Vis.	Kawhtebel	Araliaceae	Fruits cooked as vegetable
17	*Calamus gracilis* Roxb.	Kawrtai	Arecaceae	Young shoots are eaten as vegetable
18	*Plantago major* Linn.	Kel ba an	Plantaginaceae	Leaves eaten raw or cooked as pot herb
19	*Acacia pennata* (l.) Willd.	Khanghu	Mimosaceae	Young leaves with a strong smell are used as vegetable
20	*Centella asiatica* (L.) Urban.	Lambak	Apiaceae	Stalks and leaves cooked as vegetable
21	*Melocanna baccifera* (Roxb.) Kurz	Mau	Poaceae	Tender shoots cooked as vegetable
22	*Caryota mitis* Lour.	Meihle	Arecaceae	Upper part of the palm is used as vegetable
23	*Cephalostachyum capitatum* Munro	Nat tuai	Poaceae	Young shoots eaten as vegetable

Table 10g: Edible plants Contd.

1	2	3	4	5
24	*Clerodendron glandulosum* Lindl.	Phuihnam	Verbenaceae	Young leaves and shoots cooked as vegetable
25	*Dendrocalamus longispathus* (Kurz) Kurz	Raw nal	Poaceae	Young leaves and shoots cooked as vegetable
26	*Eurya japonica* Thunb.	Sihneh	Theaceae	Leaves are cooked as vegetable
27	*Solanum rudepannum* Dunal	Tawke	Solanaceae	Fruits cooked as vegetable
28	*Solanum torvum* Sw.	Tawkpui	Solanaceae	Green fruits cooked as vegetable
29	*Amorphophallus paeonifolius* (Dennst.) Nicolson	Tel hawng	Araceae	Boiled corm eaten as curry
30	*Arenga pinnata* (Wurmb) Merr.	Thangtung	Arecaceae	Young shoots are eaten as vegetable
31	*Calamus sp.*	Thil te	Arecaceae	Young shoots are eaten as vegetable
32	*Calamus erectus* Roxb.	Thil thek	Arecaceae	Young shoots are eaten as vegetable
33	*Dysoxylum excelsum* Blume	Thingthupui	Meliaceae	Young shoots and leaves with a stinky smell are cooked as vegetable
34	*Gynura bicolor* (Roxb. ex Willd.) DC.	Tlang nal	Asteraceae	Stalks and leaves cooked as vegetable
35	*Caryota urens* L.	Tum	Arecaceae	Terminal buds are cooked as vegetable
36	*Parkia timoriana* (DC.) Merr.	Zawngtah	Mimosaceae	Pods eaten as vegetable
37	*Asparagus sp.*	Zemathingthupui	Asparagaceae	Young buds eaten as vegetable
38	*Allium sp.*	Zo purun	Amarylidaceae	Leaves and roots used as vegetable

CHAPTER 6

MANAGEMENT PROBLEMS AND CONSERVATION MEASURES

6.1. Status

Lengteng Wildlife Sanctuary is one of the most important protected areas in Mizoram, covering an area of 60 sq. km. Located in the eastern part of Mizoram in Champhai district, 198 km from Aizawl (taking Ngopa road, 12 kms from Ngopa village). It lies between 23^{o}42’ N Latitude and 93^o 10’E longitude. There is another place called ‘Naunuarzo tlang’ at the highest point of Lengteng Wildlife Sanctuary peak, this point is 2141 m.a.s.l. high. The sanctuary is surrounded by seven (7) villages *viz.*, Ngopa, Kawlbem, Damzawl, Selam, Lungphunlian, Pamchung and Tualcheng. The vegetation of this area has provided an ideal habitat for wildlife. The area is said to be rich in biodiversity, harbouring rare and endangered species, however, little is known about its biodiversity. The area is infamous for illegal collection of timbers by the surrounding villagers. Due to these, it has been selected to explore its status of plant diversity from the ecological point of view.

The field work and analysis of vegetation has been carried out during 2013-2015 at different altitudinal gradient and it was observed that the species richness follow an inverted hump shaped distribution pattern and is rich in plant diversity. The present study recorded 127 species of plants in the study site belonging to 89 genera and 52 families.The present studies reveals that the sanctuary is dominated by trees having a diameter class less than 10 cm (2270 individuals) followed by trees having 10 cm -30 cm diameter class with 1684 individuals. Trees having a diameter class greater than 90cm are the least with 49 individuals. The results show that tree diversity of Lengteng

Wildlife Sanctuary follows a hump shaped pattern. This falls within the general pattern of initial increases in species richness with elevation followed by a peak in the middle and then decline with further increase in elevation. The high species richness in the elevation range of 1700 m.a.s.l. -1900 m.a.s.l. shows that greater effort should be made on conservation of biodiversity in this specific area.

Interview conducted among the villagers revealed that the socio-economic condition is poor. Most of them depend on traditional jhumming, thus depend much on forest fuelwood, timbers and NTFP's. Although they depend much on forest for various resources, most of them are not aware about the importance of conservation. Poaching of wild animals is still practiced by many hunters. Timber collection was common among the people. There is a need to develop adequate strategy and action plan for the conservation and management of the forest, so that sustainable utilization of the forest resources could be ensured. Study highlights a very poor management of forest resources in the area. Although the main aim of sanctuary is to conserve biodiversity, the area is way behind satisfactory level. Inappropriate forest management would cause a destruction of most of the forest communities and sometimes may lead to the destruction of their habitats. Presently, there is a need for increased legal protection, a well designed management practices to conserve the diversity of the study area. Some indigenous species should be planted in the buffer area which will fulfill the demand of local people. Creating awareness among the local people about biodiversity conservation and scientific management of the plant species in the study area will help making the area become one of the richest biodiversity areas of the state.

6.2. Conservation measures suggested

During the course of study, it has been observed that the area had been rather severely disturbed than was expected. The main reason is the collection of timber. For better management of the sanctuary, the following conservation measures are suggested:

1. The Lengteng Wildlife Sanctuary has suffered horribly from illegal collection of timber and the incidence happened at the very high rate. Illegal logging has been most commonly carried out in small groups of local villagers, using machineries introduced from Burmese which can saw more timbers in a short period of time. Community members also fell trees for domestic use, however majority of the timbers collected were for selling purposes. Logging causes a lot of forest degradation at a fast rate. Timber logging includes harvesting, transporting, processing, buying or selling of timber in violation of forest conservation laws This is mainly due to a conflict between the authorities and Selam villagers. Actions taken by the government since 2014 substantially reduced those illegal activities. Since then, less illegal activities were observed in 2015. However, continuous enforcement of better restriction rules to stop timber collection from the sanctuary is recommended.

2. The forest has also suffered from encroachment and illegal collection of medicinal plants which reduce their population. Continuation of these activities could lead to loss of valuable plant species and may lead to their extinction in due course of time. Monitoring and vigilance need to be given to check human activities. Proper check gate may be maintained and the encroachers should be punished under the Wildlife Protection Act, 1972 and the State Biodiversity Act,

2010. On the other hand, paying a handsome reward to those who help the officials in finding illegal collectors will be helpful.

3. Some parts of the sanctuary were still used for jhum land by local people due to shortage of forest land for agricultural purpose. Relocation of Selam village should be given serious concern.

4. The sanctuary is managed by a Ranger officer with headquarters at Lamzawl village under the control of District Forest Office (DFO), Khawzawl. Beat Officer, Forest Guard and Wildlife Guard were located at the surrounding villages other than Selam village to take care of this area. For better management of the sanctuary and protection, it is recommended that trained forest guards be stationed at Selam village since majority of the sanctuary area were easily accessible from the village.

5. Hunting is rampant – most of the men moving around in the forest area were seen with a gun. Effective management is essential to ensure that wildlife is being conserved within a sanctuary's boundaries. Management activities including monitoring the health of habitats, ensuring that the rules of the protected area are respected, and jointly working with local people to balance nature protection with their needs and aspirations. Training of anti-poaching patrols, campaign for stronger action against the illegal wildlife trade, helping local communities benefit from living alongside endangered species through wildlife tourism are recommended to tackle the problem poaching business.

6. It is also observed that some villagers of the surrounding villages move freely inside the sanctuary and used it as a short cut to travel from one village to another. Better road connecting the surrounding villages should be made to avoid the trespassing by way of eco-development plan entry-point and Joint Forest Management.

7. Collection of firewood is a daily chore as most of the village population depends on the forest for firewood. In the entire surrounding village, people still largely depend on fuel wood. Construction and proper maintenance of well weathered roads and supply of LPG/solar stove/chullah is recommended to reduce collection of fuel wood from the forest.

8. Cattle grazing inside the sanctuary was also seen during the study period, which could cause disturbance of vegetation, loss of biodiversity and environmental degradation. Proper animal fencing or other measures should be made.

9. People visit the sanctuary for picnic, students used to come for their academic purposes. It was observed that some visitors used to throw plastics bags and bottles inside the sanctuary. Proper awareness education programme should be given to the visitors about the detrimental impact of non-biodegradable resources. Clear instructions should be given regarding the items that can be carried inside the sanctuary and punishment should be given to those people who do not obey the law.

10. Due to timber collection activities, most of the forest along the road has been cleared and good forest patches were seen only in far and inaccessible places. Planting of more trees for eco-restoration purpose of fragile habitats is recommended.

11. Most of the approach roads of the surrounding villages of the sanctuary is in a bad condition causing various problems during rainy season and making living very hard for the people. Construction and maintenance of all weathered roads to the surrounding villages is a major issue for the growth and development of the socio-economic condition of this rural area.

12. Forest fire is also experienced within the sanctuary, which is highly attributable to burning of jhum land. Immediate steps need to be taken annually to prevent forest fire during the lean period that is February to March every year. Proper fire lines should be made in and around the sanctuary under constant vigilance to prevent from the breakup of forest fire.

CONCLUSIONS

From the studies carried out at Lengteng Wildlife Sanctuary, it was observed that highest density of tree species was observed in the middle range (1700 m-1900 m). Greater effort should be given on conservation of biodiversity. The sanctuary covers the entire Lengteng Mountain along with its surrounding reserve forest. The edges of the mountains are all very steep and mostly of sharp precipices. The view was amazing at the peak, blankets of clouds floating around and the surrounding villages were visible.

The area was rich in plant diversity and it is the home of many wildlife's, and serve as a corridor for wild animals from Myanmar. Due to its location in close proximity with villages, it suffers constant encroachment. Poaching of wild animals near and within the sanctuary can influence the delicate ecological balance of the sanctuary and its purpose. Majority of villagers depends on forest products, therefore, creation of transitional zone to protect the core zone is highly recommended. Eco-development programme should be intensified in the buffer zone, and constant vigilance of the sanctuary is needed. The presence of *Rhododendron arboretum and Rhododendron formosum* make the visit worthwhile. The area is frequently visited by students and other natural lovers for field trip and hiking.

People living in the surrounding villages of the sanctuary aredependent upon herbal practices due to poor condition of approach roads.The plant parts such as root, bark, leaf, flower, fruit and seeds are used by the people as a medicine and their knowledge of practice has come down through generations. But now-a-days this flow of indigenous knowledge from elder to younger generation is interrupted as the young generation is reluctant to learn about traditional medicinal practices. As a result, no local healers are found in the area Indigenous practices and knowledge regarding the sustainable harvest and utilization of plant resources as medicine should be documented andpreserved before they disappear. Therefore it is a high time to create awareness among the local people for the conservation of their resources.

Sustainable management for non-timber forest products requires consideration of three types of issues (ecological, economic, and social). The potential ecological impact of over-harvesting under current management strategies could be devastating for entire NTFP populations. The biological material, harvested for NTFPs, is a critical part in the functioning of healthy forest ecosystems. The loss of access to gathering areas, or a significant decline in plant populations could have tremendous economic impact to the collectors and associated businesses. Knowledge from research about the economic impact of NTFP activities is needed to influence policies to support the sustainable management of the region's forests.

Therefore, it can be concluded that the area has suffered various anthropogenic disturbances, over exploitation, habitat destruction, over grazing and encroachments from the people living in and around the surrounding villages. The sanctuary suffered serious damage from illegal felling of timbers. It also suffered forest fire through jhum burning from the surrounding villages as some part of the sanctuary is still used for jhum cultivation. Therefore, conservation measures recommended there in should be carried out under annual plan operation by involving local people's participation for their economic activities. Lengteng Sanctuary could be a promoting place for ecotourism area in Mizoram.

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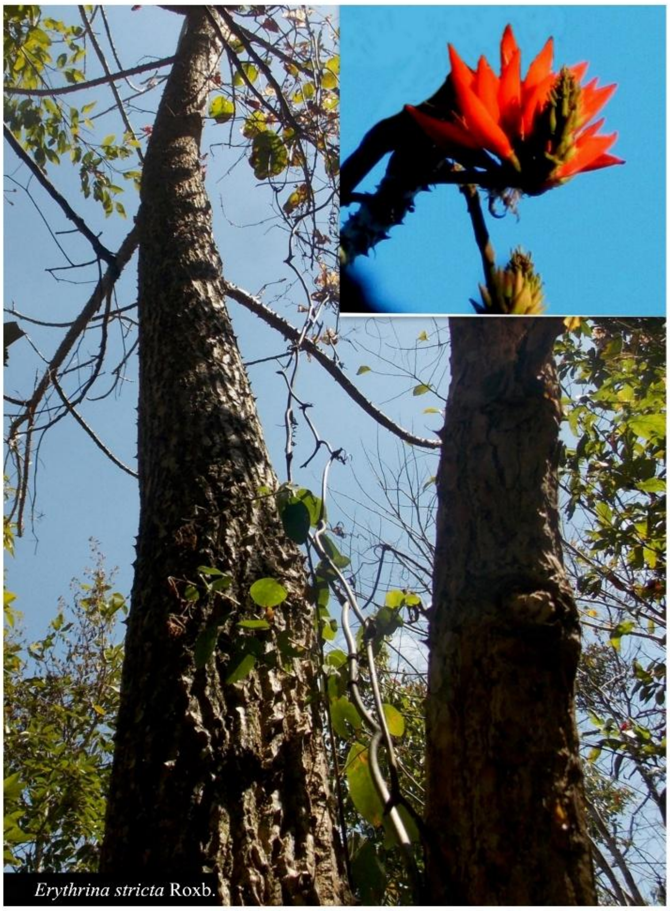
Photo plate 1: Flowers

Syzygium cuminii (L.) Skeels

Rhododendron arboreum Sm.

Rhododendron formosum Wall.

Osbeckia stellata Buch.-Ham ex Ker Gawl.

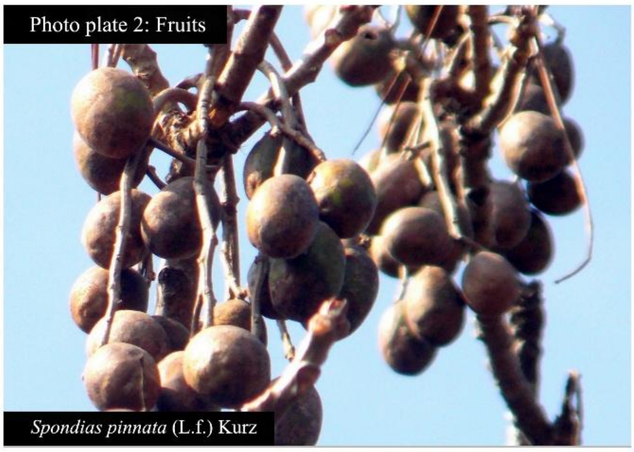


Erythrina stricta Roxb.

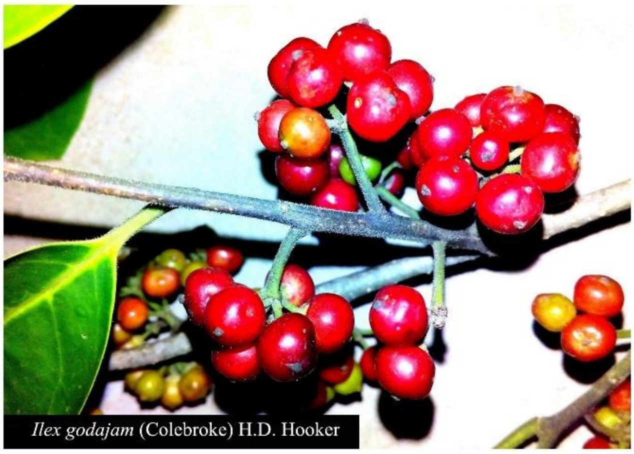
Bauhinia variegata L.

Schima wallichi Choisy

Photo plate 2: Fruits

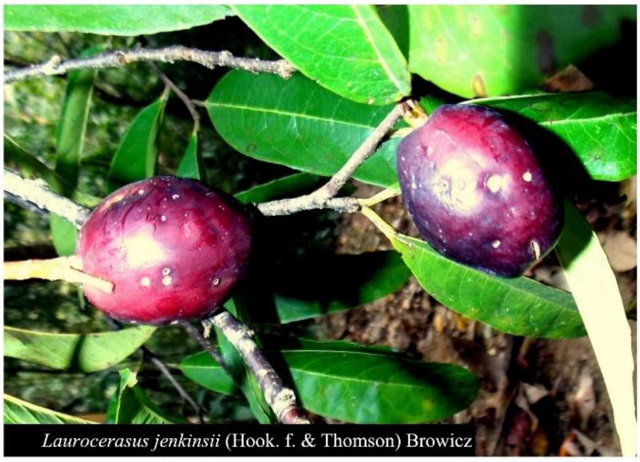

Spondias pinnata (L.f.) Kurz


Pyrus pashia Buch.-Ham. ex D.Don


Ilex godajam (Colebroke) H.D. Hooker


Calamus tennuis Roxb.


Sapindus attenuata Wall. ex. Hiern


Laurocerasus jenkinsii (Hook. f. & Thomson) Browicz


Ficus semicordata Buch. -Ham ex Sm.


Meliosma punnata (Roxb.) Maxim.

Photo plate 3: Study area

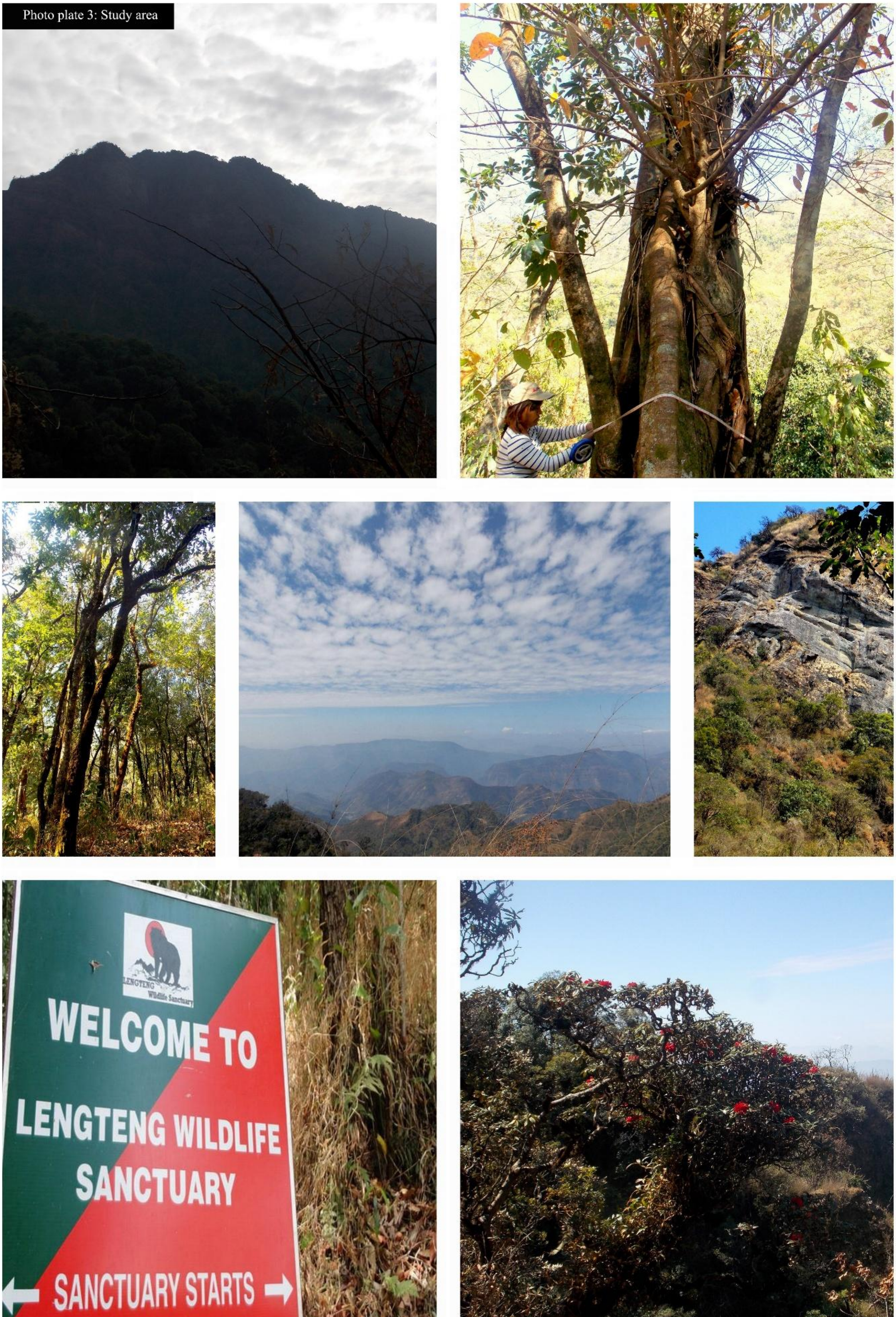


Photo plate 4: Study Area

Photo plate 5: Timber collection in and around the sanctuary

ASSESSMENT OF TREE DIVERSITY AND DISTRIBUTION PATTERN IN LENGTENG WILDLIFE SANCTUARY OF MIZORAM, INDIA

ABSTRACT

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ABSTRACT

Biodiversity is a vast and complex concept and its ramifications extend deep into all spheres of human life and activity. Diversity addresses two distinct aspects *i.e.,* species richness and evenness. Richness refers to the number of species per unit area, and evenness refers to their abundance, dominance, or spatial distribution. The focus of biodiversity measurement is typically the species, because they are easily observed and mostly used in the studies of forest ecosystems.

Biodiversity provides to humankind enormous direct economic benefits, an array of indirect essential services through natural ecosystems, and plays a prominent role in modulating ecosystem function and stability. Biodiversity is not uniformly distributed on the earth, and could comprise 5 to more than 50 million species. Biodiversity is the very basis of human survival and economic well-being, and encompasses all life forms, ecosystem and ecological processes, acknowledging the hierarchy at genetic, taxon and ecosystem levels. Biodiversity is responsible for the essential ecosystem services, including regulation of the atmospheric gaseous composition, climate, disturbance and water, soil formation and maintenance of soil fertility, processing and acquisition of nutrient, wastes assimilation, pollination, biological control, pollution control, recreation.

It provides us direct benefits the humankind in the form of timber, food, fibre, medicines, industrial enzymes, food, flavors, fragrances, cosmetics, emulsifiers, dyes, plant growth regulators, and pesticides. Studies indicate a prominent role of the composition and quantity of biodiversity in controlling ecosystem functions and ecosystem stability.

The types of biodiversity are as below:

a) Genetic Diversity (Diversity within species): It refers to the variation of genes within species. This constitutes distinct population of the same species or genetic variation within population or varieties within a species

b) Species Diversity (Diversity between species): It refers to the variety of species within a region. It can be defined as a group of inter-breeding or potentially inter-breeding natural populations that are reproductively isolated from other such groups.

c) Ecosystem diversity: An ecosystem is a community plus the physical environment that it occupies at a given time (Laverty, *et al.*, 2008). The ecosystem is the first unit in the molecule to ecosphere hierarchy that is complete, that is, it has all the components, biological and physical, necessary for survival. It is diversity at a higher level of organization, the ecosystem.

There are three levels of pattern and levels of species diversity:

i) *Alpha (α) Diversity*- It is the species diversity within a community or habitat.

ii) *Beta (β) Diversity*- It is the inter-community diversity expressing the rate of species turnover per unit change in habitat.

iii) *Gamma (¥) Diversity*- It is the overall diversity at landscape level and includes both α and β diversities.

$$¥ = \alpha + \beta + Q$$

Where,

Q= total no. of habitats or community

α = average value of α diversities

β = average value of β diver1.2

The loss of biological diversity is a global crisis. There is hardly any region on the Earth that is not facing ecological catastrophes. Of the 1.7 million species known to inhabit the earth, one fourth to one third is likely to extinct within the next few decades. According to Myers, these exponential species extinction rates have increased dramatically in the last 50,000 years from one extinction per 1,000 years to about 1,000 extinctions per year and may reach 40,000 per year until the end of this century, so that one species will be lost every hour. Although habitat loss may be greatest threat to most species, overharvesting, non sustainable use, and the illegal trade in some species are threatening not only their continued survival but also that of ecosystems and the livelihoods of communities and local economics that depend upon them.

There has been a great of worry regarding the loss of biodiversity because it represents the potential source of wealth in the form of the loss of biodiversity. Current extinction rates caused by human activities are orders of magnitude higher than natural background levels. The over-exploration of ecosystems is evident at local to global scales with profound negative impacts on biological diversity and livelihood opportunities of the people. Habitat destruction, pollution, overpopulation and species introduction are the major causes of biodiversity loss (Singh, *et al.*, 2010). The loss of biological diversity is having impacts on the local rights of people along with their cultural diversity.

The value of forests to the world's human population is becoming increasingly evident. The importance of their role in our planet's functioning is clearly reflected in multilateral environmental agreements such as the United Nations Framework Convention on Climate Change and the Convention on Biological Diversity. Yet demographic, economic and social changes around the world continue to exert considerable pressure on forest cover and condition. Tropical forests, although covering less than 10% of the land area represent the largest terrestrial reservoir of biological diversity, from the gene to the habitat level.

Forest stratification simply refers to the different layers within the community. Sometimes the stratification is very complex where community possesses a number of vertical layers of species each made up of a characteristic growth form. It refers to the different layers of plants in a forest. In older, mature forests there are typically several distinct layers of vegetation spread out from the forest floor to the tree canopy. Young forests may not show clear separations between layers.

A forest is a highly complex community of trees, shrubs and ground plants, mammals, birds, insects and soil fauna dominated by trees which shield them all beneath them from the impact of sun, wind and rain. The trees may be evergreen, deciduous or both in mixtures.

Six important vegetation types of forest are found in the North Eastern Region harboring 80000 out of 15,000 species of flowering plants, 40 out of 54 species of gymnosperms, 500 out of 1012 species of Pteridophytes, 825 out of 1145 species of orchids , 80 out of 90 species of rhododendrons, 60 out of 110 species of bamboo 25 out of 56 species of canes All these species belong to about 200 plant families out of 315 recorded from North East India (Anon., 1990). Some of the families Nepanthaceae, Illiciaceae and Clethraceae are unique in the world. According to the Indian Red Data Book, 10 % of the total flowering plants are endangered. Of the 1500 species, 800 are reported from North East India.

Of the ten protected areas in Mizoram, so far basic research work had been carried out in Tawi Wildlife Sanctuary (Lallawmkimi, 2010), Phawngpui National Park (Alfred Malsawmsanga, 2011), Murlen National Park (Lalramnghinglova and Hrahsel, 2011) and

ThorangTlang Sanctuary (Lalbiaknunga, 2012). Proper scientific investigation has not yet been carried out in Lengteng Sanctuary. So this research can be used as the first information report, and it will help a great deal in wildlife management as well. Study of tree diversity within this area will aid in further identification, conservation and management of these trees and can be of great assistance in finding out their uses of timbers, fuel wood, fruit, fodder, many traditional and medicinal values.

The forest Type of Lengteng Sanctuary is Montane sub tropical forest. The sanctuary is located in the eastern part from Aizawl in Champhai district, 198 km from Aizawl taking Ngopa road (12 km from Ngopa village). A number of studies suggest that there are zones or belts of vegetation on tropical mountains in which there is elevation-related discontinuous variation in floristic composition or structure. With increase elevation, there is a change in trees present in the areas. The variation of climate such as rainfall pattern and temperature has a large influence on the distribution pattern of trees in an area. The Sanctuary is under the management of Divisional Forest Officer, Khawzawl in Champhai district. A Ranger's headquarters was set up at Lamzawl to look after the sanctuary. As per mentioned earlier, there are seven villages in the vicinity of the sanctuary *viz.* Lamzawl, Ngopa, Kawlbem, Selam, Lungphunlian, Tualcheng and Pamchung. From these villages, Beat Officer, Forest Guard and Wildlife Guard were located to take care of this area.

The research work is focused on the following objectives:

i) To assess the composition and distribution pattern of tree species.

ii) To analyze phytosociological characteristics of tree community.

iii) To document uses of timber, fuel-wood, fodder, charcoal, food, fruit and medicinal importance.

iv) To suggest conservation measures for better management of the sanctuary.

The area is divided into the parts base on elevation. Site-1 has the lowest region (1500 m to 1700 m asl.), the middle region, Site-2 lies between 1700m to 1900 m asl. Site-3 is the uppermost region ranging from 1900 m to the highest peak which is 2141 m asl.

The field work and analysis of vegetation has been carried out during 2013-2015 at different altitudinal gradient and it was observed that the species richness follow an inverted hump shaped distribution pattern and is rich in plant diversity. The present study recorded 127 species of plants in the study site belonging to 89 genera and 52 families. The present study reveals that the sanctuary is dominated by trees having a diameter class less than 10cm (2270 individuals) followed by trees having 10-30cm diameter class with 1684 individuals. Trees having a diameter class greater than 90cm are the least with 49 individuals. The results show that tree diversity of Lengteng Wildlife Sanctuary follows a hump shaped pattern. This falls within the general pattern of initial increases in species richness with elevation followed by a peak in the middle and then decline with further increase in elevation. The high species richness in the elevation range of 1700 -1900 m shows that greater effort should be made on conservation of biodiversity in this specific area.

The area was rich in plant diversity and it is the home of many wildlife's, and serve as a corridor for wild animals from Myanmar. Due to its location in close proximity with villages, it suffers constant encroachment. Poaching of wild animals near and within the sanctuary can influence the delicate ecological balance of the sanctuary and its purpose. Majority of villagers depends on forest products, therefore, creation of transitional zone to protect the core zone is highly recommended. Eco-development programme should be intensified in the buffer zone, and constant vigilance of the sanctuary is needed. The presence of *Rhododendron arboretum and Rhododendron formosum* make the visit worthwhile. The area is frequently visited by students and other natural lovers for field trip and hiking.

Although the main aim of sanctuary is to conserve biodiversity, the area is way behind satisfactory level. Inappropriate forest management would cause a destruction of most of the forest communities and sometimes may lead to the destruction of their habitats. Presently, there is a need for increased legal protection, a well designed management practices to conserve the diversity of the study area. Creating awareness among the local people about biodiversity conservation and scientific management of the plant species in the study area will help making the area become one of the richest biodiversity areas of the state.

Due to timber collection activities, most of the forest along the road has been cleared and good forest patches were seen only in far and inaccessible places. Planting of more trees for eco-restoration purpose of fragile habitats is recommended. Most of the approach roads of the surrounding villages of the sanctuary is in a bad condition causing various problems during rainy season and making living very hard for the people. Construction and maintenance of all weathered roads to the surrounding villages is a major issue for the growth and development of the socio-economic condition of this rural area. Forest fire is also experienced within the sanctuary, which is highly attributable to burning of jhum land. Immediate steps need to be taken annually to prevent forest fire during the lean period that is February to March every year. Proper fire lines should be made in and around the sanctuary under constant vigilance to prevent from the breakup of forest fire.

Effective management is essential to ensure that wildlife is being conserved within a sanctuary's boundaries. Management activities including monitoring the health of habitats, ensuring that the rules of the protected area are respected, and jointly working with local people to balance nature protection with their needs and aspirations. Training of anti-poaching patrols, campaign for stronger action against the illegal wildlife trade, helping local communities benefit from living alongside endangered species through wildlife tourism are recommended to tackle the problem poaching business.

Sustainable management for non-timber forest products requires consideration of three types of issues (ecological, economic, and social). The potential ecological impact of over-harvesting under current management strategies could be devastating for entire NTFP populations. The biological material, harvested for NTFPs, is a critical part in the functioning of healthy forest ecosystems. The loss of access to gathering areas, or a significant decline in plant populations could have tremendous economic impact to the collectors and associated businesses. Knowledge from research about the economic impact of NTFP activities is needed to influence policies to support the sustainable management of the region’s forests.

Therefore, it can be concluded that the area has suffered various anthropogenic disturbances, over exploitation, habitat destruction, over grazing and encroachments from the people living in and around the surrounding villages. The sanctuary suffered serious damage from illegal felling of timbers. It also suffered forest fire through jhum burning from the surrounding villages as some part of the sanctuary is still used for jhum cultivation. Therefore, conservation measures recommended there in should be carried out under annual plan operation by involving local people's participation for their economic activities. Lengteng Sanctuary could be a promoting place for ecotourism area in Mizoram.

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Supervisor