STUDY ON PLANT DIVERSITY OF PUALRENG WILDLIFE SANCTUARY IN KOLASIB DISTRICT, MIZORAM

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STUDY ON PLANT DIVERSITY OF PUALRENG WILDLIFE SANCTUARY IN KOLASIB DISTRICT, MIZORAM

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In partial fulfilment of the requirement of the Degree of Doctor of Philosopy

In Environmental Science of Mizoram University, Aizawl.

CERTIFICATE

This is to certify that the thesis entitled, "Study on plant diversity of Pualreng wildlife sanctuary in Kolasib District, Mizoram" submitted by P.C. Vanlalnunpuia, 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.

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

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DECLARATION

I, P.C. Vanlalnunpuia, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to do the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.

This is being submitted to the Mizoram University for the degree of Doctor of Philosophy in Environmental Science.

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CHAPTER – 1

INTRODUCTION

1.1. Concept of Biodiversity and its definition

The concept of biological diversity can be found in the academic community as early as the mid-twentieth century, with some writers tracing it back to a description of the natural history of the southwestern North American desert by J. Arthur Harris in 1916 (Harris, 1916). The term "biodiversity" refers to the enormous variety of life on Earth. It can also be used to refer to all of the species in a specific region or ecosystem. Biodiversity encompasses all forms of life, including microorganisms, plants, animals and the genes they contain and the ecosystem they form. Each of these various species and organisms collaborate in complicated web-like ecosystems to keep things in balance and support life (Rozensweig, 1995). Raymond F. Dasmann, a wildlife scientist and naturalist, coined the term biological diversity in his book, A Different Kind of Country (1968), in which he advocated for conservation. It wasn't widely used until the 1980s when Lovejoy, a biologist, saved the term in the scientific world in 1980. The term was shortened to "biodiversity" by Walter. G. Rosen in 1985 while planning the "National Forum on Biodiversity" organized by the National Research Council (NRC) held at Washington D.C. in September 1986. The meeting's published proceedings, which were collected in the book '*Biodiversity*' (Wilson and Peter, 1988), established the concept of biodiversity and made it well-known among both the scientific community and the general public. This book draws attention to a critical global issue: the rapid extinction of plant and animal species as a result of rising human population and economic development demands.

According to Article 2 of the 'Convention on Biological Diversity' at the United Nations Conference on Environment and Development (UNCED), 'The Earth Summit' in 1992 established the definition of biodiversity (or biological diversity) as "the variability among living organisms from all sources including, *inter alia*, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems" (Agrawal, 2002).

The Biological Diversity Act of India, 2002, which was implemented to meet the obligations of the Convention on Biological Diversity (CBD) defined 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 ecosystem" (BDA, 2002).

Barnes *et al.,* (1998) addressed two distinct characteristics of diversity - species richness and evenness. Species richness refers to the number of species per unit area whereas evenness relates to the abundance, dominance, or spatial distribution. Since they are simple to detect and are frequently utilized in studies of forest ecosystems, species are typically the focus of biodiversity measurement.

1.2. Types of Biodiversity

Different categories and elaborations of biodiversity have been established by various authors. Gaston and Spicer (1998) presented a three-fold definition of "biodiversity" i.e. ecological diversity, genetic diversity, and organismal diversity. Several authors combined the genetic and organismal components, leaving genetic diversity and ecological diversity as the primary components. The two last aspects, direct use/genetics and indirect use/ecological, are connected to the two main "practical" value systems that Gaston and Spicer outlined.

Other workers have classified it as genetic diversity, species or taxonomic diversity and ecosystem diversity (Reid and Miller, 1989; Heywood, 1994; Noss and Cooperrider, 1994). According to Soulé (1991), five different levels of diversity were identified - genes, populations, species, assemblages and whole system at the landscape or ecosystem level.

1.2.1. Genetic Diversity

It refers to genetic differences between species as well as genetic variations within a single species. This refers to genetic diversity among various populations of the same species. There is no doubt that genetic diversity is a crucial aspect of biodiversity (Rao and Hodgkin, 2002).

Genetic diversity refers to the variety found at the gene level. Genes, which are made of DNA, are the building blocks that determine how an organism develops as well as its traits and abilities. It arises from the numerous genetic variations that exist between individuals and can take the form of variations in DNA sequence, biochemical traits (protein structure or isoenzyme properties), physiological traits (abiotic stress resistance or growth rate) or morphological traits like flower color or plant form (Suneson, 1960; Nevo, 1990).

It is useful to distinguish between four aspects of genetic diversity: the number of various forms (alleles) that are ultimately found in various populations, their distribution, the impact they have on functionality and the general distinctiveness across various populations. Mutation and recombination produce the variety that supports genetic diversity. The alleles present in various populations are affected by selection, genetic drift and gene flow, which results in changes in the diversity in those populations (Frankel, 1977; Brown, 1988; Hamrick *et al.*, 1992).

Genetic variety is significant because it provides the building blocks for evolution and adaptation. A species or population with more genetic diversity has a greater capacity for some of its individuals to adapt to environmental changes. Less diversity breeds homogeneity, which is detrimental over time because no member of the population would likely be able to adapt to a changing environment. The utilization of monocultures or sizable cultures of plants with the same genetic makeup is an example of current agricultural methods. This can be a benefit while growing and harvesting crops because all the plants can be picked at once, but it can also be a disadvantage if a disease or parasite attacks the field because every plant will be vulnerable (Loveless and Hamrick, 1984; Thomas, 1992).

Some scientists argue that genetic variety is the true measure of biodiversity since the gene serves as the primary unit of natural selection and, consequently, of evolution. However, it has previously been disregarded as being too complicated and expensive to employ as a fundamental unit for measuring and evaluating biodiversity (Moritz, 1994). Genetic diversity exists within a single individual, between individuals of the same species and between species (species diversity) (Laverty *et al.*, 2008).

1.2.2. Species Diversity

One of the most significant components of biodiversity is species diversity. It alludes to the variety of species found in a given region. It can be characterized as a group of naturally occurring populations that breed with one another or have the potential to do so but are reproductively isolated from other such groups. Additionally, it is also known as Taxonomic or Organismal diversity (Agrawal, 2002). Most often, biodiversity is measured at the species level. It serves as the foundation for the diversity of ecological associations such as communities and biomes, and the diversity of higher taxa (Kiester, 2001).

Species can be defined by three concepts - the morphological species concept, the biological species concept and the phylogenetic species concept. The morphological species concept (MSC) is the most traditional and easily understood method. This concept suggests that individuals with similar appearances and distinguishing characteristics are members of the same species. Based on the biological species concept (BSC), a species is an isolated group of individuals that interbreeds. Basically, if two individuals can reproduce and have fertile offspring i.e. offspring that can also reproduce, then they belong to the same species. The phylogenetic species concept (PSC) defined species as the smallest diagnosable cluster of individual organisms (i.e., the cluster of organisms that can be distinguished from other clusters) in which there is a parental pattern of ancestry (Cronquist, 1978; Mayr and Ashlock, 1991; Laverty *et al.*, 2008).

Magurran (1998) developed three ways for measurement of species diversity - species richness, species abundance and taxonomic or phylogenetic diversity. The number of different species represented in an ecological community, landscape or region is referred to as species richness. Species richness is simply a count of species; it does not take into account species abundance or relative abundance distribution, whereas species evenness measures how evenly distributed the species are in terms of abundance. Species diversity takes both species richness and evenness into account.

1.2.3. Habitat Diversity

The term "habitat" refers to a region's collection of biotic, physical, and resource elements that are essential for a specific species to thrive and reproduce. A species habitat can be thought of as the outward representation of its ecological niche. Since habitat refers specifically to a species, it differs significantly from ideas like "environment" or "vegetation assemblages," for which the word "habitat-type" is more applicable (Krausman and Morrison, 2016). Habitat diversity explores the distinctions in ecosystems within a particular geographic region. It refers to the range of different habitats found in an ecosystem or biome. Species and genetic diversity preservation generally follows the conservation and restoration of habitat diversity (Alsterberg *et al.*, 2017).

According to the "habitat heterogeneity hypothesis," a rise in the quantity of habitats or, on a smaller scale, a rise in the complexity of their structural design, leads to an increase in the diversity of species (Mac Arthur and Mac Arthur, 1961; Mac Arthur and Wilson, 1967; Connor and McCoy, 1979). Estimates of habitat diversity are frequently used as the foundation of area-based management, although assessing habitats quantitatively can be difficult (Budiansky, 1995).

1.2.4. Ecosystem Diversity

The range of life forms in a given terrain or locale, as well as the ecological processes that enable them to function, is referred to as ecosystem diversity. It is frequently assessed using measures of the diversity of constituent species, relative abundance of different species and consideration of the type of species. An ecosystem is composed of a diverse range of living organisms functioning together with their physical environments (Swingland, 2013).

Any scale, such as the size of a little tide pool or the size of the entire biosphere, can support the existence of an ecosystem. As a result, an ecosystem can be described as a square meter of grassland, a forest, the border of a pond, a tide pool or any other sizable area of nature where living things and non-living things coexist (Laverty *et al.,* 2008). The ecosystem may be:

(a) Aquatic ecosystem – (i) Fresh water ecosystem (ii) Marine ecosystem.

(b) Terrestrial ecosystem – (i) Forest ecosystem (ii) Desert ecosystem (iii) man-made ecosystem.

Ecosystem diversity is concerned with species distributions and community patterns, the function and role of key species and the interaction of species. The term "ecosystem" refers to all levels higher than species, including associations, communities and ecosystems. It is incredibly complex to comprehend how all the species in an ecosystem interact with one another, their environment and with themselves. Since there is no universally accepted classification of ecosystems, ecosystems can be considered at various scales (Harper and Hawksworth, 1994; Ghilarov, 2000). While an area's physical attributes will have a substantial impact on the diversity of species found there, organisms can also alter the ecosystem's physical attributes (Butler, 1995).

1.2.5. Landscape Diversity

Landscapes are geographical regions that are spatially heterogeneous and are characterized by a diverse array of interacting ecosystems that repeat themselves in a recognizable pattern. These ecosystems can range from relatively natural terrestrial and aquatic systems like forests, grasslands and lakes to human-dominated environments like agricultural and urban settings (Forman and Godron, 1981; Forman, 1995; Turner *et al.*, 2001).

Landscape diversity refers to the complexity and diversity of landscape features in composition, structure and function, and includes not only the number of different patch types, patch size and patch shape within a landscape mosaic, but also the spatial arrangement of different patch types, as well as the connectivity and connectedness of these patches. Landscape diversity is thus made up of patch diversity, landscape type diversity and pattern diversity. Patch diversity identifies landscape fragmentation, patch edge, perimeter-area ratio, patch size, shape and number of patches. Landscape type diversity identifies distribution richness and proportions of patch types. Land use and landscape planning, wildlife habitat protection and biodiversity conservation can all be linked to landscape diversity. Pattern diversity measures the relative order of patch types within a landscape mosaic, which also reveals the connectivity, spatial connection and neighbourhood effects between the patches. It considers not only physical distance between the patches but also the landscape connectivity. Landscape diversity may have an impact on a number of ecological phenomena, including species distribution, movement and diversity, water runoff and erosion, nutrient cycling and energy flow rates, biomass and productivity (Bojie and Liding, 1996).

The size, form and connectivity of specific patches of ecosystems within the landscape, for instance, have an impact on species composition and community viability (Noss, 1990). Therefore, in order to secure the survival of species that are extensively distributed throughout many ecosystems, conservation efforts should be focused on entire landscapes (Hunter, 2002).

1.3. Patterns of Biodiversity

Whittaker (1975 and 1977) was the first person to recognize that ecological diversity was scale-dependent or hierarchical in nature. Whittaker identified four levels of inventory diversity that could be estimated at four increasingly larger spatial scales. There are various resolutions at which inventory diversity or the diversity of a specific geographic unit, can be quantified. They are as follows:

(i) Point diversity: It is the diversity of a single sample. It demonstrates the diversity in a specific area.

(ii) α (Alpha) diversity: The diversity within a particular region or ecosystem is referred to as alpha diversity and it is typically expressed by the number of species in that ecosystem. This is equivalent to determining an area's species richness.

(iii) γ (Gamma) diversity: The diversity of a large unit, such as a landscape or an island is represented by gamma diversity.

(iv) ε (Epsilon) diversity: Epsilon diversity is the total diversity of a group of areas of gamma diversity. It is the diversity present within a large biogeographic area, such as a biome.

Whittaker (1975) also proposed three levels of differentiation diversity. Inventory diversity levels are matched by corresponding differentiation diversity categories - *Pattern diversity* is the difference between samples collected in a homogeneous environment. *Beta* (β) *diversity* is a measure of diversity between habitat. In other words, beta diversity analyses the rate of species change as one travels along any ecological gradient, from habitat to habitat or community to community. *Delta* (δ) *diversity* is defined as a change in species diversity (and abundance) that emerges between gamma diversity units within an epsilon diversity area (Magurran, 2004).

Halffter (1998) has proposed that as the effects of human activity (community alteration and fragmentation) are most pronounced at this level, diversity should be assessed at the landscape level. By differentiating and quantifying the local distribution of species, similarity between local assemblages and the rate of change in species composition with respect to environmental factors, the components of diversity can be best described.

(i) Alpha (α) diversity (*i.e*., diversity within communities) is the diversity within a specific region or ecosystem, which is typically expressed by the number of species in that ecosystem. Two important components of alpha diversity are species richness and species evenness. Species richness refers to the number of species per unit area whereas species evenness refers to the distribution of individuals within a species. The number of species is proportional to the size of the sampled area and may exhibit different patterns at different spatial scales in grassland (Singh, 1996).

(ii) Beta (β) diversity (*i.e*., diversity between communities) refers to the comparison of diversity between ecosystems, typically measured as the amount of species change between the ecosystems. Since beta diversity represents the rate of species change along a given habitat or physiognomic gradient, it evaluates the community response to habitat heterogeneity. The species diversity of biological communities frequently has major effects on ecosystem-level properties (Whittaker, 1977; Wardle *et al.*, 1997).

(iii) Gamma (γ) diversity (*i.e.,* total diversity of a region) is defined as geographic-scale species diversity by Hunter (2002). In other words, it is a measure of the overall diversity for the different ecosystems within a region. It corresponds to species richness at landscape level (Franklin, 1993).

1.4. Megadiversity and Biodiversity Hotspots

1.4.1. Megadiversity

At the 1998 Conference on Biodiversity held at the Smithsonian Institution in Washington, D.C., the term "Megadiversity" was first introduced. Megadiversity focuses on species richness, threatened species and endemic species while hotspots notion refers to rich endemism and the degree of threat or habitat degradation. This concept emphasizes the significance of certain countries that have a high level of biological diversity within their borders including plenty of endemic species (Myers *et al.*, 2000).

Russell Mittermeier, a well-known conservation biologist, proposed the concept of megadiversity countries first, with an initial emphasis on tropical primates which was later expanded to include all types of ecosystems and a variety of organism groups. It is now utilized to raise awareness about the significance of protecting natural biodiversity, particularly in countries where it is abundant and under threat. Despite accounting for only approximately 10% of the Earth's surface, the mega-diverse countries are home to at least 70% of the planet's terrestrial biological diversity including more than two-thirds of all non-fish vertebrate species and three-quarters of all higher plant species (Mittermeier and Mittermeier, 1997).

Endemism is the primary criterion of megadiversity, first at the species level and then at higher taxonomic levels such as genus and family. A nation must have at least 5000 endemic plants to qualify as a Megadiverse country (Mittermeier, 1988). The Conservation International and the United Nations Environment Program's World Conservation Monitoring Center have designated these countries as "Megadiverse". They are Australia, Brazil, China, Colombia, Democratic Republic of the Congo, Ecuador, India, Indonesia, Madagascar, Malaysia, Mexico, Papua New Guinea, Peru, Philippines, South Africa, United States and Venezuela. Thus, the world's top biodiversity-rich nations are referred to as megadiversity countries (Myers *et al.*, 2000). The world's top seventeen Megadiversity countries are included in **Table 1.1.**

Table 1.1. Megadiversity Countries: Plant Diversity and Endemism

Sl. No.	Country	Area (km^2)	Total species	Endemics
1	Brazil	8,511,965	~50,000 - 56,000	16,500 - 18,500
2	Indonesia	1,916,600	~ 37,000	14,800 - 18,500
3	Colombia	1,141,748	45,000 - 51,000	15,000 - 17,000
4	Mexico	1,972,544	18,000 -	10,000 - 15,000

			30,000	
5	Australia	7,686,810	15,638	14,458
6	Madagascar	587,045	11,000 - 12,000	8,800 - 9,600
7	China	9,561,000	27,100 - 30,000	~10,000
8	Philippines	300,780	8,000 - 12,000	3,800 - 6,000
9	India	3,287,782	> 17,000	7,025 - 7,875
10	Peru	1,285,210	18,000 - 20,000	5,356
11	Papua New Guinea	475,369	15,000 - 21,000	10,500 - 16,000
12	Ecuador	283,561	17,600 - 21,100	4,000 - 5,000
13	USA	9,372,143	18,956	4,036
14	Venezuela	912,050	15,000 - 21,070	5,000 - 8,000
15	Malaysia	329,749	15,000	6,500 - 8,000
16	South Africa	1,221,037	23,420	16,500
17	Dem. Rep. Congo/Zaire	2,344,000	11000	3,200
	Total	51,189,393		155,475 - 183,025

(Source: Mittermeier and Mittermeier, 1997)

1.4.2. Biodiversity Hotspots

Biodiversity hotspots can be defined as regions having high level of diversity but is under serious threat of destruction. The biodiversity hotspot thesis was first published in 1988 by British ecologist Norman Myers. Myers identified ten tropical forest "hotspots" based solely on high levels of habitat loss and the presence of an unusual number of plant endemism despite the lack of quantitative criteria (Mittermeier *et al.*, 2011).

Eight other hotspots were identified through additional study, including four in the Mediterranean regions (Myers, 1990). In 1989, Conservation International (CI) adopted Myers' hotspots as its institutional model. Subsequently, they collaborated on the first comprehensive update of the world's hotspots. Myers, Conservation International and collaborators later revised their estimates of remaining primary habitat and formally defined the hotspots as biogeographic zones having more than > 1500 endemic vascular plant species and ≤ 30% of original primary habitat (Myers *et al.,* 2000). This collaboration, which resulted in a comprehensive global evaluation (Mittermeier *et al.,* 1999) and a scientific publication (Myers *et al.,* 2000) saw the hotspots expand in both area and number due to improved criteria and additional data. A second significant review and update in 2004 (Mittermeier *et al.,* 2004) did not change the criteria but did add new ones that were suspected hotspots for which sufficient information either did not exist or were not easily accessible, bringing the total to 34 biodiversity hotspots (Mittermeier *et al.,* 2011). A 35th hotspot was added (Williams *et al.,* 2011), the Forests of East Australia. There are currently 36 hotspots in the world. The eight hottest hotspots according to Myers *et al.,* (2000) are shown in **Table 1.2**.

Table 1.2. The eight hottest hotspots

Hotspots	Endemic plants	Endemic vertebrates	Endemic plants/area ratio(species per 100 sq. km)	Endemic vertebrate/area ratio(species per 100 sq. km)	Remaining primary vegetation as % of original extent	Times appearing in top 10 for each of five factors
Madagascar	9,704	771	16.4	1.3	9.9	5
Phillipines	5,832	518	64.7	5.7	3	5
Sundaland	15,000	701	12.0	0.6	7.8	5
Brazil's Atlantic Forest	8,000	664	8.7	0.6	7.5	4
Caribbean	7,000	779	23.5	2.6	11.3	4
Indo-Burma	7,000	528	7.0	0.5	4.9	3
Western Ghats/Sri Lanka	2,180	355	17.5	2.9	6.8	3
Eastern Arc and Central forests of Tanzania/Kenya	1,500	121	75.0	6.1	6.7	3

(Source: Myers *et al.*, 2000)

However, Myers and his associates did not consider the oceans in their investigation. Coral reefs in particular are one of the ocean's most ecologically diverse ecosystems and provide crucial habitat and structures in tropical and subtropical coastal waters (Bellwood *et al.,* 2004). Ocean acidification and changes in sea surface temperature (Ateweberhan *et al.,* 2013) are likely to lead to significant losses of coral reefs and changes in the distribution and relative abundances of marine organisms in these regions, in which the reason for the high number of species is still under debate (Bowen *et al.,* 2013, Cowman *et al.,* 2013).

According to numerous studies, preserving biodiversity is crucial to the provision of ecosystem services (Pereira *et al.,* 2013). Nevertheless, despite the intention on a global scale to preserve and maintain biodiversity, its decline does not appear to be slowing down (Butchart *et al.,* 2010). Although protected areas have been expanded they still only cover a small number of species (Venter *et al.,* 2014) and don't appear to safeguard biodiversity as well as they could (Pimm *et al.,* 2014). Overall, the major causes of biodiversity loss are habitat change and over-exploitation, pollution, invasive species, and in particular, climate change. These anthropogenic pressures may have already begun a critical transition toward a tipping point (Barnosky *et al.,* 2012).

1.5. Loss of Biodiversity

The term "biodiversity loss" refers to a decline in the biological diversity of a species, ecosystem, area or the entire earth. The loss of biodiversity and the resulting environmental changes are happening faster than ever before in human history and there is no sign of this slowing down. Human activities have dramatically distorted and significantly altered nearly all of the Earth's ecosystems which are constantly being converted for agricultural and other uses. Countless animal and plant populations have declined in size and geographical distribution. Although the extinction of species is a natural process that has occurred throughout Earth's history, human activity has increased the rate of extinction by a factor of at least 100 (Ripple *et al.,* 2017; Bradshaw *et al.,* 2021; Cowie *et al.,* 2022). Reduced biodiversity, in particular, diminishes ecosystem services and as a result, poses an immediate threat to food security but it can also have long-term global health consequences for humans (Cardinale *et al.,* 2012).

The pursuit of increased accuracy in estimating global extinction rates is not crucial. It is more important to recognize in broad terms the extent to which unmonitored populations and species are vulnerable to fragmentation and extinction (Temple, 1986). Numerous factors contribute to biodiversity loss. Any element, natural or artificial that directly or indirectly alters an ecosystem is known as a driver. Ecosystem processes are undeniably influenced by a direct driver. An indirect driver modifies one or more direct drivers to operate more subtly. Natural and man-made factors tend to interact and amplify one another. Habitat alteration, climate change, overuse of invasive species and pollution are significant direct drivers that have an impact on biodiversity (Rawat and Agarwal, 2015).

Forest fringe villages are directly or indirectly dependent on forest products for fuel-wood, traditional medicines and food for personal and commercial purposes (Banerjee and Madhurima, 2013; Kumari *et al.,* 2019). Buffer zones of protected areas often experience high pressure from fringe villages as these areas are cleared for agricultural purposes and pasturelands which adversely disrupt the ecosystem function and services in the territory (Nacoulma *et al.,* 2012; Lal *et al.,* 2017). The advancement of remote sensing techniques, availability of high-resolution images in the optical and non-optical regions, and the high temporal availability in conjunction with geographic information system (GIS) have resulted in an efficient tool for the continuous detection, quantification and mapping of forest areas and their changes over time. Temporal satellite data provide accurate information concerning deforestation and forest alterations. On account of rapid progress in satellite technology and digital image processing, remote sensing has improved the scientific comprehension of Earth's land and waters (Sakthivel *et al.,* 2010; Nordberg and Evertson, 2003).

1.5.1. Habitat alteration and destruction

Overall, habitat alteration and destruction are the primary factors directly contributing to biodiversity loss worldwide. When an entire habitat is destroyed, the species that rely on it are no longer able to function. As a result of the displacement or eradication of existing organisms in the habitat, biodiversity is reduced (Ayoade *et al.*, 2009; Agarwal *et al.,* 2011). Since fewer species can survive in numerous small habitat fragments than they could in the original, undisturbed habitat, this can lead to the extinction of species (MacArthur and Wilson, 1967).

The man-made destruction of habitats has greatly increased in the latter half of the twentieth century. Human activity frequently results in the destruction of natural habitats in order to harvest natural resources for industrial production and urbanization. Examples of habitat destruction and fragmentation include cutting down trees for agriculture, converting riverine habitat into lacustrine (reservoir) habitat by building hydroelectric projects on rivers, mining, logging, urban sprawl and constructing highways. Therefore, the loss of genetic diversity, the extinction of species and the acceleration of ecosystem changes like haphazard population shifts, disease outbreaks and habitat fragmentation, among others, have contributed to biodiversity losses (Agarwal *et al.*, 2014). International policy commitments embodied by Sustainable Development Goals 15 (Life on Land) and 14 (Life Below Water) made an effort to address habitat destruction. However, the United Nations Environment Programme report on "Making Peace with Nature," published in 2021, discovered that the majority of these efforts had fallen short of their goals.

1.5.2. Over-exploitation of biological resources

Over-exploitation occurs when a population of a particular species is harvested at a rate that is greater than what can be supported by the population's natural reproductive rate. This could be done through trading, food gathering, hunting or fishing. Many species, including trees, animals hunted for meat, marine fish and invertebrates continue to face a serious threat from over-exploitation. Ultimately, over-exploitation can ultimately lead to resource depletion and the extinction of a number of threatened and endangered species (Rawat, 1998).

Due to the exponential increase in human populations over the past few decades, biological resources have been overused in order to meet the rising demand for sustenance (Kirkley and Squire, 1999). According to Worm *et al.,* (2016), if no immediate action is taken, 29% of fish and seafood species will either collapse before 2048 (i.e., their catch will have decreased by 90%) or have already collapsed. As per estimates from Myers and Worm (2003), the biomass of large predatory fish is only about 10% of pre-industrial levels globally. In 2020, global fish abundances have reduced by 38% compared to fish population in 1970 (Luypaert *et al.,* 2020). Fishery methods like bottom trawling and longline fishing have destroyed habitats, causing a decline in regional species richness and spatial diversity (Jones *et al.,* 2010).

1.5.3. Pollution

Pollution in all forms is a serious threat to biodiversity but nutrient loading, primarily of nitrogen and phosphorus is a significant and increasing cause of biodiversity loss and ecosystem dysfunction. Inorganic and organic pollutants have emerged as a major contributor to biodiversity loss in terrestrial, aquatic-marine and freshwater ecosystems over the last five decades. Biodiversity is also threatened by thermal pollution. Eutrophication of freshwater bodies, hypoxia in coastal marine ecosystems, nitrous oxide emissions contributing to global climate change and air pollution by NO in urban areas are all possible effects of organic pollutants in a freshwater ecosystem. The incidence of such issues varies greatly across regions (Rawat and Agarwal, 2015).

Species in their natural habitats are increasingly being harmed by industrial activities and pollution caused by excessive use of agrochemicals such as DDT, oil spills, acid precipitation etc. For instance, the decline of falcons and fish-eating birds has been linked to pesticides. Ingestion of spent shotgun pellets that fall into lakes and marshes causes many species, including ducks, swans and cranes to die from lead poisoning. DDT used as pesticides have caused thinning of egg shells leading to premature hatch and kidney failure in birds (Green *et al.,* 2004; Muralidharan *et al.,* 2008).

The noise from traffic, ships, vehicles and aircrafts can travel to untouched habitats and have an impact on the ability of certain wildlife species to survive (Sordello *et al.,* 2019). Whether it's for reproduction, navigation or to alert others to prey or predators, species such as birds, amphibians, reptiles, fishes, mammals and invertebrates use sounds to communicate with other members of their species. Nevertheless, anthropogenic noises prevent species from detecting these sounds, hindering population communication as a whole. Animals that are unable to communicate with one another will have lower levels of reproduction (unable to find mates) and higher rates of mortality (lack of communication for predator detection) (Francis et al., 2009; Kunc *et al.,* 2019).

1.5.4. Invasive species

An invasive species is an organism that is not indigenous to a particular region. Invasive species can be extremely damaging to the new region's economy and environment affecting habitats and bioregions thus creating detrimental changes to the ecosystem. Their introduction can be intentional or accidental. Some of the ecological impacts of the invasion include hybridization, out competition, disruption of original ecosystem, plant pathogenic influences, disease transmission, disruption of food-webs and to some situations extinction. Species may be intentionally introduced for ornamental purposes, agriculture, hunting and spotting activities, biotechnology for scientific research and trade (Rawat and Agarwal, 2015).

1.5.5. Climatic changes

Long-term changes in temperature and weather patterns are referred to as climate change. This is a major concern especially as CO_2 levels in the atmosphere rise, resulting in global warming. Since most species originate within a very narrow physiological limit, nature maintains a range of tolerance for ecosystem stability. The changes may be gradual or abrupt and if the upper or lower limit is exceeded, some species will become extinct. Recent climate changes, such as higher temperatures in certain areas, have already significantly impacted ecosystems and biodiversity (Rawat and Semwal, 2014). It had an impact on species distributions, population sizes, timing of reproduction or migration events and the frequency of pest and disease outbreaks. Many species that exist only in a small geographic area may go extinct as a result of predicted climate changes by 2050 (Rawat and Agarwal, 2015). According to the Intergovernmental Panel on Climate Change (IPCC), the average surface temperature of earth will increase by 2 to 6.4^{0}C by the year 2100 compared to pre-industrial levels which is expected to cause catastrophic impacts on biodiversity (Millennium Ecosystem Assessment, 2005).

1.6. Scope and objectives

The northeast region of India is regarded as one of the subcontinent's biodiversity hotspots due to its high species density and diversity. The state of Mizoram has the second highest forest cover as percentage of total geographic area (84.53%) in the country (FSI 2021). Considering the accelerated anthropogenic activities that are causing biodiversity loss, there is an immediate need to analyse the status of biological diversity in this region with a focus on natural protected areas. Proper assessment and documentation of the status of biodiversity are crucial and more valuable than ever when creating policies and programs for the efficient management and conservation of biodiversity.

Thus, the present research focuses on documenting and identifying floristic diversity while assessing the endemic, rare, threatened and endangered plant species present in Pualreng Wildlife Sanctuary. Since this sanctuary has not yet undergone a thorough scientific investigation, the current research is expected to be helpful in providing the necessary information for formulating policies and programs for effective management and conservation of valuable biodiversity, including the other related benefits, as the wildlife is completely dependent on the vegetation and floristic composition of the sanctuary. Therefore, this research will also greatly aid in the management of wildlife.

Since remote sensing technology has the ability for system observations at various scales, it can extend possible data archives from present time to several decades back which can delineate vegetation cover at a large scale efficiently (Xie *et al.*, 2008). Studies and research aimed toward monitoring the land and forest cover change of protected areas, before and after they are established is very limited. This study will also yield insight into the influence of the management of these protected areas by the administration over the period.

The aims and objectives of the study are:

1. To study plant diversity in the study area.

2. Screening of rare and threatened species.

3. To assess impact of anthropogenic activities on the environment.

CHAPTER – 2

REVIEW OF LITERATURE

Although there is disagreement over the extent of biodiversity on Earth, it is undeniable that it has reached a level of extraordinary diversity as a result of more than 3.5 billion years of biological evolution (Vitousek *et al.*, 1997). Biodiversity is richer and more diverse than ever before, but it is threatened by a major pulse of extinction which some authors have referred to as the Phanerozoic Era's sixth major extinction (May *et al.,* 1995). At the same time, human dominance over the planet is so extensive that Crutzen (2002) has dubbed the current epoch "the Anthropocene Era".

The systems of interest in biological diversity monitoring are typically ecosystems and their components which include communities and populations (Yoccoz *et al.*, 2001). Among all ecosystems, forests have the highest diversity of species, genetic material and ecological processes (Adekunle *et al.,* 2013). Plants are an essential component of the forest ecosystem and plant surveys of any kind are a very active pursuit around the world, yielding extraordinarily useful plant databases with detailed information and a large number of records. Even though botanists around the world have conducted numerous floristic and taxonomic studies, but knowledge about floristic diversity remains limited (Lozano *et al.,* 2012). Since the number and types of species present in any area determine the organismal traits which have an impact on the ecosystem processes, species diversity is an important characteristic of a natural community and has functional implications (Mishra *et al.*, 2005; Rana and Gairola, 2009; Kushwaha and Nandy, 2012).

The population structure of the forests has frequently been depicted by the density-diameter distribution of the stems (Anon., 1978). Density, diameter size and size distribution attributes are elements of the forest structure and there are numerous and gradient dependent patterns in these relationships (Huang *et al.*, 2003).

2.1. Plant diversity at international level

Biodiversity is the highest in the tropics compared to other regions indicating that it is not evenly distributed. According to Gaston (2000), terrestrial biodiversity is typically highest close to the equator because of the region's warm climate and high primary productivity (Field *et al.,* 2009). In all oceans, the mid-latitudinal band is where marine biodiversity tends to be most abundant, especially along the Western Pacific coasts where sea surface temperature is highest. There is a latitudinal gradient in the diversity of species (Tittensor *et al.,* 2010). Biodiversity has been increasing over time (McPeek *et al.,* 2007), but it is likely to slow down in the future (Robosky, 2009) because it tends to congregate in hotspots (Myers *et al.,* 2000).

Scientists have given different estimates of the number of species ranging from 2 – 100 million with current estimates putting it somewhere between 2 and 8 million (Costello *et al.,* 2013). Mora *et al.,* (2011) estimated that the number of species on earth ranges from 9 to 52 million. These estimates are based on the observation that only 1.8 million distinct species of modern animals, plants, fungi and microbes have been named; various extrapolation techniques then yield higher estimates for the true number (Benton, 2016). Approximately 85% to 95% of species are thought to be terrestrial. This is due to the enormous dominance of insects today, particularly beetles and social insects, as well as the presence of some other clades with high species diversity such as the angiosperms, flowering plants and some tetrapod groups like birds, lizards and rodents (Vermeij and Grosberg, 2010).

Some groups of vertebrate animals and plants and insects (e.g., butterflies and mosquitoes) have relatively reliable estimates, but others, particularly nematodes, fungi and mite have much less certain estimates—but the groups are certainly very large. Estimates of the total number of organism species are based on expert opinions from those who understand the level of diversity in a specific group of organisms, extrapolations from an initial estimated number or a combination of these methods. (Dirzo and

Raven, 2003). Thus, sampling with result analysis has resulted in estimates such as Erwin's (1982) of 30 million tropical arthropod species based on beetle sampling in tropical tree canopies. Pimm *et al.*, (1995) summarized the results of several expert opinions and extrapolations available. These estimates primarily deal with hypothetical orders of magnitude rather than precise numbers, which caused a fair amount of uncertainty (Gaston, 1991).

Tropical regions are home to a diverse range of plant species, many of which have medicinal and economic value. As a result, research on tropical plant species diversity and community structure is ecologically important and extensive differences in the species composition and abundance between different tropical forests are also documented (Parthasarathy and Karthikeyan, 1997). The majority of life on earth is dominated by plants, with animals making up a very small portion. Plants account for more than 82% of biomass while animals account for only 0.4% (Bar-On *et al.,* 2018).

According to the IUCN Red List of Threatened Species 2021, the number of described species are : Amphibians - 8,395; Arachnids - 110,615; Birds - 11,162; Brown algae - 4,381; Corals - 5,610; Crustaceans - 80,122; Ferns and Allies - 11,800; Fishes - 36,058; Flowering plants - 369,000; Fungi and protists - 141,381; Green algae - 12,090; Gymnosperms-1,113; Horseshoe crabs – 4; Insects - 1,053,578; Invertebrates - 1,491,386; Lichens - 17,000; Mammals - 6,578; Molluscs - 83,706; Mosses - 21,925; Mushrooms - 120,000; Other invertebrates - 157,543; Plants - 423,373; Red algae - 7,445; Reptiles - 11,690; Velvet worms – 208; Vertebrates - 73,883. The total number of described species is assumed to be 2,130,023. These numbers may be a little high, especially for less well - known groups like plants or fungi. This is due to the fact that some described species end up being synonyms (about 20%) - just another name for an existing species that has already been described (Costello *et al.,* 2013). There is a continuous evaluation process to remove synonyms (and most are eventually removed), but species are frequently added faster than synonyms can be found and removed (Solow *et al.,* 1995).

2.2. Plant diversity at national level

India is renowned for having a wide range of biological species, making it a haven for botanists. It has a coastline of more than 7500 km and a total geographic area of about 329 million hectares. Numerous different types of forests can be found there thanks to the diverse landforms and climate of the region. In addition to geography, history and culture, it has a unique identity when it comes to its vegetation, which ranges from tropical rain forests in the Andaman and Nicobar Islands to dry alpine forests higher up in the Himalayas, from sea level to the highest mountain ranges in the world, from hot and dry in the northwest to cold and dry in the trans-Himalayan region, from tropical wet evergreen forests in northeast India and the Western Ghats to mangroves in the Sundarbans. The country has a wide range of plant life in between these extremes conditions (Sharma and Singh, 2000). India is one of the World Heritage Convention's signatories and has designated a number of protected areas as World Heritage sites. These include the Sunderbans in West Bengal's Ganges delta, Kaziranga in Assam, Bharatpur in Uttar Pradesh, Nandadevi in the Himalayas, and Manas on the border between India and Bhutan. The Convention on International Trade in Endangered Species (CITES), which aims to reduce the use of threatened plants and animals by regulating trade in their products and in the pet trade, has also been signed by India.

The Indian subcontinent has been divided into 8 to 10 regions based on flora distribution. Chatterjee (1939) proposes the following sub-regions: (1) Western Himalayas, (2) Eastern Himalayas, (3) Central Himalayas, (4) Assam, (5) Gangetic plain, (6) Indus plain, (7) Deccan, and (8) Malabar. The ICAR recognized eight agro-climatic regions based on physiographic, climatic, and cultural features (Murthy and Pandey, 1978), but micro-climatic considerations point to 21 such regions (Sehgal *et al.*, 1990). Furthermore, the Planning Commission has divided the country into 15 agro-climatic zones (Sehgal *et al.*, 1990). However, in the current account, roughly eight regions have been identified which more or less superimpose over Chatterjee's phyto-geographical regions (1939).

India has 12 biogeographical provinces, 5 biomes and 3 bioregion domains (Cox and Moore, 1993). It supports a diverse array of habitats or ecosystems, each with a rich and distinctive floristic diversity, including forests, grasslands, wetlands, coastal, marine and desert environments. These biological qualities are further enhanced by the country's geographic location at the meeting point of three major global biogeographic realms, *viz.*, Indo-Malesian, Eurasian and Afro-tropical, which enables the mixing of floristic elements from these regions as well. The World Conservation Monitoring Centre acknowledged the country as one of the 17 megadiversity countries in the world in 2000. India's floral diversity is concentrated primarily in the four biodiversity hotspots: the Eastern Himalayas, the Western Ghats (and Sri Lanka), Northeast India and the Andaman Islands (Indo-Burma) and Nicobar Island (Sundaland) out of 34 biodiversity hotspots recognised in the world. These floristically significant areas have a particularly high concentration of endemic species while experiencing habitat loss and are also more likely to have threatened plant species.

Total forest and tree cover of India in 2021 is 80.9 million hectares, which is 24.62% of the geographical area of the country (FSI, 2021). Champion and Seth (1968) identified 16 major forest types and 221 subtypes in the country. Wetlands cover approximately 4.1 million hectares in India (excluding paddy fields and mangroves). Mangroves in India cover approximately 6700 km^2 and account for 7% of the world's mangroves, making it one of the best swamps in the world. The country's other unique marine ecosystem is the coral reef, which can be found in the Andaman and Nicobar Islands, Lakshadweep Islands, Gulf of Kutch and Gulf of Mannar. The desert ecosystem in India accounts for about 2% of total landmass (spread across the states of Rajasthan, Gujarat, Punjab and Haryana) and is distinguished by low precipitation and largely barren arid lands with only sparse or seasonal vegetal cover. The cold desert of Ladakh (Jammu and Kashmir) and Lahaul-Spiti (Himachal Pradesh) covers an area of approximately 1,09,990 km^2.

The Indian flora contains 47,513 plant species, accounting for 11.4% of the total world flora, with 28% of plant species being endemic to India (Aridason and Lakshminarsimhan, 2016). It has an extremely rich floristic diversity with approximately 33% of its botanical wealth (over 15,000 species of higher plants) being endemic. There are approximately 141 endemic genera spread across 47 families (Nayar, 1980). Furthermore, the Himalayas (about 2,532 species) have a higher percentage of the 4,900 endemic species than the peninsular tract (1,788 species) and the Andaman and Nicobar Islands (185 species). Angiosperms are the most numerous plant species in India accounting for 18,043 (38.01%), followed by fungi with 14,883 (31.32%), algae with 7,284 (15.33%), bryophytes with 2,523 (5.30%), lichens with 2,401 (5.05%), pteridophytes with 1,268 (2.66%) and gymnosperms with 75 (0.15%), as well as 1,036 species of bacteria and viruses (Singh and Dash, 2014). Early Portuguese and Dutch explorers laid the groundwork for modern taxonomy in India. In the country's history of systematics and taxonomy, the publication of Hooker's monumental work Flora of British India (1872–1877) was a significant turning point. There are currently a plethora of research reports available on floristic composition and other vegetation aspects from various ecological regions of India. Multiple researchers have presented quantitative phytosociological data from various Indian regions. Due to its size and geography, India is a veritable treasure trove of medicinal and aromatic plants (Panda, 2004).

2.3. Plant diversity at northeast level

About 50% of India's mega-diversity is supported by the north-eastern region, which is the nation's richest repository of plant diversity (Mao and Hynniewta, 2000). The region has the greatest variety of cultivated plants, wild relatives as well as orchids, zingibers, yams, oranges, grapes, bamboos and canes. It comprises of Assam, Arunachal Pradesh, Sikkim, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. The northeastern region of India accounts for 7.7% of the country's total geographical area (Rao and Hajra, 1986; Rao, 1994) and has a high concentration of endemism (Chatterjee, 1939; Nayar, 1996). The forest regions are characterized by high rainfall, humidity and favourable temperature (Ao *et al.*, 2020). It represents the transitional zone between the Indian, Indo-Burma-malaysian and Indo-Chinese regions. It is also a part of the Vavilovian biodiversity hotspot and the origin of many important cultivated plant species as well as some domesticated animals (Agarwal, 1996). The World Wildlife Fund (WWF) identified the entire eastern Himalayas as a priority Global 200 ecoregion (Wikramanayake *et al.*, 2002). Northeast India is geographically located in one of the world's most biodiverse regions (Singh *et al.*, 2003), which is also traversed by two Biodiversity Hotspots, the Himalaya and Indo Burma.

Due to the geographical location of the region, climatic conditions, and altitudinal variations, Northeast India supports a diverse range of ecosystems, from low-altitude mixed wet evergreen, dry evergreen and deciduous forests to subtropical broadleaved forests along the foothills to temperate broadleaved forests in the mid hills, mixed conifer and conifer forests in the higher hills, and alpine meadows above the tree line. Takhtajan (1969) referred to the region as the "cradle of flowering plants" because of the high concentration of primitive flowering plants and diverse angiosperms in the area.

The north-east region account for 23.75% of India’s total forest cover. However, these regions have lost 1,020 square kilometres of forest during 2019-2021 (FSI 2021). These areas rely heavily on forests for fuelwood, fodder, fiber, timber, and medicines, among other things, and shifting cultivation or jhum is the predominant agricultural practice in this hilly region (Ramakrishnan, 1987). Out of the 130 species of bamboo found in India, 65 species have been reported from northeast India and 14 of those species are threatened (Naithani, 2006). Additionally, the region has a diversity of 37 species of palm, most of which are endangered (Sarmah *et al.*, 2006). It is also abundant in cultivated crops, wild relatives of crop plants and wild plants with horticultural potential (Mao and Hynniewta, 2010). The variety of medicinal plants is also significant and it is estimated that the local population uses about 750 plant species in the area as traditional medicine (Handique, 2009). Chatterjee (1939) estimated that 3196 of India's total 6850 endemic species are endemic to the region. The varied micro-climate and micro-habitat created by high mountains, valleys and rivers may explain the high concentration of endemics in this region. The largest representation of endemic species is found in the families like Orchidaceae, Poaceae, Asteraceae, Fabaceae, Rubiaceae and Ericaceae. Some of the genera with a high number of endemics are *Rhondodendron*, *Hedychium*, *Impatiens* and *Begonia*.

Multiple researchers have studied the vegetation and flora of north-east India, including Clarke (1879), Kanjilal *et.al.,* (1934 - 40), Bor (1942), Rao (1974), Fischer (1938), Singh (1980), Balakrishnan (1981–1983), Haridasan and Rao (1985 - 87), Khan *et al.,* (1986, 1987), Rao and Hajra (1986), Jamir and Rao (1988), Rao (1992), Barik *et al.,* (1992) and Singh *et al.,* (2002).

2.4. Plant diversity at state level

Mizoram covers geographical area of 21,081 sq. km, which is 0.64% of the geographical area of the country. It is located in the Indo-Burma biodiversity hotspot and is well endowed with dense forests and diverse species of flora and fauna. Mizoram is composed of steep, rugged hill ranges and interspersed valley where major portion of the people rely on forests for a livelihood, such as agriculture, timber exploitation and fuelwood, all of which contribute to ecosystem degradation (Tripathi *et al.,* 2017). Thus, as a result of forest degradation and recovery during succession, the floristic composition of the vegetation gradually changes (Singh *et al.,* 2015). According to research findings, the recovery of an ecosystem after a disturbance has a significant impact on changes in species diversity, fine root biomass, production and decomposition (Singha and Tripathi, 2017; Lalnunzira and Tripathi, 2018; Wapongnungsang *et al.,* 2017; Wapongnungsang and Tripathi, 2019; Ao *et al.,* 2020).

According to the India State of Forest Report 2021, Mizoram have 157 sq. km of Very Dense Forest (VDF), 5,715 sq. km of Moderately Dense Forest (MDF) and 11,948 sq. km of Open Forest (OF), thus the total forest cover is 17,820 sq. km. In terms of total geographic area, Mizoram have the highest percentage of forest cover at 84.53% among the states of India.

However, 186 sq. km of forest was lost from 2019 which is 1.03% of total forest cover.

In accordance with literature found on Mizoram's floristic diversity, this region has not been adequately studied with only a few collections having been made in the past. As a result, our knowledge of Mizoram's plant diversity is lower than that of other states in North East India. Col. A.T. Gage made the first collection of Mizoram plants in Lunglei district during March - April 1899, recording 317 species, including 26 species of cryptogams (Gage, 1901). In December 1902, J. E. Leslie also made some collections and sent them to Calcutta. Mrs. N.E. Parry made some priceless collections between 1924 and 1928 (Parry 1932), which she sent to the Royal Botanic Garden in Calcutta. Rev. W.G.L. Wenger, Rev. R.A.Lorrain and his daughter Lorrain Foxall also made collections from Lunglei during 1926 – 1932, sending the majority to Kew and some to Calcutta. Fischer (1938) published 'the Flora of Lushai Hills,' which lists 1360 species, including 6 gymnosperms and 155 cryptogams, based on these collections.

Other noteworthy works include Hooker (1872 - 1897), Rao and Verma (1982), Deb and Dutta (1987), Jha (1997), Singh *et al.,* (2002), Sawmliana (2003) and Lalramnghinglova (1997 and 2003). Mizoram has 2 National Parks and 8 Wildlife Sanctuaries covering an area of approximately 1240.75 km^2, or 5.88% of its geographical area (SFR, 2009) which are as follows:

I. Wildlife Sanctuaries

(1).	Dampa Tiger Reserve	500.00 sq. km
(2).	Khawnglung Wildlife Sanctuary	35.00 sq. km
(3).	Lengteng Wildlife Sanctuary	60.00 sq. km
(4).	Tawi Wildlife Sanctuary	35.75 sq. km
(5).	Tokalo Wildlife Sanctuary	250 sq. km
(6).	Thorangtlang Wildlife Sanctuary	50.00 sq. km
(7).	Pualreng Wildlife Sanctuary	50.00 sq. km
(8).	Ngengpui Wildlife Sanctuary	110.00 sq. km

II. National Parks

(1).	Phawngpui National Park	50.00 sq. km
(2).	Murlen National Park	100.00 sq. km

CHAPTER – 3

STUDY AREA

3.1. Brief description of Mizoram

Mizoram is located in the northeastern part of India, with Aizawl as its capital city. The word "Mizo", which is how the native inhabitants refer to themselves, and the word "Ram", which in Mizo means "lands", are combined to form the name of the state. "Mizo-ram" thus refers to the "land of the Mizos". Mizoram has a total land area of approximately 21,087 sq. km, of which roughly 85% is covered with forest. It lies between 21° 58' and 24° 35' N latitude, and 92° 15' and 93° 20' E longitude, with the tropic of cancer passing through the center at 23° 30' N latitude.

The state shares international borders with Myanmar to the east and south (404 kilometers) and Bangladesh to the west (318 kilometers), as well as neighboring states such as Assam (123 kilometers), Manipur (95 kilometers), and Tripura (66 kilometers). A census taken in 2011 indicated that Mizoram had 1,091,014 residents, out of which 5,52,339 are male and 5,38,675 are female. The state has the second-lowest population in the nation. According to data gathered by the Economics & Statistics Dept., Government of Mizoram in 2011, the literacy rate is 91.58%.

There are eleven (11) districts in the state of Mizoram, *viz.,* Aizawl, Lunglei, Siaha, Champhai, Kolasib, Serchhip, Mamit, Lawngtlai, Hnahthial, Saitual and Khawzawl. The districts of Hnahthial, Khawzawl and Saitual were established in the year 2019. The administrative structure of Lawngtlai and Saiha districts differs from that of the other districts. These autonomous regions are governed in conformity with the provisions of the Sixth Schedule of the Indian Constitution. Within the Lawngtlai district, there are two Autonomous District Councils: the Lai Autonomous District Council (LADC) and the Chakma Autonomous District Council (CADC), with headquarters in Lawngtlai and Chawngte (Kamalanagar, respectively. The third autonomous district council, the Mara Autonomous District Council

(MADC), is located within Saiha district, with its administrative seat in Saiha town.

(a) Physiography

Mizoram is a region with lakes, rivers and mountainous terrain. The state's length and breadth are covered in up to 21 major hill ranges or peaks of various heights with plains strewn about. The hills to the west of the state are generally around 1,000 meters high (3,300 ft). To the east, these gradually rise to a height of 1,300 meters (4,300 feet). The hills are roughly 900 meters tall on average. However, some areas have higher ranges that reach heights of over 2,000 meters (6,600 ft). Phawngpui Tlang, also known as the Blue Mountain, is located in the southeastern part of the state and is Mizoram's highest peak at 2,210 meters (7,250 ft).

(b) Geology

According to the Geological Survey of India, Mizoram terrain is immature, with several almost north-south longitudinal valleys containing a series of small and flat hummocks, mostly anticlinal, parallel to sub-parallel hill ranges and narrow adjoining synclinal valleys with a series of topographic highs. Western Mizoram's geology is characterized by a repetitive succession of Neogene sedimentary rocks of the Surma Group and Tipam Formation, including sandstone, siltstone, mudstone and rare pockets of shell limestone. The eastern section is known as the Barail Group.

(c) Drainage

Surface characteristics like relief, slope and dissection play a significant role in the evolution and layout of the local drainage system. A number of rivers, streams and rivulets with different patterns and lengths drain the state of Mizoram. The area experiences heavy rainfall during summer and the majority of the streams are transient in nature. Their volumes are very limited during the dry season, but they swell rapidly during the monsoon season. Running water has been identified as the most influential agent in shaping the region's landforms.

The majority of the drainage lines originate in the state's central region and flow either north or south, as directed by the north-south trending ridges. The valleys are narrow and carved out of softer rock formations. The rivers formed deep gorges in various places and cut across the striking ridges, forming watergaps. Waterfalls frequently interrupt the upper courses of rivers. Since the drainage course is controlled by parallel ranges, drainage patterns of ephemeral and subsequent types include trellis, dendretic and parallel drainage.

The northern part of the region is drained by the rivers Tlawng (and its tributaries Teirei and Tut); Tuivawl, Tuirial, Langkaih and Tuivai, which all flow northward and eventually join the Barak river in Assam's Cachar plain. The southern hills are drained by the rivers Chhimtuipui on the east with its tributaries Mat, Tuichang, Tiau and Tuipui; while the rivers Khawthlangtuipui with its tributaries Kawrpui, Tuichawng and Phairuang forms the western boundaries with Tripura and Bangladesh, and the rivers Tiau and Chhimtuipui forms the natural boundary with Myanmar in the east and south. The two principal rivers are Tlawng (Dhaleswari) and Chhimtuipu (Kolodyne).

(d) Climate

Mizoram has a moderate climate despite its tropical location. This is primarily due to its relatively high elevation. Throughout the year, it is neither too hot nor too cold. The region is directly influenced by the south-west monsoon. As a result, the region receives adequate rainfall. The region experiences a humid tropical climate with short winters and long, rainy summers.

The lower reaches of the hills are relatively warm and humid in the summer, in contrast to the upper portions, which are cold and cool. Just before or around the summer, in the months of March and April, storms form. In the summer, the average high temperature is 30^0 Celsius while the wintertime low is typically 11^0 Celsius. Winter in Mizoram lasts for four months, from November to February and is followed by spring. In the middle of April, the storms arrive to signal the start of summer. The temperature begins to rise and a haze begins to cover the hills. The rainy season is the three months from June to August. The two months of autumn (i.e. September and October) are when the climate is most moderate when the temperature fluctuates between 19 and 24 degrees Celsius.

From May to September, there is a lot of rain. The average rainfall is 257 cms per annum. The state's northwestern region experiences the most precipitation, or more than 350 cm annually. Along with an increase in humidity, rainfall also rises southward. Aizawl which is at 23^{o}44'N and 92^{o}43'E, receives about 208 cms while Lunglei (22^{o}53'N and 92^{o}45'E) has annual rainfall records of up to 350 cms.

(e) Soil

The soils of Mizoram range from sandy loam to clayey loam with loamy skeletal, mixed, hyperthermic and typic dystrochrepts and are acidic (pH ranged from 4.56 to 6.08) in nature with low base saturation (Kumar *et al.,* 2008). Mizoram soils are classified as Inceptisols (36.0%), Entisols (28.0%), Ultisols (26.0%), Alfisols (2.0%) and Others (8.0%) according to the USDA classification system (Bhattacharyya *et al.,* 2013; Bhattacharyya and Pal, 2015). Ultisols are most common on hilly slopes, Entisols in valleys, and Inceptisols in both hills and valleys. Although 77% of Ultisols, 57-71% of Entisols and 42-100% of Inceptisols are high in available N and K, they are low to very low in available P, which is fixed at an average of 82.6% to 96% of added P. (1000 ppm). Phosphate fixation was found to be positively related to clay, organic carbon, and oxides of Fe and Al in soil, and negatively related to pH, making it the most limiting nutrient for plant growth.

(f) Forest types/Vegetation cover

Singh *et al.,* (2002) described the forest types of the state based primarily on altitude, rainfall and dominant species composition, based on previous research and field observations done by other workers like Deb and Dutta, 1987; Lalramnghinglova and Jha, 1997; and Singh, 1997. The classification is as follows:-

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 make up one of the state's main forest types and have a wide variety of species because they typically grow below an altitude of 900 meters. Patches of these forests are generally found in places that are unsuitable for shifting cultivation, such as steep slopes and rocky river banks. With temperatures ranging from 20°C to 22°C and rainfall between 2,000 and 2,500 millimeters per year on average, it can be challenging to distinguish exactly between evergreen and semi-evergreen forests. Semi-evergreen forests can be found in the northern, northwestern, and central parts of Mizoram, whereas tropical wet evergreen forests are typically found in the southern and western parts of Mizoram.

The tropical wet evergreen forests have distinct zones or canopies made up of an amalgamation of various species, as well as a thick and impenetrable undergrowth of herbaceous plants. The majority of the species that make up the top canopy are tall-boled evergreen trees. Cauliflory is fairly widespread. The lower and middle canopies are thick, evergreen, and varied. Few parasites and epiphytes exist. Common plant species include tree ferns, aroides, palms, ferns, orchids, bryophytes and lichens. In humid areas or along the banks of rivers and rivulets, lianas are plentiful and noticeable, and sedges and grasses are widespread. *Musa* species are also prevalent on hilly slopes near streams.

A few evergreen trees and deciduous plants can be found in exposed, dry areas with thin soil. These are sometimes categorized as a separate type and called tropical moist deciduous forests. It can be challenging to distinguish between tropical moist deciduous forests and tropical evergreen forests because they are both found in small hill ranges. The smallest trees and shrubs with the greatest floristic diversity make up the third storey of the canopy.

2. Montane sub-tropical forests:

In areas that are cooler and receive less precipitation, such as the eastern fringes bordering the Chin Hills of Myanmar, these forests are typically found between 900 and 1,500 meters above sea level. Mixed pine forests can be seen in subtropical vegetation. *Castanopsis purpurella*, *Duabanga grandiflora*, *Myristica* spp., *Phoebe goalparensis*, *Pinus kesiya*, *Podocarpus neriifolia*, *Prunus cerasoides*, *Quercus acutissima*, *Q. semiserrata*, *Schima wallichii* and others are common species in these forests.

3. Temperate forests:

In places like Lengteng, Naunuarzo, Pharpak, Thaltlang and Phawngpui reserve forests, these forests typically occur above the elevation of 1,600 m and exhibit impenetrable virgin primary forests. The forests in this region of the eastern Himalaya are not your typical temperate forests. *Pinus kesiya, Betula alnoides, Exbucklandia populnea, Elaeocarpus serratus, Dillenia pentagya, Michelia doltsopa, Michelia champaca, Actinodaphne microptera, Rhododendron arboreum, Myrica esculenta, Schisandra neglecta, Photinia intergrifolia, Litsea salicifolia, Garcinia anomala, Schisandra neglecta, Lithocarpus dealbata*, etc. are the main arboreal species in the forests.

4. Bamboo forests:

In tropical evergreen and subtropical mixed-deciduous forests, bamboos typically grow as an understorey to the tree species whereas *Melocanna baccifera* creates dense or pure forests in some parts of the State. Although bamboo is found in significant quantities throughout Mizoram, it is mostly found at elevations of 1,600 meters or lower.

Typically, they can be found in tropical and subtropical regions between 40 and 1,520 meters. In the colder regions of Blue Mountain and Mount Chalfilh, few species can be found. It appears that the jhumming system of cultivation produced bamboos (Deb and Dutta, 1987).

The forests are burned and various tree species are exterminated in order to practice jhum cultivation, but as soon as the right conditions and the seasonal monsoon appear, bamboo rhizomes sprout new culms. As a result, they are the first to colonize and rapidly expand in abandoned Jhumland. *Emblica officinalis, Litsea monopetala, Pterospermum acerifolium, Terminalia myriocarpa, Caryota mitis, Artocartus chama, Duabanga grandiflora, Albizia procera, Gmelina arborea* and *Syzygium* species are a few significant plant species that grow alongside bamboos.

5. Quercus forests:

The majority of these forests can be found mixed in with subtropical and temperate regions. *Quercus griffithiana* is only found in a few small areas in the eastern part of Mizoram, mostly in the vicinity of the Champhai-Baite hill ranges. Another important species is *Lithocarpus dealbata.*

6. Jhumland:

In Mizoram, jhumlands are widespread. They are divided into three categories: active jhumland, historical jhumland and deserted jhumland. Eastern Mizoram, where extensive and intense jhumming is practiced, has a higher prevalence of jhumlands. Similar to this, there are Jhumlands in the areas on the western side of the Lunglei district that face Bangladesh.

3.2. Pualreng Wildlife Sanctuary

Pualreng Wildlife Sanctuary is spread over an area of 50.0 square kilometres with altitude ranges between 260-750 msl. It contains 40% Reserve Forest and 60% Government unclassed land where most of the area is hilly terrain with 70% steep slope and 30% of gentle slope with sandy clay soil and sedimentary rocks. This sanctuary is rich in biodiversity, provides shelter and protection to many Rare, Endangered and Threatened (RET) and endemic species. It also forms an important catchment area for the Tuirial river. The name “Pualreng” is taken from an abandoned village which now resides inside the area of the sanctuary.

Pualreng Wildlife Sanctuary also conserves, protect and provides shelter to 16 endemic species of flora and fauna including *Ficus religiosa*, *Mesua ferrea*, *Michelia champaca*, *Acrocarpus fraxinifolios*, *Bombax ceiba*, Clouded leopard, Hoolock gibbon, Sun bear, Slow lorries, Phayr’s leaf monkey, Sambar, Serow, Khaleej pheasant, Peacock pheasant, Common hill partridge and Pied hornbill.

3.2.1. Location

The sanctuary is located in Kolasib district of the state of Mizoram (**Fig. 3.1**). The distance from Aizawl is about 115 km and 7.0 kilometers East of Serkhan-Baga road. It lies between 24°06'35" to 24°14'16.21"N latitudes and 92°50' 17.6" to 92°54'2.64"E longitudes.

3.2.2. Notification

Pualreng Wildlife Sanctuary was declared by the State Government of Mizoram considering its ecological, floral, faunal and natural significance, and its need for the protection, propagation and development of wildlife and its environment under the provisions of Wildlife (Protection) Act, 1972 vide notification No.B.12012/19/01-FST of 29.07.2004.

3.2.3. Surrounding villages

The sanctuary is surrounded by four village *viz*., North Hlimen, Thingthelh, North Khawdungsei and Ratu.

3.2.4. Description of the boundary

NORTH: The Northern boundary starts from N. Hlimen ghat and follows Tuirial river at a distance of 800 m from it till Malrang Lui (92°51'34.084"E, 24°14'58.542"N).

EAST: After crossing Malrang Lui (92°54'27.872"E, 24°13'52.988"N) the boundary runs at a distance of 800 m from the sanctuary boundary till it meets Tuitla Lui (92°52'24.009"E, 24°6'15.954"N).

SOUTH: After crossing Tuitla Lui, the boundary runs at a distance of 800 m from the sanctuary boundary till it meets Tuirial Lui (92°51'33.281"E, 24°6'1.044"N). Then it extends at a distance of 1000 m from the sanctuary boundary till it meets Tuiritui Lui (92°50'5.301"E, 24°11'27.953"N).

WEST: From Turitui Lui, the boundary extends at a distance of 1000 m from the sanctuary boundary upto the foot path (92°51'31.7"E, 24°15'37.764"N) and from there it extends at a distance of 2000 m till it meets Tuirial Lui.

3.2.5. Climate

The region receives a good amount of rainfall which ranges between 2000 mm. – 3900 mm. The climatic condition is very mild and pleasant, temperature in summer ranges between 20° C – 30^{o}C and in winter it ranges between 10° C – 20^{o} C.

3.2.6. Drainage system

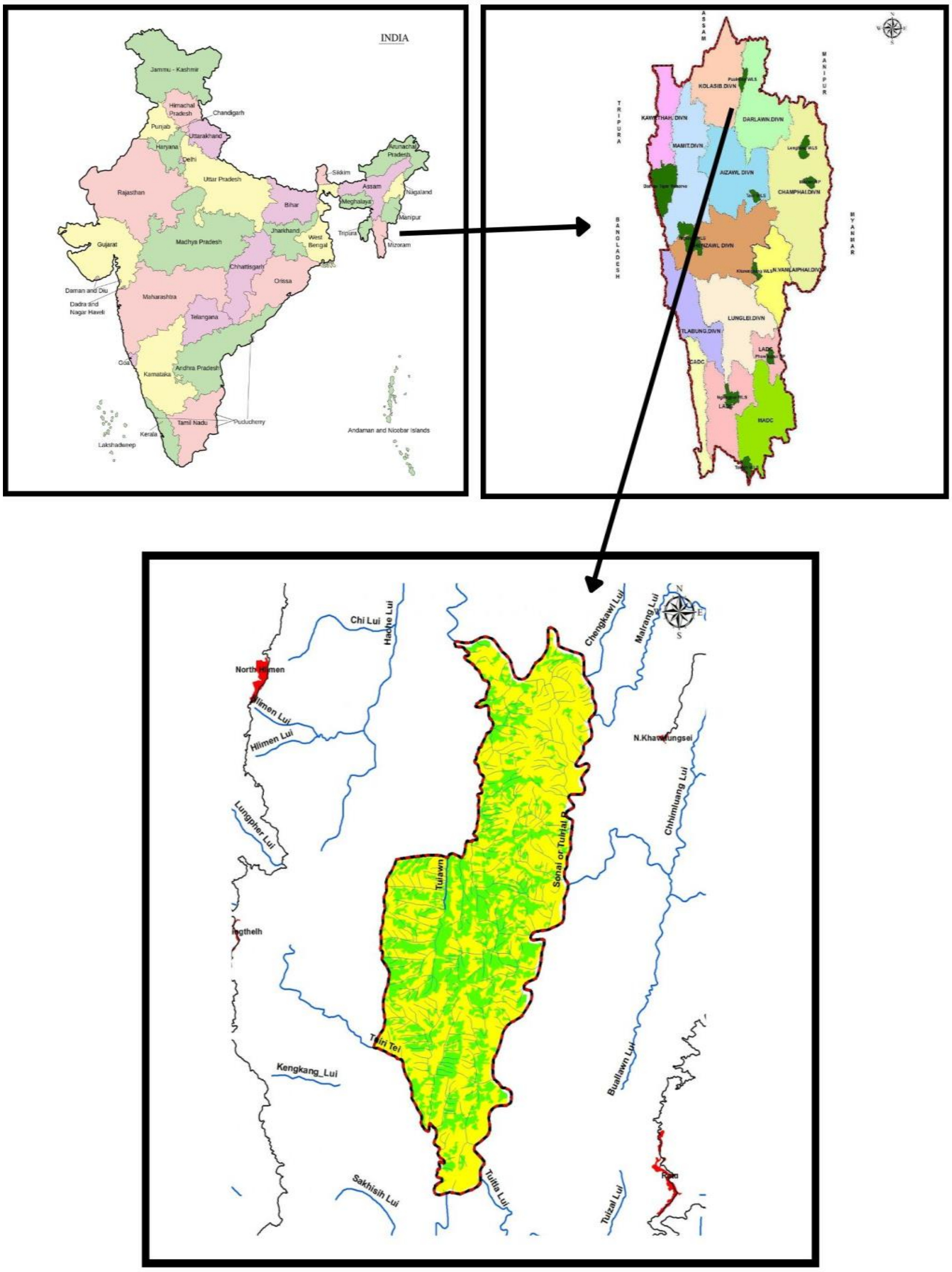
The physiography and geological structures of the area virtually shape the drainage pattern. The rivers and streams within the area are – Sakhisih Lui, Tuitla Lui, Teirei Lui, Tuiawn, Tuirial, Tuiritai, Malrang Lui and Chengkawl Lui.

3.2.7. Forest Vegetation (Fig. 3.2)

The forest types include Tropical Evergreen and Semi-evergreen forest. It conserves and supports important species of flora such as *Antocephalus chinensis, Artocarpus chama, Castanopsis tribuloides, Duabanga grandifolia, Mesua ferrea, Palaquium polyanthum, Bulbawr Terminalia myriocarpa, Helicia robusta* etc.

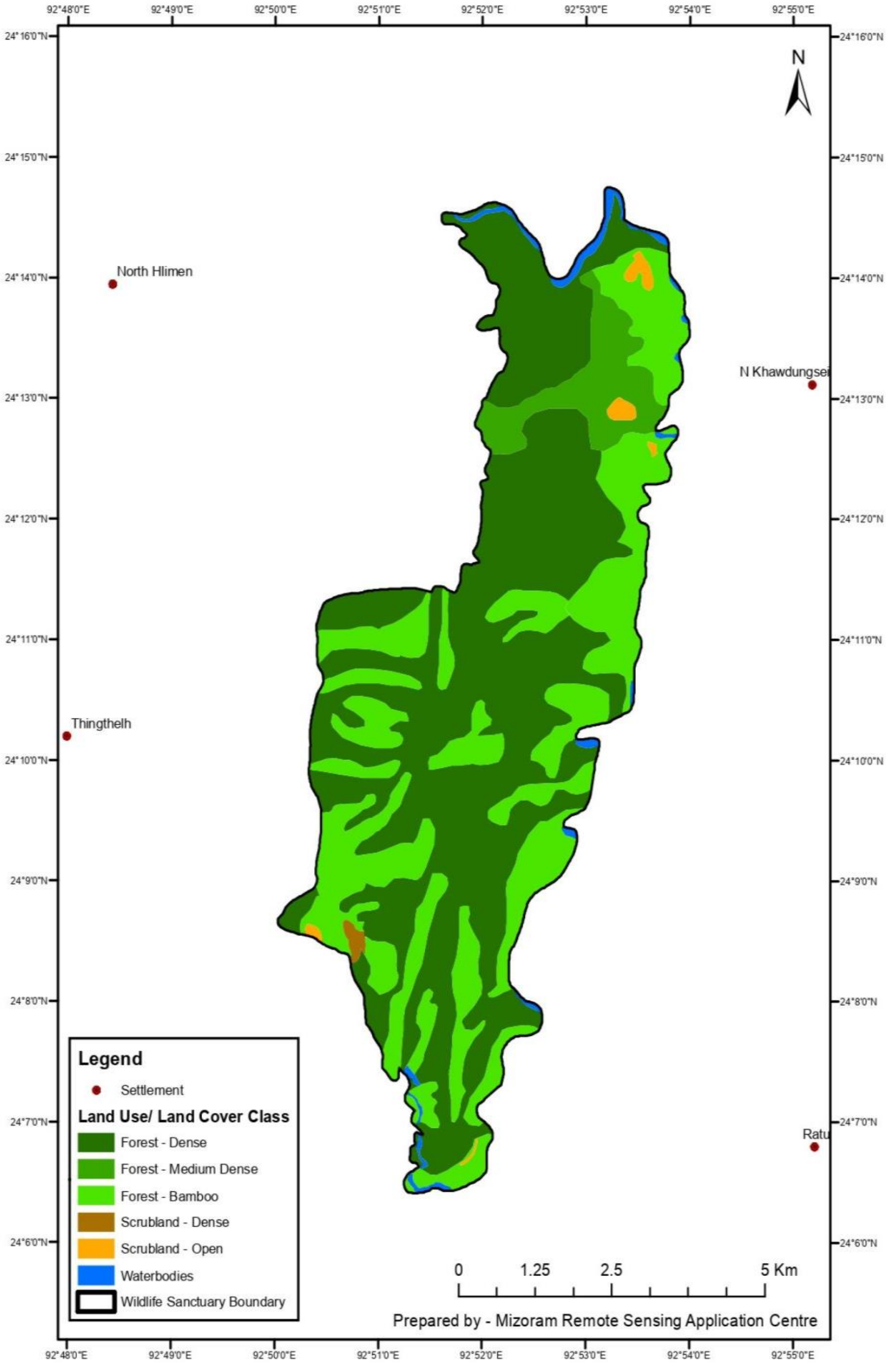
Fig. 3.1.Location map of the study site

(a) MAP OF INDIA **(b) MAP OF MIZORAM**



(c) PUALRENG WILDLIFE SANCTUARY

Fig. 3.2.Vegetation map of Pualreng Wildlife Sanctuary



CHAPTER – 4

METHODOLOGY

4.1. Pre-survey and demarcation of the study site

Preliminary survey of the study area and demarcation of the forest into two ecological zones was done during 2017. The forest was demarcated into the core zone and buffer zone:

a) Core zone: This type of forest can be found in the center of the forest. It mainly consists of densely forested areas that are relatively undisturbed.

b) Buffer zone: The buffer zone consists of secondary forests adjacent to N. Hlimen, Thingthelh, N. Khawdungsei and Ratu.

4.2. Plant Community Analysis

4.2.1. Quadrate method

To analyse the forest vegetation, quadrats of 10m X 10m size were laid randomly at 1 km intervals in both the core zone and buffer zone. In these quadrats, all individual trees having a diameter ≥5 cm at breast height were identified measured and recorded. Five quadrats of size 1 m x 1 m in each 10 m x 10 m quadrats were laid by nested quadrat method for herbs as shown in **Fig. 4.1**.

Fig. 4.1.Layout of plots/quadrats

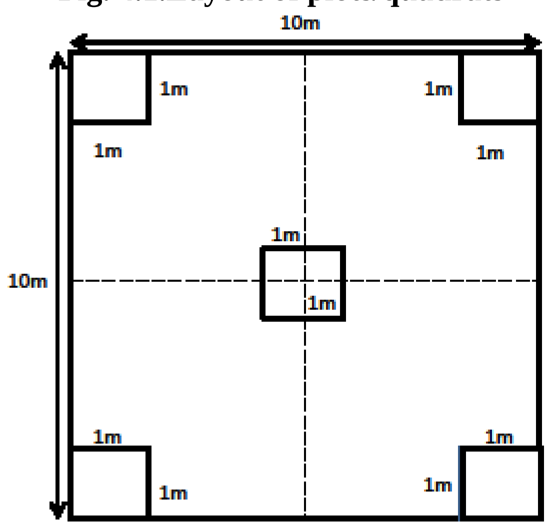


Plate 1

Plate 1a: Core zone

Plate 1b: Buffer zone

Quantitative frequency, density and abundance analyses of the vegetation data were conducted (Curtis and McIntosh, 1950). Following the works of Phillips (1959), the relative frequencies, densities and dominance values were calculated and they were added up to produce the Importance Value Index (IVI) of each species (Curtis, 1959). Shannon - Weiner's index was used to calculate the diversity index (Shannon and Weiner, 1963). Using Simpson's Index, the concentration of dominance was computed (Simpson, 1949), Pielou's evenness index (Pielou, 1969) was used to determine species evenness, and Whittaker's α diversity index was used to calculate species richness (Whittaker, 1975).

4.2.2. Quantitative analysis

Each community is distinguished by the diversity of its species, growth forms and structure, dominance, successional trend, and so on. A number of characters are considered when studying the details of these aspects of any community. They are then used to express a community's characteristics. The following formula is used to compute the quantitative characteristics of frequency, density and abundance:

(i) Frequency (%):

It refers to the percentage-based level of individual species dispersion within a given area. It was investigated by randomly sampling the study area at various locations and noting the name of the species that were present in each sampling unit or quadrat. It is calculated by the formula:

$$\text{Frequency (\%)} = \frac{\text{Number of quadrats in which species occurred}}{\text{Total number of quadrats studied}} \times 100$$

(ii) Density:

The numerical strength of a species in a community is defined as its density. Density of a species is the number of individuals in a given unit area. The degree of competition is indicated by density. It is calculated by the following formula:

$$\text{Density} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats studied}}$$

(iii) Abundance:

This is the number of individuals per quadrate of occurrence for any species. It is calculated using the following formula:

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

4.2.3. Importance Value Index (IVI)

The concept of the importance value index has been used to express the dominance and ecological success of any species with a single value. This index employs the following three characteristics: relative frequency, relative density, and relative dominance (Misra, 1968). All the tree, shrubs and herbs species counted will be used for determining dominance of a species. The relative value will be measured by the following formulae:

i) $$\text{Relative Frequency} = \frac{\text{Number of quadrats of occurrences of a species}}{\text{Number of quadrats of occurrences of all species}} \times 100$$

ii) $$\text{Relative Density} = \frac{\text{Number of individuals of a species}}{\text{Number of individuals of all species}} \times 100$$

iii) $$\text{Relative Dominance} = \frac{\text{Total basal area of a species}}{\text{Total basal area of all species}} \times 100$$

The diameter (cm) at breast height (dbh) (1.5 m above the ground) for trees and diameter at ground level for shrubs and herbs is converted to basal area (Sq.cm) as follows,

$$\text{Average basal area} = \pi r^2 D$$

$$\text{Where, } r = \frac{\text{average diameter}}{2}$$

D = Density

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

IVI = Relative Frequency + Relative Density + Relative Dominance

4.2.4. Biodiversity Indices

The following diversity indices were used in the study of plant diversity of the sanctuary:

(i) Species Diversity

Shannon – Weiner diversity index (Shannon, 1963)

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

Where,

ni = Number of individuals of each species in the sample

N = Total number of individuals

(ii) Species Evenness

Pielou's evenness index (1975)

$$E = H'/\ln S$$

Where,

H' = Shannon's index value

S = Total number of species

(iii) Species Dominance

Simpson's index of dominance (D) (Simpson, 1949)

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

Where,

ni = Number of individuals in the i^{th} species,

N = Total Number of individuals

(iv) Species Richness

Margalef's index of species richness (1972)

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

Where, S = Number of Species

N = Number of individuals

4.3. Profile diagram and stratification

Stratification in the sanctuary was carried out by drawing a profile diagram. In each location, the profile diagram was drawn along a belt transect (1 m thickness X 100 m length). The height of the trees was measured using an Abney level. Different layers of storey were depicted and presented based on tree heights and clearly defined stratifications.

4.4. Herbarium Methodology

A herbarium is a collection of plant specimens that have been gathered from different places, mounted on appropriate sheets, organized using a recognized system of classification, and stored in pigeon-holes of steel or wooden cupboards that are typically prepared for the purpose (Jain and Rao, 1977). In the collection and preparation of herbarium, the guidelines proposed by Jain and Rao (1977) and Womersley (1981) were followed. The steps involved in the preparation of herbarium are as follows:

(a) Plant collection

Flowers or fruits of various plant species were collected as far as possible within the study area, as were twigs and leaves in some cases. In the case of grasses, sedges and other herbs, the entire plant, including the underground parts was collected and prepared for identification in a herbarium.

(b) Field notes

Field note books are specially designed note books used for labeling plants and taking field notes on them. The pages are serially numbered, and there are six tags or tickets with the same number on each page; these are detachable on perforation lines and were tied to the specimens using the thread provided in the punched hole of each tag. While collecting data in the field, specific details including location, habit and growth form, flowers and fruits, the architecture of shoots and roots, the bark characteristics of trees, the nodes and internodes for bamboos, the arrangement of leaves, the shape of stems, the base of petioles, etc., were recorded in the field note book. The recording of field notes in the field note book is an important part of the plant collection work.

(c) Preservation of specimens

Poisoning is done in the field immediately after collection to prevent the formation of an abscission layer. Poisoning causes the plant to die, preventing decay so the specimen can be stored longer. To poison the specimen, a 30% para-formaldehyde solution (300g para-formaldehyde dissolved in 3000ml luke warm water) was poured over the bundles of collected specimens, so that the bundles were thoroughly soaked. The bundles were then placed in a bag and tied airtight. When the bundles arrived at the lab, they were opened and the samples were placed in the open to let any excess paraformaldehyde fumes escape.

(d) Pressing and drying plant specimens

The process of pressing involves pressing firmly on specimens while they are sandwiched between absorbents. The plant press, which consists of a wooden frame (for rigidity), ventilators made of corrugated cardboard (to let air flow through the press), blotting paper (to absorb moisture) and folded newspapers, was used to press the specimens (to contain the plant material). Plant specimens were pressed flat to no larger than 11 X 16 inches in order to fit on a typical herbarium sheet. If the specimen could not be fit to those dimensions, it was folded or divided into those dimensions. Prior to pressing, large fruits or bulbs are split lengthwise or cut into slices. Each specimen is a stem with leaves, flowers or fruits growing from it. The roots of herbaceous plants were also included.

To ensure that diagnostic features were preserved as much as possible, plant specimens were carefully arranged before being put into the press. Fruits, flowers and leaves were dispersed so that they could be seen from various angles without overlapping. In order to prevent shrinkage and wrinkling of the plant material and produce specimens that are simpler to mount securely on herbarium paper, the plant press was kept tight. In order to preserve the morphological integrity of the plant and produce material that can be easily mounted on herbarium paper for long-term storage, pressing the plants must flatten the plant and extract moisture in the shortest amount of time.

Prior to storage and mounting, the pressed plants were thoroughly dried in the sun. To achieve the best results, the plant press was placed in an oven that maintains a constant bottom temperature between 95°F and 113°F. A low ambient humidity and good airflow around and through the presses also ensures that plant material is dried quickly and thoroughly. As the specimens dried, the press straps were tightened further to reduce shrinkage and wrinkling.

(e) Fumigation

This is done to eliminate pests in both mounted and unmounted duplicate specimens. Specimens were sprayed with a solution of 2% mercuric chloride in 95% alcohol and dried in the sun or in an oven heated to 110^0 Fahrenheit. Naphthalene balls were used to keep insects at bay in boxes containing mounted specimens.

(f) Mounting and stitching

The specimen was pressed, dried and poisoned before being attached with glue (along with a label) to a mounting sheet. The mounting sheets were made of heavy, long-lasting white card in a uniform size of 28 x 42 cm (± 1 cm). The specimen was carefully attached or glued in order to allow maximum observation of diagnostic (usually reproductive) features as well as the range of variation in vegetative structures, including both sides of the leaves. Plants are typically arranged in a lifelike manner (with roots or lower stems toward the bottom of the sheet and flowers toward the top). The mounting sheets with fevicol-glued specimens were kept in the press for one day to ensure proper sticking and drying. Items that were large or bulky were sewn onto the sheet with a strong thread. The aim is to firmly secure the specimen to the mounting paper while leaving some plant pieces loose enough to be removed if necessary.

(g) Labelling

The specimens were mounted, and then herbarium labels were pasted on. A plant specimen would be incomplete without labeled information. Labeled data is a form of field data which demands accuracy. Each sheet of the herbarium was labeled after the specimens were mounted on the sheets. On the lower right-hand corner, a label was applied. The labels are crucial components of finished specimens in a herbarium. The label has a standard size of 4" X 2.5". The labels contained the following data:

(i) Collection No. and Date

(ii) Name of the family

(iii) Name of the genus and species

(iv) Locality of collection

(v) Phenology

(vi) Distribution

(vii) Notes

(viii) Collector's name and number.

4.5. Plant identification

The plant specimens collected from the study site were identified with the help of regional flora, including the books of "Flora of British India Vol 1-7" (Hooker, 1872-1897), "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 "The book of Mizoram Plants" (Sawmliana, 2003). The unidentified specimens were handed to the Botanical Survey of India, Eastern Circle, Shillong, Meghalaya, for proper identification and matching of the specimens.

4.6. Screening of rare and threatened species

The screening of rare and threatened plant species was done with the help of biodiversity indices, IVI and IUCN criteria.

4.7. Socio-economic survey

PRA technique was used to conduct a socio-economic survey of the neighbouring villages of the study area (Mukherjee, 2003). This survey was utilized to study the anthropogenic impacts on the sanctuary through observing the dependency on forest resources by the fringing villages. It is a systematic assessment of the effects of environmental development or policy change on the day-to-day quality of life of local people/communities. Participatory Rural Appraisal (PRA) refers to a growing family of approaches and techniques that allow locals to share, improve and analyze their knowledge of life and conditions, as well as plan and act (Chamber, 1994). It is a useful methodology for focusing attention on people, their livelihoods and their interactions with socioeconomic and environmental factors. It is a useful methodology for focusing attention on people, their livelihoods, and their interactions with socioeconomic and environmental factors.

PRA techniques include several methods such as village/social mapping, ranking and scoring, seasonal, diagramming and semi-structured interviews. The interview method was used in the current study. The households in each village were interviewed using structured, pretested questionnaires. These questionnaires were designed to collect data based on the requirements of the study. The Village Council Presidents were also interviewed to collect quantitavive data on literacy level, discussions and personal observations. The head of each sample household were interviewed to learn about their socio-economic conditions and dependency on forest products.

To determine the amount of fuelwood and fodder consumed per day per household, 10% of the households per village (a total of 87 households) were surveyed in the 4 villages. Their consumption quantities were recorded for 7 consecutive days in three different seasons: summer, rainy and winter. The families surveyed were selected to be reflective of all economic classes and family sizes. Based on this survey, Pearson correlation coefficient (r) table was used to represent a linear correlation between different parameters to understand the intensity of anthropogenic activities on the forest. To better understand the pressure on the forest resources, the villagers' preferences for fuelwood, fodder, agricultural implements, household articles and other uses were solicited.

4.8. GIS and Remote Sensing

GIS and remote sensing technique was also used to evaluate anthropogenic impacts by studying the forest cover change of the study area from the year 2006 to 2018. The spatial distribution of forest cover was mapped using the IRS-P6 LISS III satellite images to study the vegetation change of the study area. The spatial resolution was at 23.5 m and the path-row was 112/55 **(Table 4.1.)**. The satellite imagery from LISS III was taken in three cycles i.e. 2006, 2012, and 2018. The images were used to depict forest and non-forest (scrubland, water-bodies) regions during the year 2006 – 2018 using visual interpretation techniques and analyzing forest cover change. The ArcGis 10.5 version software was used for data preparation and geospatial analysis.

Table 4.1. Details of the data used in the study

Data Type	Date of Acquisition	Spatial Resolution	Path-row
LISS III	27th January 2006	23.5 m	112/55
LISS III	25th February 2012	23.5 m	112/55
LISS III	17th February 2018	23.5 m	112/55

CHAPTER – 5

RESULTS AND DISCUSSION

5.1. Diversity of taxa

5.1.1 Family

In the study area, 87 families in total were recorded out of which there were 75 angiosperm families (86.21%), 2 gymnosperm families (2.3%), and 10 pteridophyte families (11.49%). According to Sharma *et al.,* (2014), angiosperms make up 89.47% of all plant species in the Sangla Valley of the northwest Himalaya, so the 86.21% of angiosperms that were observed is comparable to their findings. The amount of angiosperm families identified was also similar to the findings in Pakke Wildlife Sanctuary and Tiger Reserve in East Kameng District of Arunachal Pradesh (Tag *et al.,* 2012). Despite accounting for only 5.75 % of total families, the five families with the highest diversity of species (dominant families) represented 23.08 % of total species and 22.70 % of genera. The five most species rich families were Fabaceae (14 species), Arecaceae (10 species), Poaceae (10 species), Rubiaceae (9 species) and Lamiaceae (8 species). In relation to the dominant families, 43 families were represented by one species each.

There were 12 families in the monocotyledons and 63 families in the dicotyledons. Dicotyledons thus made up 84% of all angiosperm families, while monocotyledons made up only 16%. For families, the ratio of monocotyledons to dicotyledons was 1:5. **Table 5.1** provides the distribution of monocots and dicots.

There were 84 families present in the core zone, distributed as 72 angiosperm families, 2 gymnosperm families and 10 pteridophyte families **(Table 5.2)**. 9 families of the angiosperms were monocotyledons while 63 families of them were dicotyledons.

In the buffer zone, there were 76 families present which were distributed as 67 families of angiosperms, 1 family of gymnosperm and 8 families of pteridophytes. Among the angiosperms, 56 families were dicotyledons while 11 families were monocotyledons **(Table 5.3).**

5.1.2 .Genera

The plant diversity of Pualreng wildlife sanctuary was also reflected at the genus level. Within the study area, a total of 185 genera were identified. There were 171 angiosperms, 2 gymnosperms and 12 pteridophytes among them. The dicotyledons comprised 139 genera (81.21%) of the angiosperms, while the monocotyledons comprised 32 genera (18.71%) **(Table 5.1)**. For genera, the ratio of monocotyledons to dicotyledons was 1:4.3.

Within the core zone of the forest, 149 genera were discovered, of which 136 were angiosperms, 2 were gymnosperms and 11 were pteridophytes. There were 115 dicotyledons and 21 monocotyledons among the angiosperms **(Table 5.2)**.

The buffer zone consists of 109 different genera. Out of these genera, angiosperms account for 100 genera, 1 was gymnosperm while 8 were pteridophytes. There were 82 dicotyledons and 18 monocotyledons among the angiosperms **(Table 5.3)**.

5.1.3. Species

Within the study area, 221 plant species were recorded. **Fig. 5.1.1** depicts the percentage distribution of these species. The total number of plant species identified is significantly higher when compared to the findings of other workers in different tropical forests such as Reddy *et al.,* 2011 (153 species); Sharma and Kant, 2014 (112 species) and Thakur, 2015 (82 species). It is more comparable to Mayureshwar wildlife sanctuary (268 species) and Rehekuri wildlife sanctuary (280 species) by Kharat and Mokat (2018) and also Baisipalli wildlife sanctuary in Odisha with 202 species (Pradhan *et al.*, 2020).

There were 206 angiosperms, 2 gymnosperms and 13 pteridophytes among the 221 plant species. There were 169 species of dicotyledons and 37 species of monocotyledons among the angiosperms, making dicotyledons the majority (82.04%) and monocots the minority (17.96%) **(Table 5.1)**. The species ratio of monocotyledons to dicotyledons was 1:4.6.

176 species were recorded within the core zone of the forest, including 162 angiosperms, 2 gymnosperms and 12 pteridophytes. The angiosperms were divided into 140 dicotyledons and 22 monocotyledons (**Table 5.2**).

There were 143 species found in the buffer zone, which include 132 angiosperms, 1 gymnosperm and 10 pteridophytes. There were 102 dicotyledons and 30 monocotyledons among the angiosperms (**Table 5.3**).

Of the total 221 species of plants that have been identified, 111 species of trees account for 50.23% of the total recorded species, followed by 19 species of shrubs (8.60%), 36 species of herbs (16.29%), 28 species of climbers/lianas (12.67%), 10 species of canes and palms (4.52%), 9 species of grasses (4.07%) and 8 species of epiphytes (3.62%) **(Fig. 5.1.2)**.

Table 5.1. Diversity of taxa in Pualreng Wildlife Sanctuary

Categories	**Angiosperms**			**Gymnosperms**	**Pteridophytes**	**Total**
	Dicots	**Monocots**	**Total**			
Family	63	12	75	2	10	87
Genera	139	32	171	2	12	185
Species	169	37	206	2	13	221

Table 5.2. Taxonomic diversity in the core zone

Categories	Angiosperms			Gymnosperms	Pteridophytes	Total
	Dicots	Monocots	Total			
Family	63	9	72	2	10	84
Genera	115	21	136	2	11	149
Species	140	22	162	2	12	176

Table 5.3. Taxonomic diversity in the buffer zone

Categories	Angiosperms			Gymnosperms	Pteridophytes	Total
	Dicots	Monocots	Total			
Family	56	11	67	1	8	76
Genera	82	18	100	1	8	109
Species	102	30	132	1	10	143

Fig. 5.1.1. Percentage distribution of species in Pualreng wildlife sanctuary

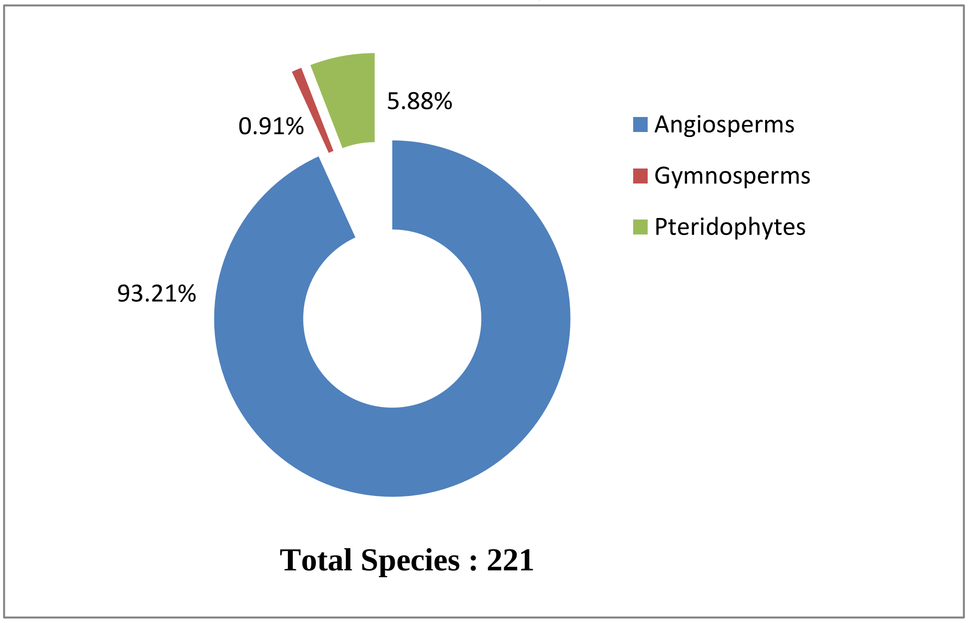
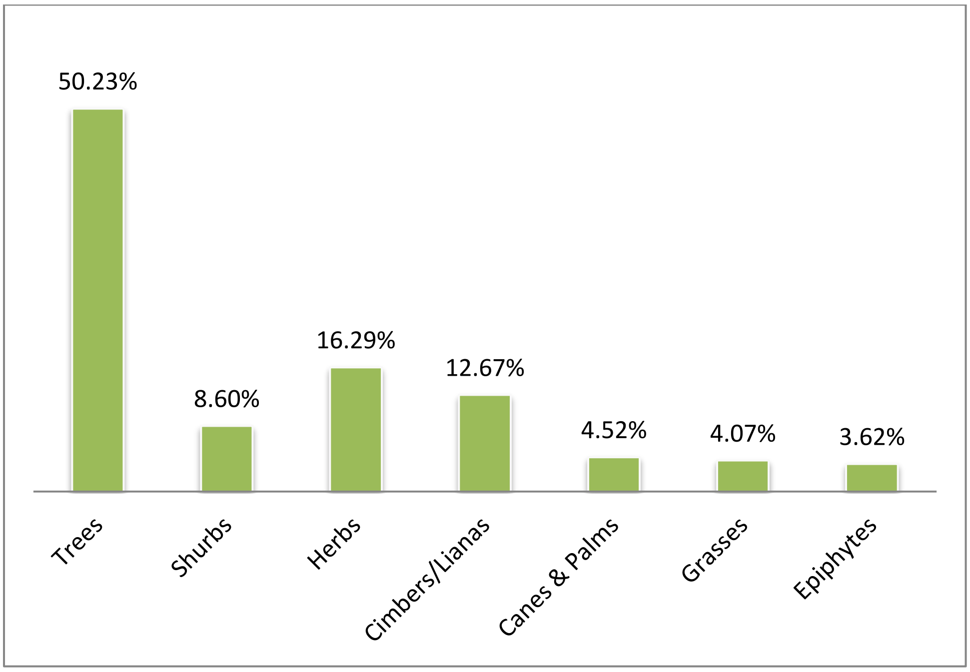


Fig. 5.1.2. Distribution of different plant species



5.2. Plant community analysis

5.2.1. Quantitative analysis of plants in Core zone

176 species under 149 genera belonging to 84 families were identified within the core zone of study area. The trees were represented by 94 species, 77 genera and 37 families. Fabaceae with 8 species and Lauraceae with 7 species are the two most dominant families in the core zone. Among the tree species, *Duabanga grandiflora* was the most dominant species with an IVI of 12.47. It was followed by *Artocarpus lacucha* (10.88*), Ficus benjamina* (10.46), *Michelia oblonga* (10.02) and *Castanopsis tribuloides* (9.15). These five dominant tree species together had an IVI value of 52.98 which account for 17.66 % of total IVI **(Table 5.4)**. 17 families were represented by 1 species each.

Shrubs were represented by 14 species, 14 genera and 14 different families. Each family was represented by one species. Most dominant species among shrubs were *Pandanus fascicularis*, *Chromolaena odorata* and *Schefflera venulosa.* These species account for 29.29 % of the total IVI **(Table 5.5)**. *Clerodendrum trichotomum* was the least dominant with IVI of 8.88.

There were 26 species, 25 genera and 18 families of herbs. Among the families, Zingiberaceae was the most dominant with 4 species and 4 genera. The most dominant species was *Diplazium maximum* with IVI of 20.68, followed by *Alpinia bracteata* and *Lindernia ruellioides* with IVI of 19 and 18.54 respectively. These three species represent 19.41 % of total IVI **(Table 5.6)**. *Arisaema speciosum* with IVI of 2.38 was the least dominant species among herbs.

Climbers were represented by 25 species, 23 genera and 16 families. The most dominant family was Vitaceae with 5 species. *Millettia pachycarpa* had the highest density followed by *Tinospora cordifolia*, *Entada rheedei* and *Vitis tuberculata*. The quantitative analysis of climbers is given in **Table 5.7**.

Canes and palms were represented by 7 species and 6 genera. The species with highest density was *Licuala peltata* **(Table 5.8)**. Epiphytes were represented by 7 species, 6 genera and 5 families. The species with the highest density was *Pyrrosia mannii* followed by *Drynaria propinqua*. The quantitative analysis of epiphytes is given in **Table 5.9**. Grasses were represented by 4 species and 4 genera. *Dinochloa compactiflora* was the species with the highest density **(Table 5.10)**.

5.2.2. Plant diversity indices in Core zone

The Shannon – Wiener diversity index (H') was the highest amongst trees (4.16) followed by herbs (3.08) and shrubs (2.60) **(Table 5.18)**. The diversity index of the core zone points towards the higher range reported for tropical forests of the Indian sub-continent having a range of 0.67 – 4.86 (Kumar *et al.,* 2010; Panda *et al.,* 2013). It is comparable to the range of 3.5 – 4.05 reported by Naidu *et al.,* (2018) from the tropical deciduous forests of Northcentral Eastern Ghats and lower than 4.64 reported by Saikia *et al.,* (2017) and 4.37 by Devi *et al.,* (2018).

Pielou's evenness index (E) revealed that shrubs were the most evenly distributed among the three communities with E value of 0.98. Herbs had a slightly lower E value of 0.95 while trees had the lowest E value of 0.92. These index values corresponds well to the evenness index recorded at Mahavir Swami Wildlife Sanctuary which has a range of 0.7 – 0.99 (Kumar *et al.,* 2022).

Simpson's Dominance Index (D) indicated that shrub community had the highest dominance index (0.08) followed by herbs (0.04) and trees (0.02). According to Knight (1975), the average value of dominance for tropical forests was 0.06. The dominance index of the core zone tends toward the lower range reported for other tropical forests, with the tropical forests of India reporting Simpson's index in the range of 0.03 - 0.92 (Bhuyan *et al.,* 2003; Nath *et al.,* 2005; Devi and Yadava, 2006; Deb and Sundriyal, 2011; Kushwaha and Nandy, 2012).

The species richness of the study area was calculated by using Margalef's species richness index (D_{mg}). Trees had the highest species richness D_{mg} of 11.95 followed by herbs with D_{mg} of 3.87 while shrubs had the lowest species richness with D_{mg} of 2.34. The diversity indices for trees, shrubs and herbs of the core zone are given in **Table 5.18**. The values for species richness falls within the range of 2.49 -19 recorded by Malik *et al.*, (2014), Pala *et al.*, (2016) and Bhatt and Bankoti (2016).

Table 5.4. Frequency, Density, Abundance and IVI of tree species in Core zone

Sl.No.	Name of species	Frequency (%)	Density ha^{-1}	Abundance	IVI
1	*Acer laevigatum* Wall.	29	43	2	**2.34**
2	*Albizia chinensis* (Osbeck) Merr.	9	23	3	**1.56**
3	*Albizia procera* (Roxb.) Benth.	60	103	2	**6.44**
4	*Alseodaphne petiolaris* (Meisn.) Hook. fil.	26	34	1	**5.19**
5	*Aporosa octandra* (Buch.-Ham. ex D.Don) A.R.Vickery	49	131	3	**4.12**
6	*Ardisia polycephala* Wall. ex A.DC.	77	91	1	**3.91**
7	*Artocarpus chama* Buch.-Ham. ex Wall.	14	29	2	**1.66**
8	*Artocarpus lacucha* Buch.-Ham.	86	180	2	**10.88**
9	*Baccaurea ramiflora* Lour.	20	29	1	**1.31**
10	*Bauhinia variegata* (L.) Benth.	17	60	4	**1.74**
11	*Bischofia javanica* Blume	51	137	3	**6.00**

12	*Bombax ceiba* L.	9	17	2	**0.95**
13	*Bridelia monoica* (Lour.) Merr.	26	31	1	**1.33**
14	*Callicarpa arborea* Roxb.	6	23	4	**0.60**
15	*Calophyllum polyanthum* Wall. ex Choisy	20	20	1	**1.16**
16	*Canarium strictum* Roxb.	29	49	2	**3.17**
17	*Carallia brachiata* (Lour.) Merr.	23	26	1	**1.31**
18	*Cassia javanica* L.	23	29	1	**1.41**
19	*Castanopsis indica* (Roxburgh ex Lindl.) A. DC.	91	217	2	**8.33**
20	*Castanopsis lanceifolia* (Oerst.) Hickel & A.Camus	9	17	2	**0.72**
21	*Castanopsis tribuloides* (Sm.) A.DC.	89	246	3	**9.15**
22	*Celtis australis* L.	57	111	2	**4.01**
23	*Chukrasia velutina* M.Roem.	46	54	1	**2.65**
24	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & C.H.Eberm.	23	23	1	**1.16**
25	*Cordia dichotoma* G.Forst.	11	26	2	**1.00**
26	*Derris robusta* Roxb. ex DC.	83	209	3	**6.83**
27	*Diospyros lanceifolia* Roxb.	11	29	3	**1.07**
28	*Diospyros stricta* Hort. ex Loudon	69	246	4	**7.39**
29	*Diospyros toposia* Buch.-Ham.	14	31	2	**1.25**
30	*Drimycarpus racemosus* (Roxb.) Hook. fil.	11	29	3	**1.25**
31	*Duabanga grandiflora* (Roxb. ex DC.) Walpers	37	157	4	**12.47**
32	*Dysoxylum gobara* (Buch.-Ham.) Merr.	31	46	1	**2.14**

33	*Elaeocarpus lanceifolius* Roxb.	46	60	1	**2.89**
34	*Emblica officinalis* L.	23	51	2	**1.82**
35	*Erythrina stricta* Roxb.	11	26	2	**0.88**
36	*Ficus benjamina* L.	23	43	2	**10.46**
37	*Ficus racemosa* L.	20	40	2	**1.72**
38	*Garcinia anomala* Planch. & Triana	6	23	4	**0.56**
39	*Garcinia sopsopia* (Buch.-Ham.) Mabb.	74	117	2	**5.50**
40	*Garcinia xanthochymus* Hook.f. ex T.Anderson	14	49	3	**1.35**
41	*Garuga pinnata* Roxb.	17	20	1	**1.10**
42	*Glochidion khasicum* (Müll.Arg.) Hook.f.	11	31	3	**0.98**
43	*Gmelina arborea* Roxb.	11	14	1	**0.75**
44	*Gmelina oblongifolia* Roxb.	77	140	2	**7.13**
45	*Helicia excelsa* (Roxb.) Blume	31	37	1	**1.89**
46	*Helicia robusta* (Roxb.) R. Br. ex Wall.	26	31	1	**1.33**
47	*Heritiera papilio* Bedd.	9	11	1	**0.60**
48	*Holigarna longifolia* Roxb.	14	63	4	**1.86**
49	*Hydnocarpus kurzii* (King) Warb.	83	246	3	**7.94**
50	*Knema erratica* (Hook.fil. & Thomson) J.Sinclair	66	134	2	**5.63**
51	*Lepisanthes senegalensis* (Poir.) Leenh.	20	29	1	**1.11**
52	*Leucaena leucocephala* (Lam.) de Wit	29	37	1	**1.60**
53	*Leucosceptrum canum* Smith	20	20	1	**0.97**
54	*Lithocarpus elegans* var. *brevipetiolatus* (Blume) Hatus. ex	49	129	3	**4.45**

	Soepadmo				
55	*Litsea cubeba* (Lour.) Pers.	77	269	3	**7.24**
56	*Litsea monopetala* (Roxb.) Pers.	9	20	2	**0.66**
57	*Macaranga denticulata* (Blume) Müll.Arg.	14	14	1	**0.74**
58	*Macaranga indica* Wight	9	26	3	**0.74**
59	*Machilus sp.*	46	154	3	**5.01**
60	*Macropanax dispermus* (Blume) Kuntze	34	51	2	**2.03**
61	*Magnolia hodgsonii* (Hook.f. & Thomson) H.Keng	63	191	3	**5.68**
62	*Mesua ferrea* L.	6	14	3	**0.47**
63	*Michelia champaca* (L.) Baill. ex Pierre	14	29	2	**2.19**
64	*Michelia oblonga* Wall. ex Hook.f. & Thomson	54	220	4	**10.02**
65	*Neolamarckia cadamba* (Roxb.) Bosser	43	106	2	**4.39**
66	*Neonauclea purpurea* (Roxb.) Merr.	9	29	3	**1.03**
67	*Nyssa javanica* (Blume) Wangerin	11	31	3	**2.59**
68	*Oroxylum indicum* (L.) Kurz	54	57	1	**2.70**
69	*Ostodes paniculata* Blume	29	80	3	**2.46**
70	*Parkia timoriana* (DC.) Merr.	89	194	2	**8.60**
71	*Persea minutiflora* Kosterm.	14	17	1	**0.73**
72	*Phobia attenuate* (Nees) Nees	14	20	1	**0.91**
73	*Podocarpus neriifolius* D. Don	29	109	4	**4.20**
74	*Polyalthia jenkinsii* Hook.f. & Thomson	86	111	1	**4.92**
75	*Protium serratum* (Wall. ex Colebr.)	94	186	2	**6.99**

	Engl.				
76	*Prunus ceylanica* (Wight) Miq.	11	14	1	**1.57**
77	*Pterospermum acerifolium* (L.) Willd.	9	9	1	**0.55**
78	*Randia wallichii* Hook.f.	37	140	4	**4.18**
79	*Sapium baccatum* Roxb.	6	20	4	**0.69**
80	*Schima wallichii* (DC.) Korth.	77	177	2	**8.70**
81	*Spondias pinnata* (L.f.) Kurz	11	17	2	**0.85**
82	*Sterculia villosa* Roxb. ex Sm.	11	17	2	**0.74**
83	*Stereospermum colais* (Buch.-Ham. ex Dillw.) D. L. Mabberley	14	14	1	**0.93**
84	*Stereospermum neuranthum* Kurz	91	117	1	**5.35**
85	*Syzygium cumini* (L.) Skeels.	9	26	3	**0.86**
86	*Terminalia crenulata* (Heyne) Roth	17	23	1	**1.29**
87	*Terminalia myriocarpa* Van Heurck and Mull.Arg	66	194	3	**7.48**
88	*Toona ciliata* M. Roem.	20	37	2	**2.84**
89	*Ulmus lanceifolia* Roxburgh ex Wall.	23	37	2	**2.89**
90	*Vitex heterophylla* L.	14	43	3	**1.42**
91	*Vitex peduncularis* Wall. ex Schauer	74	94	1	**4.71**
92	*Walsura robusta* Roxb.	17	34	2	**1.30**
93	*Wendlandia grandis* (Roxb.) DC. var. grandis Hook.f.	17	60	4	**1.59**
94	*Zanthoxylum rhetsa* (Roxb.) DC.	14	20	1	**0.78**

Table 5.5. Frequency, Density, Abundance and IVI of shrub species in Core zone

Sl. No.	Name of species	Frequency (%)	Density ha^{-1}	Abundance	IVI
1	*Ardisia sanguinolenta* Bl.	13	14	1	**14.04**
2	*Chromolaena odorata* (L.) R.M.King & H.Rob.	24	30	1	**28.24**
3	*Clerodendrum trichotomum* Thunb.	7	9	1	**8.88**
4	*Dracaena spicata* Roxb.	15	23	2	**19.75**
5	*Girardinia diversifolia* (Link) Friis	11	15	1	**15.01**
6	*Gnetum gnemon* L.	18	19	1	**26.25**
7	*Lepionurus sylvestris* Blume	14	21	2	**22.90**
8	*Melastoma malabathricum* L.	12	16	1	**17.31**
9	*Pandanus fascicularis* Lam.	19	24	1	**31.55**
10	*Schefflera venulosa* (Wight & Arn.) Harms	22	24	1	**28.09**
11	*Solanum torvum* Sw.	19	24	1	**26.41**
12	*Strobilanthes cusia* Kuntze	17	27	2	**27.83**
13	*Tabernaemontana divaricata* R.Br. ex Roem. & Schult.	11	21	2	**19.15**
14	*Wendlandia wallichii* Wight & Arn.	12	16	1	**14.57**

Table 5.6. Frequency, Density, Abundance and IVI of herb species in Core zone

Sl. No.	Name of species	Frequency %	Density ha^{-1}	Abundance	IVI
1	*Achyranthes aspera* L.	3	40	1	**3.95**
2	*Alpinia bracteata* Roxb.	16	251	2	**19.00**
3	*Amomum dealbatum* Roxb.	6	120	2	**7.13**
4	*Arisaema speciosum* (Wall.) Mart.	3	29	1	**2.38**
5	*Begonia dioica* Buch.-Ham. ex D.Don	19	269	1	**17.20**
6	*Begonia roxburghii* A.DC.	15	217	1	**18.38**
7	*Bidens biternata* (Lour.) Merr. & Sherff	17	246	1	**12.80**
8	*Chlorophytum khasianum* Hook.f.	8	177	2	**8.12**
9	*Costus speciosus* Koen ex. Retz.	12	234	2	**14.68**
10	*Curanga amara* Juss.	9	86	1	**7.13**
11	*Curculigo crassifolia* (Baker) Hook.f.	10	109	1	**7.04**
12	*Cyanthillium cinereum*(L.) H.Rob	22	257	1	**15.05**
13	*Dicliptera bupleuroides* Nees	13	131	1	**9.00**
14	*Dicranopteris linearis* (Burm.f.) Underw.	10	154	2	**9.59**
15	*Didymochlaena truncatula* (Sw.) J.Sm.	6	269	5	**10.88**
16	*Diplazium maximum* (D.Don) C.Chr.	15	251	2	**20.68**
17	*Hedychium coccineum* Buch.-Ham .ex Sm.	12	154	1	**12.39**
18	*Homalomena aromatica* (Spreng.) Schott	8	200	3	**11.38**

19	*Lepidagathis incurva* Buch.-Ham. Ex.D.Don	13	183	1	**11.49**
20	*Lindernia ruellioides* (Colsm.) Pennell	21	280	1	**18.54**
21	*Lycopodiella cernua* (L.)	11	177	2	**12.63**
22	*Lygodium salicifolium* C.Presl	10	103	1	**8.79**
23	*Microlepia strigosa* (Thunb.) C.Presl.	11	223	2	**12.51**
24	*Mimosa pudica* L.	12	183	2	**9.20**
25	*Selaginella ciliaris* (Retz.) Spring	7	211	3	**9.86**
26	*Solanum viarum* Dunal	10	160	2	**10.22**

Table 5.7. Frequency, Density and Abundance of climbers in Core zone

Sl. No.	Name of species	Frequency (%)	Density ha^{-1}	Abundance
1	*Ampelocissus latifolia* (Roxb.) Planch.	1.43	3.57	3
2	*Bauhinia scandens var. anguina* Lour. ex Raf.	2.86	6.43	2
3	*Byttneria pilosa* Roxb.	3.57	4.29	1
4	*Caesalpinia cucullata* Roxb.	4.29	8.57	2
5	*Cissus discolor* Blume	2.14	5.00	2
6	*Cissus repens* Lam.	1.43	3.57	3
7	*Combretum roxburghii* Sprengel	5.00	8.57	2
8	*Dioscorea bulbifera* L.	2.86	2.86	1
9	*Embelia ribes* Burm.f.	2.14	5.00	2
10	*Embelia vestita* Roxb.	1.43	2.86	2
11	*Entada rheedei* Spreng.	3.57	12.14	3
12	*Hedyotis capitellata* Wall. ex G.Don	6.43	9.29	1

13	*Hodgsonia macrocarpa* (Blume) Cogn.	3.57	5.71	2
14	*Jasminum laurifolium* Roxb. ex Hornem.	2.14	2.86	1
15	*Linostoma decandrum* (Roxb.) Steud.	5.00	7.86	2
16	*Marsdenia maculata* (Humb. & Bonpl. ex Schult.) E.Fourn.	0.71	2.14	3
17	*Merremia umbellata* (L.) Hallier f.	2.14	2.14	1
18	*Millettia pachycarpa* Bentham	7.14	16.43	2
19	*Mucuna nigricans* (Roxb.)DC.	5.71	6.43	1
20	*Paederia foetida* L.	2.86	7.14	3
21	*Tetrastigma leucostaphylum* (Dennst.) Alston ex Mabb.	2.86	5.00	2
22	*Tinospora cordifolia* (Thunb.) Miers	4.29	12.86	3
23	*Trichosanthes tricuspidata* Lour.	2.86	2.86	1
24	*Vitis tuberculata* Wall.	4.29	12.14	3
25	*Willughbeia edulis* Roxb.	3.57	5.00	1

Table 5.8. Frequency, Density and Abundance of canes and palms in Core zone

Sl. No.	**Name of species**	**Frequency (%)**	**Density ha^{-1}**	**Abundance**
1	*Arenga pinnata* (Wurmb) Merr.	1.43	2.86	2
2	*Calamus erectus* Roxb.	3.57	6.43	2
3	*Caryota mitis* Lour.	4.29	4.29	1
4	*Caryota urens* L.	2.14	3.57	2

5	*Licuala peltata* Roxb. ex Buch.-Ham.	5.00	12.14	2
6	*Livistona chinensis* (Jacq.) R.Br. *ex* Mart	5.00	6.43	1
7	*Pinanga gracilis* Blume	2.86	7.14	3

Table 5.9. Frequency, Density and Abundance of epiphytes in Core zone

Sl. No.	Name of species	Frequency (%)	Density ha^{-1}	Abundance
1	*Pyrrosia mannii* (Giesenh.) Ching	4.29	6.43	2
2	*Drynaria propinqua* (Wall. ex Mett.) J.S. ex Bedd.	2.14	5.71	3
3	*Platycerium wallichii* Hook.	3.57	4.29	1
4	*Dendrobium formosum* Roxb. ex Lindl.	1.43	2.14	2
5	*Vittaria flexuosa* (Fée) E.H.Crane	2.14	2.14	1
6	*Rhynchostylis retusa* (Kindl.) Bl.	1.43	1.43	1
7	*Pyrrosia lanceolata* (L.) Farw.	0.71	1.43	2

Table 5.10. Frequency, Density and Abundance of grasses in Core zone

Sl. No.	Name of species	Frequency (%)	Density ha^{-1}	Abundance
1	*Bambusa tulda* Roxb.	1.43	22.86	4
2	*Dinochloa compactiflora* (Kurz) McClure	5.00	37.14	2
3	*Eulalia trispicata* (Schult.) Henrard	2.14	11.43	1
4	*Themeda villosa* (Lam.) A.Camus	2.14	20.00	2

5.2.3. Quantitative analysis of plants in Buffer zone

There were 143 species under 109 genera belonging to 76 families identified within the buffer zone. The number of species was higher in the core zone than the buffer zone. This may be because the central part of the study area are less susceptible to human disturbances since they cannot be easily accessed hence they receive better protection. Trees were represented by 63 species, 58 genera and 29 families. Fabaceae was the most dominant family with 8 species and 8 genera. 15 families were represented by 1 species each. Most dominant tree species in the buffer zone was *Neolamarckia cadamba* with an IVI value of 16.56 followed by *Alseodaphne petiolaris* (15.06), *Celtis australis* (14.59), *Palaquium polyanthum* (13.13) and *Wendlandia grandis* (11.26). These five dominant species account for 23.50 % of the total IVI **(Table 5.11).** The least dominant tree species was *Hydnocarpus kurzii* with IVI value of 0.52.

Shrubs were represented by 12 species, 12 genera and 12 different families. Each family was represented by one species each. Most dominant species among shrubs was *Chassalia ophioxyloides* with IVI of 44.71. Followed by *Croton caudatus* with an IVI of 39.86 and *Phlogacanthus tubiflorus* with IVI of 32.2. *Dracaena spicata* was the lowest rank with IVI of 14.52 **(Table 5.12).**

Herbs were represented by 28 species, 28 genera and 23 families **(Table 5.13).** Among the families, Zingiberaceae was the most dominant with 4 species. The species with the highest rank was *Mimosa pudica* with IVI of 17.46, followed by *Curculigo crassifolia* and *Curanga amara* with IVI of 17.38 and 15.20 respectively. The lowest IVI ranking species were *Cyanthilium cinereum* (4.24) and *Glinus oppositifolius* (4.35).

There were 20 species, 19 genera and 16 families of climbers. The most dominant families were Caesalpiniaceae, Fabaceae, Myrsinaceae and Rubiaceae all represented by 2 species each. Climbers with the highest density were *Bauhinia scandens, Merremia umbellata* and *Thladiantha cordifolia*. The quantitative analysis of climbers is given in **Table 5.14.**

Canes and palms were represented by 8 species and 6 genera. The species with highest density was *Calamus erectus* **(Table 5.15).** Epiphytes were represented by 5 species, 5 genera and 4 families. Species with the highest density was *Drynaria propinqua.* The quantitative analysis of epiphytes is given in **Table 5.16.** Grasses were represented by 7 species and 6 genera all belonging to the same family of Poaceae. The species with the highest density was *Melocanna baccifera* **(Table 5.17).**

5.2.4. Plant diversity indices in Buffer zone

Within the buffer zone, Shannon – Wiener diversity index (H') was highest amongst the trees (3.85) followed by herbs (3.28) and shrubs (2.40). This was comparable to the value reported for tree diversity by Tynsong *et al.,* (2022) for three forest stands in tropical evergreen forest of the southern slopes of Meghalaya which ranged from 3.74 to 3.95. The diversity index of shrubs is also similar to Jeypore Reserve Forest, Assam with a value of 2.87 (Rajbonshi and Islam, 2018). The buffer zone had a lower species diversity of trees compared to core zone. This reduction in tree density and Shannon diversity Index from undisturbed to disturbed has been reported by various workers (Bhuyan *et al.,* 2003; Mishra *et al.,* 2004; Dutta and Devi, 2013).

Pielou’s evenness index indicated that herbs were the most evenly distributed among the three communities with E value of 0.97. Shrubs had a slightly lower E value of 0.96 while trees are the most unevenly distributed with E value of 0.93. The evenness value of the buffer zone was nearly identical to that of the core zone for all three plant communities.

According to Simpson's dominance index (D), the shrub community had the highest dominance index of 0.08, followed by herbs with value of 0.04 and trees with value of 0.03. The dominance value (D) recorded in the buffer zone corresponds well with that recorded by other workers (Ndah *et al.,* 2013; Saha *et al.,* 2016). It was observed that in disturbed communities, better adaptive species rise in number to outcompete the others due to competition. In contrast to undisturbed communities, the dominance index is typically higher in disturbed communities (Uniyal *et al.,* 2010). This is also the case for trees of the buffer zone whose dominance is higher than core zone.

Margalef's index of richness was highest for trees with D_{mg} of 8.70. Followed by herbs with D_{mg} of 4.00 and shrubs had the lowest species richness with D_{mg} of 2.36. The values were higher than those reported by Meetei *et al.*, (2017) at the subtropical forest of Manipur for two sites with value of 5.53 and 3.61. In the buffer zone, species richness index showed lower values for trees than in the core zone, but slightly higher for shrubs and herbs. The diversity indices for trees, shrubs and herbs of the buffer zone are given in **Table 5.18.**

Table 5.11. Frequency, Density, Abundance and IVI of tree species in Buffer zone

Sl. No.	Name of species	Frequency (%)	Density ha^{-1}	Abundance	IVI
1	*Acrocarpus fraxinifolius* Arn.	51	140	3	**6.93**
2	*Aglaia edulis* (Roxb.) Wall.	29	46	2	**2.98**
3	*Albizia procera* (Roxb.) Benth.	17	57	3	**4.71**
4	*Alseodaphne petiolaris* (Meisn.) Hook. fil.	49	117	2	**15.06**
5	*Anogeissus acuminata* (Roxb. ex DC.) Guillaum. & Perr.	14	29	2	**2.37**
6	*Aporosa octandra* (Buch.-Ham. ex D.Don) A.R.Vickery	6	9	2	**0.59**
7	*Ardisia polycephala* Wall. ex A.DC.	9	11	1	**0.80**
8	*Baccaurea ramiflora* Lour.	9	20	2	**1.31**
9	*Bauhinia variegata* (L.) Benth.	14	20	1	**1.58**
10	*Bischofia javanica* Blume	40	83	2	**7.32**

11	*Bombax ceiba* L.	34	57	2	**9.83**
12	*Calliandra umbrosa* (Wall.) Benth.	26	140	5	**5.77**
13	*Callicarpa arborea* Roxb.	9	17	2	**1.29**
14	*Canarium strictum* Roxb.	34	66	2	**10.48**
15	*Carallia brachiata* (Lour.) Merr.	29	43	2	**3.08**
16	*Cassia javanica var. indochinesis* L.	26	63	2	**4.50**
17	*Castanopsis indica* (Roxburgh ex Lindl.) A. DC.	31	71	2	**4.96**
18	*Castanopsis lanceifolia* (Oerst.) Hickel & A.Camus	31	46	1	**3.23**
19	*Celtis australis* L.	66	189	3	**14.59**
20	*Chrysophyllum lanceolatum* (Blume) A.DC., nom. illeg.	43	111	3	**6.10**
21	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & C.H.Eberm.	17	23	1	**1.78**
22	*Colona floribunda* (Wall. ex Voigt) Craib	29	69	2	**3.62**
23	*Cordia dichotoma* G.Forst.	29	40	1	**2.93**
24	*Diospyros malabarica* (Desr.) Kostel.	23	34	2	**2.52**
25	*Diospyros stricta* Hort. ex Loudon	9	17	2	**1.30**
26	*Duabanga grandiflora* (Roxb. ex DC.) Walpers	31	74	2	**10.26**
27	*Dysoxylum binectariferum* Hiern.	6	14	3	**0.87**
28	*Dysoxylum gobara* (Buch.-Ham.) Merr.	54	154	3	**7.50**
29	*Emblica officinalis* L.	23	31	1	**2.32**
30	*Erythrina stricta* Roxb.	40	154	4	**7.65**
31	*Ficus retusa* L.	6	14	3	**0.94**

32	*Flacourtia jangomas* (Lour.) Raeusch.	34	89	3	**6.12**
33	*Garcinia pedunculata* Roxb. ex Buch.-Ham.	29	46	2	**4.03**
34	*Garuga floribunda var. gamblei* (King ex W. Smith) Kalkman	23	49	2	**5.52**
35	*Garuga pinnata* Roxb.	26	51	2	**4.18**
36	*Gmelina arborea* Roxb.	31	51	2	**4.13**
37	*Helicia robusta* (Roxb.) R. Br. ex Wall.	9	9	1	**0.72**
38	*Heritiera papilio* Bedd.	9	17	2	**1.05**
39	*Hibiscus macrophyllus* Roxb. ex Hornem.	29	63	2	**3.38**
40	*Holigarna longifolia* Roxb.	9	20	2	**1.27**
41	*Hydnocarpus kurzii* (King) Warb.	6	6	1	**0.52**
42	*Litsea cubeba* (Lour.) Pers.	29	51	2	**3.03**
43	*Litsea monopetala* (Roxb.) Pers.	23	37	2	**2.43**
44	*Macaranga denticulata* (Blume) Müll.Arg.	17	34	2	**2.36**
45	*Maesa indica* (Roxb.) A. DC.	34	129	4	**5.49**
46	*Mesua ferrea* L.	37	60	2	**4.25**
47	*Michelia champaca* (L.) Baill. ex Pierre	26	49	2	**6.62**
48	*Mitragyna diversifolia* (Wall. ex G.Don) Havil.	26	43	2	**2.77**
49	*Neolamarckia cadamba* (Roxb.) Bosser	54	166	3	**16.56**
50	*Ostodes paniculata* Blume	69	154	2	**10.64**
51	*Palaquium polyanthum* (Wall. ex G. Don) Baill.	69	157	2	**13.13**

52	*Parkia timoriana* (DC.) Merr.	6	9	2	**0.62**
53	*Persea minutiflora* Kosterm.	9	17	2	**0.96**
54	*Protium serratum* (Wall. ex Colebr.) Engl.	29	49	2	**3.84**
55	*Randia wallichii* Hook.f.	29	37	1	**3.15**
56	*Sapium baccatum* Roxb.	11	17	2	**1.54**
57	*Saraca asoca* (Roxb.) Willd.	40	60	2	**4.12**
58	*Schima wallichii* (DC.) Korth.	63	163	3	**9.77**
59	*Spondias pinnata* (L.f.) Kurz	9	11	1	**0.85**
60	*Syzygium cumini* (L.) Skeels.	29	46	2	**3.73**
61	*Toona ciliata* M. Roem.	37	63	2	**9.31**
62	*Wendlandia grandis* (Roxb.) DC. var. grandis Hook.f.	74	209	3	**11.26**
63	*Zanthoxylum rhetsa* (Roxb.) DC.	20	83	4	**3.52**

Table 5.12. Frequency, Density, Abundance and IVI of shrub species in Buffer zone

Sl. No.	**Name of species**	**Frequency (%)**	**Density ha^{-1}**	**Abundance**	**IVI**
1	*Acacia gageana* Craib	5	10	2	**20.58**
2	*Chassalia ophioxyloides* var. *ophioxyloides* (Wall.) Deb & B.Krishna	7	21	3	**44.71**
3	*Chromolaena odorata* (L.) R.M.King & H.Rob.	5	6	1	**19.84**
4	*Clerodendrum infortunatum* L.	6	7	1	**23.13**

5	*Croton caudatus* Geiseler	6	15	2	**39.86**
6	*Dracaena spicata* Roxb.	4	6	2	**14.52**
7	*Girardinia diversifolia* (Link) Friis	4	6	2	**15.81**
8	*Gnetum gnemon* L.	6	9	1	**24.04**
9	*Lepionurus sylvestris* Blume	6	10	2	**21.83**
10	*Melastoma malabathricum* L.	6	7	1	**25.05**
11	*Phlogacanthus tubiflorus* Buch.-Ham. ex Wall.	10	10	1	**32.26**
12	*Tabernaemontana divaricata* R.Br. ex Roem. & Schult.	5	6	1	**18.39**

Table 5.13. Frequency, Density, Abundance and IVI of herb species in Buffer zone

Sl. No.	**Name of species**	**Frequency (%)**	**Density ha^{-1}**	**Abundance**	**IVI**
1	*Glinus oppositifolius* (L.) Aug.DC.	6	126	2	**4.35**
2	*Achyranthes aspera* L.	18	280	2	**11.36**
3	*Alternanthera sessilis* (L.) R.Br. ex DC.	20	286	1	**13.16**
4	*Catharanthus roseus* (L.) G.Don	5	86	2	**4.95**
5	*Homalomena aromatica* (Spreng.) Schott	22	269	1	**15.11**
6	*Thottea tomentosa* (Blume) Ding Hou	19	286	2	**12.89**
7	*Diplazium maximum* (D.Don) C.Chr.	14	194	1	**8.23**
8	*Cyanthillium cinereum*(L.) H.Rob	5	74	1	**4.24**

9	*Begonia dioica* Buch.-Ham. ex D.Don	15	229	2	**13.48**
10	*Commelina benghalensis* L.	11	126	1	**6.29**
11	*Microlepia strigosa* (Thunb.) C.Presl.	13	160	1	**8.01**
12	*Dicranopteris linearis* (Burm.f.) Underw.	25	309	1	**13.74**
13	*Didymochlaena truncatula* (Sw.) J.Sm.	15	206	1	**11.18**
14	*Phyllanthus urinaria* L.	13	246	2	**9.39**
15	*Mimosa pudica* L.	24	400	2	**17.46**
16	*Curculigo crassifolia* (Baker) Hook.f.	18	303	2	**17.38**
17	*Chlorophytum khasianum* Hook.f.	15	211	1	**11.25**
18	*Phrynium placentarium* (Lour.) Merr.	11	240	2	**14.14**
19	*Saccharum longisetosum* Nayaran. ex Bor	15	234	2	**8.59**
20	*Curanga amara* Juss.	23	309	1	**15.20**
21	*Lindernia ruellioides* (Colsm.) Pennell	14	223	2	**12.44**
22	*Solanum viarum* Dunal	13	143	1	**6.23**
23	*Tacca integrifolia* Ker Gawl.	14	200	1	**8.74**
24	*Centella asiatica* L.	15	177	1	**7.92**
25	*Alpinia bracteata* Roxb.	10	280	3	**12.63**
26	*Amomum dealbatum* Roxb.	14	200	1	**8.74**
27	*Costus speciosus* Koen ex. Retz.	13	206	2	**9.97**
28	*Hedychium coccineum* Buch.-Ham .ex Sm.	15	240	2	**12.93**

Table 5.14. Frequency, Density and Abundance of climbers in Buffer zone

Sl. No.	Name of species	Frequency (%)	Density ha^{-1}	Abundance
1	*Ampelocissus latifolia* (Roxb.) Planch.	0.71	2.14	3
2	*Bauhinia scandens var. anguina* Lour. ex Raf.	8.57	19.29	2
3	*Byttneria pilosa* Roxb.	2.14	2.14	1
4	*Caesalpinia cucullata* Roxb.	3.57	6.43	2
5	*Combretum roxburghii* Sprengel	1.43	3.57	3
6	*Dioscorea bulbifera* L.	1.43	4.29	3
7	*Embelia ribes* Burm.f.	2.86	2.86	1
8	*Embelia vestita* Roxb.	1.43	1.43	1
9	*Entada rheedei* Spreng.	3.57	4.29	1
10	*Hedyotis capitellata* Wall. ex G.Don	1.43	5.00	4
11	*Linostoma decandrum* (Roxb.) Steud.	2.86	4.29	2
12	*Merremia umbellata* (L.) Hallier f.	7.86	16.43	2
13	*Mikania micrantha* Kunth	2.86	2.86	1
14	*Millettia pachycarpa* Bentham	2.14	3.57	2
15	*Mucuna nigricans* (Roxb.)DC.	3.57	4.29	1
16	*Paederia foetida* L.	0.71	1.43	2
17	*Piper betle* L.	1.43	2.86	2
18	*Thladiantha cordifolia* (Blume) Cogn.	7.14	12.14	2
19	*Tinospora cordifolia* (Thunb.)	2.86	3.57	1

	Miers			
20	*Willughbeia edulis* Roxb.	1.43	2.14	2

Table 5.15. Frequency, Density and Abundance of canes and palms in Buffer zone

Sl. No.	Name of species	Frequency (%)	Density ha^{-1}	Abundance
1	*Arenga pinnata* (Wurmb) Merr.	1.43	2.14	2
2	*Calamus acanthospathus* Griff.	5.00	9.29	2
3	*Calamus erectus* Roxb.	4.29	9.29	2
4	*Calamus guruba* Buch.-Ham. ex Mart.	2.14	5.00	2
5	*Caryota mitis* Lour.	3.57	6.43	2
6	*Licuala peltata* Roxb. ex Buch.-Ham.	2.14	5.71	3
7	*Livistona chinensis* (Jacq.) R.Br. *ex* Mart	2.86	2.86	1
8	*Salacca wallichiana* Mart.	7.14	7.86	1

Table 5.16. Frequency, Density and Abundance of epiphytes in Buffer zone

Sl. No.	Name of species	Frequency (%)	Density ha^{-1}	Abundance
1	*Aerides odorata* Lour.	1.43	5.00	4
2	*Drynaria propinqua* (Wall. ex Mett.) J.S. ex Bedd.	3.57	9.29	3
3	*Platycerium wallichii* Hook.	1.43	3.57	3
4	*Rhynchostylis retusa* (Kindl.) Bl.	2.86	4.29	2
5	*Vittaria flexuosa* (Fée) E.H.Crane	2.14	5.71	3

Table 5.17. Frequency, Density and Abundance of grasses in Buffer zone

Sl. No.	Name of species	Frequency %	Density ha^{-1}	Abundance
1	*Bambusa khasiana* Munro	6.43	51.43	2
2	*Bambusa tulda* Roxb.	1.43	5.71	1
3	*Cymbopogon martinii* (Roxb.) Wats.	3.57	25.71	2
4	*Dendrocalamus hamiltonii* Nees & Arn. ex Munro	2.14	22.86	3
5	*Eulalia trispicata* (Schult.) Henrard	2.86	11.43	1
6	*Melocanna baccifera* (Roxb.) Kurz	7.86	54.29	2
7	*Setaria palmifolia* (J.Koenig) Stapf	5.00	28.57	1

Table 5.18. Indices of diversity for Core zone and Buffer zone of Pualreng Wildlife Sanctuary

Sl. No.	Indices	Core zone			Buffer zone		
		Trees	Shrubs	Herbs	Trees	Shrubs	Herbs
1	**Shannon Diversity index (H')**	4.16	2.60	3.08	3.85	2.40	3.28
2	**Pielou's Evenness index**	0.92	0.98	0.95	0.93	0.96	0.97
3	**Simpson's index of Dominance (D)**	0.02	0.09	0.04	0.03	0.09	0.04
4	**Margalef's index of species richness**	11.95	2.34	3.87	8.70	2.36	4.00

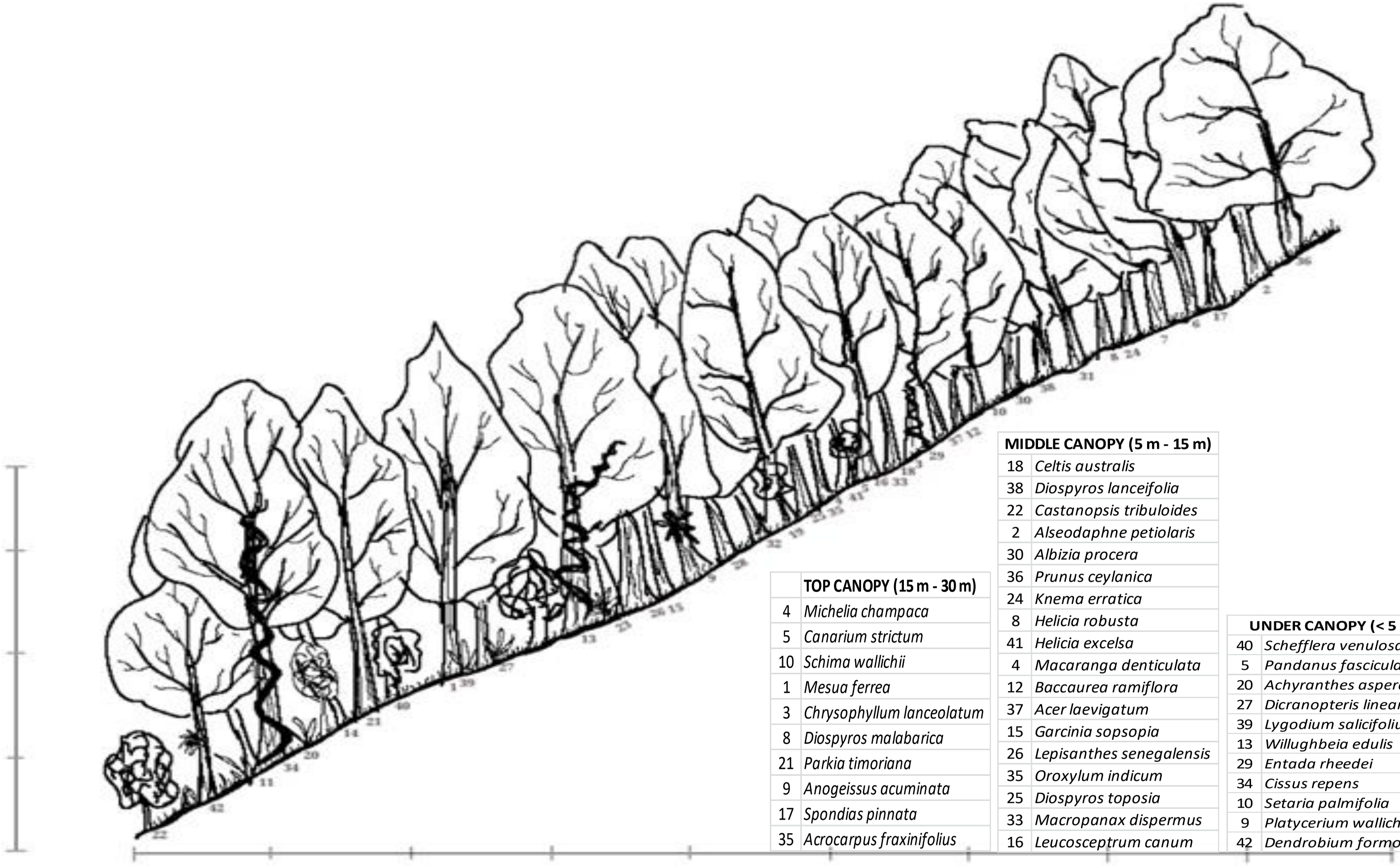
5.3. Stratification of the forest

In each zone, the stratification of the forest was studied by drawing a profile diagram along a belt transect (1 m thickness X 100 m length).

In the core zone, the top canopy species between 15 m and 30 m are *Artocarpus chama*, *Neolamarckia cadamba*, *Toona ciliata*, *Duabanga grandiflora*, *Calophyllum polyanthum*, *Ulmus lanceifolia*, *Ficus racemosa*, *Holigarna longifolia*, *Schima wallichii*, *Derris robusta*, *Syzygium cumini*, *Stereospermum colais* and *Terminalia myriocarpa*. The middle canopy species between 5 m and 15 m are *Celtis australis*, *Diospyros lanceifolia*, *Castanopsis tribuloides*, *Alseodaphne petiolaris*, *Albizia procera*, *Prunus ceylanica*, *Knema erratica*, *Helicia robusta*, *Helicia excelsa*, *Macaranga denticulate*, *Baccaurea ramiflora*, *Acer laevigatum*, *Garcinia sopsopia*, *Lepisanthes senegalensis*, *Oroxylum indicum*, *Diospyros toposia*, *Macropanax dispermus* and *Leucosceptrum canum*. The undercanopy layer consists of the ground vegetation of saplings, shrubs and herb species such as *Schefflera venulosa*, *Pandanus fascicularis*, *Achyranthes aspera*, *Dicranopteris linearis*, *Lygodium salicifolium*, *Willughbeia edulis*, *Entada rheedei*, *Cissus repens*, *Setaria palmifolia*, *Platycerium wallichii* and *Dendrobium formosum* **(Fig. 5.3.1)**. The highest tree recorded within the core zone was *Artocarpus chama* which reached a height of 23 meters.

In the buffer zone, the top canopy species are *Michelia champaca*, *Canarium strictum*, *Schima wallichii*, *Mesua ferrea*, *Chrysophyllum lanceolatum*, *Diospyros malabarica*, *Parkia timoriana*, *Anogeissus acuminate*, *Spondias pinnata* and *Acrocarpus fraxinifolius*. The highest tree recorded in the buffer zone was *Michelia champaca* which reached a height of 22 meters. The middle canopy species are *Gmelina arborea*, *Dysoxylum binectariferum*, *Bischofia javanica*, *Castanopsis indica*, *Macaranga denticulata*, *Flacourtia jangomas*, *Aglaia edulis*, *Mitragyna diversifolia*, *Litsea cubeba*, *Calliandra umbrosa*, *Callicarpa arborea* and *Ostodes paniculata*. The undercanopy layer that was below 5 meters consists of species like *Phlogacanthus tubiflorus*, *Croton caudatus*, *Melastoma malabathricum*, *Lepionurus sylvestris*, *Glinus oppositifolius*, *Thottea* *tomentosa*, *Begonia dioica*, *Curculigo crassifolia*, *Amomum dealbatum*, *Bauhinia scandens* var. *anguina*, *Embelia vestita*, *Paederia foetida*, *Platycerium wallichii* and *Pyrrosia lanceolata* **(Fig. 5.3.2).**

The profile diagram revealed that the forest in both the core zone and the buffer zone was made up of three layers: a top canopy that was between 15 and 30 meters high, a middle canopy that was between 5 and 15 meters high, and an undercanopy layer that was below 5 meters high. It is apparent from the profile diagram that the average height of trees in the buffer zone are greater than those in the core zone. This maybe due to the effect of altitude and climatic conditions that control the vertical growth of trees.



	TOP CANOPY (15 m - 30 m)
4	*Michelia champaca*
5	*Canarium strictum*
10	*Schima wallichii*
1	*Mesua ferrea*
3	*Chrysophyllum lanceolatum*
8	*Diospyros malabarica*
21	*Parkia timoriana*
9	*Anogeissus acuminata*
17	*Spondias pinnata*
35	*Acrocarpus fraxinifolius*

	MIDDLE CANOPY (5 m - 15 m)
18	*Celtis australis*
38	*Diospyros lanceifolia*
22	*Castanopsis tribuloides*
2	*Alseodaphne petiolaris*
30	*Albizia procera*
36	*Prunus ceylanica*
24	*Knema erratica*
8	*Helicia robusta*
41	*Helicia excelsa*
4	*Macaranga denticulata*
12	*Baccaurea ramiflora*
37	*Acer laevigatum*
15	*Garcinia sopsopia*
26	*Lepisanthes senegalensis*
35	*Oroxylum indicum*
25	*Diospyros toposia*
33	*Macropanax dispermus*
16	*Leucosceptrum canum*

	UNDER CANOPY (< 5 m)
40	*Schefflera venulosa*
5	*Pandanus fascicularis*
20	*Achyranthes aspera*
27	*Dicranopteris linearis*
39	*Lygodium salicifolium*
13	*Willughbeia edulis*
29	*Entada rheedei*
34	*Cissus repens*
10	*Setaria palmifolia*
9	*Platycerium wallichii*
42	*Dendrobium formosum*

Fig. 5.3.1. Profile diagram of Core zone

Fig. 5.3.2. Profile diagram of Buffer zone

TOP CANOPY (15 m - 30 m)	
11	*Artocarpus chama*
3	*Neolamarckia cadamba*
14	*Toona ciliata*
1	*Duabanga grandiflora*
21	*Calophyllum polyanthum*
6	*Ulmus lanceifolia*
23	*Ficus racemosa*
19	*Holigarna longifolia*
7	*Schima wallichii*
28	*Derris robusta*
17	*Syzygium cumini*
31	*Stereospermum colais*
32	*Terminalia myriocarpa*

MIDDLE CANOPY (5 m - 15 m)	
33	*Gmelina arborea*
26	*Dysoxylum binectariferum*
11	*Bischofia javanica*
15	*Castanopsis indica*
24	*Macaranga denticulata*
14	*Flacourtia jangomas*
25	*Aglaia edulis*
31	*Mitragyna diversifolia*
23	*Litsea cubeba*
36	*Calliandra umbrosa*
28	*Callicarpa arborea*
18	*Ostodes paniculata*

UNDER CANOPY (< 5 m)	
19	*Phlogacanthus tubiflorus*
2	*Croton caudatus*
34	*Melastoma malabathricum*
27	*Lepionurus sylvestris*
6	*Glinus oppositifolius*
20	*Thottea tomentosa*
16	*Begonia dioica*
13	*Curculigo crassifolia*
30	*Amomum dealbatum*
7	*Bauhinia scandens* var. *anguina*
32	*Embelia vestita*
29	*Paederia foetida*
12	*Platycerium wallichii*
22	*Pyrrosia lanceolata*

5.4. Rare and threatened species

The IUCN Red List of Threatened Species was used to evaluate the conservation status of all plant species collected within the study area. The IUCN has assessed 68 of the 221 species that have been recorded. A total of 153 species were yet not assessed. Out of these one species is classified as Endangered i.e. *Prunus ceylanica* while *Saraca Asoca* is classified under Vulnerable category. Two species namely *Aglaia edulis* and *Clerodendrum trichotomum* are classed as Near Threatened.

Sixty four species (64) are classified as Least Concern which is at the lowest risk, out of which there are 45 tree species, 11 herbs, 4 shrubs, 2 climbers and 2 canes and palms. These species are *Macropanax dispermus, Garuga floribunda, Celtis australis, Garcinia xanthochymus, Cordia dichotoma, Diospyros lanceifolia, Macaranga denticulate, Macaranga indica, Ostodes paniculata, Sapium baccatum, Albizia procera, Bauhinia variegate, Cassia javanica, Parkia timoriana, Castanopsis indica, Callicarpa arborea, Gmelina arborea, Vitex peduncularis, Cinnamomum tamala, Litsea cubeba, Litsea monopetala, Duabanga grandiflora, Magnolia hodgsonii, Michelia champaca, Michelia oblonga, Bombax ceiba, Hibiscus macrophyllus, Pterospermum acerifolium, Chukrasia velutina, Toona ciliata, Ficus benjamina, Ficus racemosa, Syzygium cumini, Aporosa octandra, Baccaurea ramiflora, Bischofia javanica, Emblica officinalis, Podocarpus neriifolius, Maesa indica, Helicia excels, Helicia robusta, Mitragyna diversifolia, Zanthoxylum rhetsa, Acer laevigatum, Schima wallichii, Tabernaemontana divaricate, Schefflera venulosa, Gnetum gnemon, Clerodendrum infortunatum, Glinus oppositifolius, Alternanthera sessilis, Commelina benghalensis, Dicranopteris linearis, Didymochlaena truncatula, Mimosa pudica, Lycopodiella cernua, Curanga amara, Lindernia ruellioides, Solanum viarum, Centella asiatica, Millettia pachycarpa, Embelia vestita, Caryota mitis* and *Caryota urens* **(Fig. 5.19, Fig. 5.20, Fig. 5.21, Fig. 5.22, Fig. 5.23, Fig. 5.24 & Fig. 5.25).**

Based on the Importance Value Index, species having IVI value lower than 1 and represented by not more than 3 individuals have been classed as rare species. In the core zone, 7 species are found such as *Pterospermum acerifolium, Marsdenia maculate, Merremia umbellate, Dendrobium formosum, Vittaria flexuosa, Rhynchostylis retusa* and *Pyrrosia lanceolata*. In the buffer zone, there are 6 species such as *Helicia robusta, Parkia timoriana, Aporosa octandra, Ampelocissus latifolia, Willughbeia edulis* and *Embelia vestita*.

Table 5.19. Trees - Zone where species occur and IUCN status (NE= Not Evaluated, LC= Least Concern, Vu= Vulnerable, NT = Near Threatened, En = Endangered, DD= Data Deficient, CZ = Core Zone, BZ = Buffer Zone)

Sl. No.	Name of species	Family	Local Name	Zones where species occur		IUCN
				CZ	BZ	
1	*Hydnocarpus kurzii* (King) Warb.	Achariaceae	Khawitur	✓	✓	DD
2	*Drimycarpus racemosus* (Roxb.) Hook. fil.	Anacardiaceae	Vawmbal	✓		NE
3	*Holigarna longifolia* Roxb.	Anacardiaceae	Kawhtebel	✓	✓	NE
4	*Spondias pinnata* (L.f.) Kurz	Anacardiaceae	Tawitaw	✓	✓	NE
5	*Polyalthia jenkinsii* Hook.f. & Thomson	Annonaceae	Zathuhang	✓		NE
6	*Macropanax dispermus* (Blume) Kuntze	Araliaceae	Phuanberh	✓		LC
7	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	Archangkawm	✓		NE

8	*Stereospermum colais* (Buch.-Ham. ex Dillw.) D. L. Mabberley	Bignoniaceae	Zihnghal	✓		NE
9	*Stereospermum neuranthum* Kurz	Bignoniaceae	Zihhaw	✓		NE
10	*Canarium strictum* Roxb.	Burseraceae	Beraw	✓	✓	NE
11	*Garuga floribunda* var. *gamblei* (King ex W. Smith) Kalkman	Burseraceae	Tuairam		✓	LC
12	*Garuga pinnata* Roxb.	Burseraceae	Bungbutuairam	✓	✓	NE
13	*Protium serratum* (Wall. ex Colebr.) Engl.	Burseraceae	Bil	✓	✓	NE
14	*Calophyllum polyanthum* Wall. ex Choisy	Calophyllaceae	Sentezel	✓		NE
15	*Mesua ferrea* L.	Calophyllaceae	Herhse	✓	✓	NE
16	*Celtis australis* L.	Cannabaceae	Anku	✓	✓	LC
17	*Garcinia anomala* Planch. & Triana	Clusiaceae	Dangkha	✓		NE
18	*Garcinia pedunculata* Roxb. ex Buch.-Ham.	Clusiaceae	Vawmvapui		✓	NE
19	*Garcinia sopsopia* (Buch.-Ham.) Mabb.	Clusiaceae	Vawmva	✓		NE
20	*Garcinia xanthochymus* Hook.f. ex T.Anderson	Clusiaceae	Tuaihabet	✓		LC
21	*Anogeissus acuminata* (Roxb. ex DC.) Guillaum. & Perr.	Combretaceae	Zairum		✓	NE
22	*Terminalia crenulata* (Heyne) Roth	Combretaceae	Tualram	✓		NE

23	*Terminalia myriocarpa* Van Heurck and Mull.Arg	Combretaceae	Char	✓		NE
24	*Cordia dichotoma* G.Forst.	Cordiaceae	Mukfang	✓	✓	LC
25	*Diospyros lanceifolia* Roxb.	Ebenaceae	Rutheisuak	✓		LC
26	*Diospyros malabarica* (Desr.) Kostel.	Ebenaceae	Theikum		✓	NE
27	*Diospyros stricta* Hort. ex Loudon	Ebenaceae	Thingsamkir	✓	✓	NE
28	*Diospyros toposia* Buch.-Ham.	Ebenaceae	Zothinghang	✓		NE
29	*Elaeocarpus lanceifolius* Roxb.	Elaeocarpaceae	Kharuan	✓		NE
30	*Bridelia monoica* (Lour.) Merr.	Euphorbiaceae	Phaktel	✓		NE
31	*Macaranga denticulata* (Blume) Müll.Arg.	Euphorbiaceae	Kharpa	✓	✓	LC
32	*Macaranga indica* Wight	Euphorbiaceae	Kharduap	✓		LC
33	*Ostodes paniculata* Blume	Euphorbiaceae	Beltur	✓	✓	LC
34	*Sapium baccatum* Roxb.	Euphorbiaceae	Thingvawkpui	✓	✓	LC
35	*Acrocarpus fraxinifolius* Arn.	Fabaceae	Nganbawm		✓	NE
36	*Albizia chinensis* (Osbeck) Merr.	Fabaceae	Vang	✓		NE
37	*Albizia procera* (Roxb.) Benth.	Fabaceae	Kangtek	✓	✓	LC
38	*Bauhinia variegata* (L.) Benth.	Fabaceae	Vaube	✓	✓	LC

39	*Cassia javanica var. indochinesis* L.	Fabaceae	Makpazang kang	✓	✓	LC
40	*Calliandra umbrosa* (Wall.) Benth.	Fabaceae	Sengmataw k		✓	NE
41	*Derris robusta* Roxb. ex DC.	Fabaceae	Thingkha	✓		NE
42	*Erythrina stricta* Roxb.	Fabaceae	Fartuah	✓	✓	NE
43	*Leucaena leucocephala* (Lam.) de Wit	Fabaceae		✓		NE
44	*Saraca asoca* (Roxb.) Willd.	Fabaceae	Mualhawih		✓	VU
45	*Parkia timoriana* (DC.) Merr.	Fabaceae	Zawngtah	✓	✓	LC
46	*Castanopsis indica* (Roxburgh ex Lindl.) A. DC.	Fagaceae	Sehawr	✓	✓	LC
47	*Castanopsis lanceifolia* (Oerst.) Hickel & A.Camus	Fagaceae	Vawmbuh	✓	✓	NE
48	*Castanopsis tribuloides* (Sm.) A.DC.	Fagaceae	Thingsia	✓		NE
49	*Lithocarpus elegans* var. *brevipetiolatus* (Blume) Hatus. ex Soepadmo	Fagaceae	Biruchuk	✓		NE
50	*Callicarpa arborea* Roxb.	Lamiaceae	Hnahkiah	✓	✓	LC
51	*Gmelina arborea* Roxb.	Lamiaceae	Thlanvawn g	✓	✓	LC
52	*Gmelina oblongifolia* Roxb.	Lamiaceae	Vawngthla	✓		NE

53	*Leucosceptrum canum* Smith	Lamiaceae	Kawih-thuang	✓		NE
54	*Vitex negundo* var. *heterophylla* L.	Lamiaceae	Thlengreng	✓		NE
55	*Vitex peduncularis* Wall. ex Schauer	Lamiaceae	Thingkhaw ilu	✓		LC
56	*Alseodaphne petiolaris* (Meisn.) Hook. fil.	Lauraceae	Bulpui	✓	✓	NE
57	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & C.H.Eberm.	Lauraceae	Hnahrimtui	✓	✓	LC
58	*Litsea cubeba* (Lour.) Pers.	Lauraceae	Sernam	✓	✓	LC
59	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	Nauthak	✓	✓	LC
60	*Machilus sp.*	Lauraceae	Rahpawl	✓		NE
61	*Persea minutiflora* Kosterm.	Lauraceae	Nghalenglu tar	✓	✓	NE
62	*Phoebe attenuata* (Nees) Nees	Lauraceae	Bulbawr	✓		NE
63	*Duabanga grandiflora* (Roxb. ex DC.) Walpers	Lythraceae	Zuang	✓	✓	LC
64	*Magnolia hodgsonii* (Hook.f. & Thomson) H.Keng	Magnoliaceae	Hnahkhauh	✓		LC
65	*Michelia champaca* (L.) Baill. ex Pierre	Magnoliaceae	Ngiau	✓	✓	LC
66	*Michelia oblonga* Wall. ex Hook.f. & Thomson	Magnoliaceae	Ngiau-Hnahsin	✓		LC
67	*Bombax ceiba* L.	Malvaceae	Phunchawn g	✓	✓	LC

68	*Colona floribunda* (Wall. ex Voigt) Craib	Malvaceae	Hnahthap		✓	NE
69	*Heritiera papilio* Bedd.	Malvaceae	Thingsaiphaw	✓	✓	NE
70	*Hibiscus macrophyllus* Roxb. ex Hornem.	Malvaceae	Vaiza		✓	LC
71	*Pterospermum acerifolium* (L.) Willd.	Malvaceae	Siksil	✓		LC
72	*Sterculia villosa* Roxb. ex Sm.	Malvaceae	Khaupui	✓		NE
73	*Aglaia edulis* (Roxb.) Wall.	Meliaceae	Raithei		✓	NT
74	*Chukrasia velutina* M.Roem.	Meliaceae	Zawngtei	✓		LC
75	*Dysoxylum binectariferum* Hiern.	Meliaceae	Sahatah		✓	NE
76	*Dysoxylum gobara* (Buch.-Ham.) Merr.	Meliaceae	Thingthupui	✓	✓	NE
77	*Toona ciliata* M. Roem.	Meliaceae	Teipui	✓	✓	LC
78	*Walsura robusta* Roxb.	Meliaceae	Perte	✓		NE
79	*Artocarpus chama* Buch.-Ham. ex Wall.	Moraceae	Tatkawng	✓		NE
80	*Artocarpus lacucha* Buch.-Ham.	Moraceae	Theitat	✓		NE
81	*Ficus benjamina* L.	Moraceae	Zamanhmawng	✓		LC
82	*Ficus racemosa* L.	Moraceae	Theichek	✓		LC
83	*Ficus retusa* L.	Moraceae	Rihnim		✓	NE

84	*Knema erratica* (Hook.fil. & Thomson) J.Sinclair	Myristicaceae	Thingthi	✓		NE
85	*Syzygium cumini* (L.) Skeels.	Myrtaceae	Hmuipui	✓	✓	LC
86	*Nyssa javanica* (Blume) Wangerin	Nyssaceae	Bulthur	✓		NE
87	*Aporosa octandra* (Buch.-Ham. ex D.Don) A.R.Vickery	Phyllanthaceae	Chhawntua l	✓	✓	LC
88	*Baccaurea ramiflora* Lour.	Phyllanthaceae	Pangkai	✓	✓	LC
89	*Bischofia javanica* Blume	Phyllanthaceae	Khuangthli	✓	✓	LC
90	*Emblica officinalis* L.	Phyllanthaceae	Sunhlu	✓	✓	LC
91	*Glochidion khasicum* (Müll.Arg.) Hook.f.	Phyllanthaceae	Thingpawn chhia	✓		NE
92	*Podocarpus neriifolius* D. Don	Podocarpaceae	Tufar	✓		LC
93	*Ardisia polycephala* Wall. ex A.DC.	Primulaceae	Sialtuai	✓	✓	NE
94	*Maesa indica* (Roxb.) A. DC.	Primulaceae	Arngeng		✓	LC
95	*Helicia excelsa* (Roxb.) Blume	Proteaceae	Sialhma	✓		LC
96	*Helicia robusta* (Roxb.) R. Br. ex Wall.	Proteaceae	Pasaltakaza	✓	✓	LC
97	*Carallia brachiata* (Lour.) Merr.	Rhizophoracea e	Theiria	✓	✓	NE
98	*Prunus ceylanica* (Wight) Miq.	Rosaceae	Rahphir	✓		EN

99	*Neolamarckia cadamba* (Roxb.) Bosser	Rubiaceae	Banphar	✓	✓	NE
100	*Mitragyna diversifolia* (Wall. ex G.Don) Havil.	Rubiaceae	Pualeng		✓	LC
101	*Neonauclea purpurea* (Roxb.) Merr.	Rubiaceae	Lungkhup	✓		NE
102	*Randia wallichii* Hook.f.	Rubiaceae	Saphut	✓	✓	NE
103	*Wendlandia grandis* (Roxb.) DC. var. grandis Hook.f.	Rubiaceae	Batling	✓	✓	NE
104	*Zanthoxylum rhetsa* (Roxb.) DC.	Rutaceae	Chingit	✓	✓	LC
105	*Flacourtia jangomas* (Lour.) Raeusch.	Salicaceae	Sakhithei		✓	NE
106	*Acer laevigatum* Wall.	Sapindaceae	Thingkhim	✓		LC
107	*Lepisanthes senegalensis* (Poir.) Leenh.	Sapindaceae	Che-pa-til	✓		NE
108	*Chrysophyllum lanceolatum* (Blume) A.DC., nom. illeg.	Sapotaceae	Nauvabuan		✓	NE
109	*Palaquium polyanthum* (Wall. ex G. Don) Baill.	Sapotaceae	Hnaibung		✓	NE
110	*Schima wallichii* (DC.) Korth.	Theaceae	Khiang	✓	✓	LC
111	*Ulmus lanceifolia* Roxburgh ex Wall.	Ulmaceae	Phan	✓		NE

Table 5.20. Shrubs - Zone where species occur and IUCN status (NE= Not Evaluated, LC= Least Concern, Vu= Vulnerable, NT = Near Threatened, En = Endangered, DD= Data Deficient, CZ = Core Zone, BZ = Buffer Zone)

Sl. No.	Name of species	Family	Local Name	Zones where species occur		IUCN
				CZ	BZ	
1	*Strobilanthes cusia* Kuntze	Acanthaceae	Ting	✓		NE
2	*Phlogacanthus tubiflorus* Buch.-Ham. ex Wall.	Acanthaceae	Vatekhawizu		✓	NE
3	*Tabernaemontana divaricata* R.Br. ex Roem. & Schult.	Apocynaceae	Keltebengbeh	✓	✓	LC
4	*Schefflera venulosa* (Wight & Arn.) Harms	Araliaceae	Kelbuh	✓		LC
5	*Chromolaena odorata* (L.) R.M.King & H.Rob.	Asteraceae	Tlangsam	✓	✓	NE
6	*Croton caudatus* Geiseler	Euphorbiaceae	Vawkze		✓	NE
7	*Gnetum gnemon* L.	Gnetaceae	Pelh	✓	✓	LC
8	*Clerodendrum infortunatum* L.	Lamiaceae	Phuihnamchhia		✓	LC
9	*Clerodendrum trichotomum* Thunb.	Lamiaceae		✓		NT
10	*Dracaena spicata* Roxb.	Liliaceae	Tartiang	✓	✓	NE

11	*Melastoma malabathricum* L.	Melastomataceae	Bui-lukham	✓	✓	NE
12	*Acacia gageana* Craib	Mimosaceae	Khanghu		✓	NE
13	*Lepionurus sylvestris* Blume	Olacaceae	Anpangthuam	✓	✓	NE
14	*Pandanus fascicularis* Lam.	Pandanaceae	Ram-lakhuih	✓		NE
15	*Ardisia sanguinolenta* Bl.	Primulaceae		✓		NE
16	*Chassalia ophioxyloides* (Wall.) Deb & B.Krishna	Rubiaceae	Hmuamsen		✓	NE
17	*Wendlandia wallichii* Wight & Arn.	Rubiaceae		✓		NE
18	*Solanum torvum* Sw.	Solanaceae	Tawk-pui	✓		NE
19	*Girardinia diversifolia* (Link) Friis	Urticaceae	Kangthai	✓	✓	NE

Table 5.21. Herbs - Zone where species occur and IUCN status (NE= Not Evaluated, LC= Least Concern, Vu= Vulnerable, NT = Near Threatened, En = Endangered, DD= Data Deficient, CZ = Core Zone, BZ = Buffer Zone)

Sl. No.	**Name of species**	**Family**	**Local Name**	**Zones where species occcur**		**IUCN**
				CZ	**BZ**	
1	*Lepidagathis incurva* Buch.-Ham.	Acanthaceae		✓		NE

	Ex.D.Don					
2	*Dicliptera bupleuroides* Nees	Acanthaceae		✓		NE
3	*Glinus oppositifolius* (L.) Aug.DC.	Aizoaceae	Bakhate		✓	LC
4	*Achyranthes aspera* L.	Amaranthaceae	Buchhawl	✓	✓	NE
5	*Alternanthera sessilis* (L.) R.Br. ex DC.	Amaranthaceae	Nghateril		✓	LC
6	*Catharanthus roseus* (L.) G.Don	Apocynaceae	Kumtluang		✓	NE
7	*Homalomena aromatica* (Spreng.) Schott	Araceae	Anchiri	✓	✓	NE
8	*Arisaema speciosum* (Wall.) Mart.	Araceae	Telhawng	✓		NE
9	*Thottea tomentosa* (Blume) Ding Hou	Aristolochiaceae	Hnahkhat		✓	NE
10	*Diplazium maximum* (D.Don) C.Chr.	Athyriaceae	Chakawk	✓	✓	NE
11	*Cyanthillium cinereum* (L.) H.Rob	Asteraceae	Buar	✓	✓	NE
12	*Bidens biternata* (Lour.) Merr. & Sherff	Asteraceae	Vawkpui-thal	✓		NE
13	*Begonia dioica* Buch.-Ham. ex D.Don	Begoniaceae	Sekhupthur	✓	✓	NE
14	*Begonia roxburghii* A.DC.	Begoniaceae	Sekhupthur	✓		NE
15	*Commelina benghalensis* L.	Commelinaceae	Dawng		✓	LC
16	*Microlepia strigosa* (Thunb.) C.Presl.	Dennstaedtiaceae		✓	✓	NE

17	*Dicranopteris linearis* (Burm.f.) Underw.	Dicranopteridaceae		✓	✓	LC
18	*Didymochlaena truncatula* (Sw.) J.Sm.	Didymochlaenaceae	Katchat	✓	✓	LC
19	*Phyllanthus urinaria* L.	Euphorbiaceae	Mithisunhlu		✓	NE
20	*Mimosa pudica* L.	Fabaceae	Hlonuar	✓	✓	LC
21	*Curculigo crassifolia* (Baker) Hook.f.	Hypoxidaceae	Phai-phak	✓	✓	NE
22	*Chlorophytum khasianum* Hook.f.	Liliaceae	Kepte	✓	✓	NE
23	*Lycopodiella cernua* (L.)	Lycopodiaceae		✓		LC
24	*Lygodium salicifolium* C.Presl	Lygodiaceae		✓		NE
25	*Phrynium placentarium* (Lour.) Merr.	Marantaceae	Hnahthial (pa)		✓	NE
26	*Saccharum longisetosum* Nayaran. ex Bor	Poaceae	Luang		✓	NE
27	*Curanga amara* Juss.	Scrophulariaceae	Khatual	✓	✓	LC
28	*Lindernia ruellioides* (Colsm.) Pennell	Scrophulariaceae	Thasuih	✓	✓	LC
29	*Selaginella ciliaris* (Retz.) Spring	Selaginellaceae		✓		NE
30	*Solanum viarum* Dunal	Solanaceae	Athlohling	✓	✓	LC
31	*Tacca integrifolia* Ker Gawl.	Taccaceae	Thialkha		✓	NE
32	*Centella asiatica* L.	Umbelliferae	Lambak		✓	LC

33	*Alpinia bracteata* Roxb.	Zingiberaceae	Aichal	✓	✓	NE
34	*Amomum dealbatum* Roxb.	Zingiberaceae	Aidu	✓	✓	DD
35	*Costus speciosus* Koen ex. Retz.	Zingiberaceae	Sumbul	✓	✓	NE
36	*Hedychium coccineum* Buch.-Ham .ex Sm.	Zingiberaceae	Aichhia	✓	✓	NE

Table 5.22. Climbers - Zone where species occur and IUCN status (NE= Not Evaluated, LC= Least Concern, Vu= Vulnerable, NT = Near Threatened, En = Endangered, DD= Data Deficient, CZ = Core Zone, BZ = Buffer Zone)

Sl. No.	**Name of species**	**Family**	**Local Name**	**Zones where species occur**		**IUCN**
				CZ	**BZ**	
1	*Willughbeia edulis* Roxb.	Apocynaceae	Vuakdup	✓	✓	NE
2	*Marsdenia maculata* (Humb. & Bonpl. ex Schult.) E.Fourn.	Asclepiadaceae	Ankhapui	✓		NE
3	*Mikania micrantha* Kunth	Asteraceae	Japan hlo		✓	NE
4	*Caesalpinia cucullata* Roxb.	Caesalpiniaceae	Hlingkhang	✓	✓	NE
5	*Bauhinia scandens var. anguina* Lour. ex Raf.	Caesalpiniaceae	Zawngaleih lawn	✓	✓	NE

6	*Combretum roxburghii* Sprengel	Combretaceae	Leihruisen	✓	✓	NE
7	*Merremia umbellata* (L.) Hallier f.	Convolvulaceae	Thianpa	✓	✓	NE
8	*Hodgsonia macrocarpa* (Blume) Cogn.	Cucurbitaceae	Khaum	✓		NE
9	*Thladiantha cordifolia* (Blume) Cogn.	Cucurbitaceae	Kangmang		✓	NE
10	*Trichosanthes tricuspidata* Lour.	Cucurbitaceae	Choak-a-um	✓		NE
11	*Dioscorea bulbifera* L.	Dioscoreaceae	Vawkpuibahra	✓	✓	NE
12	*Mucuna nigricans* (Roxb.)DC.	Fabaceae	Khuangtum	✓	✓	NE
13	*Millettia pachycarpa* Bentham	Fabaceae	Rulei	✓	✓	LC
14	*Tinospora cordifolia* (Thunb.) Miers	Menispermaceae	Hruivankai	✓	✓	NE
15	*Entada rheedei* Spreng.	Mimosaceae	Kawihrui	✓	✓	NE
16	*Embelia vestita* Roxb.	Myrsinaceae	Tling	✓	✓	LC
17	*Embelia ribes* Burm.f.	Myrsinaceae	Naufadawntuai	✓	✓	NE
18	*Jasminum laurifolium* Roxb. ex Hornem.	Oleaceae	Maufimhrui	✓		NE
19	*Piper betle* L.	Piperaceae	Panruang		✓	NE
20	*Hedyotis capitellata* Wall. ex G.Don	Rubiaceae	Kelhnamtur	✓	✓	NE
21	*Paederia foetida* L.	Rubiaceae	Vawihuihhrui	✓	✓	NE

22	*Byttneria pilosa* Roxb.	Sterculiaceae	Sazukngha wnghlap	✓	✓	NE
23	*Linostoma decandrum* (Roxb.) Steud.	Thymelaeaceae	Ngaihhih	✓	✓	NE
24	*Cissus repens* Lam.	Vitaceae	Hruipawl	✓		NE
25	*Cissus discolor* Blume	Vitaceae	Sanghar hmai	✓		NE
26	*Tetrastigma leucostaphylum* (Dennst.) Alston ex Mabb.	Vitaceae	Thurpui	✓		NE
27	*Ampelocissus latifolia* (Roxb.) Planch.	Vitaceae	Vawmhrui	✓	✓	NE
28	*Vitis tuberculata* Wall.	Vitaceae		✓		NE

Table 5.23. Canes and Palms - Zone where species occur and IUCN status

(NE= Not Evaluated, LC= Least Concern, Vu= Vulnerable, NT = Near Threatened, En = Endangered, DD= Data Deficient, CZ = Core Zone, BZ = Buffer Zone)

Sl. No.	Name of species	Family	Local Name	Zones where species occur		IUCN
				CZ	BZ	
1	*Arenga pinnata* (Wurmb) Merr.	Arecaceae	Thangṭung	✓	✓	NE
2	*Calamus guruba* Buch.-Ham. ex Mart.	Arecaceae	Tairua		✓	NE
3	*Calamus acanthospathus* Griff.	Arecaceae	Mitperh		✓	NE
4	*Calamus erectus* Roxb.	Arecaceae	Hruipui	✓	✓	NE
5	Caryota mitis Lour.	Arecaceae	Meihle	✓	✓	LC
6	*Caryota urens* L.	Arecaceae	Tum	✓		LC
7	*Licuala peltata* Roxb. ex Buch.-Ham.	Arecaceae	Laisua	✓	✓	NE
8	*Livistona chinensis* (Jacq.) R.Br. *ex* Mart	Arecaceae	Buarpui	✓	✓	NE
9	*Pinanga gracilis* Blume	Arecaceae	Tartiang	✓		NE
10	*Salacca wallichiana* Mart.	Arecaceae	Thilthek		✓	NE

Table 5.24. Epiphytes - Zone where species occur and IUCN status (NE= Not Evaluated, LC= Least Concern, Vu= Vulnerable, NT = Near Threatened, En = Endangered, DD= Data Deficient, CZ = Core Zone, BZ = Buffer Zone)

Sl. No.	**Name of species**	**Family**	**Local Name**	**Zones where species occur**		**IUCN**
				CZ	**BZ**	
1	*Drynaria propinqua* (Wall. ex Mett.) J.S. ex Bedd.	Drynariaceae	Katchat	✓	✓	NE
2	*Aerides odorata* Lour.	Orchidaceae	Katchat		✓	NE
3	*Dendrobium formosum* Roxb. ex Lindl.	Orchidaceae	Banpui	✓		NE
4	*Rhynchostylis retusa* (Kindl.) Bl.	Orchidaceae	Vaihniang	✓	✓	NE
5	*Platycerium wallichii* Hook.	Polypodiaceae	Awmvel	✓	✓	NE
6	*Pyrrosia lanceolata* (L.) Farw.	Polypodiaceae	Katchat	✓		NE
7	*Pyrrosia mannii* (Giesenh.) Ching	Polypodiaceae	Katchat	✓		NE
8	*Vittaria flexuosa* (Fée) E.H.Crane	Vittariaceae	Katchat	✓	✓	NE

Table 5.25. Grasses - Zone where species occur and IUCN status (NE= Not Evaluated, LC= Least Concern, Vu= Vulnerable, NT = Near Threatened, En = Endangered, DD= Data Deficient, CZ = Core Zone, BZ = Buffer Zone)

Sl. No.	**Name of species**	**Family**	**Local Name**	**Zones where species occur**		**IUCN**
				CZ	**BZ**	
1	*Themeda villosa* (Lam.) A.Camus	Poaceae	Phaiphek	✓		NE
2	Cymbopogon martinii *(Roxb.) Wats.*	Poaceae	Thalthing		✓	NE
3	*Eulalia trispicata* (Schult.) Henrard	Poaceae	Thang	✓	✓	NE
4	*Setaria palmifolia* (J.Koenig) Stapf	Poaceae	Hnahhrat		✓	NE
5	*Dinochloa compactiflora* (Kurz) McClure	Poaceae	Sairil	✓		NE
6	*Bambusa khasiana* Munro	Poaceae	Rawte		✓	NE
7	*Bambusa tulda* Roxb.	Poaceae	Rawthing	✓	✓	NE
8	*Dendrocalamus hamiltonii* Nees & Arn. ex Munro	Poaceae	Phulrua		✓	NE
9	*Melocanna baccifera* (Roxb.) Kurz	Poaceae	Mautak		✓	NE

5.5. Socio - Economic Status

5.5.1. Demographic and Livelihood

The demographic and livelihood data for the neighboring villages of North Hlimen, Thingthlelh, North Khawdungsei and Ratu has been given in **Table 5.26**. Ratu had the largest population among the four villages with 2398 residents, while North Khawdungsei had the smallest population with 235 residents. The average family size varied between 4.70 persons per household in Thingthelh and 5.34 persons per household in N. Khawdungsei. The mean annual income in Indian national rupees ranged between Rs. 15,307 per household in N. Khawdungsei village and Rs. 34,645 per household in Ratu village, which exceeds the Below Poverty Line threshold established by the Indian government for rural areas (Rs. 12,000). According to the study, there is a strong connection between income and livestock population (r = 0.928), demonstrating the importance of animal husbandry to the rural economy. The asterisks at the end of the correlations indicate that the correlation is significant. The asterisks indicate the correlations that exceed the usual alpha levels of .05 or .01. In this case, the p-value is .000, which means the odds of finding this relationship between these two variables just due to chance is less than .001, or less than 1 in a thousand. This indicates that there is a significant relationship between family income and the amount of livestocks per household (**Table 5.37**).

The majority of the families (80.69%) in the four villages rely on jhum (slash-and-burn) cultivation for their livelihoods, while the rest are engaged in small businesses, government services and cottage industries. The positive relationship between income and fodder consumption (r = 0.899) can also be credited to the extraction of large quantities of fodder to sustain animal husbandry (**Table 5.37**). Despite the fact that almost every family raises pigs or poultry, they are mainly used as a supplement and not as a source of income.

5.5.2. Education and Local Institutional level

There are 3 Anganwadi Centers, 10 Pimary Schools, 8 Middle Schools and 4 High Schools in the villages surrounding the sanctuary **(Table 5.27).** Three Primary schools, two Middle schools and one High school were privately owned, while the rest were government-owned. Literacy rate was highest in N. Khawdungsei (91.14%) and lowest in Thingthelh village (78.76%). A negative correlation between income and literacy level (r = -0.059) was discovered which can be directly attributed to lack of employment among the villages educated people. This tends to increase people's reliance on agriculture and forest resources for income from which they earn substantial amounts of money, despite the fact that agricultural work does not always require educated people. Despite high literacy rate, the majority of people were unemployed due to lack of job opportunities.

5.5.3. Standard of Living and Social Welfare Services

Out of the 870 households, 840 households were electrified. Despite the fact that 97% of households have LPG connections, the majority of them still rely on wood for cooking due to a lack of supply and the high cost of LPG cylinders. The average liquefied petroleum gas (LPG) consumed per household per year was 37.78, 43.89, 48.60 and 63.08 Litres in N. Khawdungsei, N. Hlimen, Thingthleh and Ratu villages, respectively. More than 80% of the households collect firewood from nearby forests. Average fuelwood consumption per household per week was recorded as 22.07, 24.63, 28.91 and 14.50 kg for N. Hlimen, Thingthelh, N. Khawdungsei and Ratu villages, respectively. In terms of average fuelwood consumption per household per day, fuelwood consumption ranged from 2.07 to 4.13 kg. Results of comparable studies conducted in other hilly regions reveal that consumption levels in the study area are significantly higher than those of rural and tribal communities in the western Himalayas, where it averages 1.5 kg per household per day (Bhatt *et al.*, 1994) and 1.6–2.4 kg per household per day inSouth-East Asia (Donovan, 1981).

A negative relationship (-0.936) between the consumption of LPG and fuelwood was recorded (**Table 5.37**). A study by Nautiyal and Kaechele (2008) revealed a significant decrase in the amount of fuelwood consumed per household in the villages where LPG is used.Income and fuelwood consumption were found to be negatively correlated (r = -0.998), which is most likely due to the poor economic conditions that encourages reliance on the forest for fuelwood as a free source of energy (**Table 5.37**). A significantly positive relationship (0.955) was found between LPG consumption and income (**Table 5.37**), implying that increased purchasing power will reduce pressure on forests from fuelwood extraction and encourage people to use alternative energy sources such as LPG, kerosene and solar energy.

Since the majority of the houses are constructed with local materials, their reliance on the forest for timber wood remains significant. There are only 2 Health Centers present in the four villages. As a result, traditional healing practices prevail so the collection of valuable medicinal plants from the forests is extensive. About 67.4 % still rely on medicinal plants for their ailments. The standard of living and social welfare services is given in **Table 5.28.**

5.5.4. Pressure on forests

The number of households that relied on agriculture for sustenance was high. The region's agriculture production system is primarily monocropped and subsistence-based. All the farmers engaged in jhum farming which required burning and clearing of vast tracts of land. The primary crop grown on all the farms was paddy, along with a variety of seasonal vegetable crops. *Curcuma longa*, *Solanum melongena*, *Oryza collina*, *Capsicum minimum*, *Zingiber officinale*, *Capsicum frutescens* and *Lycopersicon esculentum* are some of the main vegetables grown. Some of the common agricultural crops grown in the villages are given in **Table 5.29.** The inhabitants of the 4 villages also cultivated 18 different species of fruit crops. 19 fruit tree species were recorded growing naturally in and around the villages which were consumed by the villagers. **Table 5.30** lists cultivated fruit trees while **Table 5.31** lists the wild fruit trees.

It is estimated that wood still accounts for up to 90% of total energy consumption in many developing countries, and that firewood has become a tradable commodity due to the unaffordability of other energy sources (Eberhard, 1990). It has been reported that 54% of the total global wood harvest is for fuel (Nautiyal and Kaechele, 2008). As a result, fuelwood plays a significant role in the progression of forest degradation. The annual fuelwood consumption of India's 854 million people is estimated to be 216.4 million tonnes (FSI, 2011). About 84 % of all houses were wooden houses with tin-roofs so the consumption of wood is very high. Timber was also used to make furniture and tool handles. Despite the fact that the majority of families in the four villages had LPG connections, almost all households still rely on fuelwood collected from the forests as a supplement to meet their energy needs due to lack of cylinders. The common timber and fuelwood species used in the villages are given in **Table 5.32.** These species include *Wendlandia grandis, Terminalia myriocarpa, Mesua ferra, Schima wallichi, Michelia champaca, Artocarpus chama, Tectona grandis, Gmelina arborea, Duabanga grandifolia,* etc.

Medicinal plants have served as a source of healing in local communities all over the world for thousands of years. It is still important today as a primary healthcare mode for approximately 85% of the world's population (Pešić, 2015) and as a resource for drug discovery, accounting for 80% of all synthetic drugs (Bauer and Brönstrup, 2014). 67.4 % of the households still rely on medicinal plants along with modern medicine so extraction of these precious species from the forests is high. 25 species of medicinal plants used by the local people were identified and listed in **Table 5.33.** The species are *Homalomena aromatic, Oroxylum indicum, Cajanus cajan, Blumea lanceolaria, Aporusa octandra, Erythrina stricta, Mimosa pudica, Nervilia picata, Mikania micrantha, Dillenia pentagyna, Hedyotis capitella, Hedyotis scandens, Centella asiatica, Phyllanthus urinaria, Bombax insigne, Helicia robusta, Scoparia dulcis, Flueggea virosa, Costus speciosus, Lindernia ruellioides, Picrasma javanica, Alstonia scholaris,* *Thunbergia alata*, *Croton caudatus* and *Mallotus roxburghianus*. They were used to treat a variety of ailments ranging from fever, cough, headache, stomach problems, etc. The leaves, tubers, roots, shoots, rhizomes, fruit, seeds, bark, flowers and the entire plant are often used to prepare juice, powder or decoction.

Millions of people in many developing countries lack sufficient food to meet their daily needs. The custom of consuming wild plants has not entirely disappeared despite agricultural societies' primary reliance on domesticated plants and animals for food. Millions of people in many developing countries, particularly tribal and rural communities continue to collect and consume a diverse range of wild plant resources to meet their nutritional needs (Bharucha and Pretty, 2010; Panda, 2014). According to Yadav *et al.*, (2019), 10,000 of the 300,000 plant species have been used for human food since the origin of agriculture. In India, approximately 800 species of wild edible plants are consumed as food plants (Singh and Arora, 1978). 18 species of wild edible plants were collected by the people living in the 4 villages and is given in **Table 5.34.** Six different species of cane and palm used by the villagers were also recorded. The tender shoots and pith were also consumed but they were mainly used for thatching, furniture, crafts, etc. 7 bamboo species that were used by the residents have been identified. Bamboos were harvested for a variety of uses, including the building of houses, fences, handicrafts, etc.; the tender shoots were also consumed. The different species of bamboo, cane and palms used by the villagers are given in **Table 5.35.**

The aforementioned discussion clearly indicates that the local people of the adjoining villages continue to heavily rely on forest resources for their livelihood. The primary factors contributing to rural people's reliance on forests for their way of life are a lack of employment opportunities and low income. Clearing of lands for agriculture and collection of fuelwoods are the major anthropogenic activities leading to deforestation. This places enormous strain on the forest, potentially leading to overexploitation of various forest products. Some plant species may eventually become extinct as a result of this pressure. To ensure the sustainable use of the forest, an adequate action plan and strategy must be put in place for proper management and conservation of the natural resources which should include improving the socio-economic status of the local people and providing them access to alternative fuel and timber sources.

Table 5.26. Demographic and Livelihood Data

Name of Village	**No. of Household**	**Population**				**Occupation**				**No. of animals/ household**	**Annual income/ family (Rs.)**
		Male	Female	Total	Avg. family size	Cultivators	Business	Govt. service	Industry/ Carpentry		
North Hlimen	236	557	593	1150	4.87	195	14	26	1	4.8	24,046
Thingthelh	112	269	257	526	4.70	96	4	12	Nil	4.7	21,845
North Khawdungsei	44	120	115	235	5.34	40	1	3	Nil	5.1	15,307
Ratu	478	1260	1138	2398	5.02	371	26	79	2	4.5	34,645

Table 5.27. Education and Local Institutional level

Name of Village	Educational level				Local Institutional level								Literacy level
					High School		Middle School		Primary School		Anganwadi		
	PG	Grad	12	10	No.	Teacher/Students	No.	Teacher/Students	No.	Teacher/Students	No.	Teacher/Students	
North Hlimen	31	96	126	142	1	4/49	2	5/88	3	9/140	1	3/102	83.34%
Thingthelh	18	33	58	72	1	3/22	1	4/41	1	5/50	1	1/42	78.76%
North Khawdungsei	2	5	15	33	Nil	Nil	1	4/15	1	4/23	1	2/22	91.14%
Ratu	97	161	243	280	2	6/171	4	12/348	5	15/370	1	4/215	88.03%

Table 5.28. Standard of Living and Social Welfare Services

Name of Village	House Electrified	House with LPG	House with Mobile / landline	RCC building	Tin roof building	Rest House	Health Center	Road Communication	Fodder consumed/ household/ week (kg)	Fuel wood consumed/ household/ week (kg)	LPG consumed/ household/ year (L)
North Hlimen	233	232	236	37	199	1	1	Metal Road	23.91	22.07	43.89
Thingthelh	88	112	112	21	91	1	Nil	Metal Road	21.56	24.63	48.60
North Khawdungsei	44	26	44	5	39	Nil	Nil	Metal/ Katcha Road	30.13	28.91	37.78
Ratu	475	473	475	78	397	2	1	Metal/ Katcha Road	18.45	14.50	63.08

Table 5.29. Agricultural crops

Sl. No.	Botanical name	Family	Local name
1	*Curcuma longa*	Zingiberaceae	Ai-eng
2	*Eryngium foetidum*	Umbelliferae	Bahkhawr
3	*Ipomoea batatas*	Convolvulaceae	Bahra
4	*Solanum melongena*	Solanaceae	Bawkbawn
5	*Vignia unguiculata*	Papilionaceae	Behlawi
6	*Cajanus cajan*	Papilionaceae	Behliang
7	*Oryza collina*	Oryzeae	Buh
8	*Citrullus lanatus*	Cucurbitaceae	Dawnfawh
9	*Cucumis sativus*	Cucurbitaceae	Fanghma
10	*Capsicum frutescens*	Solanaceae	Hmarchapui
11	*Capsicum minimum*	Solanaceae	Hmarchate
12	*Cucumis melo*	Cucurbitaceae	Hmazil
13	*Elsholtzia communis*	Labiatae	Lengser
14	*Benincasa hispida*	Cucurbitaceae	Maipawl

15	*Momordica mixta*	Cucurbitaceae	Maitamtawk
16	*Manihot esculenta*	Euphorbiaceae	Pangbal
17	*Solanum anguivi*	Solanaceae	Samtawk
18	*Zingiber officinale*	Zingiberaceae	Sawhthing
19	*Lycopersicon esculentum*	Solanaceae	Tomato
20	*Zea mays*	Graminae	Vaimim

Table 5.30. Cultivated fruit trees

Sl. No.	Botanical Name	Family	Local name
1	*Musa paradisiaca*	Musaceae	Balhla
2	*Persea americana*	Lauraceae	Butterfruit
3	*Cocos nucifera*	Arecaceae	Coconut
4	*Saccharum officinarum*	Poaceae	Fu
5	*Vitis vinifera*	Ampelidaceae	Grape
6	*Phyllanthus acidus*	Euphorbiaceae	Kawlsunhlu

7	*Psidium guajava*	Myrtaceae	Kawlthei
8	*Ananas comosus*	Bromeliaceae	Lakhuithei
9	*Artocarpus heterophyllus*	Moraceae	Lamkhuang
10	*Citrus limon*	Rutaceae	Nimbu
11	*Passiflora edulis*	Passifloraceae	Sapthei
12	*Citrus grandis*	Rutaceae	Sertawk
13	*Citrus reticulata*	Rutaceae	Serthlum
14	*Tamarindus indica*	Caesalpinaceae	Tengtere
15	*Mangifera indica*	Anacardiaceae	Theihai
16	*Averrhoa carambola*	Oxalidaceae	Theiherawt
17	*Carallia bravhiata*	Rhizophoraceae	Theiria
18	*Prunus domestica*	Rosaceae	Theite

Table 5.31. Wild fruit trees

Sl. No.	Botanical name	Family	Local name
1	*Garcinia cowa*	Guttiterae	Chengkek
2	*Dillenia indica*	Dillaniaceae	Kawrthindeng
3	*Juglans regia*	Juglandaceae	Khawkherh
4	*Rhus semialata*	Anacardiaceae	Khawmhma
6	*Baccaurea ramiflora*	Euphorbiaceae	Pangkai
7	*Aglaia endulis*	Meliaceae	Raithei
8	*Eleagnus caudata*	Eleagnaceae	Sarzuk
9	*Emblica officinalis*	Euphorbiaceae	Sunhlu
10	*Rubus accuminatus*	Rosaceae	Theihmu
11	*Bruinsmia polysperma*	Styraceae	Theipalingkawh
12	*Carallia brachiata*	Rhizophoraceae	Theiria
13	*Artocarpus lacucha*	Moraceae	Theitat
14	*Castanopsis tribuloides*	Fagaceae	Thingsemim
15	*Embelia vestita*	Myrsinaceae	Tling

16	*Antidesma bunius*	Euphorbiaceae	Tuaitit
17	*Garcinia sopsopia*	Guttiferae	Vawmvapui
18	*Willughbeis edulis*	Apocynaceae	Vuakdup
19	*Alphonsea ventricosa*	Annonaceae	Zawngbalhla

Table 5.32. Timber and Fuelwood species

Sl. No.	Botanical name	Family	Local name
1	*Wendlandia grandis*	Rubiaceae	Batling
2	*Alseodaphne petiolaris*	Lauraceae	Bulpui
3	*Garuga pinnata*	Burseraceae	Bungbutuairam
4	*Terminalia myriocarpa*	Combretaceae	Char
5	*Lithocarpus dealbata*	Fagaceae	Fah
6	*Ziziphus incurva*	Rhamnaceae	Hel
7	*Mesua ferra*	Guttiferae	Herhse
8	*Betula cylindrostachys*	Betulaceae	Hriangzau
9	*Schima wallichi*	Theaceae	Khiang

10	*Cinnamomum glanduliferum*	Lauraceae	Khiangzo
11	*Michelia champaca*	Magnoliaceae	Ngiau
12	*Bombax insigne*	Bombadaceae	Pang
13	*Ervatamia coronaria*	Apocynaceae	Pararsi
14	*Stephrgyne diversifolia*	Rubiaceae	Pualeng
15	*Aglaia spectabilis*	Meliaceae	Sahatah
16	*Eurya cerasifolia*	Pentaphylaceae	Sihneh
17	*Emblica officinalis*	Euphorbiaceae	Sunhlu
18	*Artocarpus chama*	Moraceae	Tatkawng
19	*Tectona grandis*	Verbanaceae	Teak
20	*Toona ciliata*	Meliaceae	Teipui
21	*Cinnamomum verum*	Lauraceae	Thakthing
22	*Bruinsmia polysperma*	Styraceae	Theipalingkawh
23	*Tetrameles nudiflora*	Datiscaceae	Thingdawl
24	*Heritiera acuminata*	Sterculiaceae	Thingsaiphaw
25	*Castanopsis tribuloides*	Fagaceae	Thingsia

26	*Gmelina arborea*	Verbanaceae	Thlanvawng
27	*Drimycarpus racemosus*	Anacardiaceae	Vawmbal
28	*Duabanga grandifolia*	Lythraceae	Zuang

Table 5.33. Medicinal plants

Sl. No.	Botanical name	Family	Local name
1	*Homalomena aromatica*	Araceae	Anchiri
2	*Oroxylum indicum*	Bignoniaceae	Archangkawm
3	*Cajanus cajan*	Papillionaceae	Behliang
4	*Blumea lanceolaria*	Compositae	Buarze
5	*Aporusa octandra*	Euphorbiaceae	Chhawntual
6	*Erythrina stricta*	Papillionaceae	Fartuah
7	*Mimosa pudica*	Mimosaceae	Hlonuar
8	*Nervilia picata*	Orchidaceae	Hnahkhat
9	*Mikania micrantha*	Compositae	Japan hlo
10	*Dillenia pentagyna*	Dilleniaceae	Kaihzawl

11	*Hedyotis capitella*	Rubiaceae	Kelhnamtur
12	*Hedyotis scandens*	Rubiaceae	Laikingtuibur
13	*Centella asiatica*	Apiaceae	Lambak
14	*Phyllanthus urinaria*	Euphorbiaceae	Mithi sunhlu
15	*Bombax insigne*	Bombacaceae	Pang
16	*Helicia robusta*	Proteaceae	Pasaltakaza
17	*Scoparia dulcis*	Scrophulariaceae	Perhpawngchaw
18	*Flueggea virosa*	Euphorbiaceae	Saisiak
19	*Costus speciosus*	Zingziberaceae	Sumbul
20	*Lindernia ruellioides*	Scrophulariaceae	Thasuih
21	*Picrasma javanica*	Simarubaceae	Thingdamdawi
22	*Alstonia scholaris*	Apocynaceae	Thuamriat
23	*Thunbergia alata*	Acanthaceae	Vako
24	*Croton caudatus*	Euphorbiaceae	Vawkze
25	*Mallotus roxburghianus*	Euphorbiaceae	Zawngtenawhlung

Table 5.34. Wild edible plants

Sl. No.	Botanical name	Family	Local name
1	*Spilanthes acmella*	Compositae	Ankasa
2	*Glinus oppositifolia*	Aizoaceae	Bakhate
3	*Diplazium maxima*	Polypodiaceae	Chakawk
4	*Zanthoxylum rhetsa*	Rutaceae	Chingit
5	*Calamus flagellum*	Arecaceae	Hruipui
7	*Trevesia palmata*	Araiaceae	Kawhtebel
8	*Acacia pennata*	Mimosaceae	Khanghu
9	*Curanga amara*	Schrophulariaceae	Khatual
10	*Centella asiatica*	Apiaceae	Lambak
11	*Melocanna baccifera*	Poaceae	Mautak
12	*Agaricus sp*	Agaricaceae	Pasawntlung
13	*Clerodendrum colebrookianum*	Verbanaceae	Phuihnam
14	*Dendrocalamus hamiltonii*	Poaceae	Phulrua
15	*Dendrocalamus longispathus*	Poaceae	Rawnal

16	*Bambusa tulda*	Poaceae	Rawthing
17	*Eurya cerasifolia*	Theaceae	Sihneh
18	*Arisaema speciosum*	Araceae	Telhawng
19	*Musa sp.*	Musaceae	Tumbu

Table 5.35. Bamboos, palms and canes

Sl. No.	Botanical name	Family	Local name
1	*Livistona chinensis*	Arecaceae	Buarpui
2	*Pseudostachynum polymorphum*	Poaceae	Chalte
3	*Calamus flagellum*	Arecaceae	Hruipui
4	*Melocanna baccifera*	Poaceae	Mautak
5	*Caryota mitis*	Arecaceae	Meihle
6	*Dendrocalamus hamiltonii*	Poaceae	Phulrua
7	*Dendrocalamus longispathus*	Poaceae	Rawnal
8	*Bambusa tulda*	Poaceae	Rawthing
9	*Schizostachyum dulloa*	Poaceae	Rawthla
10	*Dinochloa compactiflora*	Poaceae	Sairil
11	*Calamus tenuis*	Arecaceae	Thilte
12	*Calamus erectus*	Arecaceae	Thilthek
13	*Caryota urens*	Arecaceae	Tum

Table 5.36. Pearson's correlation coefficients between different parameters.

Correlation / Parameter	1. Fodder consumed/ household	2. Income/ Family	3. No. of animals/ household	4. Fuelwood consumed/ household	5. LPG consumed/ household	6. Average family size	7. Literacy level
1. Fodder consumed/ household	1.000						
2. Income/ Family	0.899*	1.000					
3. No. of animals/ household	0.997*	0.928**	1.000				
4. Fuelwood consumed/ household	-0.875**	-0.998*	-0.906*	1.000			
5. LPG consumed/ household	0.918	0.955*	0.942*	-0.936	1.000		
6. Average family size	0.665	0.321	0.609	-0.292	0.318*	1.000	
7. Literacy level	0.458	-0.059*	0.391*	0.025	-0.082	0.963	1.000

* Correlation is significant at the 0.05 level.

** Correlation is significant at the 0.01 level.

5.6. Forest cover change

The multi-temporal satellite images from the year 2006 - 2018 were used to delineate forest and non-forest cover in the study site. The satellite-based survey revealed a decrease in forest cover with an overall change of 5.23 km^2 (- 10.45% change) between 2006 and 2018. Periodical observations showed that forest cover was 48.82 km^2 (97.64% coverage of study area) in 2006, which moderately declined to 48.17 km^2 (96.33% coverage; - 1.31% change) in 2012, losing 0.65 km^2 of forest cover. From 2012 to 2018, forest cover was further reduced to 43.59 km^2 (87.19% coverage; - 9.14% change) losing 4.58 km^2 of forest area. On the other hand, the satellite-based survey revealed an increase in non-forest cover with an overall change of 5.23 km^2 (10. 45 % change) from 2006 – 2018 **(Fig. 5.6.1; Table 5.37).**

As shown in **Table 5.38**, there was a gradual decline in open forest area from 2006 (33.85%) to 2012 (33.11%) to 2018 (31.91%), while medium dense forest area also decreased from 5.96% to 3.97% between 2006 and 2018. The majority of the study site is covered by dense forests, and while there was a slight decline between 2006 and 2012 (57.84% to 57.54%), a sharp decline was observed in 2018 (51.31%). Dense scrubland area increased from 0.30% to 2.04% between 2006 and 2012, but then decreased to 0.74% in 2018. Open scrubland area declined sharply that it was no longer present in 2018. From 2006 to 2012, the percentage of land covered by water bodies remained constant at 1.30% but by 2018, it had increased to 12.08%, submerging many areas of the sanctuary.

Forest cover has decreased over time as a result of anthropogenic influences that have resulted in habitat destruction, vegetation loss and vulnerability to the flora and fauna due to cutting of trees and bamboos for firewood, construction of houses and clearing of lands for cultivation. The major cause of deforestation in Asia, Africa and Latin America are attributed to rural community population growth and economic development programs which causes changes in species composition and modifying forest structures to the point where vast areas of forest have been replaced by scrubland. The gradual loss of forest cover in the sanctuary may be attributed to the combined impact of anthropogenic and natural factors of varying intensity.

In addition to routine anthropogenic disturbances such as fuelwood collection, logging and agricultural practices, it was discovered that the construction of hydroelectric project throughout the study area was one of the most significant source of anthropogenic disturbance. The vegetation of this sanctuary has been severely impacted by the construction of this project. Tropical and temperate forests are the most susceptible to species losses brought on by changes in land use (Pandit *et al.,* 2007), yet 88% of proposed dams are situated in these ecosystems and more than half of the dams would be in dense, largely untouched forests (Grumbine and Pandit, 2013). Disturbance brought on by dam construction is predicted to decrease tree species richness by 35%, tree density by 42%, and tree basal cover by 30% in dense forests (Pandit and Grumbine, 2012). If these predictions are accurate, the construction of all proposed dams in hilly and mountainous regions, combined with relatively weak national environmental impact assessment and implementation would lead to significant loss of species (Malik, 2014).

About 5.39 km^2 of forest area have become submerged due to the reservoirs of Tuirial power plant which is constructed based on the rivers alongside the sanctuary. Dense forest regions have lost the most area (6.24 % coverage) due to the increasing reservoir of the power plant. Migratory birds, animals and fishes have been adversely affected and the transportation of sediments to the low lands has also been disrupted. Many plants and animal habitats have been submerged leading to formation of many small fragmented and inhabitable lands. Since the submerged trees are not chopped down and left to rot in the reservoir, they release carbon dioxide and methane through decomposition consequently contributing to climate change.

To minimize the anticipated loss of vegetation, various agents of disturbance should be assessed cumulatively and any development activities such as hydropower projects, which cause a variety of natural and anthropogenic disturbances should be combined with proper cumulative environmental impact assessments and effective implementation. Regular estimation of forest cover is among the crucial data for the management and preservation of protected areas.

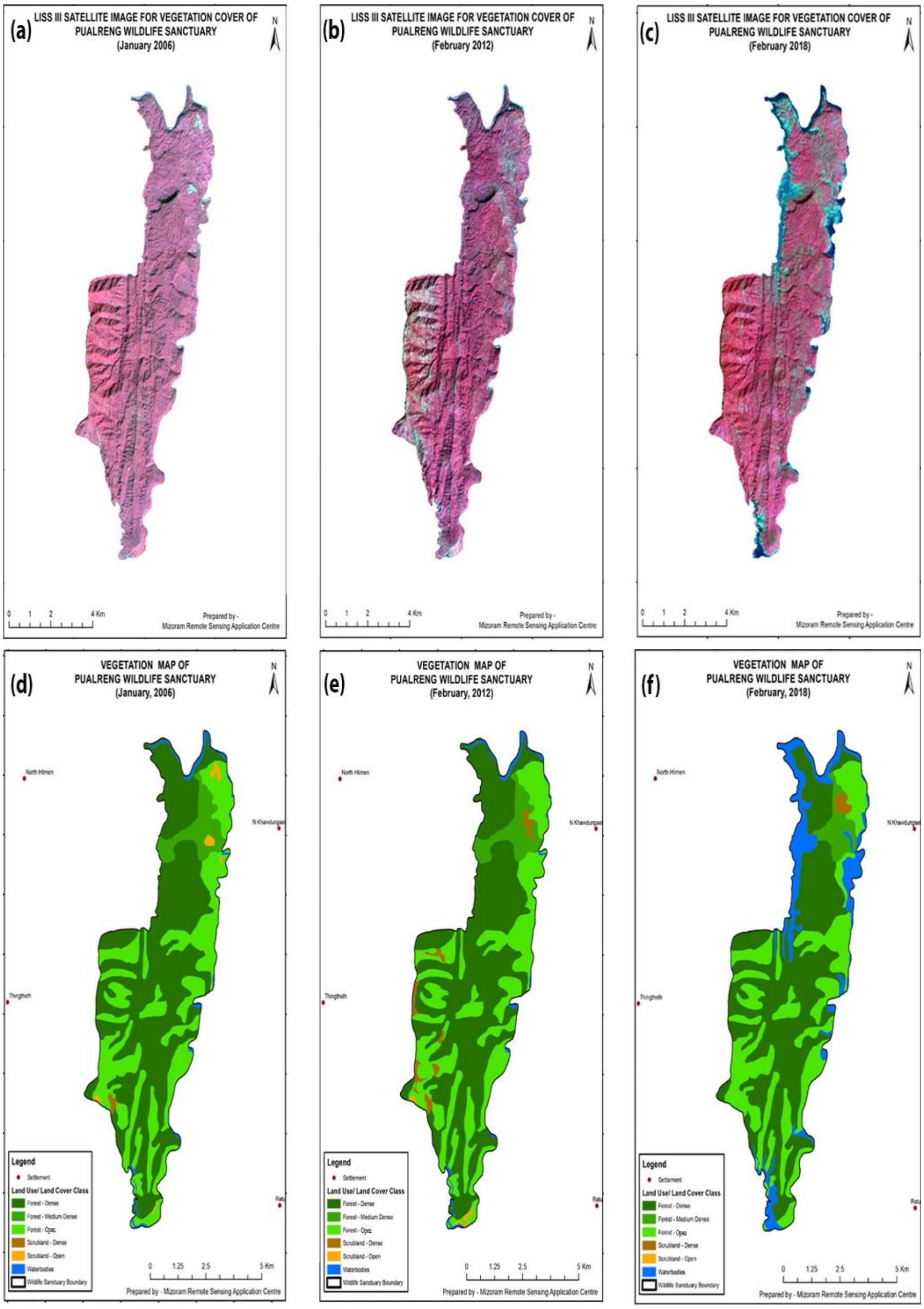
Table 5.37. Total area statistics of forest and non-forest cover in Pualreng Wildlife Sanctuary during 2006 – 2018

Years	Area (km^2)		Area (%)	
	Forest	Non-forest	Forest	Non-forest
2006	48.82	1.18	97.64	2.36
2012	48.17	1.83	96.33	3.66
2018	43.59	6.41	87.19	12.81
Total change	-5.23	5.23	-10.45	10.45

Table 5.38. Statistics of different vegetation class in Pualreng Wildlife Sanctuary during 2006 - 2018

	2006		**2012**		**2018**	
CLASS	**Area (km^2)**	**Percent age**	**Area (km^2)**	**Percent age**	**Area (km^2)**	**Percent age**
Forest - Open	16.92	33.85	16.56	33.11	15.95	31.91
Forest - Dense	28.92	57.84	28.77	57.54	25.66	51.31
Forest - Medium Dense	2.98	5.96	2.84	5.68	1.99	3.97
Scrubland - Dense	0.15	0.30	1.02	2.04	0.37	0.74
Scrubland - Open	0.38	0.76	0.16	0.33	0.00	0.00
Water-bodies	0.65	1.30	0.65	1.30	6.04	12.08
Grand Total	50.00	100.00	50.00	100.00	50.00	100.00

Fig. 5.6.1. Forest & non-forest cover in the study site as observed in satellite images and classified map for the year 2006 (a,d), 2012 (b,e) & 2018 (c,f)



CHAPTER – 6

SUMMARY AND CONCLUSION

6.1. Summary

Pualreng Wildlife Sanctuary lies between 24°06'35" to 24°14'16.21"N latitudes and 92°50' 17.6" to 92°54'2.64"E longitudes. It is located in Kolasib district of Mizoram. The distance from Aizawl is about 115 km. The sanctuary covers an area of 50.0 square kilometres with altitude ranging between 260-750 msl. It contains 40% Reserve Forest and 60% Government unclassed land where most of the area is hilly terrain with 70% steep slope and 30% of gentle slope with sandy clay soil and sedimentary rocks. The fringing villages of the sanctuary are North Hlimen, Thingthelh, North Khawdungsei and Ratu. The climatic condition is very mild and pleasant, temperature in summer ranges between 20° C – 30^{o}C and in winter it ranges between 10° C – 20^{o} C. The region receives good rainfall ranging from 2000 mm. – 3900 mm. The sanctuary was declared by the State Government of Mizoram as “Pualreng Wildlife Sanctuary” under the provisions of Wildlife (Protection) Act, 1972 vide notification No.B.12012/19/01-FST of 29.07.2004.

The research was conducted for a period of 5 years starting from May of 2017. The study site have been demarcated into two zones – the core zone which is found at the central part with undisturbed forest and the buffer zone found alongside the nighbouring villages with disturbed forest.

The thesis is divided into six chapters which are as follows:

The First chapter addresses the concept of biodiversity and its definition, types and patterns of biodiversity, megadiversity and biodiversity hotspots, loss of biodiversity, scope and objectives.

The Second chapter deals with the review of at the international level, national level, northeast level and state level.

The Third chapter deals with the study area, its location, description of the boundaries, climate, drainage system and vegetation.

The Fourth chapter is concerned with the research methodology for the analysis of plant communities and socio-economic survey.

The Fifth chapter deals with the results and discussions. The significant findings of the study are summarized below:

1. A total of 221 plant species were recorded belonging to 185 genera and 87 families. Out of which there were 75 angiosperm families, 2 gymnosperm families, and 10 pteridophyte families. The dicotyledons consist of 63 families, 139 genera and 169 species while the monocotyledons comprised of 12 families, 32 genera and 37 species.

2. Within the core zone, 176 species under 149 genera belonging to 84 families were identified. Within the buffer zone, 143 species under 109 genera belonging to 76 families were also identified.

3. Of the total 221 species, there were 111 species of trees (50.23%), 19 species of shrubs (8.60%), 36 species of herbs (16.29%), 28 species of climbers/lianas (12.67%), 10 species of canes and palms (4.52%), 9 species of grasses (4.07%) and 8 species of epiphytes (3.62%).

4. The five most species rich families were Fabaceae (14 species), Arecaceae (10 species), Poaceae (10 species), Rubiaceae (9 species) and Lamiaceae (8 species). 43 families were represented by only one species each.

5. In the core zone, *Duabanga grandiflora* was the most dominant tree species with an IVI of 12.47. Most dominant species among shrubs was *Pandamus fascicularis* with IVI of 31.55. The most herb species was *Diplazium maximum* with IVI of 20.68. *Millettia pachycarpa* had the highest density among climbers. Among canes and palms, *Licuala peltata* had the highest density. The epiphyte species with the highest density was *Pyrrosia mannii* and *Dinochloa compactiflora* was the species with the highest density among grasses.

6. Most dominant tree species in the buffer zone was *Neolamarckia cadamba* with an IVI value of 16.56. Most dominant species among shrubs was *Chassalia ophioxyloides* with IVI of 44.71 and the species with the highest rank was *Mimosa pudica* with IVI of 17.46 among herbs. The species which had the highest density were *Bauhinia scandens* among climbers, *Calamus erectus* among canes and palms and *Melocanna baccifera* among grasses.

7. Shannon – Wiener diversity index (H') for core zone revealed that species diversity ranged between 2.60 to 4.16. The Peilou's evenness index (E) ranged from 0.92 – 0.98 and Simpson's dominance index (D) ranged between 0.02 – 0.08 for the three communities. Margalef's richness index (D_{mg}) revealed that trees had the highest species richness 11.95 followed by herbs (3.87) and shrubs (2.34).

8. Within the buffer zone, Shannon – Wiener diversity index (H') ranged from 2.40 – 3.85. Pielou's evenness index indicated that herbs were most evenly distributed with E value of 0.97 follwed by shrubs (0.96) and trees (0.93). Simpson's dominance index (D) ranged from 0.03 – 0.08 for the three communities. Margalef's index of richness was highest for trees (8.70) followed by (4.00) and shrubs (2.36).

9. Stratification of the forest was done by drawing a profile diagram which shows that there are 3 layers or stratification in Pualreng Wildlife Sanctuary i.e. top canopy, middle canopy and under canopy. The top canopy and middle canopy were dominated by tree species while the under canopy was dominated by shrubs and herbaceous species.

10. The IUCN Red List of Threatened Species has assessed 68 of the 221 species recorded. Out of these *Prunus ceylanica* is classified as Endangered while *Saraca asoca* is classified under Vulnerable category. Two species namely *Aglaia edulis* and *Clerodendrum trichotomum* are classed as Near Threatened. Sixty four species (64) are classified as Least Concern which is at the lowest risk, out of which there are 45 tree species, 11 herbs, 4 shrubs, 2 climbers and 2 canes and palms.

11. Among the fringing villages, Ratu had the largest population among the four villages with 2398 residents, while North Khawdungsei had the smallest population with 235 residents. The majority of the families (81 %) in the four villages rely on agriculture for sustenance, while the rest are engaged in small businesses, government services and cottage industries.

12. The majority of the villager still used wood for cooking because there is a scarcity of LPG cylinders. Over 80% of households get their firewood from nearby forests. Approximately 67.4% still rely on medicinal plants to treat their ailments.

13. There were 20 agricultural crops grown by the local people. The main crops were *Oryza collina, Curcuma longa, Eryngium foetidum, Ipomoea batatas, Solanum melongena, Citrullus lanatus, Cucumis sativus, Elsholtzia communis, Zingiber officinale* and *Manihot esculenta*.

14. 18 cultivated fruit crops were identified while 19 species of wild fruit trees were also identified growing near the villages. The major cultivated fruit trees were *Musa paradisiaca, Phyllanthus acidus, Psidium guajava, Citrus limon, Citrus grandis, Mangifera indica, Artocarpus heterophyllus* and *Ananas comosus*. The main wild fruit trees include *Garcinia cowa, Rhus semialata, Baccaurea ramiflora, Eleagnus caudate, Emblica officinalis, Castanopsis tribuloides* and *Artocarpus lacucha*.

15. 28 species of timber and fuelwood species were utilized by the local people. Some of these species include *Wendlandia grandis, Schima wallichi, Cinnamomum glanduliferum, Michelia champaca, Aglaia spectabilis, Eurya cerasifolia, Artocarpus chama, Duabanga grandifolia, Cinnamomum verum, Heritiera acuminate, Gmelina arborea* and *Toona ciliata.*

16. 25 species of medicinal plants have been recorded. It consist of species such as *Homalomena aromatic, Croton caudatus, Mikania micrantha, Dillenia pentagyna, Hedyotis scandens, Scoparia dulcis, Flueggea virosa, Alstonia scholaris* and *Blumea lanceolaria.*

17. The wild edible plants collected by the villagers consist of 19 species. The major wild edible species include *Diplazium maxima, Zanthoxylum rhetsa, Acacia pennata, Clerodendrum colebrookianum, Dendrocalamus longispathus, Arisaema speciosum* and *Eurya cerasifolia*.

18. 13 species of bamboo, canes and palms were used by the villagers such as *Livistona chinensis, Pseudostachynum polymorphum, Calamus flagellum, Melocanna baccifera, Caryota mitis, Dendrocalamus hamiltonii, Dendrocalamus longispathus, Bambusa tulda, Schizostachyum dulloa, Dinochloa compactiflora, Calamus tenuis, Calamus erectus* and *Caryota urens.*

19. Multi-temporal satellite images from the year 2006 - 2018 revealed that forest cover was 48.82 km^2 (97.64% coverage of study area) in 2006, which moderately declined to 48.17 km^2 (96.33% coverage; - 1.31% change) in 2012, losing 0.65 km^2 of forest cover. From 2012 to 2018, forest cover was further reduced to 43.59 km^2 (87.19% coverage; - 9.14% change) losing 4.58 km^2 of forest area. There was an overall 5.23 km^2 decrease in forest cover over the 12 years period.

The Sixth chapter consists of the summary and conclusion of the entire text.

6.2. Conclusion

Pualreng Wildlife Sanctuary is rich in biodiversity providing protection and habitat for rare, endangered and endemic plant species. Evergreen trees dominate the sanctuary. As a result, the forest can be classified as either evergreen or semi-evergreen.

Anthropogenic disturbances such as logging of timber, over exploitation of natural resources, habitat destruction and encroachment from the local population of the neighbouring villages are the main threat to the sanctuary. Since agriculture through jhum cultivation (slash-and-burn) is the main economic activity of the people, this causes serious problem to the forest as large areas close to the boundary are often cleared and burned.

The State Government must take actions and measures specific to this area so that the rare, threatened and endemic species can be protected from anthropogenic threats. The local people must also be made aware to conserve and protect their natural resources from dwindling. Periodic monitoring with multi-temporal satellite observations also aided in the accurate estimation of change in forest areas and can provide critical information. This research work will be useful in formulating future forest monitoring and management plans.

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Plate 2a: *Saraca asoca* (Roxb.) Willd.

Plate 2b: *Prunus ceylanica* (Wight) Miq

Plate 2c: *Ardisia sanguinolenta* Bl.

Plate 3

Plate 3a: *Aporosa octandra* (Buch.-Ham. ex D.Don)

Plate 3b: C*lerodendrum trichotomum* Thunb.

Plate 3c: *Ficus racemosa* L.

Plate 4

Plate 4a: ***Mesua ferrea*** **L.**

Plate 4b: ***Sterculia villosa*** **Roxb. ex Sm.**

Plate 4c: ***Clerodendrum infortunatum*** **L**

Plate 4d: ***Merremia umbellata*** **(L.) Hallier f.**

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TITLE OF THESIS: STUDY ON PLANT DIVERSITY OF PUALRENG WILDLIFE SANCTUARY IN KOLASIB DISTRICT, MIZORAM

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PAPER PUBLICATION:

1. **Vanlalnunpuia, P.C**., Lalzarzovi, S.T., Lalbiaknii, P.C. and Pachuau, Joney Vanlalnunpuii. (2021). Assessment of tree species composition and diversity of core and buffer zones in Pualreng Wildlife Sanctuary, Mizoram, India. *Indian Journal of Ecology*, 48(4): 1056-1061.

2. **Vanlalnunpuia, P.C**., Lalzarzovi, S.T., Lalbiaknii, P.C. and Pachuau, Joney Vanlalnunpuii. (2022). An evaluation of anthropogenic impacts using Remote Sensing Approach on forest coverage of Pualreng Wildlife Sanctuary, Mizoram, India. *Applied Ecology and Environmental Sciences,* 10(1): 19-24.

PAPER PRESENTATION:

1. Presented a paper entitled,” Tree species composition and conservation status of Tropical forest of Pualreng Wildlife Sanctuary in Kolasib district, Mizoram” at the Regional Seminar on Climate Change: Impact, Adaptation & Response in the Eastern Himalayas during 1st – 2nd November, 2018, organized by the Department of Environmental Science, MZU in collaboration with IHCAP-Indian Himalayas Climate Adaptation Programme at Mizoram University, Aizawl, Mizoram.

2. Presented a paper entitled,” An Evaluation of Anthropogenic Impacts Using Remote Sensing Approach on Forest Coverage of Pualreng Wildlife Sanctuary, Mizoram, India” at the International Conference on Environment, Agriculture & Biotechnology (ICEABT) held in Bareilly, India on 29th October, 2021, organized by Academics Conference Network (ACN).

DECLARATION: I hereby declare that the above information is correct to the best of my knowledge.

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ABSTRACT

STUDY ON PLANT DIVERSITY OF PUALRENG WILDLIFE SANCTUARY IN KOLASIB DISTRICT, MIZORAM

AN ABSTRACT SUBMITTED IN PARTIAL FULFILLMIENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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JANUARY,

ABSTRACT

STUDY ON PLANT DIVERSITY OF PUALRENG WILDLIFE SANCTUARY IN KOLASIB DISTRICT, MIZORAM

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In Environmental Science of Mizoram University, Aizawl

ABSTRACT

The term "biodiversity" refers to the enormous variety of life on Earth. It encompasses all forms of life, including microorganisms, plants, animals and the genes they contain and the ecosystem they form. Each of these various species and organisms collaborate in complicated web-like ecosystems to keep things in balance and support life. The Convention on Biological in 1992 defined biodiversity (or biological diversity) as "the variability among living organisms from all sources including, *inter alia*, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems". Diversity addresses two distinct characters - species richness and evenness. Species richness refers to the number of species per unit area whereas evenness relates to the abundance, dominance, or spatial distribution.

Different categories and elaborations of biodiversity have been established by various authors. The different types of biodiversity are:

i) Genetic Diversity: It refers to genetic differences between species as well as genetic variations within a single species. This refers to genetic diversity among various populations of the same species.

ii) Species Diversity: It refers to the variety of species found in a given region. It can be characterized as a group of naturally occurring populations that breed with one another or have the potential to do so but are reproductively isolated from other such groups.

iii) Habitat Diversity: The term "habitat" refers to a collection of biotic, physical, and resource elements that are essential for a specific species to thrive and reproduce in a region. Habitat diversity explores the distinctions in ecosystems within a particular geographic region. It refers to the range of different habitats found in an ecosystem or biome.

iv) Ecosystem Diversity: The range of life forms in a given terrain or locale, as well as the ecological processes that enable them to function, is referred to as ecosystem diversity. The ecosystem may be:

(a) Aquatic ecosystem – (i) Fresh water ecosystem (ii) Marine ecosystem.

(b) Terrestrial ecosystem – (i) Forest ecosystem (ii) Desert ecosystem (iii) man-made ecosystem.

v) Landscape Diversity: Landscape diversity refers to the complexity and diversity of landscape features in composition, structure and function, and includes not only the number of different patch types, patch size and patch shape within a landscape mosaic, but also the spatial arrangement of different patch types, as well as the connectivity and connectedness of these patches.

The term "biodiversity loss" refers to a decline in the biological diversity of a species, ecosystem, area or the entire earth. The loss of biodiversity and the resulting environmental changes are happening faster than ever before in human history and there is no sign of this slowing down. Reduced biodiversity, in particular, diminishes ecosystem services and as a result, poses an immediate threat to food security but it can also have long-term global health consequences for humans. Any element, natural or artificial that directly or indirectly alters an ecosystem is known as a driver. Ecosystem processes are undeniably influenced by a direct driver. An indirect driver modifies one or more direct drivers to operate more subtly. Habitat destruction, over-exploitation of biological resources, pollution, invasive species and climatic changes are the primary factors directly contributing to biodiversity loss worldwide. Natural and man-made factors tend to interact and amplify one another. Buffer zones of protected areas often experience high pressure from fringe villages as these areas are cleared for agricultural purposes and pasturelands which adversely disrupt the ecosystem function and services in the territory.

Biodiversity is highest in the tropics compared to other regions indicating that it is not evenly distributed. Tropical regions are home to a diverse range of plant species, many of which have medicinal and economic value. As a result, research on tropical plant species diversity and community structure is ecologically important. The majority of life on earth is dominated by plants, with animals making up a very small portion. Plants account for more than 82% of biomass while animals account for only 0.4%. Numerous different types of forests can be found in India thanks to the diverse landforms and climate of the region. According to the 2021 Forest Survey of India report, the total forest and tree cover of India is 80.9 million hectares, which is 24.62% of the geographical area of the country.

The northeast region of India is regarded as one of the subcontinent's biodiversity hotspots due to its high species density and diversity. The state of Mizoram has the second highest forest cover as percentage of total geographic area (84.53%) in the country. However, 186 sq. km of forest was lost from 2019 which is 1.03% of total forest cover. Considering the accelerated anthropogenic activities that are causing biodiversity loss, there is an immediate need to analyse the status of biological diversity in this region with a focus on natural protected areas. Thus, the present research focuses on documenting and identifying floristic diversity while assessing the endemic, rare, threatened and endangered plant species present in Pualreng Wildlife Sanctuary. Since this sanctuary has not yet undergone a thorough scientific investigation, the current research is expected to be helpful in providing the necessary information for formulating policies and programs for effective management and conservation of valuable biodiversity, including the other related benefits, as the wildlife is completely dependent on the vegetation and floristic composition of the sanctuary. Therefore, the aims and objectives of this study are:

1. To study plant diversity in the study area.

2. Screening of rare and threatened species.

3. To assess impact of anthropogenic activities on the environment

Pualreng Wildlife Sanctuary is spread over an area of 50.0 square kilometres with altitude ranges between 260-750 msl. The sanctuary is surrounded by four village *viz*., North Hlimen, Thingthelh, North Khawdungsei and Ratu. The forest was demarcated into:

a) Core zone: This type of forest can be found in the center of the forest. It mainly consists of densely forested areas that are relatively undisturbed.

b) Buffer zone: The buffer zone consists of secondary forests adjacent to N. Hlimen, Thingthelh, N. Khawdungsei and Ratu.

In the study area, 87 families in total were recorded out of which there were 75 angiosperm families (86.21%), 2 gymnosperm families (2.3%), and 10 pteridophyte families (11.49%). The five most species rich families were Fabaceae (14 species), Arecaceae (10 species), Poaceae (10 species), Rubiaceae (9 species) and Lamiaceae (8 species). In relation to the dominant families, 43 families were represented by one species each. There were 12 families in the monocotyledons and 63 families in the dicotyledons. Dicotyledons thus made up 84% of all angiosperm families, while monocotyledons made up only 16%. There were 84 families present in the core zone, distributed as 72 angiosperm families, 2 gymnosperm families and 10 pteridophyte families. 9 families of the angiosperms were monocotyledons while 63 families of them were dicotyledons. In the buffer zone, there were 76 families present which were distributed as 67 families of angiosperms, 1 family of gymnosperm and 8 families of pteridophytes. Among the angiosperms, 56 families were dicotyledons while 11 families were monocotyledons.

Within the study area, a total of 185 genera were identified. There were 171 angiosperms, 2 gymnosperms and 12 pteridophytes among them. The dicotyledons comprised 139 genera (81.21%) of the angiosperms, while the monocotyledons comprised 32 genera (18.71%). Within the core zone of the forest, 149 genera were discovered, of which 136 were angiosperms, 2 were gymnosperms and 11 were pteridophytes. There were 115 dicotyledons and 21 monocotyledons among the angiosperms. The buffer zone consists of 109 different genera. Out of these genera, angiosperms account for 100 genera, 1 was gymnosperm while 8 were pteridophytes. There were 82 dicotyledons and 18 monocotyledons among the angiosperms.

A total of 221 plant species were recorded in the study area. There were 206 angiosperms, 2 gymnosperms and 13 pteridophytes among the 221 plant species. There were 169 species of dicotyledons and 37 species of monocotyledons among the angiosperms, making dicotyledons the majority (82.04%) and monocots the minority (17.96%)**.** 176 species were recorded within the core zone of the forest, including 162 angiosperms, 2 gymnosperms and 12 pteridophytes. The angiosperms were divided into 140 dicotyledons and 22 monocotyledons. There were 143 species found in the buffer zone, which include 132 angiosperms, 1 gymnosperm and 10 pteridophytes. There were 102 dicotyledons and 30 monocotyledons among the angiosperms.

Of the total 221 species of plants that have been identified, 111 species of trees account for 50.23% of the total recorded species, followed by 19 species of shrubs (8.60%), 36 species of herbs (16.29%), 28 species of climbers/lianas (12.67%), 10 species of canes and palms (4.52%), 9 species of grasses (4.07%) and 8 species of epiphytes (3.62%).

The trees were represented by 94 species, 77 genera and 37 families in the core zone .Fabaceae with 8 species and Lauraceae with 7 species are the two most dominant families in the core zone. Among the tree species, *Duabanga grandiflora* was the most dominant species with an IVI of 12.47. Shrubs were represented by 14 species, 14 genera and 14 different families. Most dominant species among shrubs were *Pandamus fascicularis*, *Chromolaena odorata* and *Schefflera venulosa.* These species account for 29.29 % of the total IVI. There were 26 species, 25 genera and 18 families of herbs. The most dominant species was *Diplazium maximum* with IVI of 20.68. Climbers were represented by 25 species, 23 genera and 16 families. *Millettia pachycarpa* had the highest density among the climbers. Canes and palms were represented by 7 species and 6 genera. The species with highest density was *Licuala peltata*. Epiphytes were represented by 7 species, 6 genera and 5 families. The species with the highest density was *Pyrrosia mannii* followed by *Drynaria propinqua*. Grasses were represented by 4 species and 4 genera. *Dinochloa compactiflora* was the species with the highest density.

The Shannon – Wiener diversity index (H') in the core zone was the highest amongst trees (4.16) followed by herbs (3.08) and shrubs (2.60). Pielou's evenness index (E) revealed that shrubs were the most evenly distributed among the three communities with E value of 0.98. Herbs had a slightly lower E value of 0.95 while trees had the lowest E value of 0.92. Simpson's Dominance Index (D) indicated that shrub community had the highest dominance index (0.08) followed by herbs (0.04) and trees (0.02). Trees had the highest species richness D_{mg} of 11.95 followed by herbs with D_{mg} of 3.87 while shrubs had the lowest species richness with D_{mg} of 2.34.

In the buffer zone, there were 143 species under 109 genera belonging to 76 families identified. Trees were represented by 63 species, 58 genera and 29 families. Fabaceae was the most dominant family with 8 species and 8 genera. 15 families were represented by 1 species each. Most dominant tree species in the buffer zone was *Neolamarckia cadamba* with an IVI value of 16.56. Shrubs were represented by 12 species, 12 genera and 12 different families. Most dominant species among shrubs was *Chassalia ophioxyloides* with IVI of 44.71. Herbs were represented by 28 species, 28 genera and 23 families. The species with the highest rank was *Mimosa pudica* with IVI of 17.46. There were 20 species, 19 genera and 16 families of climbers. Climbers with the highest density were *Bauhinia scandens*, *Merremia umbellata* and *Thladiantha cordifolia*. Canes and palms were represented by 8 species and 6 genera. The species with highest density was *Calamus erectus*. Epiphytes were represented by 5 species, 5 genera and 4 families. Species with the highest density was *Drynaria propinqua.* Grasses were represented by 7 species and 6 genera all belonging to the same family of Poaceae. The species with the highest density was *Melocanna baccifera*.

Within the buffer zone, Shannon – Wiener diversity index (H') was highest amongst the trees (3.85) followed by herbs (3.28) and shrubs (2.40). Pielou's evenness index indicated that herbs were the most evenly distributed among the three communities with E value of 0.97. Shrubs had a slightly lower E value of 0.96 while trees are the most unevenly distributed with E value of 0.93. The evenness value of the buffer zone was nearly identical to that of the core zone for all three plant communities. According to Simpson's dominance index (D), the shrub community had the highest dominance index of 0.08, followed by herbs with value of 0.04 and trees with value of 0.03. Margalef's index of richness was highest for trees with D_{mg} of 8.70. Followed by herbs with D_{mg} of 4.00 and shrubs had the lowest species richness with D_{mg} of 2.36.

The IUCN has assessed 68 of the 221 species that have been recorded. A total of 153 species were yet not assessed. Out of these one species is classified as Endangered i.e. *Prunus ceylanica* while *Saraca Asoca* is classified under Vulnerable category. Two species namely *Aglaia edulis* and *Clerodendrum trichotomum* are classed as Near Threatened.

The socio-economic survey through PRA techniques revealed the impact and high dependency on the forests of the study area by the fringing villages. Activities such as collection of timber, NTFPs, medicinal plants and clearing of lands for cultivation are the primary threats. Multi-temporal satellite images from the year 2006 - 2018 revealed that forest cover was 48.82 km^2 (97.64% coverage of study area) in 2006, which moderately declined to 48.17 km^2 (96.33% coverage; - 1.31% change) in 2012, losing 0.65 km^2 of forest cover. From 2012 to 2018, forest cover was further reduced to 43.59 km^2 (87.19% coverage; - 9.14% change) losing 4.58 km^2 of forest area. There was an overall 5.23 km^2 decrease in forest cover over the 12 years period. The local people must also be made aware to conserve and protect their natural resources from dwindling. Periodic monitoring with multi-temporal satellite observations also aided in the accurate estimation of change in forest areas and can provide critical information. This research work will be useful in formulating future forest monitoring and management plans.