ASSESSMENT AND MAPPING OF PLANT DIVERSITY OF JAPFÜ MOUNTAIN ECOSYSTEM, NAGALAND.

BY

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JUNE 2018

DECLARATION

I, Ms. **Kikruneino Sachü**, bearing Registration Number 536/2013, dated 18th June 2013 hereby, declare that the subject matter of my thesis entitled " **Assessment and Mapping of Plant Diversity of Japfü Mountain Ecosystem, Nagaland"** is the record of work done by me, and that the contents of this thesis did not form the basis for award of any degree to me or to anybody else to the best of my knowledge. The thesis has not been submitted by me for any research degree in any other University/ Institute.

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CERTIFICATE

The thesis entitled **"Assessment and Mapping of Plant Diversity of Japfü Mountain Ecosystem, Nagaland"** submitted by Ms. Kikruneino Sachü, bearing Registration No. 536/2013, dated 18th June, 2013 embodies the results of investigations carried out by her under my supervision and guidance.

Further, certified that this work has not been submitted for any degree elsewhere and that the candidate has fulfilled all conditions laid down by the University.

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CHAPTER I

INTRODUCTION

The term 'biological diversity' was first coined by A.E Norse and R.E McManus in 1980 and its shortened form 'biodiversity' was first used by Walter G Rosen in 1985 (Sharma, 2012). Biodiversity is defined "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (CBD, 1992). Biodiversity can be described in three levels i.e., genetic, species and ecosystem diversity. Whittaker (1972) introduced the idea of measuring biodiversity over spatial scales as alpha, beta and gamma diversity. Alpha diversity means the diversity of species within a specific habitat or ecosystem, beta diversity is the rate of change in species with a change in spatial scale and gamma diversity is the overall diversity of species in a region i.e., sum of alpha and beta diversity. Biodiversity of an area can also be measured in terms of species richness, evenness or differences in the abundance of the species from each other in a community. Species richness is the number of species present in an area and it is highly influenced by the sample size. It gives equal weight to both rare species and commonly found species in the region. Species evenness is the distribution of individuals among the species in an area. Species of a region are considered to be evenly distributed if all species are equally represented.

Mathematical measure of species diversity in a community is calculated using biodiversity indices. It provides information regarding species composition like how rare or common a species is in the community. It also gives the relative abundance of different species. Study of distribution of individual species and their different girth classes, association between species, patterns of dispersion and biodiversity indices are important for understanding the structure of forest community (Longman and Jenk, 1987). Diversity indices generally used to assess the diversity status of an area are Shannon-Weiner's diversity index, Pielou's evenness index, Simpson's dominance index and Whittaker's richness index.

Phytosociology is the quantitative study of vegetation which aims to describe the vegetation, explain or predict its pattern and classify it in a meaningful way. The term "Phytosociology" and its fundamental concept and methods were developed by Josias Braun-Braunquet (1964). Phytosociological study of vegetation is prerequisite for understanding the community structure and organisation. Next to floristic composition, study of life form is an important aspect of vegetation description (Cain, 1950). Life form is commonly defined as the sum of adaptation of plant to climate (Humbolt, 1805). Raunkiaer (1934) used life forms to describe the physiognomy of vegetation of an area. Life form spectra shows the structure of vegetation and also indicates the micro and macro climate of an area (Shimwell, 1971). Vegetation and soils are mutually associated with each other as both are the result of the same environmental variables (Hironaka *et al.,* 1990).

Remote sensing and GIS are important tools used for mapping and monitoring biodiversity across large spatial scales. Remote sensing and GIS can be used to obtain information on the plant richness, dominance, fragmentation, patchiness and patch density at landscape level. Remote sensing is particularly important in mapping of biodiversity in mountainous regions which are inaccessible due to steep slopes, high altitude, overall terrain conditions and seasonal hazards. Normalized difference vegetation index (NDVI) measures vegetation density and condition based on the spectral signature of plants. NDVI is also a useful predictor of difference in species richness in a region (Gould, 2000).

The main setback with the use of remote sensing in biodiversity characterization is the identification of species, as we can see only the crown in the air borne or space borne data (Jayakumar *et. al*., 2011). The details such as the species composition and stand density of forest can be obtained only through field floristic sampling studies. Mapping and assessment of plant diversity thus requires the use of both the information collected at the field level as well as from the remote sensor.

Mountains occupy 24% of the global land surface and directly support 12% of the world's population who live within mountain regions (Sharma *et. al*., 2010). Mountains harbor an exceptionally high level of biodiversity, which is the result of diverse habitats produced by different climatic zones present at different altitudes. However, mountain ecosystems are among the most fragile in the world and are under severe threat from climate change, urbanization, invasive alien species and other anthropogenic changes. Considering the vulnerability of mountain biodiversity and its importance in maintaining the global environment and supporting economic, cultural and social sectors, the global community recognized the value of mountains at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992 and the World Summit on Sustainable Development (WSSD) in Johannesburg in 2002 (Chettri *et. al*., 2012).

India is one of the worlds 17 mega diverse countries with 10 biogeographic zones (CBD, 2014). India has rich diversity of plants and represents about 11.8% of the world's flora and 7% of the world's known flowering plant species. About 30% of the plant species are reported to be endemic. Four of the 39 biodiversity hotspots namely the Himalaya, Indo-Burma, the Western Ghats and Sri Lanka and Sundaland are represented in India. Northeast India is part of the Indo-Burma biodiversity hotspot (Myers *et al*., 2000) therefore it is one of the most biodiversity rich regions of the world however more vulnerable to anthropogenic activities. Nearly 50% of Indian flora is confined to this region (Rao, 1994). Northeast India has high endemism of plant species. About 52% (7000 species) of the total plant species are endemic to the region (CBD, 2014). This region represents the transition between the Indian, Indo-Malayan, Indo-Chinese phytosociological region as well as a meeting place of Himalayan mountains with that of Peninsular India. Therefore, Northeast region is considered as the biogeographical gateway for plant migration. Many primitive plants are found in Northeast region, therefore Takhtajan (1969) has referred to this region as the 'cradle of flowering plants'.

Nagaland is part of Northeast India and therefore falls within the Indo-Burma Biodiversity hotspot. Nagaland has indigenous tribal population with 17 major tribes and more than 25 language groups co-exist within the state. It is well known for its rich culture and indigenous knowledge. The state has a geographical area of 16,579 km sq and 72.22% of its total area is covered by forest (FSI, 2015). It has a wide altitudinal variation ranging from 194 m to 3826 m which led to formation of different types of forest from Tropical forest at lower elevations to Temperate and Alpine forest at high elevations. Nagaland being a hilly region, most of the plant diversity is conserved in the mountain ecosystems.

Kohima is one of the 11 districts of Nagaland and is inhabited by the two major tribes of Nagas namely Angami and Rengma. The total forest area of Kohima district is 2,863 km^2 which is 87.21% of the total geographical area (FSI, 2015). The climatic conditions in the district ranges from sub tropical to sub alpine. Kohima district has Pulie-Badze Wildlife Sanctuary in Jotsoma village, Biodiversity Reserved Area in Kigwema village and Nature Conservation and Tragopan Sanctuary in Khonoma village. Mt. Japfü is the second highest mountain of Nagaland and it is located 15 km south of Kohima town. The tallest *Rhododendron arboreum* featured in the Guinness Book of World Records is found in the Japfü mountain range. The forest area comes under the community forest of three Angami villages namely Kigwema, Jotsoma and Phesama. To conserve the rich biodiversity of the region, Kigwema village council has marked the area as Biodiversity Reserved Area and certain laws has been implemented which prohibits hunting, fishing, logging and exploitation of bioresources and the defaulters are imposed fines.

Mao *et al.* (2016) from BSI has reported 2239 species of plants from Nagaland.Earlier workers such as Clarke (1983), Jamir and Rao (1988), Deb and Imchen (2008) and Mao and Gogoi (2012) have contributed to the flora of the present study area. Very few studies has been done on plant diversity assessment and phytosociology of Nagaland forests. Mao *et al.* (2009) studied the distribution pattern of *Rhododendron* in Manipur and Nagaland. Jamir (2011) has studied the diversity and phytosociology of four community forests of Nagaland and Chase (2016) studied the phytosociology of the forest of Khonoma village of Nagaland.

Use of satellite imagery is the latest trend in mapping of biodiversity today. However till date no studies have been conducted on mapping of plant diversity using GIS and Remote Sensing in Nagaland. The proposed study on assessment and mapping of plant diversity of Japfü mountain ecosystem has been chosen considering the importance of mountain ecosystem which is among the most fragile environment yet supports a rich variety of plants. The present study could contribute in formulating plans for conserving native vegetation in Mt. Japfü. Much research and assessment are needed for study of plants in mountain areas so as to create awareness of the significance of biodiversity and to reduce the loss of biodiversity in the mountains.

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LITERATURE REVIEW

PLANT DIVERSITY OF INDIA

India is one of the worlds 17 mega diverse countries with 10 biogeographic zones (CBD, 2014). Four of the 39 biodiversity hotspots namely the Himalaya, Indo-Burma, the Western Ghats and Sri Lanka and Sundaland are found in India. The diverse climatic conditions and topography have resulted to rich biodiversity in the region. About 30% of the plant species are reported to be endemic. Most of the endemic and endangered species are known to occur in 24 critical plant sites which may be termed as micro hotspots (Nayar, 1997). Champion and Seth (1968) classified the forests of India into 16 types.

Sir J.D. Hooker (1872-1897) was one of the first to work on the flora of India. He recorded 14,312 species of flowering plants under 2,325 generea and 171 families. Brandis (1874) described 700 tree and shrub species of North West and Central India. Tablot (1894) collected 869 plants from southern part of Bombay Presidency. Collet (1902) recorded 1326 species of plants in Shimla. Theodare Cooke (1958) worked on the flora of Bombay. Gamble and Fischer (1915-1936) reported 4516 plant species from Indian Peninsular region. Bor (1960) studied the grass flora of Burma, Ceylon, India and Pakistan and described 1243 species. Ramaswamy and Razi (1973) documented 979 species of Angiosperm from Bangalore. Bhandari (1978) assessed the flora of Indian Desert, Majumdar (1979) carried out the study of flora of Rajasthan and Jain (1986) assessed the grass flora of India. Misra (1990) recorded the orchids of Orissa and Karthideya. Dhaliwal and Sharma (1999) studied the flora of Kullu district, Himachal Pradesh and recorded 930 species of plants. Murti (2001) explored the flora of North-West Himalaya and described 347 species of monocots. Joshi *et al.* (2004) collected 109 species of fern from Chamoli district of Garhwal Himalaya. Mao *et al.* (2016) from BSI has reported that over 48,158 species of flora are found in India out of which 18,259 species are Angiosperms, 1,288 species of Pteridophytes and 78 species are Gymnosperms.

PLANT DIVERSITY OF N.E. INDIA

Northeast India comprises of eight states namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. The region is part of the Indo-Burma biodiversity hotspot (Myers *et al.*, 2000) therefore it is one of the most biodiversity rich regions of the world however more vulnerable to anthropogenic activities. N.E. region represent the transition zone between the Indian, Indo-Malayan and Indo-Chinese biogeographical regions as well as a meeting place of Himalayan mountains with that of Peninsular India (Rao, 1994). The region is therefore known as the biogeographic gateway for plant migration. The region is estimated to have about 13,500 vascular plant species of which 7,000 (52%) are endemic (CBD, 2014). The region is known as the centre of rice germplasm, centre of origin of Citrus, Musa, centre of genetic diversity for *Bambusa, Dendrocalamus, Arundinaria* and *Cephalostachym*. National Bureau of Plant Genetic Resources also identified the region as rich in wild relatives of crop plants. Takhtajan in 1969 has referred to N.E. India as the cradle of flowering plants due to the presence of a great number of primitive flowering plants. Northeast India is also one of the richest repositories of medicinal and aromatic plants in the world (Chakraborty *et al.,* 2012).

Biswas (1941) wrote the flora of Aka hills, Bor (1942) worked on the flora of Naga and Khasi hills, Haridasan and Rao (1986) on the flora of Meghalaya, Kanjilal *et al.* (1934-40) on flora of Assam, Kataki *et al.* (1984) distribution of orchids in Sikkim and N.E India and Deb (1981, 1983) on flora of Tripura. Others workers who have contributed to the flora of North eastern states are; Bhattacharya and Dutta (1956) have described 52 taxa of Citrus and 5 probable hybrids from Assam, Zeven and Zhukovsky (1975) estimated over 50 economic plant species have their genetic diversity in N.E. region, 350 species of ferns have been recorded from Meghalaya and Nagaland by Baishya and Rao (1982) and Jamir and Rao (1985). Rao (1981), Rao and Jamir (1982) and Rao and Haridasan (1991) have documented numerous medicinal plants from this region. Haridasan and Rao (1987) recorded the flora of Meghalaya. Biswas (1988) stated that 15 genera and 63 species of bamboo are found in East Himalaya. Haridasan and Hedge (1991) reported 35 species of Hedychium in

East Himalaya. Handique (2009) documented 751 species of medicinal plants from Northeast India. Chowdhery (2009) recorded 856 species of orchid from Northeast India out of which 34 species are threatened plants (Nayar and Sastry, 1990, Ahmedullah *et al.,* 1999) and 85 species are endemic (Das and Deori, 1983).

PLANT DIVERSITY OF NAGALAND

The state of Nagaland harbors a very rich floristic diversity, however there is no complete flora of the state. Champion and Seth (1968) recognized six types of forest in Nagaland viz. Northern Tropical Wet Evergreen forests, Northern Tropical Semi Evergreen Forests, northern sub tropical broad leaved wet hill forests, northern sub tropical pine forests, northern montane wet temperate forests and temperate forests. The Forest Survey of India (2015) reported that the total forest cover of the state is 12,966 km^2 which is 78.22% of its geographical area.

Masters (1844, 1848) was the first who remark on the flora of the Naga Hills. Hooker (1872-1897) also mentioned plants of Naga hills on his book 'The Flora of British India'. Sir George Watt, the first economic Botanist of British India surveyed and collected plants of Nagaland and Manipur from 1882-1885 (Watt, 1889). Frank Kingdon-Ward, a British explorer also collected plants from the hills of Nagaland and Manipur bordering Myanmar (Kingdon-Ward, 1949, 1960). Kanjilal *et al.* (1934-40) studied the flora of Assam which included the low laying Naga hills adjoining Assam valley. Clarke (1983) collected 1,050 species of plants from Kohima and Manipur. He also remarked that the flora of Nagaland closely resemble with that of Sikkim. Hynniewta (1999) reported that the flowering plants of the state are represented by 2,431 species belonging to 963 genera and 186 families. Mao *et al*. (2016) from BSI reported 2,239 species of plants from Nagaland out of which 278 species were Pteridophytes, 1,243 species Dicotyledons, 6 Gymnosperms and 712 Monocotyledons. Jamir and Rao (1988) collected and studied 280 species of Pteridophytes belonging to 98 genera and 37 families. Singh and Sinha (1994) worked on the lichen flora of Nagaland and reported 346 species under 86 genera. Deb and Imchen (2008) studied the flora of orchid of Nagaland and documented 396 species of orchid under 92 genera. Chankija *et al*. (2010) enumerated 656 species of medicinal and aromatic plants of Nagaland. Mao and Gogoi (2012) reported 11 taxa of *Rhododendron* from Nagaland and Manipur. Jamir *et. al*. (2012) described 52 plant species under 32 families traditionally used for medicinal purpose by the Nagas. Lanusunep and Jamir (2015) recorded a total of 312 medicinal plant species from the state which belongs to 120 families and 254 genera.

Gurung and Tripathi (2004) recorded 56 species of orchids belonging to 28 genera from Mokokchung district, Nagaland. Mao and Gogoi (2010) studied the flora of dzukou valley, Kohima and recorded 332 species belonging to 223 genera and 113 families. Rongsensashi and Chankija (2015) enumerated a total of 656 species of plants from Fakim wildlife sanctuary. Moaakum and Chaturvedi (2015) documented a total of 656 taxa of flowering plants belonging to 377 genera and 101 families from Zunheboto district of Nagaland. Mozhui and Chankija (2016) recorded a total of 523 plant species from Dimapur district. Jamir (2011) studied the plant diversity of four community forest of Nagaland *viz* Akhoya, Khonoma, Longkhum, Mangkolemba and recorded 520 plant species. Jamir *et al.* (2010) documented 55 medicinal plants used by Lotha Naga tribes in Wokha district of Nagaland. Imchen and Jamir (2011) studied 66 species of ethnomedicinal plants used by Phom-Naga tribes of Nagaland. Sangtam *et al*. (2012) documented 53 species of medicinal plants used by the Sangtam Nagas in Kiphire district. Panda (2012) reported 30 taxa of Ericaceae from Tuensang district of Nagaland, of which 25 were collected from Mt. Saramati. Jamir *et al*. (2015) reported 3 new records of orchids from Intangki National Park, Nagaland. Chase and Singh (2013, 2016) reported 64 medicinal herbs used by Angami Naga tribe and 57 wild fruits from Khonoma community forest. Jamir *et al.* (2016) studied 56 species of ethnomedicinal plants utilized by the Chang Naga tribes from Tuensang district. Santanu *et al.* (2014) recorded new species of *Musa nagalandiana* from Zunheboto district and Odyuo *et al.* (2017) also reported a new species *Gleadovia Konyakianorum* from Mon district.

PHYTOSOCIOLOGICAL STUDIES

Phytosociology is the quantitative study of vegetation in an area. Josias Braun-Blanquet (1964) was the first to develop the fundamental concepts, methods and terminology of phytosociology. Phytosociological investigations involves measurements of analytical characters such as frequency, density, abundance, basal area and Importance value index (IVI). The concept of IVI was developed by Curtis and McIntosh (1951), Curtis (1959) and Phillips (1959). IVI expresses the dominance of a species in a plant community. As there is a relationship of species to area, Cain (1932) suggested different sizes of study units/ quadrats in ecological studies. Phytosociological study not only describes the vegetation but also predict its pattern and classify it in a meaningful way (Llorkar and Khatin, 2003). The principal goals of phytosociology are the delimitation and characterization of vegetation types based on the complete floristic composition (Jürgen Dengler, 2017).

Whittaker (1956) studied the vegetation of the great smoky mountains with the aim to use the complex patterns of natural communities for research into the theory of community units or associations. Mishra (1968) developed several methods for phytosociological analysis based on objectives of study, topography and types of vegetation. Gaaur *et al.* (1985) studied the community structure of plants in Garhwal Himalaya. Joshi and Tiwari (1990) suggested that the variation in distribution pattern across the slopes and vegetation strata is associated with multiple factors specially micro-environment and biotic. Rawal *et al.* (1994) identified different forest communities within the Pindari region of Kumaun Himalaya and suggested that the vegetation types overlap along the elevational gradient. Gilbert and Lechowicz (2004) studied the niches and distribution of species in temperate forest. They reported that although environmental factors are important in determining distribution of all plant groups, different plant groups are not affected equally by various environmental gradients. Carpenter (2005) analysed the species density of Nepal Himalayas forest and reported that the patterns of leafing phenology on the elevation gradient supports the hypothesis of environmental control of species density. Mishra *et al.* (2005) studied the two climax sub tropical humid forest of

Meghalaya and revealed that contagious distribution was prevalent in both forests. Ahmed *et al.* (2006) conducted a phytosociological survey in different climatic zones of Himalaya, Pakistan and reported 24 diverse communities and 4 monospecific forest vegetations. Sahu *et al*. (2007) analyzed the deciduous forests of Boudh district, Orissa and concluded that tree height are heavily influenced by the abundance of saplings, richness of nutrients and anthropogenic pressures. Phytosociological analysis of Kishtwar district, Jammu & Kashmir was done by Kumar and Raina (2012) which reported the high species richness and evenness of trees and shrubs whereas herbaceous vegetation was found to be low. Bhatti *et al.* (2014) studied the herbaceous plant community in Yusmarg forest, Kashmir. Mukherjee and Sarma (2014) analysed the community structure of plants in Okhla bird sanctuary, Delhi. Sarkar (2015) carried out a study to investigate the composition and biodiversity status of tree species of Moraghat forest range. Phytosociological studies were carried out in four community based religious conserved forests of Garwhal himalaya by Pala *et al.* (2016). Dolezal *et al*. (2016) studied the vegetation dynamics of vascular plants in Himalaya and found that climate change in the arid Himalayas produces a complex pattern of plant responses which involves an uphill migration due to warming and vegetation decline due to increased precipitation and soil disturbance. Sheikh *et al.* (2017) phytosociologically analyzed the tree and shrubs of sacred grove 'Siddhkho' in Gwalior district of Madhya Pradesh.

BIODIVERSITY INDICES

Species diversity is one of the most widely used measurement for assessing patterns and process of biodiversity at both ecological and biogeographic scales (Chiarucci *et al.,* 2011). Diversity indices takes into account the number of species present as well as the abundance of each species (Gibson and Gibson, 2006). Indices aim to describe common properties of communities that allow us to compare different regions, taxa and trophic levels (Morris *et al*., 2014). Diversity and dominance indices are useful and convenient for quantification of diversity and comparison of species diversities between different ecosystems in various climatic conditions (Mcdash, 1998). Diversity in all its dimensions and facets cannot be captured by a single definition or mathematical formalism (Joust, 2006). Griffiths *et al.* (2000) suggested a positive relationship between species diversity, richness and ecosystem stability while Pfisterer and Schmidt (2002) reported a negative one. Species diversity of a community is determined by the number of different species (richness) and the relative numbers of individuals in each species (evenness) (Gibson and Gibson, 2006). Evenness is the degree of which individuals are divided among species. Low values of evenness indicate that one or a few species dominate and high values indicate that relatively equal numbers of individuals belong to each species (Morris *et al.,* 2014).

Considering links between biomass and biodiversity in different climates, Tilman and Pacala (1993) observed that biomass increases with biodiversity initially to a certain point in temperate herbaceous community. Ojeda *et al.* (2000) described the patterns and quantified the levels of plant biodiversity in Ajibe mountains. Paramathma *et al.* (2002) reported that the herbaceous species in Eastern Ghat of Tamil Nadu shows dominance in Shannon-Wiener and Simpson indices than that of all life forms. Upadhaya *et al.* (2003) investigated the tree diversity in sacred groves of Jaintia hills, Meghalaya. Kromer *et al.* (2005) studied the elevational patterns of epiphytes species richness in the Andes and found that richness declines at high elevations as a result of extreme climatic conditions. Chiarucci and Bonini (2005) assessed the plant diversity if Tuscan forests and found that species richness was unimodally linked to elevation and negatively related to tree stem density and total basal area. Kumar *et al.* (2006) stated that the study of species diversity and distribution pattern is important to understand the complexity and assess the resources of forests. Devi and Yadava (2006) studied the diversity of *Dipterocarpus tuberculatus* dominated forest of Manipur and reported that shrubs and herbs were more diverse than trees but concentration of dominance was recorded highest in tree species. Pant and Samant (2007) studied the diversity and distribution pattern of plant species in Mornaula reserve forest, Himachal Pradesh. Baneija (2010) observed that species richness and distribution patterns are highly scale dependent at all levels of spatio-temporal gradients. Qian *et al.* (2011) reported that species diversity and evenness indices show increase in elevation while dominance indices decreases then increases with elevation. Sobrej and Rahman (2011) assessed the quantitative structure and diversity of trees, shrubs and herbs in Khadimnagar National Park, Bangladesh. Zaara kidwai (2013) analyzed species richness, diversity, basal cover and importance value index of the vegetation in Sariska National Park, Rajasthan. Rao (2015) studied tree species diversity of Khamman District, Telangana. Dar and Sundarapandian (2016) studied the plant biodiversity patterns in seven temperate forest types of Western Himalayas. Tambe and Rawat (2016) studied the alpine vegetation of Khangchenzonga National Park and reported that the dry alpine zone in the northern part showed higher levels of alpha diversity when compared to the moist alpine zone in the southern and central part.

LIFE FORM

Humbolt (1805) defined life form as the sum of adaptation of plant to climate. Shimwell (1971) stated that life form spectra are the indicators of micro and macro climate. It is important to study the floristic compositions and life forms of different plants to find out phytoclimatic zones of the area (Dabgar *et al.*, 2010). Warming (1909) described life form as the sum of adaptive characters in a species and thus it is an expression of the harmony between plants and its environment. In 1934, Raunkiaer classified plant life forms based on the position and degree of protection of the perennating organs in relation to soil surface. Mueller - Dombois and Ellenberg (1974) modified Raunkiaer's classification and included plants features in the favourable season. Raunkiaer (1934) also proposed the 'biological spectrum' to describe the life-form distribution in a flora as well as the phytoclimate under which the prevailing life forms evolved. Normal spectrum was used as a null model to compare against different life form spectra.

Bhattarai and Vetaas (2003) found that only woody life forms had significant relationship with climate along the elevation gradient in the Himalayas. Batalha and Martin (2004) used the Raunkiaer's system to classify life forms of vascular plants in

Cerrado, Brazil. The study found that the floristic and frequency spectra were similar but both differed from the vegetation spectrum. Study of life form spectrum of Tuscan forests by Chiarucci and Bonini (2005) showed a decrease in abundance of phanerophytes and an increase of hemicryptophytes in relation to elevation. Jamir *et al.,* (2006) studied the life form composition and stratification in montane humid forest of Meghalaya and reported the dominance of phanerophytes and similarity of vegetation to humid broad leaved and subtropical forest of China. Dabgar *et al.* (2010) studied life forms of Visnagar Taluka, Gujarat and reported the dominance of therophytes as the area is semi arid zone. Rashid *et al.* (2011) studied the vegetation around Malam Jabba, Pakistan and concluded that therophytic, hemi cryptophytic and micro-nanophyllous leaf sizes life form are dominant in the area. Gazal and Raine (2013) analysed the vegetation of Ramnagar wildlife sanctuary, Jammu and Kashmir and found that therophytes were dominant which is influenced by biotic pressures in the area indicating a disturbed environmental condition.

SOIL, CLIMATE - PLANT RELATIONSHIP

The interaction between the plant community and the abiotic environment of the habitat (climate, soil and light) forms an ecosystem (Gibson, 2006). Jenny (1980) also stated that soil is generally the largest repository for most nutrient elements in the ecosystem and the direct recipient of inputs from weathering. Soil fertility also affects species diversity of tropical forest plants (Wright, 1992). An inverse relation has been reported between tree species diversity and soil fertility in Costa Rica and Ghana (Huston 1980, 1994). Grime (1979) stated that species richness and nutrient availability in soil have a relationship. Tilman (1982) made observations which showed that species richness is low when nutrient is poor and species richness increases to a peak at intermediate levels and then declines at high nutrient level. In depth knowledge of local soil characteristics are associated soil biology is essential for a better prediction and management of long term potentiality of forest (Rahman *et al.,* 2012).

Soil organic carbon content generally depicts soil fertility. Swift *et al.* (1979) and Cadish and Giller (1997) stated that the change from dead organic matter into carbon dioxide and inorganic nutrients available for plant and microbial uptake is a fundamentally important ecosystem process. Carbon storage appears to be indirectly influenced by plant biodiversity through the changes of nutrients or water availability and by quality, quantity and distribution of leaf and root litter (Langley and Hungate, 2003).

Soil is one of the vital medium of regulating forest ecosystem processes of nutrient uptake, decomposition, water availability etc which is very important for plant community. At the same time flora is one of the important factors responsible for creation of new soil as leaves and other vegetation decompose after expiry of their living cycle. Forest and forest soils interact in a manner which creates and helps in maintaining the environmental conditions, including microclimate (FSI, 2015). Ecosystem functioning depends on recycled nutrients from decomposition. The chemical and physical properties of plant litter have a major influence on nutrient cycling and accumulation of soil organic matter within a particular ecosystem, and hence on the properties and functioning of that ecosystem (Hattenschwiler *et al.,* 2005). The effects of mixed tree species on the nutrient balance and sustainability of forests play a major role in forestry research and it is expected that species composition influences litter quality, nutrient availability and decomposition of organic matter (Vesterdal and Raulund- Rasmussen, 1998; Prescott *et al.,* 2000; Rothe and Binkley, 2001; Berger *et al*., 2002; Prescott, 2002).

Perakis and Sinkhorn (2011) studied the soil nitrogen gradient in temperate forest of Oregon coast Range, USA and concluded that unpolluted temperate forests accumulate sufficient soil nitrogen to foster excess nitrogen availability and disequilibrium in ecosystem nitrogen dynamic leading to elevated NO3- loss characteristic of nitrogen saturation. Sharma *et al.* (2009) studied the structure, composition and diversity of vegetation in relation to soil characteristics of temperate mixed broad leaved forest along an altitudinal gradient in Garwhal himalaya. The study revealed that the physico chemical properties of soils have shown that availability of higher average total nitrogen and moisture content might have given rise to higher total basal cover values at middle altitude. Braakhekke and Hooftman (1999) found that maximum species richness occur at intermediate values of the nutrient ratios N/P, P/K and K/N.

Camargo and Kapos (1995) investigated the influence of complex edge effect on soil moisture and vertical profiles of air vapour pressure deficit within the Amazon forest. James *et al.* (2003) suggested that the differences in the temporal heterogeneity of soil moisture content are related to resource uptake. Wang *et al.* (2012) studied soil moisture and evapo transpiration of different land cover types in Loiss Plateau China and concluded that the interactions between vegetation and soil moisture dynamics contribute to structure and function of the ecosystems.

pH is an environmental parameter related to nutrient and toxic element availability (Pausas and Austin, 2001). Vetaas (1997) reported that in the Himalayas, vascular plants, climbers and herbaceous species richness were positively related to pH. Janssens *et al.* (1998) reported that maximum number of species is found below the optimum soil phosphorus level for plant nutrition in European grassland and beyond this optimum species richness declines. Ma *et al.* (2014) studied soil moisture variability in temperate deciduous forest using ERI. Hector *et al.* (1999) stated that nitrate losses were reduced with diversity and also the rate of litter degradation increased with diversity. This shows that diversity of plants is important to maintain the productivity of a plant community (McDash, 1998).

Studies by Holdridge *et al.* (1971) and Hall and Swaine (1981) showed that a strong positive relationship is found between diversity and rainfall. Kharkwal *et al.* (2005) studied the plant diversity and growth form in relation to altitudinal gradient in central Himalayan region of India and concluded that species richness and distribution pattern mainly depend on altitude and climatic variables like rainfall and temperature. Richerson and Lum (1980) stated that plant species richness and rainfall showed a positive logarithmic relationship in California. Rainfall was accounted as the environmental variable with the greatest variance in species richness in their study. Leathwick *et al.* (1998) analysed the tree species richness patterns in New Zealand and found that humidity is the second most important predictor of species richness after temperature. Knight *et al.* (1982) reported a positive relationship between tree species diversity and temperature in South Africa. Austin *et al.* (1996) also reported an increase in richness of tree species with increase in temperature in New South Wales forest. Pausas and Austin (2001) stated that the existence of environmental or resource heterogeneity may create high niche diversity and hence allow species to coexist at a large spatial scale. Schneir and Benayas (1994) suggested that climate variability and landscape heterogeneity are important factors which explains species diversity at landscape level. Climate determines the type of forest present in an area (Kimmins, 1997). In temperate regions, the northern limit of warm temperate evergreen trees is mainly determined by low temperature , most probably by absolute minimum (Yoshioka, 1963; Sakai, 1975). Kershaw (1973) stated that an environmental pattern in vegetation is developed in response to a general and overall variation of any major environmental factors, so much so that extremely small variations in them are capable of producing a corresponding variation in vegetation. Acharya *et al.* (2011) assessed the effect of climatic variables on orchid species richness and found that more number of terrestrial orchids occurred at higher elevations. Pausus and Austin (2001) emphasized on the need to understand species richness patterns in relations to the environment before drawing conclusions on the effect of biodiversity in ecosystem processes.

REMOTE SENSING AND GIS

With the use of high resolution satellite imageries and GIS, biodiversity rich regions can be identified and studied in both time and space. Many studies have been carried out all over the world on various aspects of biodiversity assessment and mapping using GIS and Remote Sensing. The earlier studies on biodiversity mapping have been done by workers like Barret and Curtis (1982), Cohen *et al.* (1990), Everitt *et al.* (1991), Brossard and Joly (1994), and McGraw *et al.* (1998). Currie (1993) studies have dealt with the relationship between richness patterns and various ecological, geographical or other factors. Fuller *et al.* (1998) used field surveys of plant and animals with satellite remote sensing of broad vegetation types to map biodiversity and plan conservation strategy in Sango Bay area. Recent studies have been done by Gould (2000) on remote sensing of vegetation, Miller and Rogan (2007) on ecological mapping using GIS and Remote Sensing, Carlson *et al.* (2007) on use of Remote Sensing on canopy biodiversity in Hawaii. Gilbert *et al.* (2010) mapped forest plot in a mixed species Mediterranean zone forest in California to compare the patterns of diversity and structure with other tropical and temperate forests. Dufour (2006) used high resolution remotely sensed data to assess the environmental heterogeneity and patterns of species richness of Swiss Jura mountains. Hasmadi *et al.* (2010) studied the diverse tropical forest of mount Tahan, Malaysia and mapped the vegetation using GIS. Mapping of plants or vegetation nowadays come from three types of approaches; a phytosociological basis, the use of remote sensing and GIS, and multi scale approach including landscape ecology (Hasmadi *et al.,* 2010). Aranha *et al.* (2008) used satellite imagery in association with field methods to develop prediction models for estimating biomass from forested and shrub lands. Wildi (2008) presented a detailed descriptions of classification methods to analyze plants and vegetation data's. Walker *et al.* (1992) correlated plant species richness to aggregated NDVI in California. Many studies have shown that NDVI integrates the influence of climatic variables and other environmental factors (Cihlar *et al.,* 1991).

Hyperspectral data can be used to record information pertaining to a range of critical plant properties including leaf pigment, water content and chemical composition (Curran, 1989; Martin and Aber, 1997; Townsend *et al.,* 2008). Hyperspectral data is also used to document information related to species identity and can be very effectively used for discriminating tree species in tropical forests, despite the greater complexity of such environments (Nagendra and Rocchini, 2008). High spatial resolution satellite sensors like IKONOS, QuickBird and Orb View-3 as well as high spectral resolution sensors such as Hyperion provides researchers the opportunity to study the ecological systems at far greater detail than previously possible (Levin *et al.,* 2007; Rocchini, 2007). Field surveys provide higher levels of accuracy than remote sensing but use of remote sensing techniques makes it easier to can analyse a landscape at greater speed and frequency (Steininger and Horning, 2007). In mountainous areas, rugged topography adds further complexity to image interpretation primarily because of shading, which in some areas can be quite severe (Strittholt and streininger, 2007). Remote sensing has become an important tool for evaluating forest ecosystems at multiple spatial and temporal scales to examine and monitor forest composition, structure and function (Kerr and Ostrovsky, 2003). Remote sensing and GIS together can provide information about landscape history, topography, soil, rainfall, temperature and other climatic condition on which the distribution of species depend (Noss, 1996).

In India, studies of biodiversity assessment and mapping using Remote Sensing have been done by workers like Nagendra and Gadgil (1999) on biodiversity assessment using remote sensing and field data, Nagendra (2000) on assessment of biodiversity, Roy *et al.* (2002) on development of BIS for Northeast India using GIS, Roy and Behera (2002) used GIS and GPS technique to assess the disturbed and biologically rich sites, Vijayarahavan and Sundaramoorthy (2004) on hyperspectral analysis of trees and shrubs in semi arid region. Shi and Singh (2002) assessed the status of world's remaining closed forests (WRCF), population distribution and protected areas in global biodiversity hotspots using remote sensing and GIS. The study identified and quantified relationships between the WRCF, human population and protected areas in biodiversity hotspots. Roy and Behera (2005) used remote sensing to assessed the biological richness at landscape level in Eastern Himalaya, Arunachal Pradesh. Nagendra and Rocchini (2008) on use of satellite imagery in tropical biodiversity studies. Parviainen *et al.* (2010) studied the NDVI based productivity and heterogeneity as indicators of plant species richness in boreal landscapes. Tambe *et al.* (2011) studied forest type, density and change dynamic of Sikkim using satellite remote sensing data. Vijayarahavan and Sundaramoorthy (2012) on mapping of *Prosopis juliflora* using satellite data. Wang *et al.* (2016) studied the seasonal variation in NDVI and species richness in grasslands in Cedar Creek.

CHAPTER II

STUDY AREA

The study area Mt. Japfü is located in Kohima district of Nagaland state. Nagaland is situated in the north eastern part of India sharing international border with Myanmar. It lies between latitudes of 25°10'N and 27°04'N and longitudes of 93°15'E and 95°06'E and has geographical area of 16,579 km^2. Nagaland consists of a narrow strip of hilly area running northeast to southwest which is located in the northern extension of the Arakan Yoma ranges. Nagaland is predominantly a hilly area consisting of high, mid and low hills with limited plain area or foot hills. The terrain is mountainous and covered mostly by forest. The climate ranges from Tropical to Alpine with an altitude varying from 200 m to 3,800 m above sea level. The state is also blessed with rich biodiversity and is part of the Indo-Burma global biodiversity hotspot.

The state capital is Kohima, which is located at an elevated altitude of 1444.12m above sea level. The total geographical area of Kohima district is 3,283 km^2 and its total forest cover is 87.20% out of which 288 km^2 areas is composed of very dense forest, 1,146 km^2 moderate forest and 1,489 km^2 open forest. Geographically, it lies between 25°67' N latitude and 94°12' E longitude. Kohima lies north of the Japfü Barial intersection.

Nagaland has two important mountain systems namely the Patkai and the Barail mountain system. The Barail mountain system run in an east west direction and the highest peak of this mountain system is Mt. Japfü which stands 3048m above sea level. It is also the second highest mountain of Nagaland. Mt. Japfü is located 15 km away from the state capital, Kohima. The altitude of the study area ranges from 1900 m to 3048 m ASL and it lies at 25°35' 900"N and 94°04'075"E with total geographical area 4.5 km^2. It borders Dzukou valley and extends up to Manipur. The climate of the area is monsoon type with warm moist summer and cool dry winter. It is well known as the site for the world's tallest *Rhododendron arboreum* featured in Guinness Book of World Record. Japfü mountain range has patches of primary undisturbed forests. The vegetation type is Montane Wet Temperate forest on the slopes and Sub Alpine vegetation at the peak. The area of Mt. Japfü comes under the community forest of three villages of Angami tribe namely Kigwema, Jotsoma and Phesama. The villages at the foothills of the mountain are dependent on the natural resources of the forest. Japfü mountain range is a water catchment area and it is also the sole water source for cultivation and domestic use for the villages.

Angami village lands are mostly owned by individuals. Some lands belong to the clans and the common land of the village are considered as reserve forest area. The management of the common land is in the hands of the village councils. They enact laws relating to use of forest and its resources. The village councils prohibits logging, fishing and exploitation of bioresources in the community forests. Hunting is restricted only to few months in winter i.e., from December to February. Hefty fines are imposed to those who break the law.

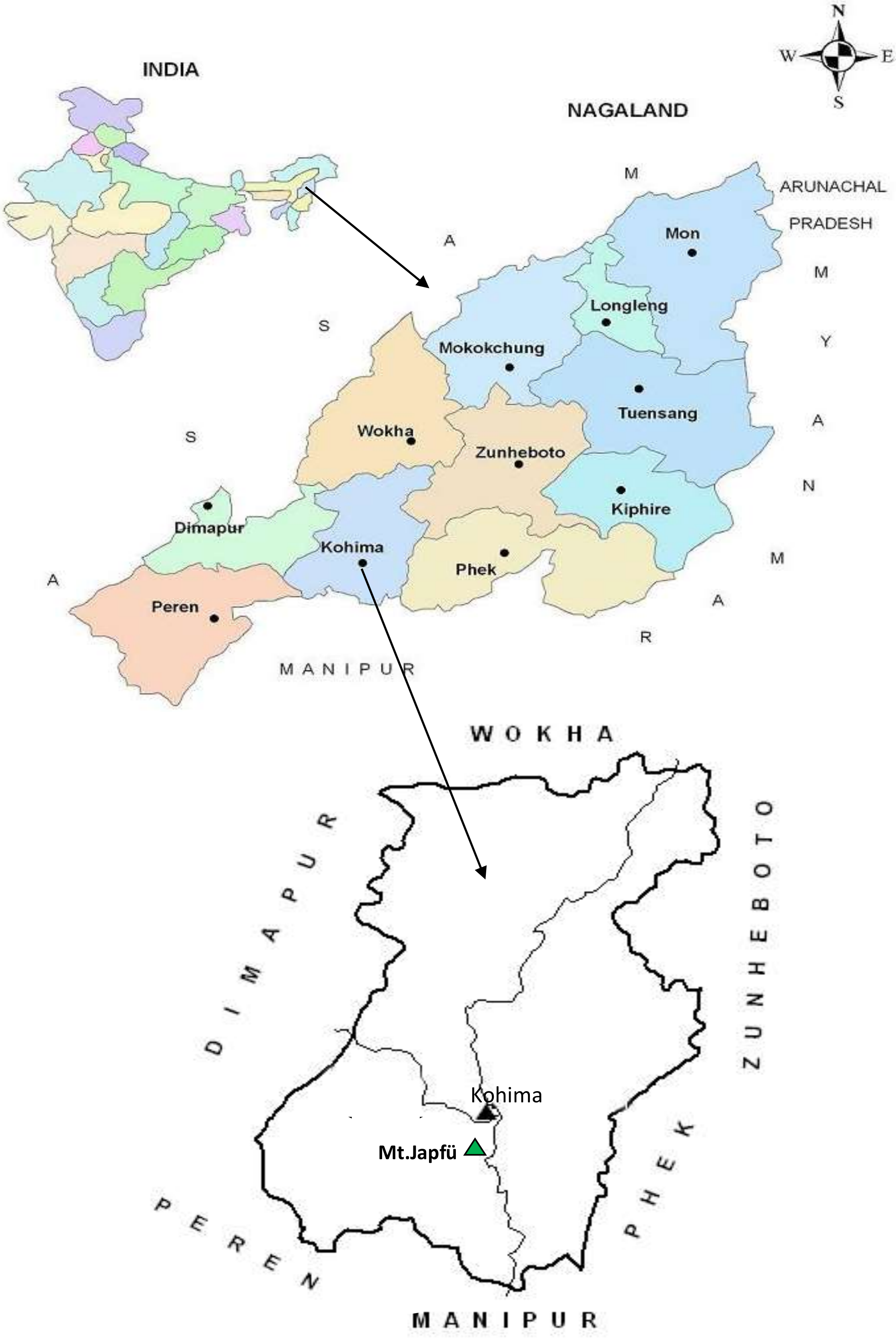

Fig. 2.1: Map showing location of Study Area △

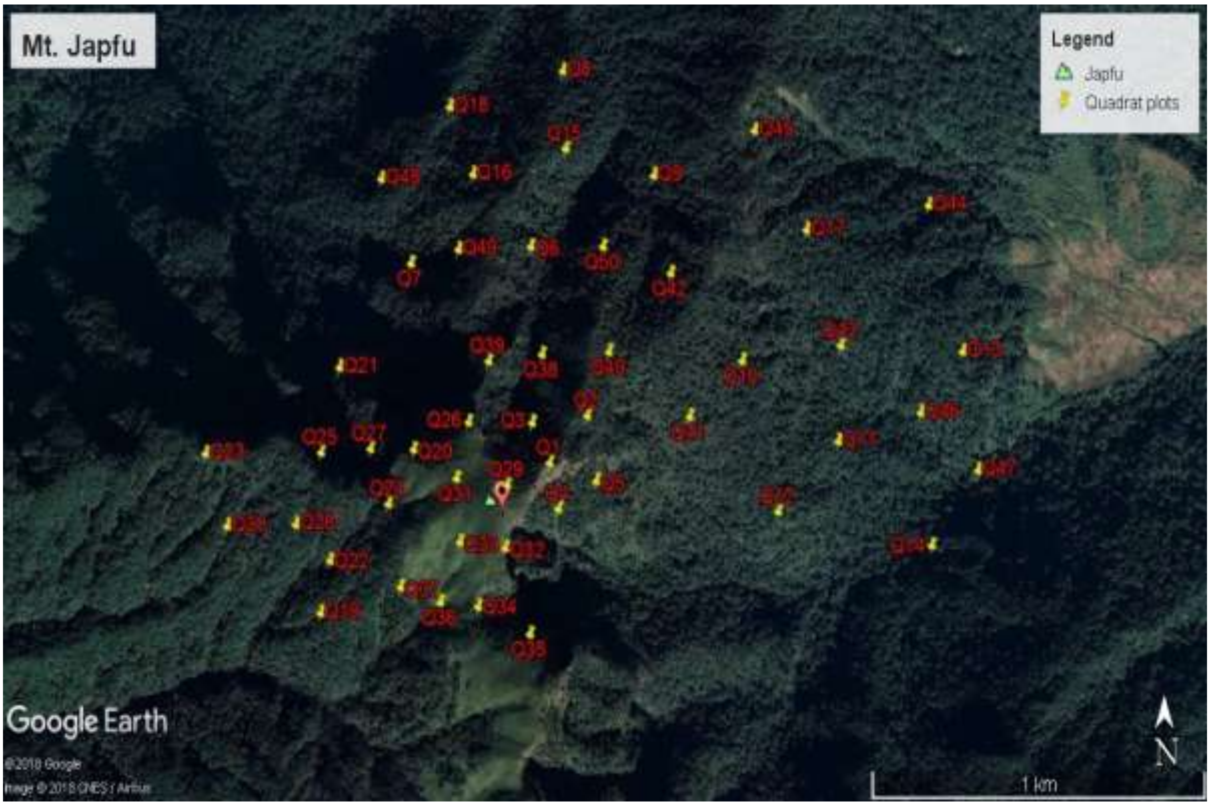

Fig. 2.2: Google earth map showing the area studied.

Fig. 2.3: Photo of the study area, Mt. Japfü.

METHODOLOGY

PLANT DIVERSITY STUDY

Field work for the study of plant diversity and floristic composition of the area was carried out from the year 2013 to 2016. Frequent field visits was conducted to cover the entire area during all the mentioned seasons. Plant specimens were collected and photographed for identification and herbarium. Collected plant specimens were processed using the standard herbarium technique. The plant parts are pressed and dried following the dry method proposed by Jain and Rao (1977). The specimens are poisoned by dipping it in a solution of 1% mercuric chloride in ethyl alcohol which is followed by drying of the specimens and then they are affixed to the herbarium sheet with glue. Each specimen is labelled which includes taxonomic denomination along with date and place of collection and other ecological notes about the locality.

Plants specimens were identified consulting the herbaria of Botany Department, Nagaland University and also with the help of various flora and literatures available for the region (Hooker, 1872-79; Clarke, 1889; Kanjilal *et al*., 1934-40; Haridasan and Rao, 1985-87; Pearce and Cribb, 2002; Wu *et al*., 1994-2009; Mao and Gogoi, 2016). Some plant species were identified with the help of taxonomic experts.

Floristic surveys were aimed to document the plant species in the study area, to study different types of vegetation present, elevation range of the area and the ecological and threatened status of plants and their medicinal value. Rare plants in the area was identified with the help of red data book and other literatures.

PHYTOSOCIOLOGICAL STUDIES

Sampling in the study area was done using random sampling method to analyse the phytosociological parameters. Quadrats of sizes 10x10m, 5x5m and 1x1m were placed for trees, shrubs and herbs respectively. Quadrats of shrubs and herbs were nested within the quadrat for trees (Fig. 2.4). The quadrats were spatially distributed in the study site considering different altitudes and slopes so as to cover all types of environment present and minimize the autocorrelation among the vegetation. Various plant species found in the quadrat areas were recorded for quantitative analysis of the community.

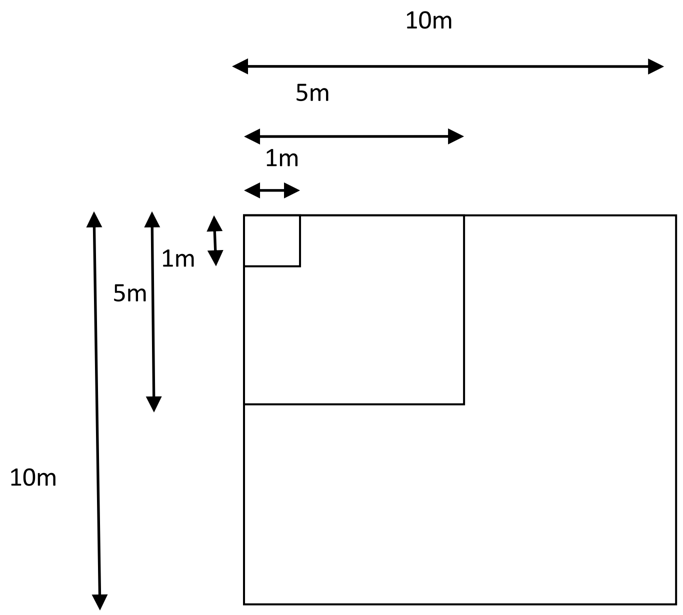

Fig. 2.4: Quadrat Structure (not to scale).

(a) Density, Frequency and Abundance

Quantitative analysis of density, frequency and abundance of plant species were calculated as per the formula given by Curtis and McIntosh (1950).

$$\text{Density} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total no. of quadrats studied}}$$

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

$$\text{Abundance} = \frac{\text{Total number of individuals}}{\text{No. of quadrats of occurrence}}$$

(b) Raunkiaer's Law of Frequency Class

Plant species are divided into 5 classes based on percentage frequency (Raunkiaer (1934).

Class A	1 - 20% frequency
Class B	21 - 40% frequency
Class C	41 - 60% frequency
Class D	61 - 80% frequency
Class E	81 - 100% frequency

The percentage of the total no of species coming into each class on Y axis is plotted against the five frequency classes on X axis, as shown in Fig. 2.5.

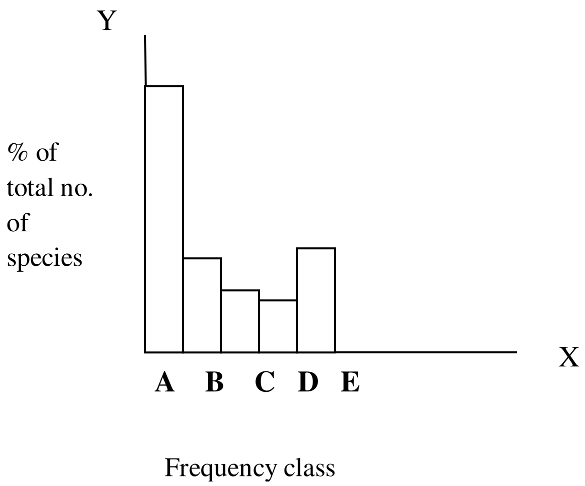

Fig. 2.5: Raunkiaer's Normal Frequency Diagram.

Raunkiaer's frequency law is A > B > C ≤ ≥ D < E and the frequency diagram represents the homogeneity or heterogeneity of a community.

(c) Importance Value Index

The sum of relative frequency, relative density and relative dominance gives the Importance Value Index of species (Curtis, 1959; Philips, 1959).

$$\text{Relative frequency} = \frac{\text{Number of occurrences of all the species}}{\text{Number of occurrences of all species}} \times 100$$

$$\text{Relative density} = \frac{\text{Number of individuals of the species}}{\text{Number of individuals of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all species}} \times 100$$

$$\text{IVI} = \text{Relative frequency} + \text{Relative density} + \text{Relative dominance}$$

(d) Basal Area

For the calculation of Relative dominance, basal area was determined using the following formula (Mishra, 1968).

Basal Area = (GBH) 2/ 4π

Where, GBH is Girth at Breast Height measured at 1.37 m height.

(e) Whitford Index

Whitford Index (Whitford, 1949) is used to interpret the distribution pattern of species in a community.

WI = Abundance / Frequency,

Where the value below 0.025 indicates regular distribution, between 0.025 – 0.050 indicates random distribution and when above 0.050 indicates contagious distribution.

DIVERSITY INDICES

Diversity of plant in an area can be determined using indices which represents the different parameters of diversity such as species richness, evenness and dominance. The following are the diversity indices used in the present study.

(a) Shannon Wiener Diversity Index

Species diversity index was calculated using the formula given by Shannon and Wiener (1963).

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

where ‘ni’ is the IVI of i^{th} species, ‘N’ is the total IVI and ‘ln’ is the natural log.

(b) Pielou’s Evenness Index

Evenness index of the species was determined using Pielou's Index (1966).

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

where ‘H’ is Shannon-Wiener diversity index and ‘S’ is total number of species.

(c) Simpson's Dominance index

The index of dominance was computed by using Simpson's Index (1949).

$$D = \Sigma (ni/Ni)^2$$

where 'ni' is the important value of the i^{th} species and 'N' is the important value of all species.

(d) Whittaker's Species richness index

Species richness in the study area was calculated using the following formula given by Whittaker (1960, 1975).

$$D = S / \log N$$

where 'S' is the number of species in a sample and' N' is the total number of individuals in the sample

LIFE FORM STUDIES

Raunkiaer (1934) classified plants in to different groups which is known as life forms, based on the position of the perennating buds from the ground.

Life form	**(Position of perennating buds from the ground)**
Phanerophyte	Perennating bud well above ground.
It is subdivided to-	
i) Megaphanerophyte	above 30m high
ii) Mesophanerophyte	between 8m and 30m
iii) Microphanerophyte	between 2m and 8m
iv) Nanophanerophyte	Up to 2m
Chamaephyte	Up to 0.25m (Herbaceous or low woody plants)
Hemicryptophyte	Buds close to ground (half hidden in soil)
Cryptophyte	Perennating bud below soil surface or water.
It is further sub divided to-	
i) Geophyte	Perennating bud underground.
ii) Helophyte	Marsh plants with bud in logged mud.
iii) Hydrophyte	Perennating bud beneath water.
Therophyte	Annuals: survival in unfavourable season through seeds or spores.
Epiphyte	Plants growing on other plants.
Liana, climber & scandent	Mechanically dependent on other plants.

SOIL ANALYSIS

Soil samples were collected during dry and wet seasons and at different altitudinal range of the study area. Soil samples were collected from both top soil (15cm depth) and sub soil (30cm depth) for analysis. The soil samples were air dried for weeks and then it was sieved through 2.0 mm mesh, leaving out the gravels and rocks. These fine soil were used for estimation of soil physico-chemical properties.

Soil Moisture Content

Soil moisture content of the samples were analysed following the method outlined by Anderson and Ingram (1993). 10 g of the soil sample were dried by keeping it in hot air oven at 105° C for 24 hours. Then the dried soil samples were weighed to measure the final dry weight. Soil moisture content was calculated by the following formula:

$$\text{Soil Moisture Content (\%)} = \frac{\text{Initial weight - Final dry weight}}{\text{Final dry weight}} \times 100$$

Soil pH

10 g of soil sample is added to 25 ml of distilled water to make the soil water suspension ratio 1:2.5. The soil suspension is stirred mechanically for 1 hour. Then the pH value was recorded using the digital pH meter.

where pH < 4.5 is extremely acidic	6.6-7.3 is neutral
4.5-5.0 is very strongly acidic	7.4-7.8 is mildly alkaline
5.1-5.5 is strongly acidic	7.9-8.4 is moderately alkaline
5.6-6.0 is medium acidic	8.5-9.0 is strongly alkaline 6.1-
6.5 is slightly acidic	9.0< is very strongly alkaline

Available Nitrogen

Available Nitrogen content test was done by Kjeldahl distillation method given by Subbiah and Asija (1956).

Weigh 5g of soil sample in a micro-Kjeldahl tube. To this add 20ml water and wash down the soil adhering to the neck, if any. Add a few glass beads and 2-3ml of paraffin liquid to prevent frothing and bumping during distillation. Measure 20ml of 2% Boric acid containing mixed indicator in a 250ml conical flask and place it under the receiver tube. Dip the receiver tube end in the Boric acid. Add 50ml of

0.32% $KMnO_4$ and 50ml of 2.5% NaOH solution. Distil the contents until about 100ml of distillate is collected. Titrate the distillate against 0.02N H_2SO_4 taken in burette until pink colour starts appearing. Run a blank without soil.

$$\text{Available N in soil (Kg ha}^{-1}) = \frac{(S-B) \times 0.00028 \times 2.24 \times 10^6}{\text{weight of soil sample (gm)}}$$

where, S = the volume of 0.02N H_2SO_4 required for sample

B = volume of 0.02N H_2SO_4 required for blank

N < 280 kg/ha = Low, N between 280-560 kg/ha = Medium, N> 560kg/ha = High

Organic Carbon

Soil Organic Carbon (OC) content was analysed by following Walkley - Black method (Walkley and Black, 1934).

Weigh 1g of soil sample into 500ml dry conical flask. Add 10ml of 1N $K_2Cr_2O_7$ and 20ml of conc. H_2SO_4. Swirl the flask 2-3 times and keep on an asbestos sheet for 30 minutes. Add 200ml of distilled water and 10ml of orthophosphoric acid. Add 1ml of diphenylamine indicator. Take 0.5N ferrous ammonium sulphate solution in 50ml burette. Titrate the content till the colour flashes from violet through blue to bright green colour starts appearing. Carry out the blank titration.

$$\text{Organic Carbon (\%) in soil} = \frac{10(B-S) \times 0.003 \times 100}{B \times \text{weight of soil (g)}}$$

where, B = volume (ml) of Ferrous ammonium sulphate solution required for blank titration

S = volume (ml) of Ferrous ammonium sulphate solution required for soil sample titration.

OC < 0.5% = Low, OC between 0.5-0.75% = Medium, OC > 0.75% = High

Available Phosphorus

Available Phosphorus in the soil was estimated using molybdenum blue method as described by Allen *et al.* (1974).

Weigh 2.5gm of soil sample in a 150ml conical flask. Add 25ml of NH_4F and shake for 5 minutes. Filter through Whatman no.1 filter paper. Take 5ml of the filtrate and 4ml of reagent B and make the volume 25ml with distilled water. Keep it for 5-10 minutes and measure the intensity of blue colour at 730 nm in a visible spectrophotometer. Run a blank without soil under identical manner. Note the reading.

$$\% P = \frac{C\ (mg) \times \text{solution volume (ml)}}{10 \times \text{aliquot volume (ml)} \times \text{sample weight (g)}}$$

where C mg P obtained from graph

P < 36 kg/ha = Low, P between 36-68 kg/ha = Medium, P > 68 kg/ha = High

Available Potassium

Available Potassium in soil was determined using Ammonium acetate method (Hanway and Heidal, 1952).

Dilute suitable volume of standard K solutions to get 100ml of working standards containing 10,15,20,30 and 40 ppm of K. Draw the calibration curve by plotting the flame photometer readings against different concentrations.

Weigh 5g of soil sample in 100ml conical flask. Add 25ml of neutral 1N NH_4OAc solution and shake for 5 minutes. Filter through Whatman no.1 filter paper. Measure K concentration in the filtrate using flame photometer.

$$\text{Available K (kg/ha)} = \frac{C\ (ppm) \times 25 \times 25 \times 2.24}{\text{sample weight (g)} \times \text{Dilution factor}}$$

where C is the concentration of Potassium in the soil sample obtained from standard curve.

K < 120 kg/ha = Low, K between 120-240 kg/ha = Medium, K> 240 kg/ha = High

Remote Sensing and GIS

The satellite image has been obtained from NASTEC, Science and Technology Department, Government of Nagaland.

Layer stacking was done to get image with required band combination. ERDAS IMAGINE 2014 is the GIS software used for the present study. Some corrections have been done to reduce the atmosphere effect on the image. Radiometric enhancement was also used. Images were cropped to get the specific image of the study area.

Satellite Data Used

Indian satellite IRS-P6, LISS-IV sensor data (Path 123, Row 53) of 2nd November 2013, imagery has been taken for this work. The three band b2 Green, b3 Red, b4 NIR are used.

Spectral band	Swath width	Spatial Resolution	Radiometric Resolution
b2 : 520-590 b3 : 620-680 b4 : 770-860	70/23 Km	5.8m	10 bit

Table 2.1 : LISS IV sensor data specification.

Normalized Difference Vegetation Index (NDVI)

Kriegler *et al.* (1969) formulated the vegetation index. NDVI value were calculated on composite image using equation given below. The three spectral bands as shown in Table 2.1, are used for making NDVI map. NDVI values ranges from -1 to +1.

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

NIR = Near infra red

RED = the red portion of electromagnetic spectrum (0.6-0.7μm)

Vegetation Map

Unsupervised classification method was used for conduction of the classification process. NDVI and texture of the image has been used to determine the different classes on the map. High value of NDVI and rough texture of the image represents dense vegetation and NDVI value close to -1 with smooth texture represents barren or agriculture lands in the study site. Each classes produced in the satellite image has been verified on the ground.

CHAPTER-III

RESULTS

1. ENVIRONMENTAL VARIABLES

Nagaland has a monsoon type climate with high humidity levels. The average annual rainfall of the state varies between 200 mm to 250 mm. Most of the heavy rainfall occurs during June to September. The average relative humidity is high during rainy season and it varies between 75% and 90%. The temperature during summer varies from 15^{o}C to 30^{o}C and in winter it varies from 4^{o}C to 25^{o}C.

Kohima has a pleasant climate with cool winter and very rainy summers. There are four seasons in a year- spring, summer, autumn and winter. Spring seasons include the months of March to May, Summer in the months of June to August, Autumn in the month of September and October and Winter from the month of November to February. The coldest months are from December to February during which frost occur and in high altitudes snowfall is occasionally observed. Warmest part of the year is during the months of June to August in the study period. Heavy rainfall is recorded in summer. During the study period i.e., from the year 2013 to 2016, the average minimum temperature range from 2.9 ^{o}C to 16.6 ^{o}C and the average maximum temperature varies from 15.8 ^{o}C to 27.6 ^{o}C (Fig.3.1). The heaviest rainfall is recorded in the months of July and August (350 mm & 370 mm). Annual rainfall recorded in the study period was 1598.05 mm (Fig.3.2). Humidity was found to be highest (85.5% to 86.2%) during the months of July, August and September (Fig. 3.3).

2. EDAPHIC FACTORS

2.1 Soil Moisture Content: Maximum soil moisture content was recorded during rainy season in both the peak and forest area. In dry season , soil moisture content in the top soil (0-15cm depth) and sub soil (16-30cm depth) at the peak was 54.3% and 43.37% and in the forest it was 57.65% and 42.65%. In rainy season soil moisture

Months	Mean Temp (°C)								Average mean Temp. (°C)	
	2013		2014		2015		2016			
	M	**m**	**M**	**m**	**M**	**m**	**M**	**m**	**M**	**m**
January	16.7	4.2	17.1	4.1	17.2	4.7	15.8	2.9	16.7	3.9
February	21.8	7.2	18.5	5.3	19.1	5.9	20.4	6.6	19.9	6.3
March	24.3	9.8	22.5	9	24.6	9.9	24.5	9.8	23.9	9.6
April	25.4	12.5	27.6	13.2	24.7	11.2	25.5	12.6	25.8	12.4
May	24.8	14.3	26.9	14.3	25.8	13.5	24.6	14.5	25.5	14.2
June	27.2	16.1	26.7	16.6	27.1	15.5	25.1	18.4	26.5	16.7
July	26.4	16.6	26.5	16.2	26.2	16.1	25.6	19.5	26.2	17.1
August	27	16.6	25.6	15.8	25.6	15.7	27	19.7	26.3	16.9
September	26	15.7	25.3	15.4	25.5	15.2	25.4	18.7	25.6	16.3
October	25.1	12.6	24.5	12.2	22.4	12.4	25.3	16.2	24.3	13.4
November	22.4	7.4	21.9	8.4	23.1	7.8	22.8	10.8	22.6	8.6
December	17.7	4.1	18.8	5	17.3	3.6	20.9	9.2	18.7	5.48

Table 3.1: Average minimum (m) and maximum (M) temperature (°C) in Kohima district during the study period (2013-2016).

Source: Meteorological report of Kohima, Directorate of Soil and Water Conservation, Govt. of Nagaland.

Months	Mean Rainfall (mm)				Average mean rainfall (mm)
	2013	2014	2015	2016	
January	0	0	25.8	4.3	7.53
February	0	16.8	18.4	5.7	10.23
March	45.2	31.8	18.4	36.2	32.90
April	115.4	77.6	200.7	97.8	122.88
May	332.5	145.5	50.3	243.8	193.03
June	298.2	139	224.1	317.2	244.63
July	350.9	332.4	316.4	255.2	313.73
August	268.5	350.6	374.1	256.4	312.40
September	226.3	231.4	212.2	242.7	228.15
October	112.1	58.2	74	204.2	112.13
November	0	0	2.1	72.8	18.73
December	0	0	5.6	1.4	1.75

Table 3.2: Mean monthly rainfall (mm) in Kohima district during the study period (2013-2016).

Source : Meteorological report of Kohima, Directorate of Soil and Water Conservation, Govt. of Nagaland.

Months	Mean. RH%				Average mean RH%
	2013	2014	2015	2016	
January	54.8	65.2	74.9	75.9	67.7
February	43.5	67.5	78	75	66
March	38.9	70.7	80.2	70.9	65.2
April	48.2	63.5	84.6	69.6	66.5
May	74.4	79.8	86.1	82.3	80.7
June	73.5	82.5	87.1	87.1	82.6
July	84.6	83.2	87.3	89.6	86.2
August	80.5	85.8	89.3	86.2	85.5
September	76.9	85.8	88.2	91.2	85.5
October	71.7	75	84.2	85.7	79.2
November	61.5	71.4	78.7	70	70.4
December	57.5	54.2	78.9	61.6	63.1

Table 3.3: Mean monthly Relative Humidity (%) in Kohima district during the study period (2013-2016).

Source: Meteorological report of Kohima, Directorate of Soil and Water Conservation, Govt. of Nagaland.

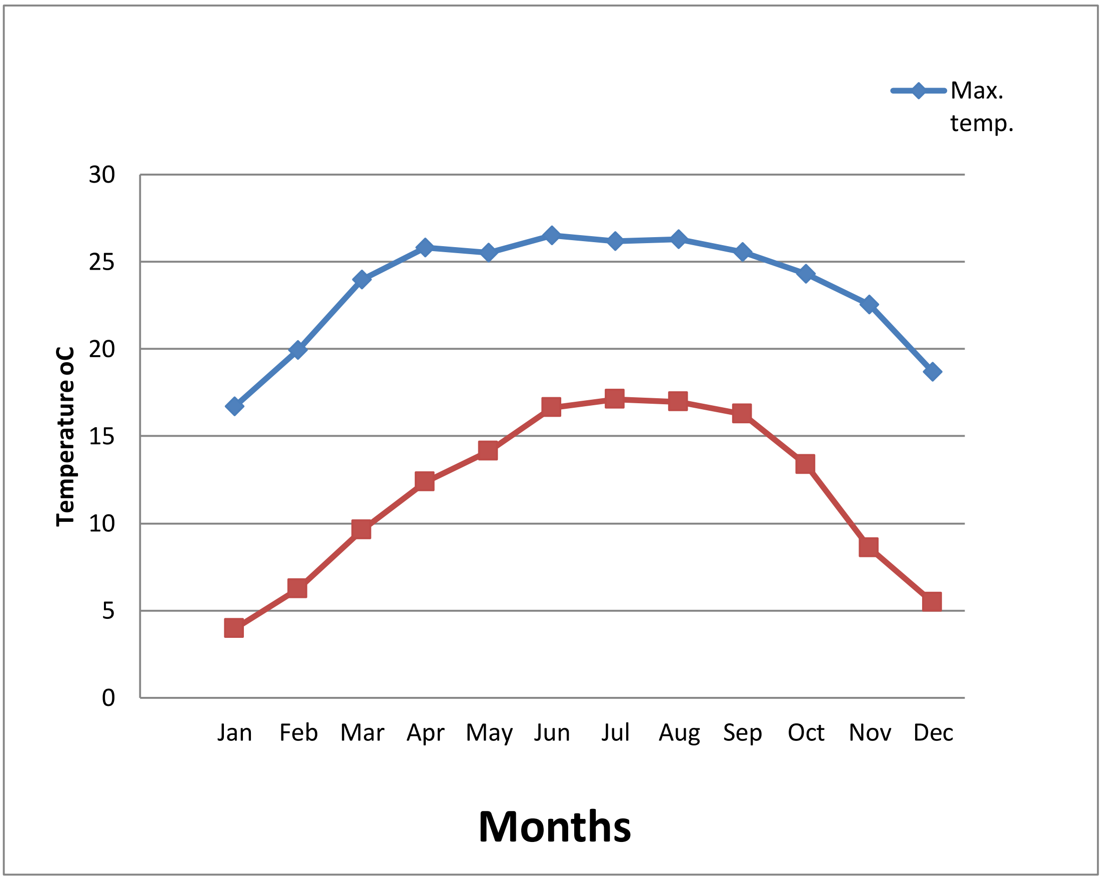

Fig. 3.1: Average minimum and maximum temperature (°C) in Kohima district during the study period (2013-2016).

Source : Meteorological report of Kohima, Directorate of Soil and Water Conservation, Govt. of Nagaland.

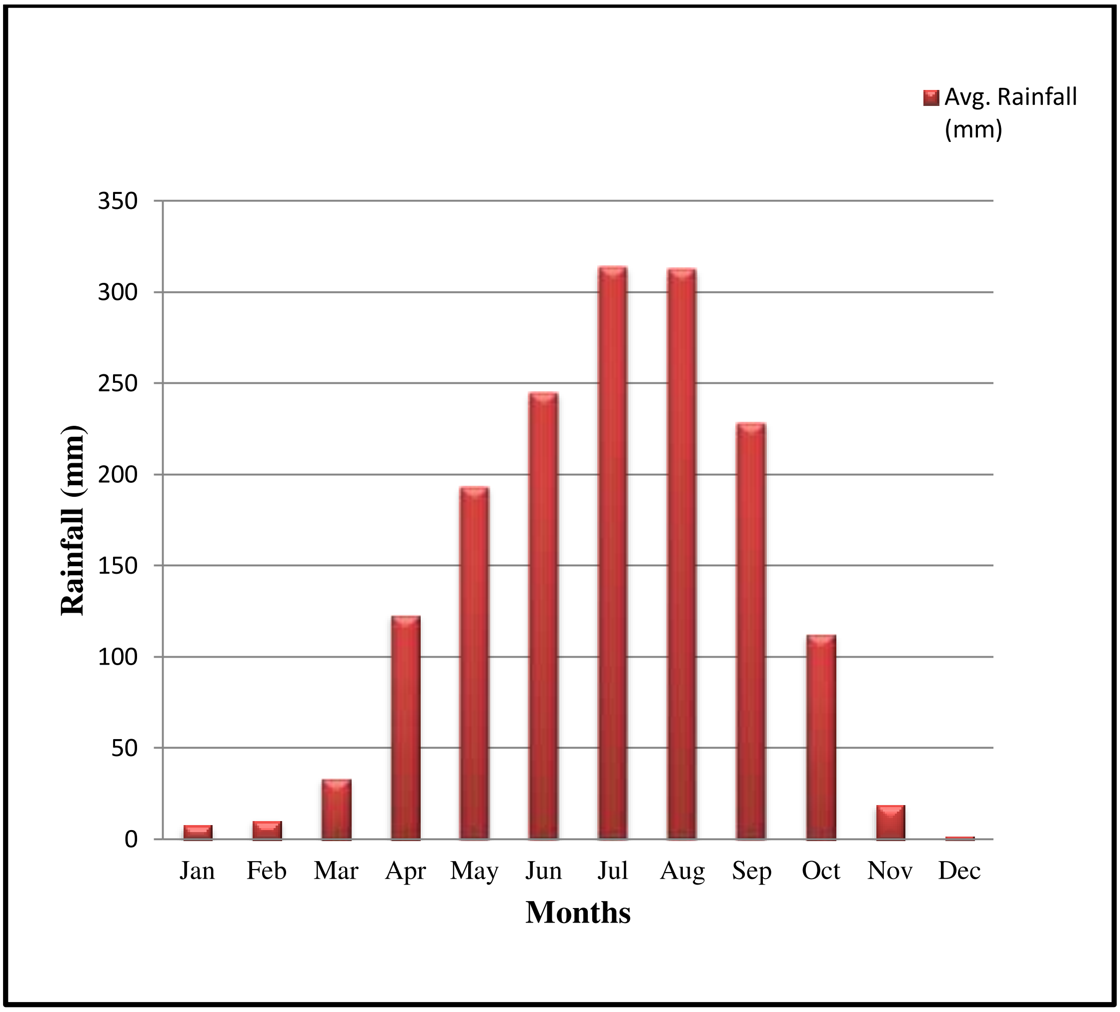

Fig. 3.2 : Mean monthly rainfall (mm) in Kohima district during the study period (2013-2016).

Source: Meteorological report of Kohima, Directorate of Soil and Water Conservation, Govt. of Nagaland.

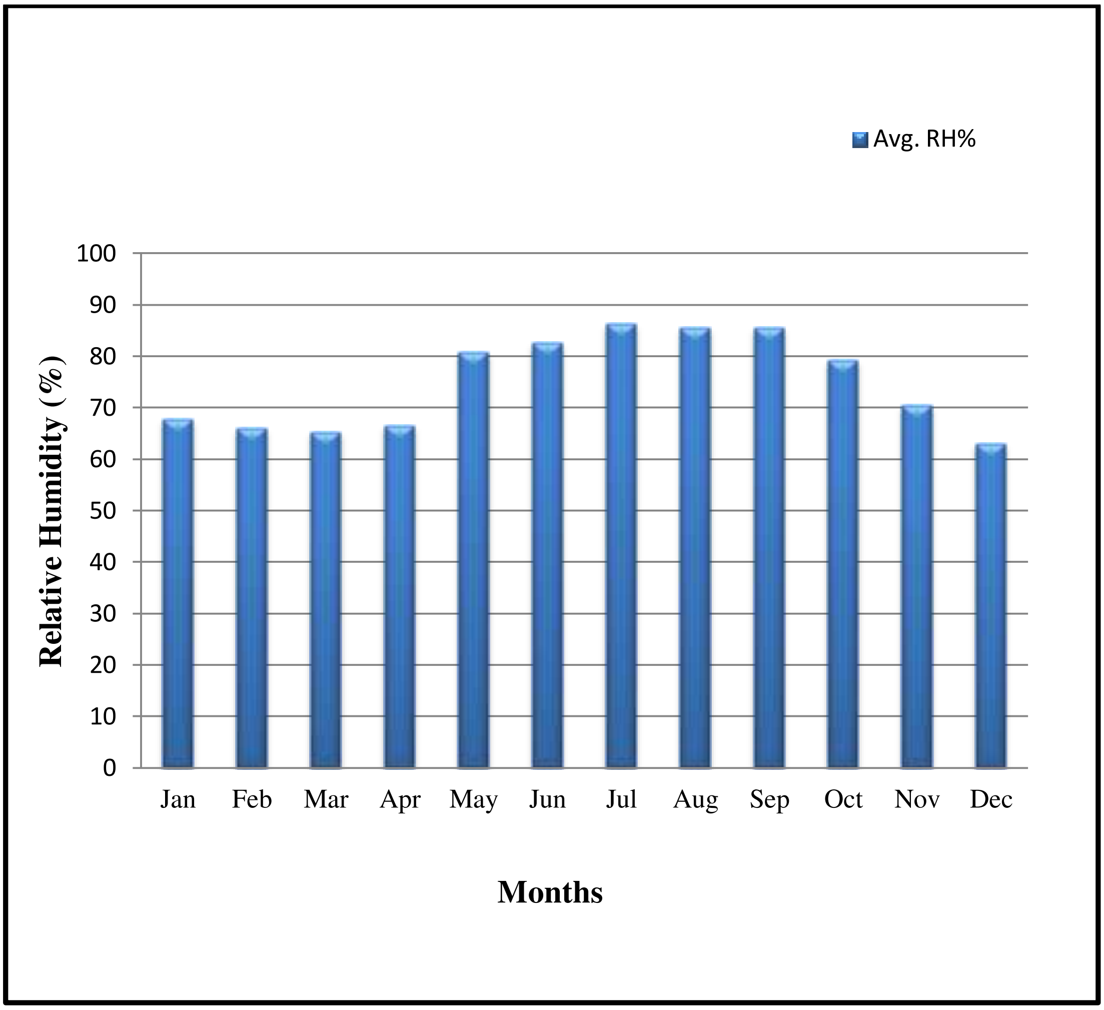

Fig. 3.3 : Mean monthly Relative Humidity (%) in Kohima district during the study period (2013-2016).

Source: Meteorological report of Kohima, Directorate of Soil and Water Conservation, Govt. of Nagaland.

Location	Samples	Season	Soil	Moisture content (%)
Peak (3018m)	1	Dry season (Winter)	Top Soil	54.30
			Sub Soil	43.37
	2	Rainy season (Summer)	Top Soil	85.36
			Sub Soil	69.38
Forest (2416m)	3	Dry season (Winter)	Top Soil	57.65
			Sub Soil	42.65
	4	Rainy season (Summer)	Top Soil	81.13
			Sub Soil	72.35

Table 3.4: Soil moisture content (%) in the study area during dry and rainy season (2013 to 2016).

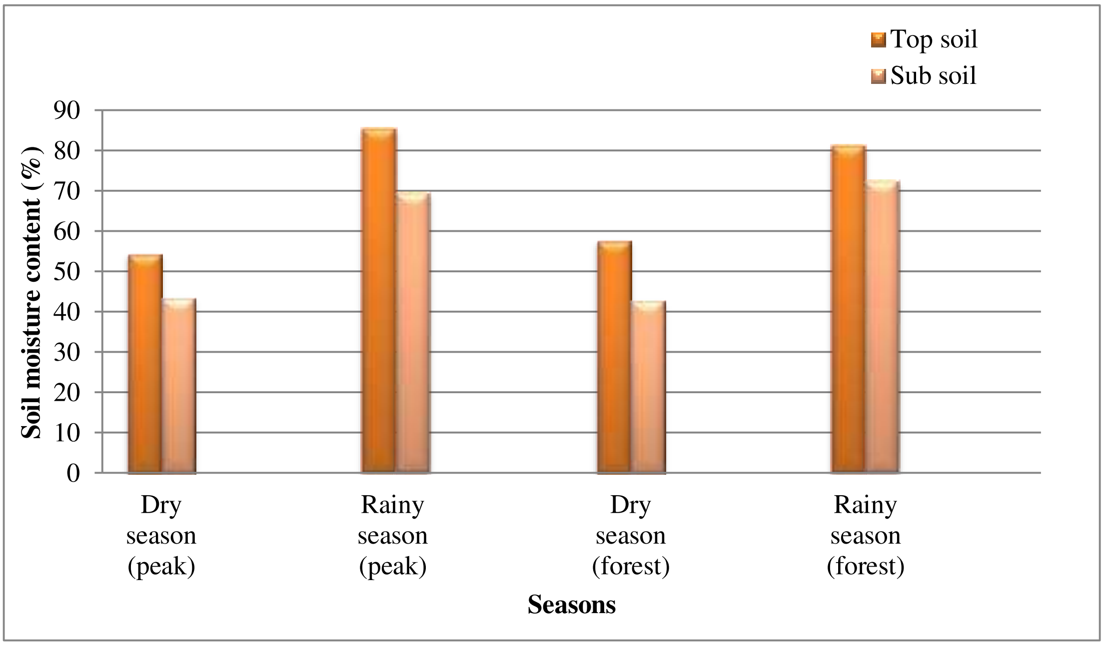

Fig. 3.4: Chart showing soil moisture content (%) during dry and rainy season in Mt. Japfü (2013-2016).

content was found to be 85.36% and 69.38% at the peak and 81.13% and 72.35% in the forest area. There was considerable difference in soil moisture content between the top soil and sub soil and also between dry season and rainy season throughout the study period (Table 3.4). The result shows that soil moisture content difference between the top soil and sub soil in dry season is 10.93% and 15% and in rainy season, it is 15.98% and 8.78%.

2.2 Soil pH : Soil samples were collected for analysis from different slopes between the altitudinal range of 2014 m to 3018 m ASL. Soil pH was in the range of 3.88 to 5.87, which indicates the acidic nature of the soil. Approximately 7 soil samples collected from the altitudinal range between 2084m to 2751m ASL, showed pH below 4.5 which indicates that the soil was extremely acidic in these sites. Most of the soil samples showed pH between 4.5 to 5.5 which suggest that the soil of the study area is strongly acidic in nature (Table 3.5).

2.3 Organic Carbon: Organic Carbon content in the soil was found to be high in the study area. The range of organic Carbon content was recorded between 0.50% to 3%. Percentage of organic Carbon content in the top soil was found to be either equal or higher than sub soil (Table 3.6).

2.4 Available Nitrogen: Available l Nitrogen in soil in the study site was found to be mostly medium in content. The range of available Nitrogen in the soil was found between 101.5 kg/ha and 677.2 kg/ha . The study showed that available Nitrogen content in the soil was higher in the altitudinal range between 2580 m and 2750 m asl (Fig.3.7).

2.5 Available Phosphorus: Majority of the soil samples showed low content of available Phosphorus in the present study. The available Phosphorus content in the soil varies from 8.4 kg/ha to 62.81 kg/ha. Higher value of available Phosphorus was found at the peak and lower altitudes whereas it was low in the middle altitudes (Fig. 3.8).

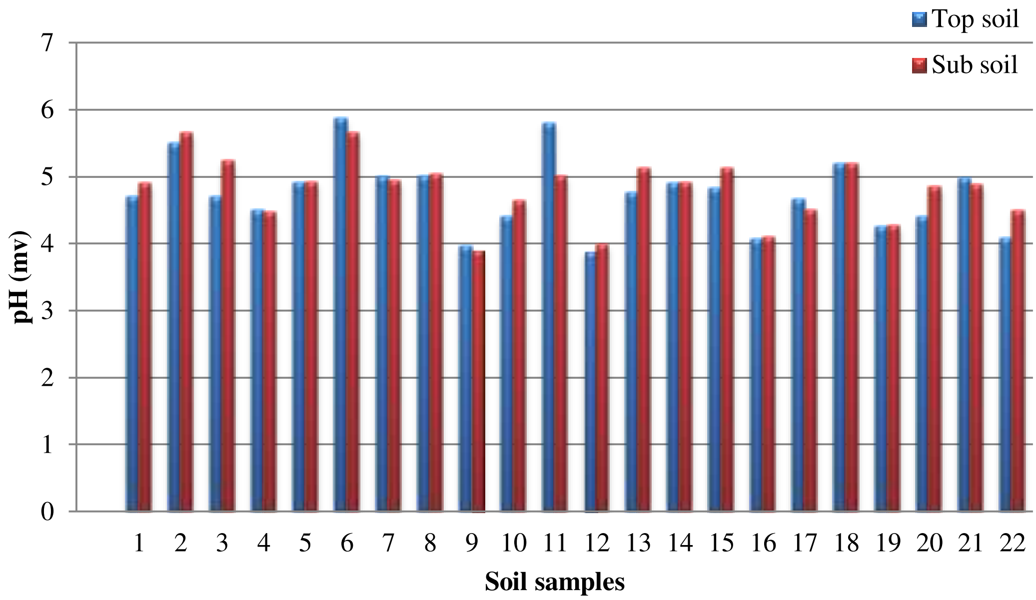

Fig. 3.5 : Chart showing pH of soil in Mt. Japfü.

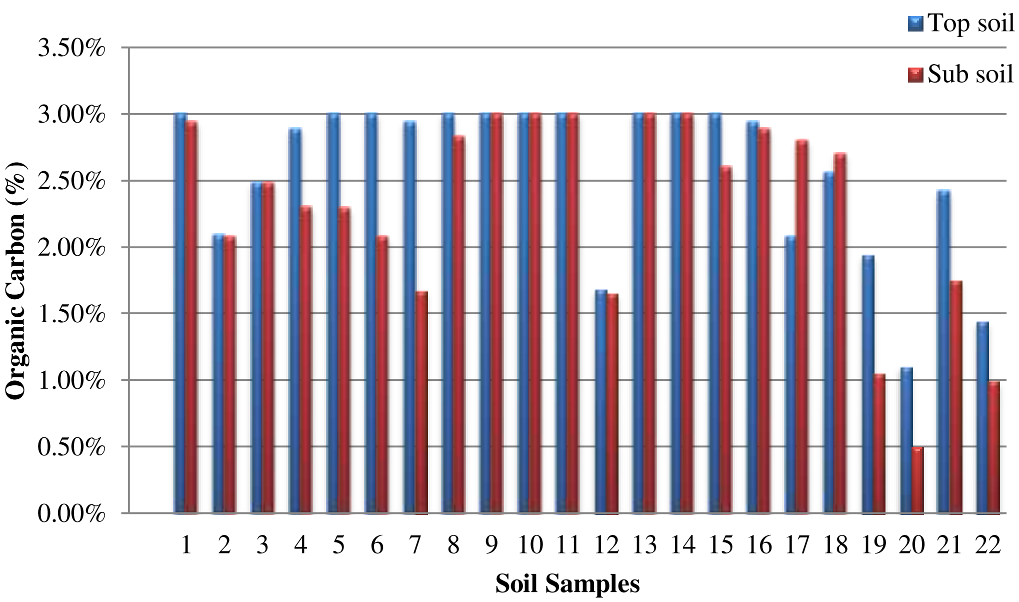

Fig. 3.6 : Chart showing soil organic carbon content in Mt. Japfü.

Table 3.5 : Soil pH content in Mt. Japfü (2013-2016).

Soil Sample	Slope	Altitude (m)	pH			
			Top soil		Sub soil	
1	S	3018m	4.7	Strongly Acidic	4.9	Strongly Acidic
2	SW	2991m	5.5	Strongly Acidic	5.7	Medium Acidic
3	S	2952m	4.7	Strongly Acidic	5.2	Strongly Acidic
4	NW	2859m	4.5	Strongly Acidic	4.5	Strongly Acidic
5	E	2831m	4.9	Strongly Acidic	4.9	Strongly Acidic
6	NE	2803m	5.9	Medium Acidic	5.7	Medium Acidic
7	E	2797m	5.0	Strongly Acidic	4.9	Strongly Acidic
8	N	2790m	5.0	Strongly Acidic	5.0	Strongly Acidic
9	W	2751m	4.0	Extremely Acidic	3.9	Extremely Acidic
10	N	2746m	4.4	Extremely Acidic	4.6	Strongly Acidic
11	NE	2698m	5.8	Medium Acidic	5.0	Strongly Acidic
12	NW	2684m	3.9	Extremely Acidic	4.0	Extremely Acidic
13	W	2681m	4.8	Strongly Acidic	5.1	Strongly Acidic
14	N	2674m	4.9	Strongly Acidic	4.9	Strongly Acidic
15	W	2660m	4.8	Strongly Acidic	5.1	Strongly Acidic
16	N W	2579m	4.1	Extremely Acidic	4.1	Extremely Acidic
17	NE	2489m	4.7	Strongly Acidic	4.5	Strongly Acidic
18	N	2416m	5.2	Strongly Acidic	5.2	Strongly Acidic
19	NE	2298m	4.3	Extremely Acidic	4.3	Extremely Acidic
20	E	2215m	4.4	Extremely Acidic	4.9	Strongly Acidic
21	E	2167m	5.0	Strongly Acidic	4.9	Strongly Acidic
22	E	2084m	4.1	Extremely Acidic	4.5	Strongly Acidic

Table 3.6 : Organic Carbon content in the soil of Mt. Japfü.

Soil sample	Slope	Altitude	Organic Carbon (%)			
			Top soil		Sub soil	
1	S	3018m	3.00%	High	2.94%	High
2	SW	2991m	2.09%	High	2.08%	High
3	S	2952m	2.48%	High	2.48%	High
4	NW	2859m	2.89%	High	2.30%	High
5	E	2831m	3%	High	2.29%	High
6	NE	2803m	3%	High	2.08%	High
7	E	2797m	2.94%	High	1.67%	High
8	N	2790m	3%	High	2.83%	High
9	W	2751m	3%	High	3%	High
10	N	2746m	3%	High	3%	High
11	NE	2698m	3%	High	3%	High
12	NW	2684m	1.68%	High	1.65%	High
13	W	2681m	3%	High	3%	High
14	N	2674m	3%	High	3%	High
15	W	2660m	3%	High	2.60%	High
1 6	N W	2579m	2.94%	High	2.89%	High
17	NE	2489m	2.08%	High	2.80%	High
18	N	2416m	2.56%	High	2.70%	High
19	NE	2298m	1.94%	High	1.05%	High
20	E	2215m	1.10%	High	0.5%	Medium
21	E	2167m	2.42%	High	1.75%	High
22	E	2084m	1.44%	High	0.99%	High

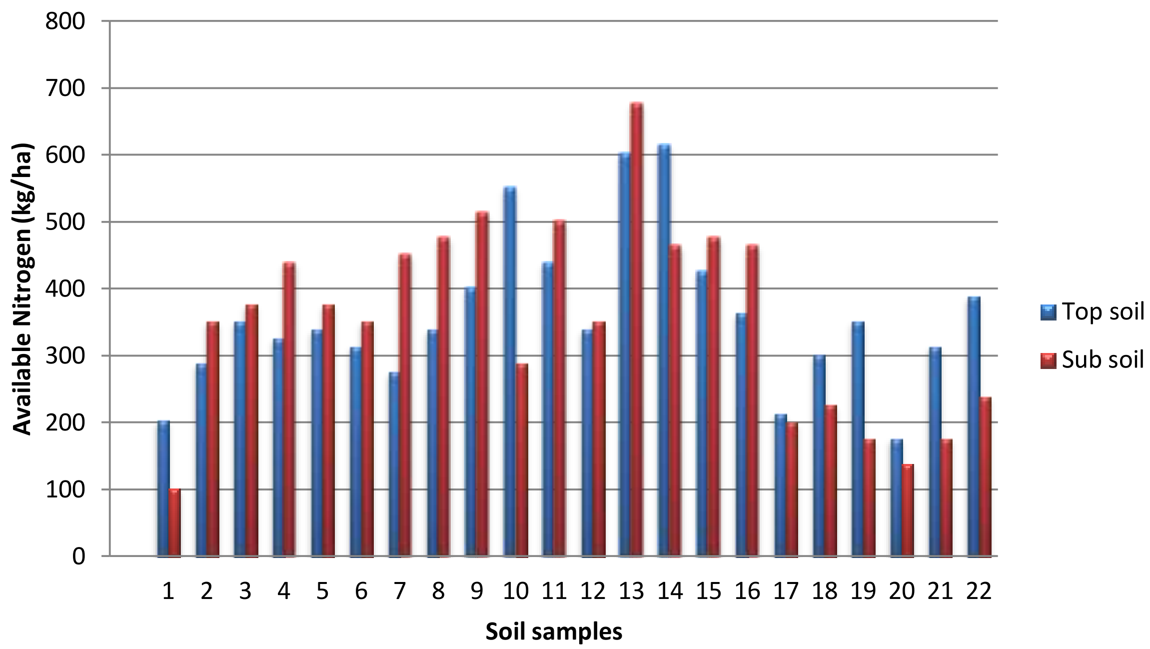

Fig. 3.7 : Chart showing available Nitrogen content in the soil in Mt. Japfü.

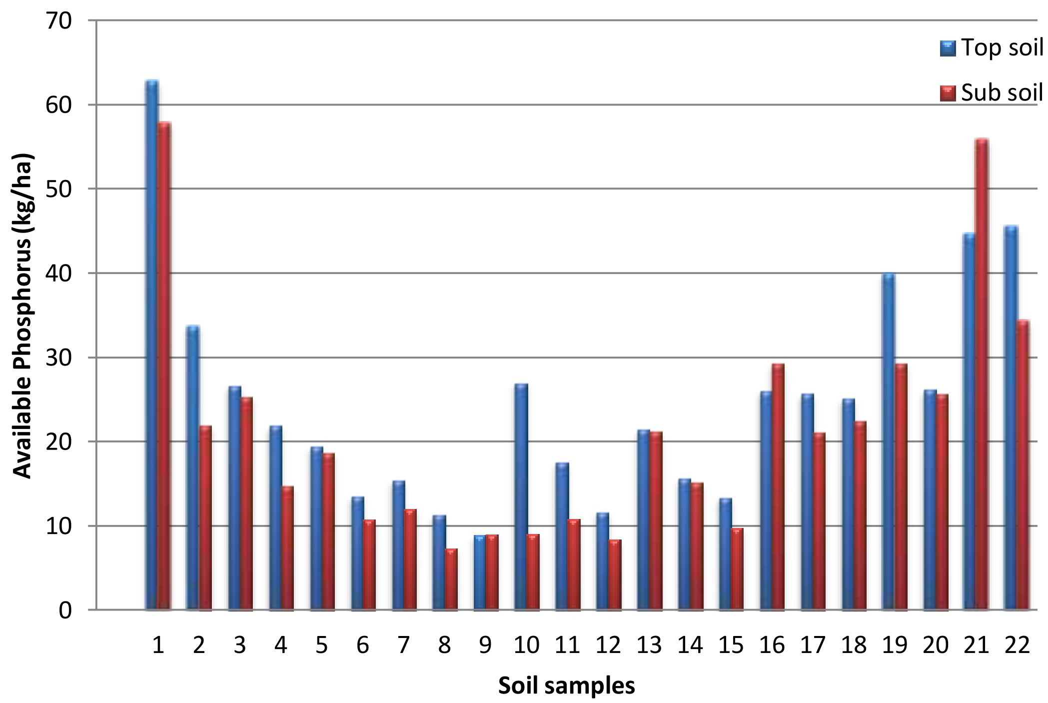

Fig. 3.8: Chart showing available Phosphorus in the soil of Mt. Japfü.

Table 3.7 : Available Nitrogen in the soil of Mt. Japfü.

Soil sample	Slope	Altitude	Available Nitrogen (kg/ha)			
			Top soil		Sub soil	
1	S	3018m	202.99	Low	101.49	Low
2	SW	2991m	288.42	Medium	351.12	Medium
3	S	2952m	351.12	Medium	376.2	Medium
4	NW	2859m	326.04	Medium	438.9	Medium
5	E	2831m	338.58	Medium	376.2	Medium
6	NE	2803m	313.5	Medium	351.12	Medium
7	E	2797m	275.88	Low	451.44	Medium
8	N	2790m	338.58	Medium	476.52	Medium
9	W	2751m	401.28	Medium	514.14	Medium
10	N	2746m	551.76	Medium	288.42	Medium
11	NE	2698m	438.9	Medium	501.6	Medium
12	NW	2684m	338.58	Medium	351.12	Medium
13	W	2681m	601.92	High	677.16	High
14	N	2674m	614.46	High	463.93	Medium
15	W	2660m	426.36	Medium	476.52	Medium
1 6	N W	2579m	363.66	Medium	463.93	Medium
17	NE	2489m	213.1	Low	200.6	Low
18	N	2416m	300.9	Medium	225.7	Low
19	NE	2298m	351.12	Medium	175.5	Low
20	E	2215m	175.5	Low	137.9	Low
21	E	2167m	313.5	Medium	175.5	Low
22	E	2084m	388.7	Medium	238.2	Low

Table 3.8 : Available Phosphorus content in the soil of Mt. Japfü.

Soil sample	Slope	Altitude	Available Phosphorus (kg/ha)			
			Top soil		Sub soil	
1	S	3018m	62.81	Medium	57.9	Medium
2	SW	2991m	33.71	Low	21.95	Low
3	S	2952m	26.66	Low	25.31	Low
4	NW	2859m	21.89	Low	14.78	Low
5	E	2831m	19.38	Low	18.65	Low
6	NE	2803m	13.44	Low	10.75	Low
7	E	2797m	15.34	Low	12.04	Low
8	N	2790m	11.26	Low	7.34	Low
9	W	2751m	8.9	Low	9.02	Low
10	N	2746m	26.94	Low	9.07	Low
11	NE	2698m	17.53	Low	10.81	Low
12	NW	2684m	11.59	Low	8.4	Low
13	W	2681m	21.45	Low	21.22	Low
14	N	2674m	15.57	Low	15.18	Low
15	W	2660m	13.33	Low	9.74	Low
1 6	N W	2579m	26.04	Low	29.29	Low
17	NE	2489m	25.7	Low	21.11	Low
18	N	2416m	25.08	Low	22.45	Low
19	NE	2298m	39.92	Medium	29.28	Low
20	E	2215m	26.15	Low	25.64	Low
21	E	2167m	44.63	Medium	55.88	Medium
22	E	2084m	45.52	Medium	34.32	Low

Table 3.9 : Available Potassium content in soil of Mt. Japfü.

Soil sample	Slope	Altitude	Available Potassium (kg/ha)			
			Top soil		Sub soil	
1	S	3018m	200.47	Medium	209.58	Medium
2	SW	2991m	116.76	Low	119.28	Low
3	S	2952m	41.16	Low	57.12	Low
4	NW	2859m	72.8	Low	140	Low
5	E	2831m	25.76	Low	44.52	Low
6	NE	2803m	29.68	Low	40.88	Low
7	E	2797m	102.48	Low	95.2	Low
8	N	2790m	15.12	Low	27.16	Low
9	W	2751m	45.36	Low	54.32	Low
10	N	2746m	249.76	High	27.72	Low
11	NE	2698m	21.28	Low	50.4	Low
12	NW	2684m	36.68	Low	55.44	Low
13	W	2681m	15.12	Low	34.44	Low
14	N	2674m	112.84	Low	30.8	Low
15	W	2660m	33.04	Low	48.72	Low
1 6	N W	2579m	42.56	Low	143.93	Medium
17	NE	2489m	101.64	Low	54.04	Low
18	N	2416m	42.28	Low	28.56	Low
19	NE	2298m	110.04	Low	42.56	Low
20	E	2215m	59.64	Low	14.84	Low
21	E	2167m	51.52	Low	22.96	Low
22	E	2084m	146.72	Medium	91.56	Low

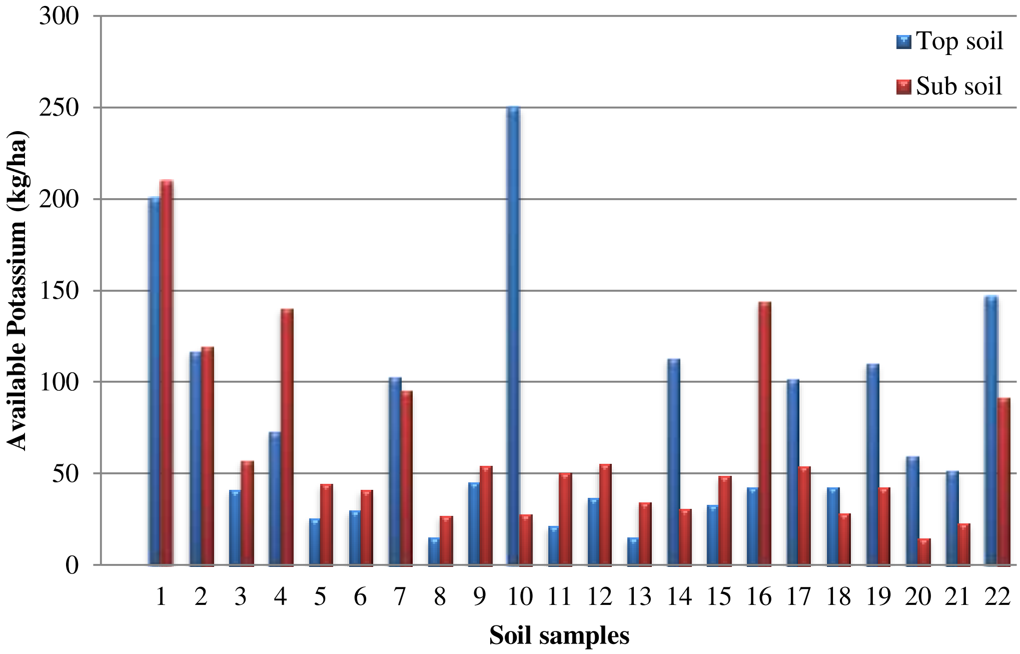

Fig. 3.9 : Chart showing available Potassium content in the soil of Mt. Japfü.

2.6 Available Potassium: Soil samples of the study area was found to be mainly low in available Potassium content. The result of available Potassium in the soil revealed that it varies from 14.84 kg/ha to 249.76 kg/ha. Available Potassium content was found to be higher in sub soil than top soil (Fig.3.9).

3. VEGETATION

3.1 Vegetation Composition

During the study, a total of 297 species belonging to 218 genera and 97 families have been recorded from Mt. Japfü. Herbaceous species were found to have the most number of species with 151 species, followed by 54 species of shrubs, 45 species of trees, 23 species of epiphytes and 24 species of climbers and lianas. About 93.58% of the total number of plants were Angiosperms, 6.08% were Pteridophytes and 0.34% were Gymnosperms. Angiosperms were represented by 277 species, 200 genera and 85 families and Pteridophytes were represented by 18 species, 17 genera and 11 families. Gymnosperm was represented with 1 species, 1 genera and 1 family.

Among the Angiosperms, Dicotyledons were the dominant component with 224 species, 152 genera and 73 families, followed by Monocotyledons with 54 species, 48 genera and 12 families.

Dominant families in the present study were Orchidaceae (24 spp.), Asteraceae (20 spp.), Rosaceae (20 spp.), Ericaceae (15 spp.), Urticaceae (11 spp.) and Rubiaceae (10 spp.). The six dominant families contributed to 60 genera and 100 species of the total flora. Out of the total plant families recorded, 57 families were represented by a single genus and 181 genera were represented by a single species.

A total of 20 primitive angiosperm species belonging to 10 families i.e., Betulaceae, Fagaceae, Juglandaceae, Lardizabalaceae, Lauraceae, Magnoliaceae, Piperaceae, Saururaceae, Schisandraceae and Urticaceae, were recorded from the study area. Altogether a total of 31 endemic species belonging to 24 genera and 18 families have been documented. 11 rare species with 8 genera 5 families and 8 threatened, endangered and vulnerable species with 6 genera and 6 families have been observed from the present study. Around 92 plant species belonging to 85 genera and 44 families with medicinal values has been documented from Mt. Japfü.

<table>
<tr><th colspan="2">Orders</th><th>Families</th><th>Genera</th><th>Species</th></tr>
<tr><td colspan="2">Pteridophytes</td><td>11</td><td>17</td><td>18</td></tr>
<tr><td colspan="2">Gymnosperms</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td rowspan="2">Angiosperms</td><td>i) Dicotyledons</td><td>73</td><td>152</td><td>224</td></tr>
<tr><td>ii) Monocotyledons</td><td>12</td><td>48</td><td>54</td></tr>
<tr><td colspan="2">Total</td><td>97</td><td>218</td><td>297</td></tr>
</table>

Table 3.10 : Representation of Pteridophytes, Gymnosperms and Angiosperms in Mt. Japfü.

Table 3.11 : List of plant species documented from Mt. Japfü.

Name of Species	Family	Habit
Acer campbelli Hook.f. & Thom. ex Hiern	Aceraceae	Tree
Acer caudatum Wall.	Aceraceae	Tree
Acer pectinatum Wall. ex G. Nich.	Aceraceae	Tree
Aconitum nagarum Stapf.	Ranunculaceae	Herb
Aconogonum molle (D.Don) H. Hara	Polygonaceae	Shrub
Achyranthes bidentata Blume	Amaranthaceae	Herb
Actinodaphne obovata (Nees) Blume	Lauraceae	Tree
Aeshynanthus hookeri Clarke	Gesneriaceae	Epiphytes
Aeschynanthes micrantha Clarke	Gesneriaceae	Epiphytes
Agapetes smithiana var *major* Sleum.	Ericaceae	Epiphytes
Ageratina adenophora (Spreng) R.M. King & H. Rob.	Asteraceae	Shrub
Agrostophyllum callosum Reichb.	Orchidaceae	Epiphytes
Ainsliaea aptera DC.	Asteraceae	Herb
Alnus nepalensis D.Don	Betulaceae	Tree
*Anaphalis contor*ta (D.Don) Hk.f.	Asteraceae	Herb
Anaphalis margaritaceae(L.) Ben. & Hk.f.	Asteraceae	Herb
Anaphalis triplinervis (Sim.) Clarke	Asteraceae	Herb
Anemone elongata D.Don	Ranunculaceae	Herb
Anemone rupestris Wall. ex Hk.f. & Thom.	Ranunculaceae	Herb
Angiopteris evecta (Forst.) Hoffm.	Marattiaceae	Shrub
Ardisia macrocarpa Wall.	Myrsinaceae	Shrub
Arisaema ciliatum Gus. & Goud.	Araceae	Herb
Arisaema concinnum Schott.	Araceae	Herb
Arisaema erubescens (Wall.) Schott.	Araceae	Herb
Arisaema nepenthoides (Wall.) Mart.	Araceae	Herb

Artemisia nilagirica Pampan	Asteraceae	Herb
Arundinella pumila (Hoc. ex A.Rich.) Sterd.	Poaceae	Herb
Asplenium ensiforme (Hay.) Ch. ex S.H. Wu	Aspleniaceae	Epiphyte
Asplenium phyllitidis D.Don	Aspleniaceae	Epiphyte
Aster thomsonii Clarke	Asteraceae	Herb
Astilbe rivularis Bch.-Hm. ex D.Don	Saxifragaceae	Herb
Astragalus concretus Benth.	Fabaceae	Shrub
Bambusa tulda Roxb.	Poaceae	Tree
Begonia thomsonii A.DC.	Begoniaceae	Herb
Begonia sp.	Begoniaceae	Herb
Berberis wallichiana DC.	Berberidaceae	Shrub
Betula alnoides Buch.-Ham. ex D.Don	Betulaceae	Tree
Betula utilis D.Don	Betulaceae	Tree
Biden pilosa Linn.	Asteraceae	Herb
Boehmeria platyphylla D.Don	Urticaceae	Herb
Brassiopsis polycantha (Wall.) R.N. Ban.	Araliaceae	Tree
Bromus inermis Leyss.	Poaceae	Herb
Buddleja macrostachya Benth.	Loganiaceae	Shrub
Calanthe brevicornu Lindl.	Orchidaceae	Herb
Calanthe metoensis Z.H.Tsi & K.Y.Lang	Orchidaceae	Herb
Callicarpa macrophylla Vahl	Lamiaceae	Shrub
Campanula pallida Wall.	Campanulaceae	Herb
Cardamine hirsuta L.	Brassicaceae	Herb
Cardiocrinum giganteum(Wall.) Mak.	Liliaceae	Herb
Carex polycephala Boott	Cyperaceae	Herb
Carex baccans Nees	Poaceae	Herb
Carpesium cernuum L. var. *penduncuIosum* Wall. ex Clarke	Asteraceae	Herb
Caryopteris bicolor (Roxb. ex Hardw.) Mabb.	Lamiaceae	Shrub

Cautleya gracilis (Sm.) Dandy	Zingiberaceae	Herb
Cayratia japonica (Thunb.) Gagnepain.	Vitaceae	Climber
Casearia kurzii Clarke	Flacourtiaceae	Tree
Cephalostaychum capitatum (Munro) Majumder	Poaceae	Shrub
Chaerophyllum villosum DC.	Apiaceae	Herb
Chimonocalamus griffithianus (Munro) Chao & Renv.	Poaceae	Shrub
Chirita pumila D.Don	Gesneriaceae	Herb
Chrysoplenium nepalensis D.Don	Saxifragaceae	Herb
Cicerbita macrorhiza (Royle) P.Beauv.	Asteraceae	Herb
Circaea alpina L.	Onagraceae	Herb
Cirsium falconeri (Hook.f.) Petr.	Asteraceae	Herb
Cirsium verutum (D.Don) Spreng.	Asteraceae	Herb
Clematis montana Buch.-Ham. ex DC.	Ranunculaceae	Climber
Clintonia udensis Tra. & C.A.Mey.	Liliaceae	Herb
Coelogyne corymbosa Lindl.	Orchidaceae	Epiphytes
Coelogyne punctulata Lindl.	Orchidaceae	Epiphytes
Coniogramme affinis Wall. ex Hieron	Hemionitidaceae	Herb
Corybas himailaicus (King & Pant.) Schl.	Orchidaceae	Herb
Corydalis leotocarpa Hook.f. & Thom.	Papaveraceae	Herb
Corydalis cornuta Royle	Papaveraceae	Herb
Cornus capitata (Wall.) Hara	Cornaceae	Tree
Cotoneaster acuminatus Wall. ex Lindl.	Rosaceae	Shrub
Cotoneastera adpressus Bois	Rosaceae	Shrub
Cotoneaster microphyllus Wall. ex Lindl.	Rosaceae	Shrub
Craibiodendron henyri W.W.Smith	Ericaceae	Tree
Crawfurdia speciosa Clarke	Gentianaceae	Climber
Cyananthus inflatus Hk.f. & Thom.	Campanulaceae	Herb
Cyperus involucratus Rottb.	Cyperaceae	Herb

Cyphostemma auriculatum (Roxb.) P. Singh & B.V. Shetty	Vitaceae	Climber
Daphne papyracea Wall. ex Steud.	Thymelaeceae	Shrub
Debregeasia longifolia (Burm.f.) Wedd.	Urticaceae	Tree
Dendrobium longicornu Lindl.	Orchidaceae	Epiphytes
Dicentra scandens (D. Don) Hutch.	Papaveraceae	Climber
Dichroa febrifuga Lour.	Hydrangeaceae	Shrub
*Dichrocephala integrifolia (*Linn.f.) Kun.	Asteraceae	Herb
Diphylax urceolata (Clarke) Hk.f	Orchidaceae	Herb
Diplazium esculentum (Retz.) Sw.	Athyriaceae	Herb
Drynaria propinqua (Wall. ex Mett.) J.Sm., J.Bot. (Hook.)	Polypodiaceae	Epiphyte
Dryopteris hirtipes (Bl.) Kunze	Dryopteridaceae	Herb
Dryopteris odontoloma (Bedd.) C.Chr.	Dryopteridaceae	Herb
Edgeworthia gardeneri (Wall.) Meisn.	Thymelaeaceae	Shrub
Elatostema acuminatum Brongn.	Urticaceae	Herb
Elatostema obtusum Wedd.	Urticaceae	Herb
Elatostema platyphyllum Wedd.	Urticaceae	Herb
Elsholtzia strobilifera Benth.	Lamiaceae	Herb
Engelhardtia spicata Lechen ex Bl.	Juglandaceae	Tree
Epilobium brevifolium D.Don.	Onagraceae	Herb
Eria spicata (D.Don) Hand & Mazz.	Orchidaceae	Epiphyte
Euonymus echinatus Wall. ex Roxb.	Celastraceae	Herb
Eurya acuminata DC.	Theaceae	Tree
Fagopyrum esculentum Moench.	Polygonaceae	Herb
Ficus auriculata Lour.	Moraceae	Tree
Ficus hederacea Roxb.	Moraceae	Climber
Fissistigma verrucosum (Hook.f. & Thom.) Merr.	Annonaceae	Climber

Fragaria nubicola Lindley ex Lacaita	Rosaceae	Herb
Galeola lindleyana (Hk. f. & Thm.) Rch.f.	Orchidaceae	Herb
Galium elegans Wall. ex Roxb	Gentianaceae	Herb
Galium aparine L.	Gentianaceae	Herb
Galium asperuloides Edgew.	Gentianaceae	Herb
Gaultheria hookeri Clarke	Ericaceae	Shrub
Gaultheria griffithiana Wight	Ericaceae	Shrub
Gentiana quadriferia Bl.	Gentianaceae	Herb
Gentiana tibetica King ex Hook.	Gentianaceae	Herb
Geranium nepalense Sweet	Geraniaceae	Herb
Girardinia heterophylla Decaisne	Urticaceae	Herb
Globba racemosa Sm.	Zingiberaceae	Herb
Goodyera schlechtendaliana Rchb.f.	Orchidaceae	Herb
Goodyera vittata (Lindl.) Benth. & Hk.f.	Orchidaceae	Herb
Gynura bicolor (Roxb. ex Wil.) DC.	Asteraceae	Herb
Habernaria arietina Hook. f.	Orchidaceae	Herb
Hedera nepalensis K.Koch	Araliaceae	Climber
Hedychium coccineum Buch.-Ham. ex Sm.	Zingiberaceae	Herb
Helwingia himalaica Hk.f. & Thm. ex Cl.	Helwingiaceae	Shrub
Hemiphragma heterophyllum Wall.	Scrophulariaceae	Herb
Heracleum wallichii DC.	Apiaceae	Herb
Herpetospermum pedunculosum (Ser.) Clarke	Cucurbitaceae	Climber
Himalaiella deltoidea (Cand.) Raab-Strau.	Asteraceae	Herb
Hoeboelia latifolia Wall.	Lardizabalaceae	Climber
Houttuynia cordata Thunb.	Saururaceae	Herb
Hoya lanceolata Wall. ex D. Don	Apocynaceae	Epiphytes

Hydrocotyle javanica Thunb.	Arialaceae	Herb
Hypericum hookerianum Wight & Arn.	Hypericaceae	Shrub
Ilex dipyrena Wall.	Aquifoliaceae	Tree
Ilex sikkimensis Kurz	Aquifoliaceae	Shrub
Impatiens bracteolata Hook.f.	Balsaminaceae	Herb
Impatiens dolichoceras Pritz. ex Diels	Balsaminaceae	Herb
Impatiens graciliflora Hook.f.	Balsaminaceae	Herb
Impatiens radiata Hook.f.	Balsaminaceae	Herb
Impatiens siculifer Hook.f.	Balsaminaceae	Herb
Inula cappa (Buch.-Ham. ex D. Don) DC.	Asteraceae	Herb
Ione bicolor Lindl.	Orchidaceae	Epiphytes
Itea macrophylla Wall.	Iteaceae	Tree
Jasminum dispermum Wall.	Oleaceae	Climber
Jasminum flexile Vahl var *ovatum* Wall.	Oleaceae	Climber
Juncus thomsonii Buch.	Juncaceae	Herb
Juncus sp.	Juncaceae	Herb
Laportea bulbifera (Siec. & Zucc.) Wedd.	Urticaceae	Herb
Leea asiatica (L.)Rids.	Vitaceae	Shrub
Lepisorus excavatus (Bory) Ching	Polypodiaceae	Herb
Leptodermis kumaonensis R. Park.	Rubiaceae	Shrub
Leucosceptrum canum Sm.	Lamiaceae	Shrub
Ligularia fischeri (Ledeb.) Turcz.	Asteraceae	Herb
Lithocarpus pachyphylla Rehder	Fagaceae	Tree
Litsea monopetala (Roxb.) Pers.	Lauraceae	Tree
Litsea cubeba (Lour.) Pers.	Lauraceae	Tree
Lobelia doniana Skottsb.	Lobeliaceae	Herb
Lonicera acuminata Wall.	Caprifoliaceae	Climber
Lycopodium pseudoclavatum Ching.	Lycopodiaceae	Herb
Lyonia ovalifolia (Wall.) D.Don	Ericaceae	Tree
Lysimachia laxa Baudo	Primulaceae	Herb

Macropanax dispermus Kuntze	Araliaceae	Tree
Mahonia manipurensis Takeda.	Berberidaceae	Shrub
Maianthemum fuscum (Wall.) LaFrankie	Asparagaceae	Herb
Magnolia campbelli Hook. f.	Magnoliaceae	Tree
Michelia velutina DC.	Magnoliaceae	Tree
Microlepia platyphylla (D.Don) J. Sm.	Dennstaedtiaceae	Herb
Microsorum superficiale (Bl.) Ching	Polypodiaceae	Epiphyte
Monotropa uniflora L.	Ericaceae	Herb
Mussaenda roxburghii Hook. f.	Rubiaceae	Shrub
Myriactis wallichi Less.	Asteraceae	Herb
Myrsine semiserrata Wall.	Myrsinaceae	Shrub
Neillia thyrsiflora D.Don	Rosaceae	Shrub
Neohymenopogon parasitus (Wall.) Benn.	Rubiaceae	Herb
Neottianthe secundiflora (Hk.f.) Sch.	Orchidaceae	Herb
Oberonia pyrulifera Lindl.	Orchidaceae	Epiphytes
Oenanthe thomsonii Clarke	Apiaceae	Herb
Onychium japonicum (Thunb.) Kunze	Cryptogrammatacea e	Herb
Ophiopogon intermedus D.Don	Asparagaceae	Herb
Ophiorrhiza succirubra King ex Hk.f.	Rubiaceae	Shrub
Osbeckia sp.	Melastomaceae	Herb
Otochilus lancilabius Seidenf.	Orchidaceae	Epiphytes
Oxalis corniculata Linn.	Oxalidaceae	Herb
Paris polyphylla Sm.	Melanthiaceae	Herb
Parochetus communis Buch.- Ham.ex D.Don.	Fabaceae	Herb
Passiflora assamica Chakravarty	Passifloraceae	Climber
Passiflora jugorum W.W.Smith	Passifloraceae	Climber
Pedicularis curvipes Hook.f.	Orobanchaceae	Herb
Pedicularis porrecta Wall.	Orobanchaceae	Herb

Persicaria campanulata (Hk.f.) Ron. Decr.	Polygonaceae	Shrub
Persicaria chinense (L.) H. Gross	Polygonaceae	Shrub
Persicaria nepalensis (Meisn.) H.Gross	Polygonaceae	Herb
Persicaria runcinata (Buch.-Ham. ex D.Don) H.Gross	Polygonaceae	Herb
Phlomoides hamosa (Benth.) Mathi.	Lamiaceae	Shrub
Phoebe hainesiana Brandis	Lauraceae	Tree
Pholidota imbricata (Roxb.) Lindl. var *coriaceae* Hk.	Orchidaceae	Epiphytes
Pholidota articulata Lindl.	Orchidaceae	Epiphytes
Pieris formosa (Wall.) D.Don.	Ericaceae	Shrub
Pilea bracteosa Wedd.	Urticaceae	Herb
Pilea scripta (Buch.-Ham ex D.Don) Wedd.	Urticaceae	Herb
Piper boehmeriaefolium Wall.	Piperaceae	Climber
Plantago erosa Wall.	Plantaginaceae	Herb
Platenthera leptocaulon (Hook.f.) Soo'	Orchidaceae	Herb
Pleione humilis (Sm.) D.Don	Orchidaceae	Epiphytes
Pleione praecox (Sm.) D.Don	Orchidaceae	Epiphytes
Pollia japonica Thunb.	Commelinaceae	Herb
Polygala arillata Buch.-Ham ex D.Don	Polygalaceae	Shrub
Polygonatum kingianum Coll. and Hem.	Liliaceae	Herb
*Polypodiodes amoena (*Wall. ex Mett.) Chn.	Polypodiaceae	Herb
Polystichum semifertile (Clarke) Ching	Dryopteridaceae	Herb
Potentilla lineata Trev. ex Reich.	Rosaceae	Herb
Potentilla sundaica (Bl.) Kuntz	Rosaceae	Herb
Pouzolzia sanguinea (Bl.) Merr.	Urticaceae	Herb
Pratia begonifolia (Wall.) Lindl.	Campanulaceae	Herb
Primula geraniifolia Hook.f.	Primulaceae	Herb
Prunus cerasoides D.Don	Rosaceae	Tree

Pseudognaphalium affine (D. Don) Ander.	Asteraceae	Herb
Psychotria erratica Hook.	Rubiaceae	Climber
Quercus lamellosa Sm.	Fagaceae	Tree
Ranunculus cantoniensis DC.	Ranunculaceae	Herb
Rhodiola bupleroides (Hook.f. & Thom.) Fu	Crassulaceae	Herb
Rhododendron arboreum Sm. subsp. *delavayi* (Fran.) Cham.	Ericaceae	Tree
Rhododendron elliotti Watt.	Ericaceae	Shrub
Rhododendron formosum Wall. var. *inequale* (Hut.) Cull.	Ericaceae	Epiphytes
Rhododendron johnstoneanum Watt. ex Hut.	Ericaceae	Shrub
Rhododendron macabeanum Watt. ex I.B. Balf.	Ericaceae	Tree
Rhododendron maddenii Hk f. subsp. *crassum* (Fran.) Cull.	Ericaceae	Tree
Rhododendron triflorum Hk.f. var. *bauhiniflorum* (Watt. ex Hut.) Cull.	Ericaceae	Shrub
Rohdea wattii (Clarke) Yama. & M.N. Tam.	Asparagaceae	Herb
Rosa sericea Lindl.	Rosaceae	Shrub
Rubia manjith Roxb. ex Flem.	Ericaceae	Herb
Rubus calophyllus Clarke	Rosaceae	Shrub
Rubus calycinus Wall. ex D.Don	Rosaceae	Herb
Rubus ellipticus Sm.	Rosaceae	Shrub
Rubus fockeanus Kurz J.	Rosaceae	Herb
Rubus hirtus Heget.	Rosaceae	Shrub
Rubus lineatus var lineatus Reinw	Rosaceae	Shrub
Rubus pedunculosus. D.Don.	Rosaceae	Shrub
Rubus sumatranus Miq.	Rosaceae	Shrub
Rubus sp.	Rosaceae	Shrub

Rumex nepalenis Spreng.	Polygonaceae`	Herb
Sarcopyramis nepalensis Wall.	Melastomataceae	Herb
Sambucus adnata Wall. ex DC.	Adoxaceae	Shrub
Satyrium nepalense D.Don.	Orchidaceae	Herb
Saurauia nepaulensis DC.	Actinodaceae	Tree
Saxifraga brachypoda D.Don	Saxifragaceae	Herb
Saxifraga brunonis Wall. ex Ser.	Saxifragaceae	Herb
Schima khasiana Dyer	Theaceae	Tree
Schisandra grandiflora (Wl.) Hk.f. & Thom.	Schisandraceae	Climber
Schleffera shweliensis W. W. Smith	Araliaceae	Tree
Sedum linearifolium var *ovatisepalum* Ray.-Ham.	Crassulaceae	Herb
Sedum sp.	Crassulaceae	Herb
Selaginella martensii Spring.	Selaginellaceae	Herb
Senecio laetus Edgen	Asteraceae	Herb
Senecio scandens Buch.-Ham. ex D.Don	Asteraceae	Herb
Skimmia laureola Fran.	Rutaceae	Shrub
Smilax sp.	Smilacaceae	Climber
Solanum nigrum Linn.	Solanaceae	Herb
Sorbus foliolosa (Wall.) Spach.	Rosaceae	Tree
Sorbus insignis (Hook.f.) Hedl.	Rosaceae	Tree
Spiraea canescens D.Don	Rosaceae	Shrub
Sterculia villosa Roxb.	Malvaceae	Tree
Streptolirion volubile Edgew.	Commelinaceae	Climber
Streptopus simplex D.Don	Liliaceae	Herb
Strobilanthes pterygorrhachis Clarke	Acanthaceae	Shrub
Swertia franchetiana Harry Sm.	Gentianaceae	Herb
Symplocos dryophila D.Don	Symplocaceae	Tree
Symplocos thaefolia D.Don	Symplocaceae	Tree

Symplocos sp.	Symplocaceae	Tree
Taxillus vestitus (Wall.) Danser	Loranthaceae	Epiphyte
Taxus wallichiana Zucc.	Taxaceae	Tree
Tectaria polymorpha (Wall. ex Hk.f.) Copel.	Tectariaceae	Herb
Tetrastigma dubium (Laws.) Planch.	Vitaceae	Climber
Thalictrum reniforme Wall.	Ranunculaceae	Herb
Thalictrum foliolosum DC.	Ranunculaceae	Herb
Thladiantha cordifolia (Blume) Cogn.	Cucurbitaceae	Climber
Theropogon pallidus (Wall. ex Kun.) Max.	Asparagaceae	Herb
Tiarella polyphylla D.Don	Saxifragaceae	Herb
Tipularia josephi Rchb. f. ex Lindl.	Orchidaceae	Herb
Trevesia palmata (Roxb.)Vis.	Araliaceae	Tree
Turpina pomifera DC.	Sapindaceae	Tree
Urtica mairei H. Lev.	Urticaceae	Herb
Vaccinium retusum Hk.f. ex Clarke	Vaccineaceae	Shrub
Vaccinium vacciniaceum (Roxb.) Sleum.	Vaccineaceae	Epiphytes
Vaccinium sp.	Vaccineaceae	Shrub
Valeriana hardwickii Wall.	Valerianaceae	Herb
Valeriana jatamansi Jones	Valerianaceae	Herb
Viburnum erubescens Wall.	Adoxaceae	shrub
Viola betonicifolia Sm.	Violaceae	Herb
Viola pilosa Blume	Violaceae	Herb
Vitex quinata (Lour.) F.N. Will.	Lamiaceae	Tree
Wendlandia coriacea (Wall.) DC.	Rubiaceae	Shrub
Yushania rolloana (Gamble) Chao & Renv.	Poaceae	Shrub
Zanthoxyllum acanthopodium DC.	Rutaceae	Tree
Zanthoxyllum sp.	Rutaceae	Herb

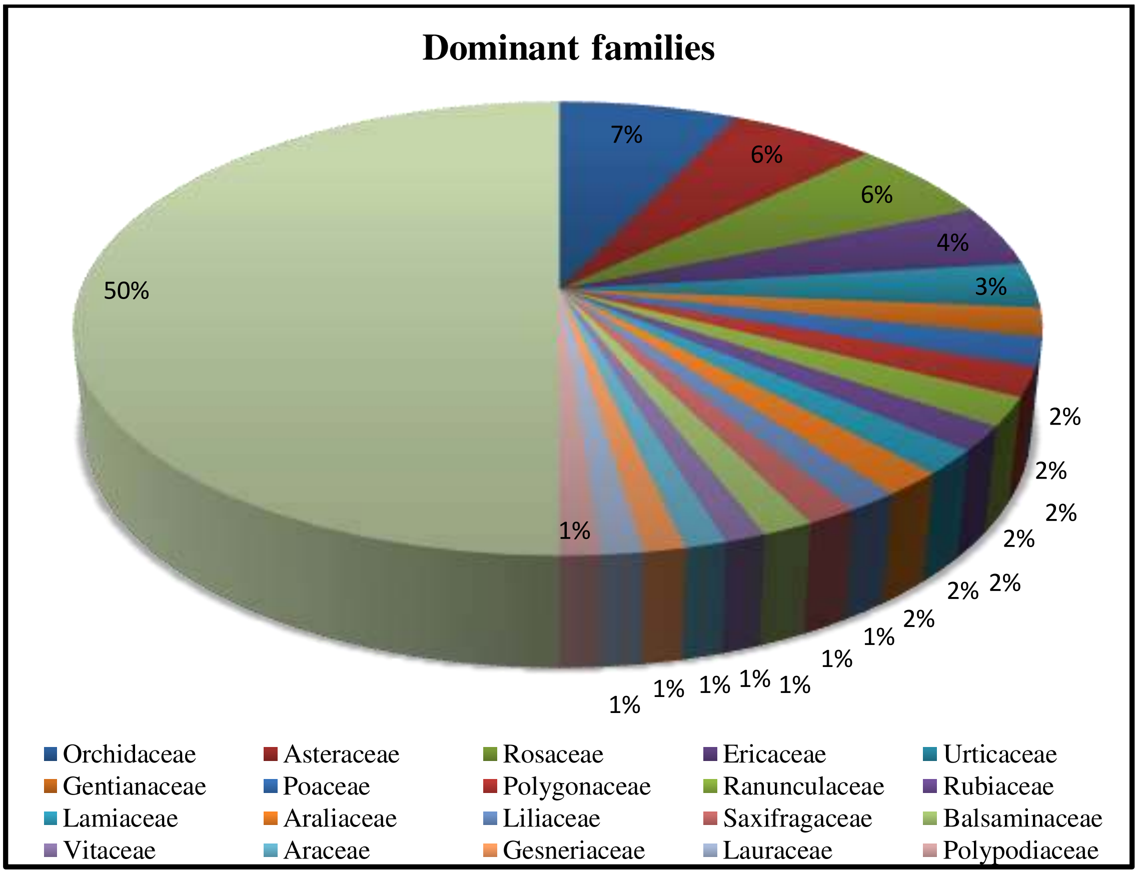

Fig. 3.10 : Dominant plant families in Mt. Japfü.

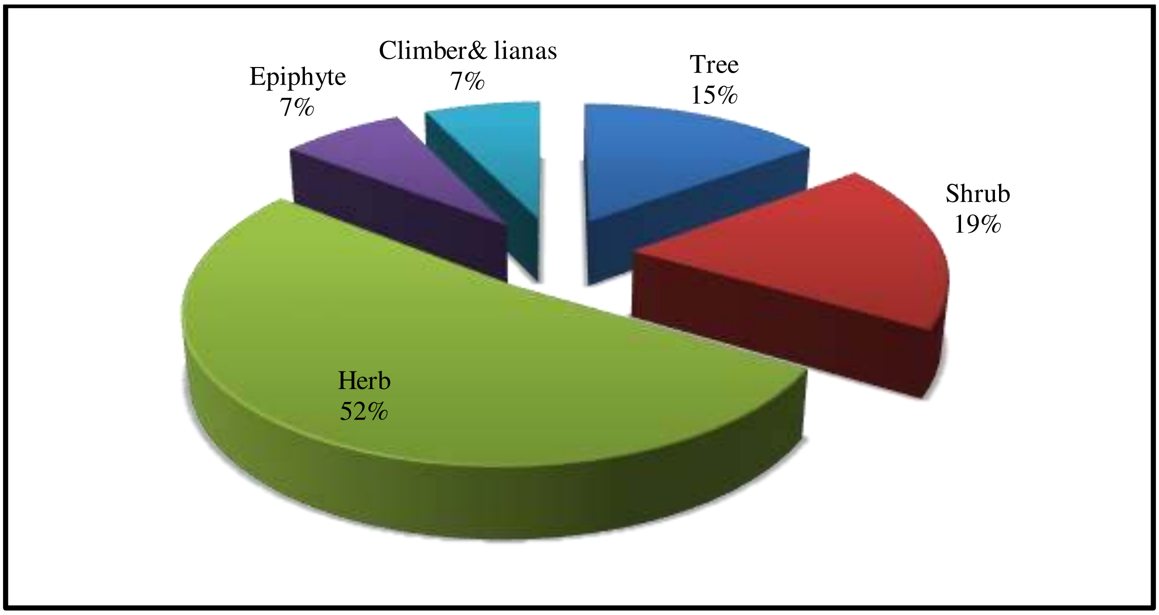

Fig. 3.11 : Habit wise distribution of plants in Mt. Japfü.

Table 3.12 : Endemic (E), Endangered (En), Threatened (T), Vulnerable (V) and Rare (R) species of Mt. Japfü.

Sl.no.	Plant species	Family	Status
1	*Actinodaphne obovata* (Nees) Bl.	Lauraceae	E
2	*Clematis montana* Buch.-Ham. ex DC.	Ranunculaceae	E & R
3	*Corybas himailaicus* (King & Pant.) Schlech.	Orchidaceae	E
4	*Daphne papyracea* Wall. ex Sted.	Thymelaeceae	E
5	*Elatostema platyphyllum* Wedd.	Urticaceae	E
6	*Galeola lindleyana* (Hk. f. & Thm.) Rch.f.	Orchidaceae	E & R
7	*Hedera nepalensis* K.Koch	Araliaceae	E & T
8	*Helwingia himalaica* Hk.f. & Thm. ex Clarke	Helwingiaceae	E & R
9	*Itea macrophylla* Wall.	Iteaceae	E
10	*Leucosceptrum canum* Sm.	Lamiaceae	E
11	*Lithocarpus pachyphylla* Rehder	Fagaceae	E
12	*Macropanax dispermus* Kuntze	Araliaceae	E
13	*Paris polyphylla* Sm.	Melanthiaceae	E & V
14	*Phoebe hainesiana* Brandis	Lauraceae	E & V
15	*Pleione humilis* (Sm.) D.Don	Orchidaceae	E & R
16	*Pleione praecox* (Sm.) D.Don	Orchidaceae	E & R
17	*Psychotria erratica* Hook.	Rubiaceae	E
18	*Quercus lamellosa* Sm.	Fagaceae	E
19	*Rhododendron arboreum* Sm. subsp. *delavayi* (Fran.) Cham.	Ericaceae	E & R
20	*Rhododendron elliotti* Watt.	Ericaceae	E & En
21	*Rhododendron johnstoneanum* Watt	Ericaceae	E & En

	ex Hutch.		
22	*Rhododendron macabeanum* Watt ex I.B. Balf.	Ericaceae	E & R
23	*Rhododendron maddenii* Hook f. subsp. *crassum* (Franchet) Cullen	Ericaceae	E & R
24	*Rhododendron triflorum* Hook.f. var. *bauhiniflorum* (watt ex Hutch.) Cullen	Ericaceae	E & R
25	*Rubia sikkimense* Kurze	Ericaceae	E & V
26	*Rubus sumatranus* Miq.	Rosaceae	E
27	*Taxus wallichiana* Zucc.	Taxaceae	En & R
28	*Vaccinium vacciniaceum* (Roxb.) Sleum.	Vaccineaceae	E
29	*Valeriana hardwickii* Wall.	Valerianaceae	E & V
30	*Valeriana jatamansi* Jones	Valerianaceae	E & E
31	*Zanthoxyllum acanthopodium* DC.	Rutaceae	E

Table 3.13 : Medicinal plants found in Mt. Japfu.

Sl. no.	Name of species	Family	Local name	Diseases treated
1	*Aconitum nagarum* Stapf.	Ranunculaceae		Tubers used in snake bite, nausea and analgesic.
2	*Aconogonum molle* (D.Don) H. Hara	Polygonaceae	Gagei	Leaves used in stomach ache.
3	*Ageratina adenophora* (Spreng) R.M. King & H. Rob.	Asteraceae	Japan nha	Leaves haemostatic and used in malaria.

4	*Alnus nepalensis* D.Don	Betulaceae	Rüpruo	Leaves haemostatic and roots taken for diarrhoea.
5	*Anaphalis margaritaceae* (L.) Benth. & Hk.f.	Asteraceae		Antiseptic, astringent, expectorant and sedative.
6	*Angiopteris evecta* (Forst.) Hoff.	Marattiaceae	Janger	Stipe is used for leprosy and skin diseases.
7	*Arisaema concinnum* Schott.	Araceae		Rhizome used in menstrual disorder
8	*Artemisia nilagirica* Pampan	Asteraceae	Ciena	Leaves haemostatic and used in asthma and febrifuge.
9	*Berberis wallichiana* DC.	Berberidaceae	Ayaktepa-aing tong	Bark and roots anti malaria, blood purifier and diuretic.
10	*Betula alnoides* Buch.-Ham. ex D.Don	Betulaceae	Entsung	Bark used to improve digestion .
11	*Biden pilosa* Linn.	Asteraceae	Temvü tsüthu	Used for leprosy and skin diseases.
12	*Boehmeria platyphylla* D.Don	Urticaceae		Used as sedative and anxielytic.
13	*Campanula pallida* Wall.	Campanulaceae		Roots used in dysentery and diarrhoea.
14	*Cardamine hirsuta* L.	Brassicaceae	Seguoga	Leaves used in urinary problem.
15	*Carpesium cernuum*	Asteraceae		Aerial parts used to

	L. var. *pendunculosum* Wall. ex Clarke			relieve inflammation, pain and detoxification.
16	*Caryopteris bicolor* (Roxb. ex Hardw.) Mabb.	Lamiaceae		Bark used in scabies
17	*Cautleya gracilis* (Sm.) Dandy	Zingiberaceae		Anti cancer
18	*Cayratia japonica* (Thunb.) Gagnepain.	Vitaceae		Leaves used to relieve swelling, detoxification and fever.
19	*Cephalostaychum capitatum* (Munro) Majumder	Poaceae	Kera	Shoot used in diarrhoea and stomach disorder.
20	*Chaerophyllum villosum* DC.	Apiaceae	Gakra	Powdered root used for sexual stimulation.
21	*Cicerbita macrorhiza* (Royle) P.Beauv.	Asteraceae		Used in fever.
22	*Clematis montana* Buch.-Ham. ex DC.	Ranunculaceae		Used in fever, promte lactation and menstruation.
23	*Clintonia udensis* Trautv. & C.A.Mey.	Liliaceae		Rhizomes used as uterine tonic.
24	*Coelogyne corymbosa* Lindl.	Orchidaceae		Bulb is used for fractures or soft tissue injury.
25	*Corydalis cornuta* Royle	Papaveraceae		Used as stimulant.

26	*Cornus capitata* (Wall.) Hara	Cornaceae		Bark used as astringent.
27	*Cotoneaster acuminatus* Wall. ex Lindl.	Rosaceae		Used for hypertension.
28	*Cotoneaster microphyllus* Wall. ex Lindl.	Rosaceae		Stolons used as astringent.
29	*Craibiodendron henyri* W.W.Smith	Ericaceae		Roots used as antioxidant.
30	*Crawfurdia speciosa* Clarke	Gentianaceae		Root and flower is haemostatic.
31	*Daphne papyracea* Wall. ex Steud.	Thymelaeceae		Febrifuge and purgative
32	*Debregeasia longifolia* (Burm.f.) Wedd.	Urticaceae	Tsunyu	Fruits used as digestive.
33	*Dendrobium longicornu* Lindl.	Orchidaceae		Stem juice used for fever and cough.
34	*Dicentra scandens* (D. Don) Hutch.	Papaveraceae		Used in malaria, diabetes and high BP.
35	*Dichroa febrifuga* Lour.	Hydrangeaceae		Roots and leaves used in malarial fever.
36	*Dichrocephala integrifolia (*Linn.f.) Kuntze.	Asteraceae		Leaves anti viral and flower buds are diuretic.
37	*Edgeworthia gardeneri* (Wall.) Meisn.	Thymelaeaceae		Flowers used in diabetes.

38	*Elatostema platyphyllum* Wedd.	Urticaceae		Root used in vomitting.
39	*Engelhardtia spicata* Lechen ex Bl.	Juglandaceae		Bark used in diarrhoea.
40	*Epilobium brevifolium* D.Don.	Onagraceae		Used in muscular pain
41	*Eria spicata* (D.Don) Hand & Mazz.	Orchidaceae		Pseudobulb used in stomach ache.
42	*Eurya acuminata* DC.	Theaceae	Siesenuo	Leaves used in dysentery and diarrhoea.
43	*Fagopyrum esculentum* Moench.	Polygonaceae	Garei	Used in arthritis and reduce BP.
44	*Fragaria nubicola* Lindley ex Lacaita	Rosaceae	Tsulapolong	Plant juice used in menstrual problems.
45	*Gaultheria hookeri* Clarke	Ericaceae		Leaves stimulant and used in rheumatism.
46	*Geranium nepalense* Sweet	Geraniaceae	Nilingken	Plant diuretic and astringent.
47	*Girardinia heterophylla* Decaisne	Urticaceae		Leaves diuretic, anti rheumatic and anti allergy.
48	*Globba racemosa* Sm.	Zingiberaceae		Fruits used in stomach ache and dyspepsia.
49	*Gynura bicolor* (Roxb. ex Willd.) DC.	Asteraceae	Liezienuo	Leaves haemostatic and juice used in constipation.
50	*Hedera nepalensis* K.Koch	Araliaceae	Duddela	Leaves and berry are stimulant, cathartic

				and diaphoretic.
51	*Hemiphragma heterophyllum* Wall.	Scrophulariaceae		Plant haemostatic.
52	*Heracleum wallichii* DC.	Apiaceae		Roots aphrodiasic and tonic.
53	*Herpetospermum pedunculosum* (Ser.) Clarke	Cucurbitaceae		Fruits used in malaria and as liver tonic.
54	*Houttuynia cordata* Thunb.	Saururaceae	Gatha	Used in ulcer, dysentery, diarrhoea and bood purifier.
55	*Hydrocotyle javanica* Thunb.	Arialaceae		Bark used in gastric troubles, dtsentery and fever.
56	*Ilex dipyrena* Wall.	Aquifoliaceae		Leaves diuretic and purgative.
57	*Inula cappa* (Buch.-Ham. ex D. Don) DC.	Asteraceae		Leaves are haemostatic.
58	*Jasminum dispermum* Wall.	Oleaceae		Used in intestinal problems.
59	*Leucosceptrum canum* Sm.	Lamiaceae	Teizü	Tomentum of leaves is haemostatic and flowers is astringent and stimulant.
60	*Litsea monopetala* (Roxb.) Pers.	Lauraceae		Seeds used as depressant, hypotensive and bark is astringent.
61	*Litsea cubeba* (Lour.) Pers.	Lauraceae		Fruits used in cough, cold and indigestion.

62	*Lyonia ovalifolia* (Wall.) D.Don	Ericaceae		Leaves used in skin diseases.
63	*Otochilus lancilabius* Seidenf.	Orchidaceae		Plant used in fracture and dislocated bones.
64	*Oxalis corniculata* Linn.	Oxalidaceae	Keve	Plant used in headache, gum swelling, bowel disorder and snake bite.
65	*Paris polyphylla* Sm.	Melanthiaceae	Naga ginseng	Tubers used for anti cancer properties and stimulant.
66	*Persicaria chinense* (L.) H. Gross	Polygonaceae	Psüzie	Used in bronchitis, jaundice and lung problems.
67	*Pholidota imbricata* (Roxb.) Lindl. var *coriaceae* Hook.	Orchidaceae		Plant used as tonic.
68	*Pholidota articulata* Lindl.	Orchidaceae		Bulb used in bronchitis and toothache.
69	*Pieris formosa* (Wall.) D.Don.	Ericaceae		Fruits and roots used for oedema.
70	*Plantago erosa* Wall.	Plantaginaceae	Gapa	Leave is haemostatic and used in toothache and pile problem.
71	*Pleione humilis* (Sm.) D.Don	Orchidaceae		Bulb is haemostatic.

72	*Pleione praecox* (Sm.) D.Don	Orchidaceae		Bulb is haemostatic and used as tonic.
73	*Polygonatum kingianum* Coll. and Hem.	Liliaceae		Root is antiseptic and vasodilator.
74	*Rhododendron arboreum* Sm. Subsp. *delavayi* (Franchet) Chamberlain	Ericaceae	Nthuo	Flowers used for infantile diarrhoea, anticancer and hypotensive.
75	*Rubia sikkimense* Kurze	Ericaceae	Awali	Root paste applied in snake bite
76	*Rubus calycinus* Wall. ex D.Don	Rosaceae		Fruits used in stomach disorder.
77	*Rubus ellipticus* Sm.	Rosaceae	Ruomvü	Fruits used in indigestion.
78	*Rumex nepalenis* Spreng.	Polygonaceae`	Palak	Roots and leaves used on boils and body swelling.
79	*Sarcopyramis nepalensis* Wall.	Melastomataceae		Used in diabetes.
80	*Satyrium nepalense* D.Don.	Orchidaceae		Used in malaria, dysentery and tonic.
81	*Saurauria nepaulensis* DC.	Saurauriaceae	Achijila	Leaves is central nervous system depressant and spasmolytic.
82	*Schima khasiana* Dyer	Theaceae	Merimesang	Leaves haemostatic.
83	*Senecio scandens*	Asteraceae	Mesakraza	Leaves used in

	Buch.-Ham. ex D.Don			jaundice and eye disease.
84	*Solanum nigrum* Linn.	Solanaceae	Gadzü	Used in skin diseases and oedema.
85	*Taxus wallichiana* Zucc.	Taxaceae	Seipehü	Leaves antiseptic, aphrodisiac and bark is anti cancer.
86	*Thalictrum reniforme* Wall.	Ranunculaceae		Anti parasitic
87	*Thalictrum foliolosum* DC.	Ranunculaceae		Malaria, eye disease and diuretic.
88	*Urtica mairei* H. Lev.	Urticaceae	Zozie	Roots and leaves used in hepatitis, dog bite and blood purifier.
89	*Valeriana hardwickii* Wall.	Valerianaceae		Sedative, skin disease and urinary problems.
90	*Valeriana jatamansi* Jones	Valerianaceae		Roots is antipyretic, liver disorder and epilepsy.
91	*Viola betonicifolia* Sm.	Violaceae		Aerial parts used in ulcers and sores.
92	*Zanthoxyllum acanthopodium* DC.	Rutaceae	Ganyasei	Fruits used in toothache.

3.2 Structure of Vegetation

In the present study area, the vertical vegetation structure was studied based on the different heights of the individual plants. The plant species were grouped into different growth forms such as canopy, sub canopy, understorey, shrubs, climbers and scandents, epiphytes and herbs.

Canopy : The canopy layer comprised of tree species with average height between 18 m and above. The forest canopy was composed of 12 species belonging to 11 genera and 9 families. *Betula alnoides, Betula utilis, Ilex dipyrena, Lithocarpus pachyphylla, Magnolia campbelli, Michelia velutina, Phoebe hainesiania, Prunus cerasoides, Quercus lamellosa*, *Rhododendron arboreum, Schleffera shweliensis* and *Schima khasiana* represented the canopy trees. Compared to the other layers, canopy layer is represented by lowest number of species.

Sub canopy : This layer comprised of medium sized trees with height around 6 m to 18 m. A total of 29 tree species with 21 genera and 21 families were present in the sub canopy layer. Aceraceae, Araliaceae, Ericaceae, Lauraceae, Rosaceae and Symplocaceae are the dominant families in this layer. *Acer* spp.*, Eurya japonica, Engelhardtia spicata, Litsea* spp.*, Macropanax dispermus, Rhododendron* spp.*, Sorbus* spp.*, Symplocos* spp.*, Taxus wallichiana* etc. were some common species found in the sub canopy layer.

Understorey: Small trees and large shrubs represents the understorey layer in the forest. 31 species with 29 genera and 17 families were documented in this layer. Ericaceae, Lamiaceae, Poaceae, Rosaceae, Rubiaceae, Rutaceae and Thymelaceae are the dominant plant families in the understorey layer. *Cephalostachyum capitatum, Chimonocalamus griffithiana, Daphne papyracea, Debregeasia longifolia, Leucoseptrum canum, Lyonia ovalifolia, Mussaenda roxburghii, Pieris formosa, Polygala arillata, Rhododendron* spp.*, Rubus ellipticus, Sambucus adnata, Wendlandia coriacea* were some of the prominent species present.

Shrubs : A total of 30 species belonging to 21 genera and 15 families have been recorded from the study area. Berberidaceae, Ericaceae, Polygonaceae, Rosaceae, Rubiaceae and Vaccinaceae are the dominant families of shrubs. *Ardisia macrocarpa, Mahonia manipurensis, Berberis wallichiana, Vaccinium* spp.*, Cotoneaster* spp.*, Gaultheria* spp.*, Hypericum hookerianum, Rubus* spp.*, Ophiopogon intermedius* and *Persicaria* spp. are some of the commonly found shrubs.

Herbs : Herbaceous species were found to have the highest number of species in the study site. Altogether 151 species of herbs belonging to 114 genera and 52 families were documented from the area. With 19 species Asteraceae is the most dominant family followed by Orchidaceae with 12 species, Urticaceae with 11 species, Rosaceae with 7 species and Gentianaceae with 6 species. Terrestrial orchids found in the area are *Calanthe brevicornu, Calanthe metoensis, Corybas himailaicus, Diphylax urceolata, Galeola lindleyana, Goodyera schlechtendaliana, Goodyera vittata, Habernaria arietina, Neottianthe secundiflora, Platenthera leptocaulon, Satyrium nepalense* and *Tipularia josephi.* Other herb species found are *Aconitum nagarum, Ainsliaea aptera, Anaphalis* spp.*, Anemone* spp.*, Arisaema* spp.*, Begonia* spp.*, Circaea alpina, Clintonia udensis, Corydalis* spp.*, Dryopteris* spp.*, Elatostemma* spp.*, Fagopyrum esculentum, Fragaria nubicola, Galium* spp.*, Gentiana* spp.*, Impatiens* spp.*, Juncus* spp.*, Ophiopogon intermedus, Parochetus communis, Pedicularis* spp.*, Persicaria* spp.*, Potentilla* spp.*, Rubus* spp.*, Senecio* spp.*, Thalictrum* spp.*, Valeriana* spp. and *Viola* spp.

Climbers & Lianas : 24 species of climbers and scandents belonging to 22 genera and 19 families were documented from the study area. The dominant families were Vitaceae, Cucurbitaceae, Passifloraceae and Oleaceae. Some of the climbers and scandents commonly found are *Cayratia japonica, Clematis montana, Cyphostemma auriculatum, Euonymus echinatus, Hedera nepalensis, Herpetospermum pedunculosum, Hoebolia latifolia, Jasminum* spp.*, Passiflora* spp.*, Piper boehmeriaefolium Psychotria erratica* and *Rubia sikkimense.*

Epiphytes : A total of 23 species of epiphytes with 18 genera and 9 families have been recorded from Mt. Japfü. Orchidaceae with 12 species was the most dominant family. Other families present are Apocynaceae, Aspleniaceae, Ericaceae, Gesneriaceae, Loranthaceae, Polypodiaceae and Vacciniaceae. *Aeschynanthus* spp., *Agrostophyllum callosum, Asplenium* spp., *Coelogyne* spp., *Drynaria propinqua, Eria spicata, Hoya lanceolata, Microsorum superficiale, Pholidota* spp., *Pleione* spp., *Rhododendron formosum* var. *inequale, Taxillus vestitus and Vaccinium vacciniaceum* are some epiphytes present in the study area.

Synusiae	No. of Species	No. of Genera	No. of families
Canopy trees	12	11	9
Sub canopy trees	29	21	21
Understorey	31	29	17
Shrubs	30	21	15
Herbs	151	114	52
Climbers & Lianas	24	22	19
Epiphytes	23	18	9

Table 3.14 : Distribution of species, genera and families at different Synusiae in the study site.

3.3 Types of Vegetation

The vegetation in Mt. Japfü can be classified into two types namely Montane wet temperate forest and Sub alpine vegetation based on classification of forest types in India by Champion and Seth (1968). In India, this type of forest occurs along Assam/Burma border between 1,800 m to 3,000 m ASL altitude (Champion and Seth, 1968).

3.3.1 Temperate forest

Montane wet temperate forest is present at high altitudes with low temperature and high rainfall. The temperate forest in Mt. Japfu lies between the altitudinal range of 1900m to 3000 m ASL. The forest is characterized by presence of temperate species like *Acer* spp.*,* *Betula* spp.*,* *Ilex* spp.*,* *Lithocarpus pachyphylla, Litsea* spp.*,* *Macropanax dispermus, Magnolia campbelli, Michelia velutina, Prunus cerasoides, Quercus lamellosa, Rhododendron* spp.*,* *Sorbus* spp.*,* *Symplocos* spp. *and Taxus wallichiana.*

Based on dominant species in the forest, the plant community in Mt. Japfü can be further divided into three types **:**

a) *Litsea - Lithocarpus* Forest zone

This plant community is found at the northern slopes between the altitudinal range of 1900 m and 2500 m ASL in Mt. Japfü. *Litsea* spp. and *Lithocarpus pachyphylla* are the dominant tree species. Lauraceae is the dominant family of tree species in this community with presence of laurels like *Actinodaphne obovata, Litsea cubeba, Litsea monopetala* and *Phoebe hainesiana.* Around 32 tree species are found in this plant community which indicates that maximum of the trees species are present in this region. Other tree species also found are *Acer caudatum, Alnus nepalensis, Brassiopsis polycantha, Casearia kurzii, Cornus capitata, Craibiodendron henyri, Debregeasia longifolia, Engelhardtia spicata, Eurya acuminata, Ficus auriculata, Itea macrocarpa, Magnolia campbelli, Michelia velutina, Rhododendron arboreum, Saurauria nepaulensis, Sorbus foliolosa, Symplocos* spp.*, Taxus wallichiana* and *Vitex quinata.* Patches of *Bambusa tulda* and *Cephalostaychum capitatum* are observed in the lower altitudes of the forest. Shrubs and herbs are represented by species such as *Aconogonum molle, Arisaema* spp., *Begonia* spp.*, Chaerophyllum villosum, Cirsium* spp.*, Corydalis spp., Daphne papyracea, Dichroa febrifuga, Dryopteris* spp.*, Elatostema* spp., *Galium* spp., *Galeola lindleyana, Gentiana* spp.*, Girardiana heterophylla, Habernaria arietina, Hedychium coccineum, Impatiens* spp.*, Pilea* spp.*, Urtica marei, Mussaenda roxburghii, Rubus* spp.*, Rumex nepalensis, Strobilanthes pterygorrhachis, Tectaria* *polymorpha, Valeriana* spp., *Viola pilosa*. Majority of the epiphytes, climbers and lianas of Mt. Japfü are also found in this community. *Aeschynanthus* spp., *Agapetes smithiana* var *major, Agrostophyllum callosum, Asplenium* spp., *Cayratia japonicum, Coelogyne* spp., *Cyphostemma auriculatum, Drynaria propinqua, Eria spicata, Euonymus echinatus, Ficus hederacea, Fissistigma verrucosum, Hedera nepalensis, Herpetospermum pedunculosum, Hoya lanceolata, Ione bicolor, Jasminum* spp., *Lonicera acuminata, Pholidota* spp., *Piper boehmeriaefolium, Pleione* spp., *Psychotria erratica, Rhododendron formosum, Rubia manjith* and *Taxillus vestitus.*

b) *Rhododendron - Symplocos* Forest zone

This plant community occurs in the northern slopes at altitudinal range between 2500 m to 3000 m ASL. Dominant tree species in this region are *Rhododendron macabeanum, Rhododendron maddenii* and *Symplocos dryophila.* Other tree species recorded from the area are *Acer* spp., *Betula utilis, Eurya acuminata, Ilex dipyrena, Lithocarpus pachyphylla, Lyonia ovalifolia, Macropanax dispermus, Prunus cerasoides, Quercus lamellosa, Schleffera shweliensis, Sorbus* spp., *Symplocos thaefolia* and *Taxus wallichiana*. Shrubs are represented by *Buddleja macrostachya*, *Daphne papyracea, Gaultheria* spp., *Persicaria* spp., *Pieris formosa, Rhododendron* spp., *Rubus* spp. and *Vaccinium* spp.. Herbs are mostly dominated by terrestrial orchids such as *Calanthe* spp., *Corybas himailaicus*, *Diphylax urceolata, Goodyera* spp., *Neotthianthe secundiflora, Platenthera leptocaulon* and *Tipularia josephi.* Other herbaceous species present in this plant community are *Ainsliaea aptera, Anemone elongata, Arundinella pumila, Aster thomsonii, Cardamine hirsuta, Carpesium cernuum* var *penduncułosum, Chrysoplenium nepalensis, Circaea alpina, Clintonia udensis, Dicrocephala integrifolia, Dryopteris* spp., *Epilobium brevifolium, Galium* spp., *Impatiens* spp., *Lepisorus excavatus, Ligularia fischeri, Monotropa uniflora, Ophiopogon intermedus, Paris polyphylla, Polygonatum kingianum, Primula geraniifolia, Ranunculus cantoniensis, Rohdea wattii, Sarcopyramis nepalensis, Sedum linearifolium* var *ovatisepalum* and *Swertia franchetiana.* Few epiphytes, climbers and lianas found in this area are *Aeschynanthus hookeri, Agapetes smithiana* var *major, Clematis montana,* *Crawfurdia speciosa, Euonymus echinatus, Hedera nepalensis, Pleione humilis, Rubia sikkimense, Smilax* sp.*, Taxillus vestitus* and *Tetrastigma dubium.*

c) *Rhododendron - Betula* Forest zone

This plant community is found at the southern slope and between the altitudinal range of 2600 to 2900 m ASL. The vegetation on this slope is less diverse when compared to other communities. The dominant tree species in this community are *Rhododendron macabeanum* and *Betula utilis. Acer pectinatum, Lithocarpus pachyphylla, Litsea cubeba, Sorbus foliolosa, Symplocos dryophila, Ilex dipyrena* are also found in this community. *Chimonocalamus griffithiana , Ilex sikkimense, Astragalus concretus and Berberis wallichiana* were the only species of shrub recorded from this area. Herbaceous species are represented by *Bromus inermis, Euonymus echinatus*, *Impatiens* spp., *Maianthemum fuscum, Ophiopogon intermedus, Pilea scripta, Paris polyphylla, Persicaria* spp., *Primula geraniifolia, Rubia sikkimense* and *Sedum* spp.

3.3.2. Sub Alpine Vegetation

Sub alpine vegetation in Mt. Japfu is found at the peak and the southern slope between the altitudinal range of 2900 m to 3048 m ASL. Vegetation is composed mainly of shrubs and herbs. Few number of trees such as *Rhododendron macabeanum* and *Betula utilis* are found among the scrub vegetation. *Yushiana rolloana* and *Gaultheria hookeri* are the dominant shrub species of the plant community. *Aconogonum molle, Buddleja macrostachya, Cotoneaster* spp., *Leucoseptrum canum, Hypericum hookerianum, Persicaria chinense, Rhododendron johnstoneanum, Rhododendron triflorum* var *bauhiniflorum, Rosa sericea, Rubus* spp.*, Sambucus adnata, Spiraea canescens* and *Viburnum erubescens* are other commonly found shrubs species. Dominant herbs are *Parochetus communis, Fagopyrum esculentum, Fragaria nubicola* and *Aconitum nagarum.* Other herb species recorded from the peak are *Anaphalis* spp.*, Campanula pallida, Cicerbita macrorhiza, Cyananthus inflatus, Hemiphragma heterophyllum, Heracleum wallichi, Impatiens* spp.*, Juncus* spp.*, Ligularia fischeri, Lobelia doniana, Pedicularis* spp., *Persicaria* spp., *Potentilla lineata*, *Ranunculus cantoniensis*, *Rubus fockeanus*, *Satyrium nepalense, Saxifraga* spp., *Senecio* spp., *Swertia franchetiana* and *Thalictrum foliolosum.*

4 Quantitative Analysis

4.1 Density and Frequency

Rhododendron macabeanum (1.82 m^2) had the highest density followed by *Lithocarpus pachyphylla* (0.88 m^2), *Debregeasia longifolia* (0.76 m^2), *Betula utilis* (0.72 m^2) and *Rhododendron maddenii* (0.64 m^2). Among the shrub species the highest density was recorded in *Yushiana rolloana* (15.36 m^2) followed by *Chimonocalamus griffithiana* (6.44 m^2), *Gaultheria hookeri* (5.50 m^2), *Cephalostachyum capitatum* (1.16 m^2) and *Daphne papyracea* (1.04 m^2). In herbaceous species, maximum density was reported from *Parochetus communis* (1.34 m^2) and *Fragaria nubicola* (1.18 m^2) followed by *Dryopteris odontoloma* (0.88 m^2)*, Aconitum nagarum* (0.78 m^2)*, Goodyera schlechtendaliana* (0.72 m^2) *and Ophiopogon intermedus* (0.72 m^2).

The most frequent tree species recorded in the present study were *Lithocarpus pachyphylla* (44%) and *Rhododendron macabeanum* (44%) followed by *Acer pectinatum* (22%), *Quercus lamellosa* (22%), *Rhododendron maddenii* (22%) and *Betula utilis* (20%). Maximum frequency in shrubs was found in *Daphne papyracea* (34%), *Chimonocalamus griffithiana* (20%), *Rhododendron triflorum* var *bauhiniflorum* (18%), *Berberis wallichiana* (16%), *Aconogonum molle* (14%) and *Vaccinium* sp. (14%). Highest frequency in herbaceous species was recorded in *Dryopteris odontoloma* (34%) followed by *Ainsliaea aptera* (26%), *Goodyera schlechtendaliana* (26%), *Rohdea watti* (24%), *Ophiopogon intermedus* (22%) and *Rubia sikkikmense* (22%).

4.2 Raunkiaer's frequency class

From the present study, 89.1% of the tree species fall under class A of Raunkiaer's frequency and only 10.9% fall in class B Raunkiaer's frequency. In case of shrubs, 98.1% of species were of Raunkiaer's frequency class A and 1.9% of species belong to frequency class B. Among the herbs, 97.7% of species showed frequency class A and only 2.3% were under the frequency class B.

4.3 Abundance

Among tree species, *Debregeasea longifolia* (12.67) was found to be the most abundant species in Mt. Japfü. Other abundantly present trees are *Rhododendron macabeanum* (4.14), *Casearia kurzii* (4), *Betula utilis* (3.6), *Lyonia ovalifolia* (3) and *Ilex dipyrena* (2.67). In shrubs, *Yushania rolloana* (153.6) and *Gaultheria hookeri* (45.83) was reported to be most abundant species followed by *Chimonocalamus griffithianus* (32.2), *Cephalostachyum capitatum* (19.33), *Cotoneaster adpressus* (9.5) and *Cotoneaster microphyllus* (7.67). In case of herb species, *Chaerophyllum villosum* (13), *Parochetus communis* (9.57) and *Fragaria nubicola* (7.38) have the highest abundance in the study site. *Viola betonicifolia* (6), *Aconitum nagarum* (5.57), *Arundinella pumila* (5.3), *Carex polycephala* (5), *Swertia franchetina* (4.8) and *Anaphalis contorta* (4.5) are other abundant herb species recorded.

4.4 Basal area, IVI and Stem density

Quercus lamellosa (105.57 m^2/ha) has the highest basal area of tree species followed by *Magnolia campbelli* (76.76 m^2/ha) and *Acer campbelli* (29.38 m^2/ha).

Rhododendron macabeanum (30.93%), *Quercus lamellosa* (28.55%) and *Lithocarpus pachyphylla* (24.78%), and has highest percentage of Importance Value Index (IVI) in the area. Other species with high IVI are *Magnolia campbelli* (16.81%), *Betula utilis* (13.13%) and *Rhododendron maddenii* (12.33%),

The stem density in Mt. Japfü is recorded as 488 individuals / ha^{-1}. Maximum number of tree species (33) are found at 21-30 cm Diameter at Breast Height (DBH) class followed by 10-20 cm DBH class with 23 species. Least number of species occur at 71-80 cm and 91-100 cm DBH classes (2 species). Highest number of individuals (237) are present at 10-20 cm DBH class followed by 21-30 cm DBH class with 122 individuals. 91-100 cm DBH class has the least number of individuals (4 individuals).

4.5 Species Distribution Pattern

The distribution pattern of plant species was determined by calculating Whitford index. The result showed that about 95.7% of the tree species had Whitford index value above 0.050, which signify contagious distribution and only 6.3% of species had Whitford index values between 0.025 - 0.050 which indicate random distribution of trees. Whitford index values of all the shrub and herb species were more than 0.050 which showed contagious distribution pattern of plants in the study area.

Table 3.15 : Frequency (F), Density (D), Abundance (A), Raunkiaer's frequency class (RFC), Whitford index (WI) and distribution pattern of tree species in the Mt. Japfü.

Tree species	F (%)	D	A	RFC	WI	Distribution pattern
Acer campbelli Hook.f.& Thom. ex Hiern.	8	0.1	1.25	A	0.16	Contagious
Acer caudatum Wall.	4	0.06	1.5	A	0.09	Contagious
Acer pectinatum Wall. ex G. Nich.	22	0.42	1.91	B	0.38	Contagious
Actinodaphne obovata (Nees) Bl.	2	0.04	2	A	1	Contagious
Alnus nepaulensis D.Don	2	0.02	1	A	0.5	Contagious
Betula alnoides Buch.-Ham. ex D.Don	2	0.04	2	A	1	Contagious
Betula utilis D.Don	20	0.72	3.6	A	0.18	Contagious
Brassiopsis polycantha (Wall.) R.N. Ban.	16	0.28	1.75	A	0.11	Contagious
Casearia kurzii Clarke	2	0.08	4	A	2	Contagious
Cornus capitata (Wall.) Hara	2	0.04	2	A	1	Contagious

Debregeasia longifolia (Burm.f.) Wedd	6	0.76	12.67	A	2.11	Contagious
Engelhardtia spicata Lech. ex Bl.	2	0.04	2	A	1	Contagious
Eurya acuminata DC.	12	0.22	1.83	A	0.15	Contagious
Ficus auriculata Lour.	2	0.02	1	A	0.5	Contagious
Ilex dipyrena Wall.	18	0.48	2.67	A	0.15	Contagious
Lithocarpus pachyphylla Reh.	8	0.12	3	B	1.5	Contagious
Litsea cubeba (Lour.) Pers.	14	0.3	2.14	A	0.15	Contagious
Litsea monopetala (Roxb.) Pers.	44	0.88	2	A	0.05	Random
Lyonia ovalifolia (Wall.) D.Don	2	0.06	1.33	A	0.22	Contagious
Macropanax dispermus Kun.	6	0.08	1	A	0.17	Contagious
Magnolia campbelli Hk. f.	6	0.06	2	A	1	Contagious
Michelia velutina DC.	2	0.04	1	A	0.25	Contagious
Phoebe hainsiana Bran.	4	0.04	1.5	A	0.38	Contagious
Prunus cerasoides D.Don	4	0.06	1.09	A	0.05	Random
Quercus lamellosa	22	0.24	2	B	0.5	Contagious

Sm.						
Rhododendron arboreum Sm. Subsp. *delavayi* (Fran.) Cham.	4	0.04	4.14	A	0.09	Contagious
Rhododendron macabeanum Watt ex I.B. Balf.	44	1.82	2.91	B	0.13	Contagious
Rhododendron maddenii Hook f. subsp. *crassum* (Fran.) Cullen	22	0.64	2	B	1	Contagious
Saurauia nepaulensis DC.	2	0.04	1.5	A	0.38	Contagious
Schima khasiana Dyer	2	0.04	1.4	A	0.14	Contagious
Schleffera shweliensis W. W. Smith	4	0.06	1	A	0.5	Contagious
Sorbus foliolosa (Wall.) Spach.	10	0.14	2.14	A	0.15	Contagious
Sorbus insignis (Hook.f.)Hedl.	2	0.02	1.5	A	0.38	Contagious
Symplocos dryophila D.Don	14	0.3	1.33	A	0.22	Contagious
Symplocos thaefolia D.Don	4	0.06	1	A	0.5	Contagious
Symplocos sp.	6	0.08	2.5	A	0.63	Contagious

Sterculia villosa Roxb.	2	0.02	1.75	A	0.22	Contagious
Taxus wallichiana Zucc.	4	0.1	1.5	A	0.38	Contagious
Trevesia palmata (Roxb.)Visiani	8	0.14	1	A	0.5	Contagious
Turpina pomifera DC.	4	0.06	3.71	A	0.27	Contagious
Vitex quinata (Lour.) F.N. Will.	2	0.02	1.5	A	0.38	Contagious
Zanthoxyllum acanthopodium DC.	6	0.1	1.5	A	0.19	Contagious
Species 1	14	0.52	3.5	A	0.44	Contagious
Species 2	4	0.06	2	A	1	Contagious
Species 3	8	0.28	1	A	0.5	Contagious
Species 4	2	0.02	1.67	A	0.28	Contagious
		9.76				

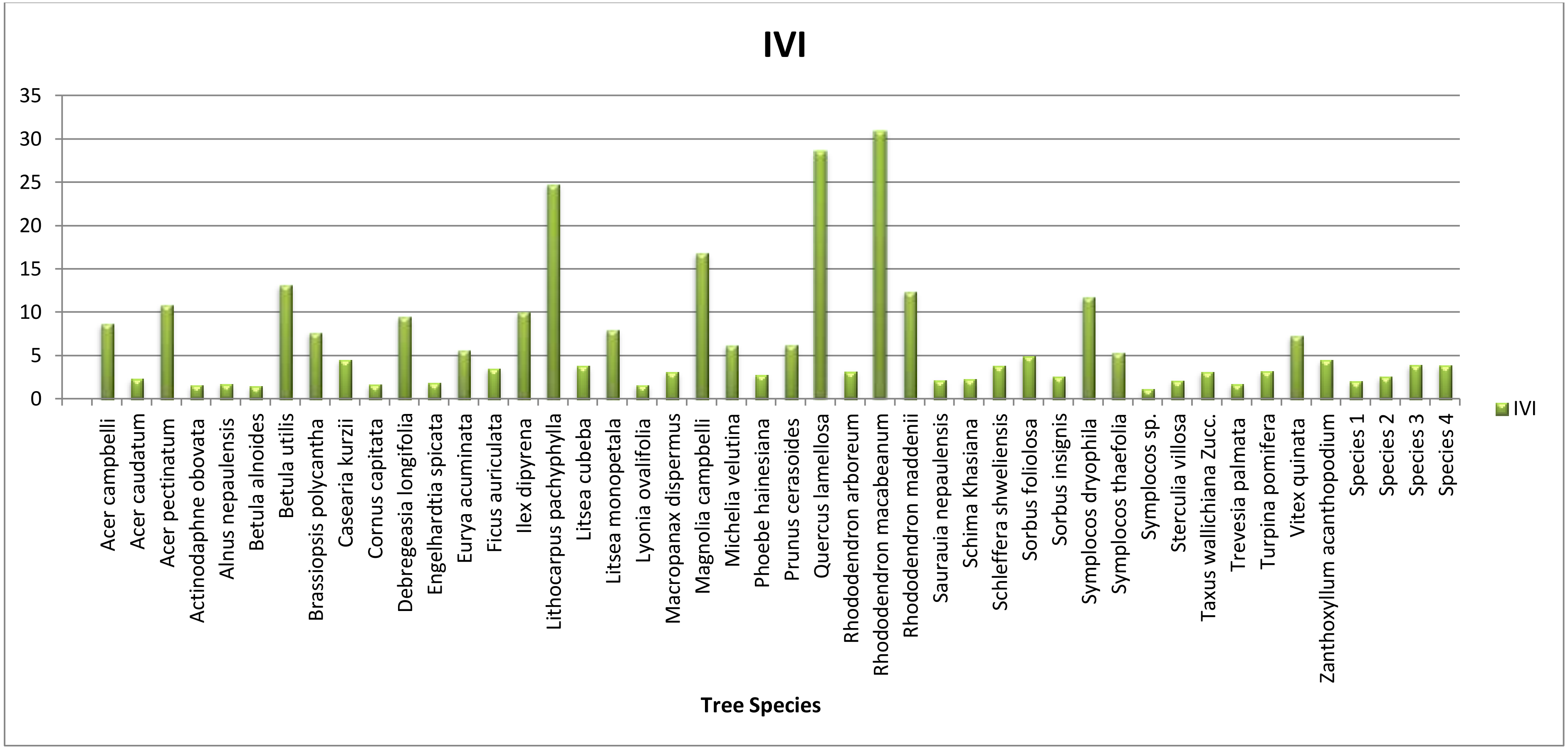

Fig 3.12 : Important value index (IVI) of the tree species in Mt. Japfü

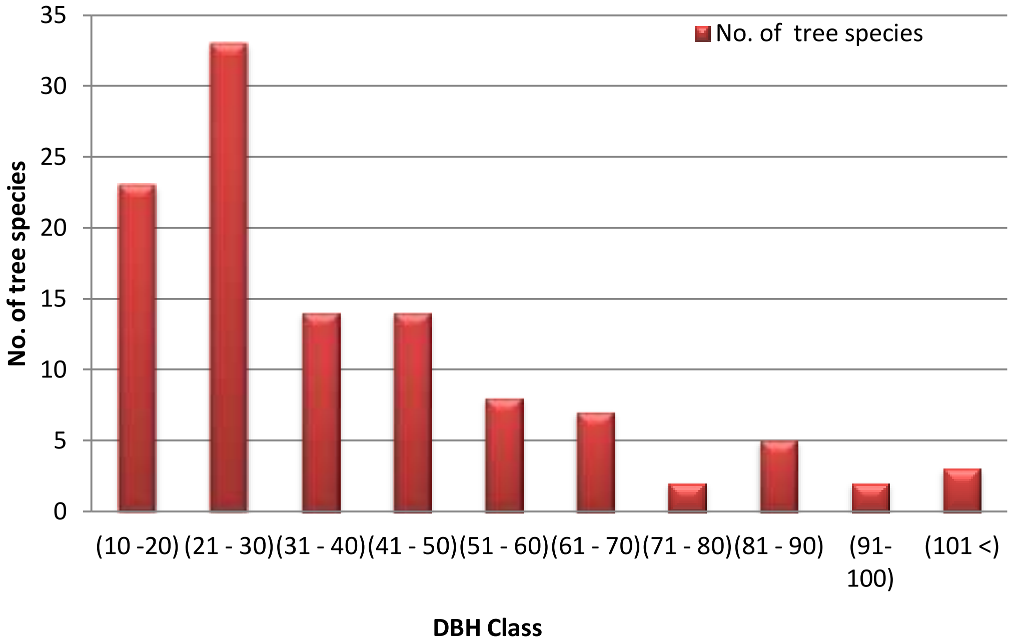

Fig. 3.13 : Number of tree species at different diameter at breast height (DBH) classes.

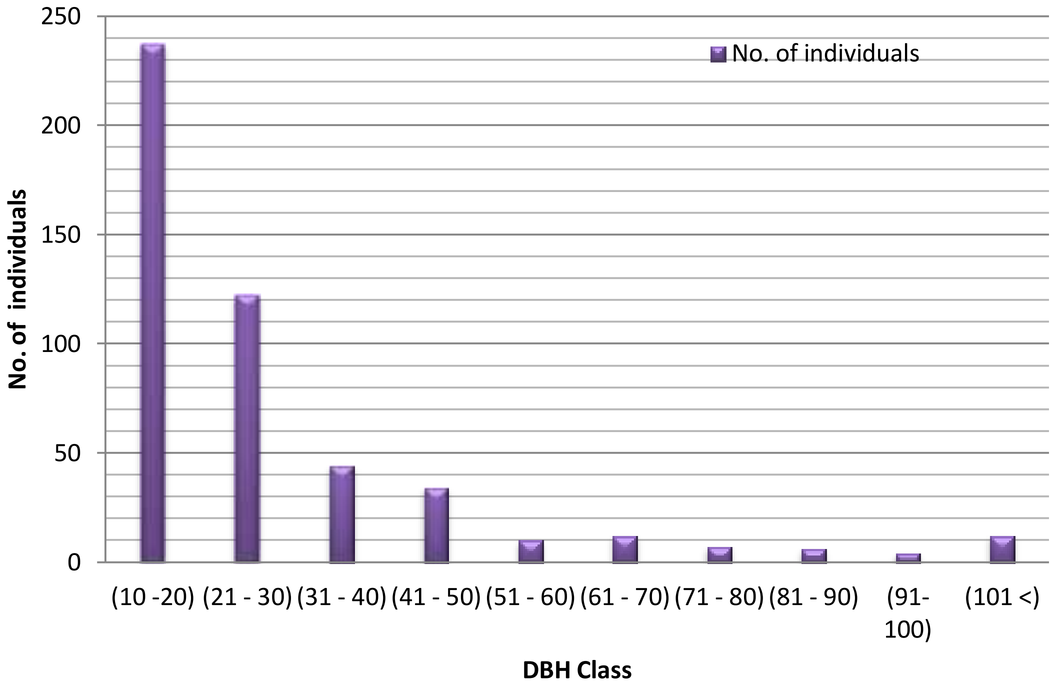

Fig. 3.14 : Number of individual tree species in different diameter at breast height (DBH) classes.

Table 3.16 : Frequency (F), Density per quadrat (D), Abundance (Ab), Raunkiaer's frequency class (RFS), Whitford index (WI) and Distribuion pattern of shrub species in Mt. Japfü.

Shrub Species	**F %**	**D**	**Ab.**	**RFS**	**WI**	**Distribution pattern**
Aonogonum molle (D.Don) H. Hara	14	0.62	4.43	A	0.32	Contagious
Ageratina adenophora (Spr.) R.M. Kn. & H. Rob.	8	0.4	5	A	0.63	Contagious
Angiopteris evecta (Forst.) Hoffm.	8	0.16	2	A	0.25	Contagious
Ardisia macrocarpa Wall.	2	0.04	2	A	1	Contagious
Astragalus concretus Bn.	2	0.14	7	A	3.5	Contagious
Berberis wallichiana DC.	16	0.46	2.88	A	0.18	Contagious
Buddleja macrostycha Bn.	8	0.12	1.5	A	0.19	Contagious
Callicarpa macrophylla Vahl	4	0.16	4	A	1	Contagious
Caryopteris bicolor (Roxb. ex Hardw.) Mabb.	4	0.2	5	A	1.25	Contagious
Cephalostachyum capitatum (Munro) Maj.	6	1.16	19.33	A	3.22	Contagious
Chimonocalamus griffithianus (Munro) Chao and Renv.	20	6.44	32.2	A	1.61	Contagious
Cotoneaster acuminatus Wall. ex Lindl.	4	0.28	7	A	1.75	Contagious
Cotoneastera adpressus Bois	4	0.38	9.5	A	2.38	Contagious

Cotoneaster microphyllus Wall. ex Lindl.	6	0.46	7.67	A	1.28	Contagious
Daphne papyracea Wall. ex Steud.	34	1.04	3.06	B	0.09	Contagious
Dichroa febrifuga Lour.	6	0.18	3	A	0.5	Contagious
Edgeworthia gardeneri (Wall.) Meisn.	2	0.04	2	A	1	Contagious
Ficus hederacea Roxb.	2	0.02	1	A	0.5	Contagious
Gaultheria hookeri Clarke	12	5.5	45.83	A	3.82	Contagious
Gaultheria griffithiana Wight	6	0.2	3.33	A	0.56	Contagious
Helwingia himalaica Hk.f. & Thom. ex Clarke	4	0.12	3	A	0.75	Contagious
Hypericum hookerianum Wight and Arn.	6	0.48	8	A	1.33	Contagious
Ilex sikkimensis Kurz	12	0.3	2.5	A	0.21	Contagious
Leea asiatica (L.) Rids.	2	0.02	1	A	0.5	Contagious
Leptodermis kumaonensis R. Park.	2	0.1	5	A	2.5	Contagious
Leucosceptrum canum Sm.	8	0.24	3	A	0.38	Contagious
Mahonia manipurensis Takeda.	6	0.08	1.33	A	0.22	Contagious
Myrsine semiserrata Wall.	4	0.06	1.5	A	0.38	Contagious
Ophiorrhiza succirubra King ex Hook.f.	6	0.16	2.67	A	0.44	Contagious
Persicaria campanulata (Hook.f.) Ronse Decr.	6	0.26	4.33	A	0.72	Contagious

Phlomoides hamosa (Benth.) Mathi.	6	0.18	3	A	0.5	Contagious
Pieris formosa (Wall.) D.Don.	12	0.3	2.5	A	0.21	Contagious
Polygala arillata Buch.-Ham ex D.Don	2	0.04	2	A	1	Contagious
Rhododendron elliotti Wt.	6	0.28	4.67	A	0.78	Contagious
Rhododendron johnstoneanum Wt. ex Hch.	8	0.2	2.5	A	0.31	Contagious
Rhododendron triflorum Hook.f. var. *bauhiniflorum* (watt ex Hutch.) Cullen	18	0.86	4.78	A	0.27	Contagious
Rosa sericea Lindl.	10	0.28	2.8	A	0.28	Contagious
Rubus calophyllus Clarke	4	0.14	3.5	A	0.88	Contagious
Rubus ellipticus Sm.	6	0.26	4.33	A	0.72	Contagious
Rubus hirtus Heget.	6	0.2	3.33	A	0.56	Contagious
Rubus lineatus var lineatus Reinw.	10	0.24	2.4	A	0.24	Contagious
Rubus pedunculosus. D.Don.	8	0.22	2.75	A	0.34	Contagious
Rubus sumatranus Miq.	4	0.1	2.5	A	0.63	Contagious
Rubus sp.	4	0.14	3.5	A	0.88	Contagious
Sambucus adnata Wall. ex DC.	8	0.32	4	A	0.5	Contagious
Schisandra grandiflora (Wall.) Hook.f. & Thom.	4	0.06	1.5	A	0.38	Contagious
Skimmia laureola Franch.	6	0.18	3	A	0.5	Contagious

Spiraea canescens D.Don	4	0.14	3.5	A	0.88	Contagious
Strobilanthes pterygorrhachis Clarke	12	0.42	3.5	A	0.29	Contagious
Vaccinium retusum Hk.f. ex Clarke	4	0.18	4.5	A	1.13	Contagious
Vaccinum sp	14	0.44	3.14	A	0.22	Contagious
Viburnum erubescens Wl.	2	0.08	4	A	2	Contagious
Wendlandia coriacea (Wl.) DC.	2	0.1	5	A	2.5	Contagious
Yushania rolloana (Gamble) Chao and Renv.	10	15.36	153.6	A	15.36	Contagious
		40.54				

Table 3.17 : Frequency (F), Density per quadrat (D), Abundance (Ab), Raunkiaer's frequency class (RFC), Whitford index (WI) and Distribuion pattern of herb species in Mt. Japfü.

Herb species	F (%)	D	Ab	RFC	WI	Distribution pattern
Aconitum nagarum Stapf.	14	0.78	5.57	A	0.4	Contagious
Achyranthes bidentata Bl.	2	0.06	3	A	1.5	Contagious
Ainsliaea aptera DC.	26	0.52	2	B	0.08	Contagious
Anaphalis contorta (D.Don) Hk.f.	12	0.54	4.5	A	0.38	Contagious
Anaphalis margaritaceae (L.) Benth. & Hk.f.	4	0.10	2.5	A	0.63	Contagious
Anemone rupestris Wall. ex Hook.f. and Thom.	2	0.08	4	A	2	Contagious
Arisaema erubescens (Wall.) Schott.	4	0.04	1	A	0.25	Contagious
Arisaema nepenthoides (Wall.) Mart.	8	0.10	1.25	A	0.16	Contagious
Arundinella pumila (Hoch. Ex A. Rich.) Sterd.	8	0.42	5.3	A	0.7	Contagious
Aster thomsonii Clarke	2	0.02	1	A	0.5	Contagious
Astilbe rivularis Buch.-Ham. ex D.Don	4	0.06	1.5	A	0.4	Contagious
Begonia thomsonii A.DC.	6	0.14	2.33	A	0.39	Contagious
Begonia sp.	2	0.04	2	A	1	Contagious
Biden pilosa Linn.	2	0.02	1	A	0.5	Contagious

Boehmeria platyphylla D.Don	4	0.04	1	A	0.25	Contagious
Bromus inermis Leyss.	8	0.22	2.8	A	0.3	Contagious
Calanthe brevicornu Lindl.	12	0.18	1.5	A	0.13	Contagious
Calanthe metoensis Z.H.Tsi and K.Y.Lang	2	0.02	1	A	0.5	Contagious
Campanula pallida Wall.	2	0.02	1	A	0.5	Contagious
Cardamine hirsuta L.	2	0.04	2	A	1	Contagious
Cardiocrinum giganteum (Wall.) Mak.	2	0.06	3	A	1.5	Contagious
Carex polycephala Boott	10	0.50	5	A	0.5	Contagious
Carpesium cernuum L. var. *pendunculosum* Wl. ex Cl.	4	0.04	1	A	0.25	Contagious
Cautleya gracilis (Sm.) Dn.	2	0.04	2	A	1	Contagious
Chaerophyllum villosum DC.	4	0.52	13	A	3.25	Contagious
Chirita pumila D.Don	2	0.06	3	A	1.5	Contagious
Chrysoplenium nepalensis D.Don	4	0.14	3.5	A	0.88	Contagious
Cicerbita macrorhiza (Royle) P.Beauv.	4	0.06	1.5	A	0.38	Contagious
Circaea alpina L.	6	0.10	1.7	A	0.3	Contagious
Cirsium falconeri (Hook.f.) Petr.	2	0.02	1	A	0.5	Contagious
Clintonia udensis Trautv. and C.A.Mey.	8	0.14	1.75	A	0.22	Contagious

Coniogramme affinis Wall. ex Hieron	6	0.10	1.7	A	0.28	Contagious
Corydalis cornuta Royle	2	0.10	5	A	2.5	Contagious
Corydalis leptocarpa Hook.f. and Thom.	2	0.06	3	A	1.5	Contagious
Cyananthus inflatus Hook.f. and Thom.	2	0.04	2	A	1	Contagious
Cyperus involucratus Rottb.	4	0.06	1.5	A	0.38	Contagious
*Dichrocephala integrifolia (*Lin.f.)Kun.	4	0.10	2.5	A	0.6	Contagious
Diphylax urceolata (Clarke) Hook.f	12	0.24	2	A	0.17	Contagious
Diplazium esculentum (Rz.) Sw.	4	0.06	1.5	A	0.4	Contagious
Dryopteris hirtipes (Bl.) Kz.	8	0.18	2.3	A	0.3	Contagious
Dryopteris odontoloma (Bedd.) C.Chr.	34	0.88	2.59	B	0.08	Contagious
Elatostema acuminatum Br.	6	0.24	4	A	0.67	Contagious
Elatostema platyphyllum Wedd.	14	0.60	4.29	A	0.31	Contagious
Elsholtzia strobilifera Ben.	6	0.18	3	A	0.5	Contagious
Epilobium brevifolium D.Don	4	0.04	1	A	0.25	Contagious
Euonymus echinatus Wall. ex Roxb	16	0.26	1.63	A	0.1	Contagious
Fagopyrum esculentum Mn.	10	0.22	2.2	A	0.22	Contagious
Fragaria nubicola Lin. ex	16	1.18	7.38	A	0.46	Contagious

Lac.						
Galeola lindleyana (Hk. f. & Thom.) Reich.f.	2	0.06	3	A	1.5	Contagious
Galium elegans Wl. ex Rxb.	6	0.14	2.3	A	0.4	Contagious
Galium aparine L.	4	0.10	2.5	A	0.6	Contagious
Galium asperuloides Edge.	8	0.26	3.3	A	0.4	Contagious
Gentiana quadriferia Bl.	4	0.16	4	A	1	Contagious
Geranium nepalense Sweet	2	0.04	2	A	1	Contagious
Girardinia heterophylla De.	6	0.14	2.33	A	0.39	Contagious
Globba racemosa Sm.	2	0.06	3	A	1.5	Contagious
Goodyera schlechtendaliana Rchb.f.	26	0.72	2.77	B	0.11	Contagious
Goodyera vittata (Lindl.) Benth. and Hk.f.	4	0.06	1.5	A	0.38	Contagious
Gynura bicolor (Roxb. ex Willd.) DC.	2	0.02	1	A	0.5	Contagious
Habernaria arietina Hk. f.	2	0.02	1	A	0.5	Contagious
Hedychium coccineum Buch.-Ham. ex Sm	2	0.02	1	A	0.5	Contagious
Hemiphragma heterophyllum Wall.	2	0.02	1	A	0.5	Contagious
Heracleum wallichii DC.	4	0.12	3	A	0.75	Contagious
Himalaiella deltoidea (Cand.) Raab-Strau	4	0.10	2.5	A	0.6	Contagious
Houttuynia cordata Thunb.	2	0.02	1	A	0.5	Contagious

Hydrocotyle javanica Thunb.	4	0.10	2.5	A	0.63	Contagious
Impatiens bracteolata Hk.f.	14	0.20	1.43	A	0.1	Contagious
Impatiens dolichoceras Pritz. ex Diels	16	0.46	2.88	A	0.18	Contagious
Impatiens graciliflora Hk.f.	12	0.14	1.17	A	0.1	Contagious
Impatiens radiata Hk.f.	6	0.08	4	A	0.67	Contagious
Impatiens siculifer Hk.f.	4	0.14	3.5	A	0.88	Contagious
Inula cappa (Buch.-Hm. ex D. Don) DC.	2	0.02	1	A	0.5	Contagious
Juncus thomsonii Buch.	8	0.22	2.75	A	0.34	Contagious
Laportea bulbifera (Siec. & Zucc.) Wedd.	4	0.12	3	A	0.8	Contagious
Ligularia fischeri (Led.) Tr.	6	0.12	2	A	0.33	Contagious
Lobelia doniana Skott.	4	0.14	3.5	A	0.88	Contagious
Lycopodium pseudoclavatum Ching.	10	0.26	2.6	A	0.26	Contagious
Maianthemum fuscum (Wall.) LaFrankie	4	0.04	1	A	0.25	Contagious
Monotropa uniflora L.	2	0.08	4	A	2	Contagious
Myriactis wallichi Less.	2	0.04	2	A	1	Contagious
Oenanthe thomsonii Clarke	4	0.04	1	A	0.25	Contagious
Ophiopogon intermedus D.Don	22	0.72	3.27	B	0.15	Contagious

Osbeckia sp.	6	0.10	1.67	A	0.28	Contagious
Oxalis corniculata Linn.	4	0.10	2.5	A	0.63	Contagious
Paris polyphylla Sm.	8	0.12	1.5	A	0.19	Contagious
Parochetus communis Buch.- Ham.ex D.Don.	14	1.34	9.57	A	0.68	Contagious
Pedicularis curvipes Hk.f.	4	0.04	1	A	0.25	Contagious
Persicaria nepalensis (Meisn.) H.Gross	4	0.10	2.5	A	0.63	Contagious
Persicaria runcinata (Bch.-Hm. ex D.Don) H.Gross	4	0.06	1.5	A	0.38	Contagious
Pilea bracteosa Wedd.	12	0.42	3.5	A	0.29	Contagious
Pilea scripta (Buch.-Ham ex D.Don) Wedd.	2	0.08	4	A	2	Contagious
Plantago erosa Wall.	2	0.04	2	A	1	Contagious
Platenthera leptocaulon (Hk.f.) Soo'	8	0.10	1.25	A	0.16	Contagious
Pollia japonica Thb.	4	0.08	2	A	0.5	Contagious
Polygonatum kingianum Coll. & Hm.	6	0.06	1	A	0.17	Contagious
*Polypodiodes amoena (*Wall. ex Mett.) Ching	6	0.08	1.3	A	0.2	Contagious
Polystichum semifertile (Clarke) Ching	4	0.04	1	A	0.3	Contagious
Potentilla lineata Trv. ex Rch.	8	0.22	2.75	A	0.34	Contagious
Pouzolzia sanguinea (Bl.) Mer.	2	0.06	3	A	1.5	Contagious

Primula geraniifolia Hk.f.	2	0.02	1	A	0.5	Contagious
Pseudognaphalium affine (D. Don) Ander.	4	0.06	1.5	A	0.38	Contagious
Ranunculus cantoniensis DC.	4	0.06	1.5	A	0.38	Contagious
Rhodiola bupleroides (Hk.f. & Thom.) Fu	4	0.06	1.5	A	0.4	Contagious
Rohdea wattii (Clarke) Yama. & M.N. Tam.	24	0.36	1.5	B	0.06	Contagious
Rubia manjith Rxb. ex Flm.	20	0.26	1.3	A	0.07	Contagious
Rubus fockeanus Kur. J.	10	0.10	1	A	0.1	Contagious
Rubus calycinus Wl. ex D.Don	2	0.02	1	A	0.5	Contagious
Rumex nepalenis Spr.	6	0.14	2.33	A	0.39	Contagious
Satyrium nepalense D.Don.	6	0.12	2	A	0.33	Contagious
Saxifraga brachypoda D.Don	4	0.18	4.5	A	1.13	Contagious
Saxifraga brunonis Wl. ex Ser.	6	0.28	4.67	A	0.78	Contagious
Sedum linearifolium var ovatisepalum Ray.-Hm.	10	0.20	2	A	0.2	Contagious
Sedum sp.	2	0.02	1	A	0.5	Contagious
Senecio laetus Edgen	6	0.08	1.33	A	0.22	Contagious
Senecio scandens Buch.-Hm. ex D.Don	4	0.06	1.5	A	0.38	Contagious
Solanum nigrum Linn.	2	0.02	1	A	0.5	Contagious

Streptopus simplex D.Don	2	0.02	1	A	0.5	Contagious
Swertia franchetiana H. Sm.	8	0.38	4.8	A	0.6	Contagious
Tectaria polymorpha (Wall. ex Hk.f.) Copel.	2	0.02	1	A	0.5	Contagious
Thalictrum reniforme Wall.	4	0.06	1.5	A	0.38	Contagious
Tiarella polyphylla D.Don	6	0.06	3	A	0.5	Contagious
Tipularia josephi Rchb. f. ex Lindl.	2	0.02	1	A	0.5	Contagious
Urtica mairei H. Lev.	10	0.26	2.6	A	0.26	Contagious
Valeriana hardwickii Wall.	4	0.04	1	A	0.25	Contagious
Valeriana jatamansi Jon.	4	0.06	1.5	A	0.38	Contagious
Viola betonicifolia Sm.	4	0.24	6	A	1.5	Contagious
Species 1	14	0.62	4.43	A	0.32	Contagious
Species 2	4	0.04	1	A	0.25	Contagious
	808	**21.54**				

5. Diversity Indices

In the present study, four diversity indices namely Whittaker's index, Shannon Wiener's index, Pielou's index and Simpson's index, were used to assess the plant diversity in Mt. Japfü.

5.1 Whittaker's Species richness Index (D)

Highest species richness index in Mt. Japfu was recorded in the herb species with index value 42.21. Shrubs and tree species was found to have low species richness index values, 16.33 and 17.11.

5.2 Shannon-Wiener's Diversity Index (H)

Maximum diversity was recorded in the herb species with index value 4.286 followed by trees with 3.433 and shrubs with 2.482 . Among the herb species the highest value of H was found in *Parochetus communis* (0.173), in shrubs it was documented in *Yushania rolloana* (0.368) and in tree species it was observed in *Rhododendron macabeanum* (0.234).

5.3 Pielou's Evenness Index (E)

Pielou's evenness index of tree species was 0.897, for shrub species 0.622 and for herbs 0.883. Tree and herb species were found to be more evenly distributed in the area when compared to shrubs. In herb species, *Parochetus communis* (0.0356) was recorded to have the highest Pielou's index value, in shrubs it was *Yushania rolloana* (0.0922) and in tree species it was documented in *Rhododendron macabeanum* (0.0.0612).

5.4 Simpson's Dominance Index (D)

The value of Simpon's dominance index showed reverse trend as compared to species diversity. In the present study the highest value of Simpson's dominance index was recorded in shrub with 0.1909, followed by tree species with 0.0451. Herbs were found to have the lowest value of Simpson's index with 0.0212, this indicates that herbs have higher dominance in the area than trees and shrubs.

Among the tree species, *Rhododendron macabeanum* (0.0106), *Quercus lamellosa* (0.0091) and *Lithocarpus pachyphylla* (0.0068) were the most dominant species. In case of shrubs, *Yushiana rolloana* (0.1435), *Chimonocalamus griffithianus* (0.0252) and *Gaultheria hookeri* (0.0184) were recorded to have the most dominance in the plant community. Whereas in herbs, *Parochetus communis* (0.00386), *Aconitum nagarum* (0.00131), *Goodyera schlechtendaliana* (0.00112) and *Ophiopogon intermedus* (0.0112) showed the highest dominance.

6. Life Form Composition

Life forms of various species recorded from Mt. Japfü were classified into major life forms according to Raunkiaer's system. 134 species are Phanerophytes which is 45.11% of the total plant species recorded from Mt. Japfü. This major class is further divided into sub classes viz. 3 species of Megaphanerophytes (1.01%), 30 species of Mesophanerophytes (10.1%), 37 species of Microphanerophytes(12.46%), 27 species of Nanophanerophytes (9.09%), 23 species of Epiphytes (7.74%) and 14 species of Lianas (4.71%). Chamaephytes are comprised of 19 species (6.4%) and Hemicryptophyte has 79 species (26.6%). Cryptophyte is represented only by Geophyte which has 37 species (12.46%). Therophyte is composed of 28 species (9.42%) in the plant community.

Table 3.18 : Basal area (BA), Importance value index (IVI), Shannon Wiener index (H), Pielou index (E) and Simpson index (D) of tree species in the study site.

Tree species	BA (m^2/ha)	IVI	H	E	D
Acer campbelli Hk.f.& Thom. Ex Hiern.	29.38	8.65	0.102	0.02671	0.000831
Acer caudatum Wall.	3.61	2.31	0.037	0.00977	0.000059
Acer pectinatum Wall. ex G. Nich.	5.34	10.82	0.12	0.03131	0.001302
Actinodaphne obovata (Nees) Blume	3.46	1.57	0.028	0.00719	0.000027
Alnus nepaulensis D.Don	5.35	1.73	0.03	0.00776	0.000034
Betula alnoides Buch.-Ham. ex D.Don	2.82	1.45	0.026	0.00673	0.000023
Betula utilis D.Don	3.93	13.13	0.137	0.03577	0.001915
Brassiopsis polycantha (Wall.) R.N. Banerjee	3.97	7.63	0.093	0.02439	0.000647
Casearia kurzii Clarke	16.61	4.5	0.063	0.01645	0.000225
Cornus capitata (Wl.) Hr.	3.79	1.63	0.028	0.00742	0.000029
Debregeasia longifolia (Burm.f.) Wedd	0.81	9.44	0.109	0.02843	0.00099
Engelhardtia spicata Lechen ex Bl.	4.84	1.84	0.031	0.00815	0.000037
Eurya acuminata DC.	1.75	5.59	0.074	0.01938	0.000347
Ficus auriculata Lour.	14.64	3.51	0.052	0.01359	0.000137

Ilex dipyrena Wall.	3.12	10.01	0.113	0.02964	0.001114
Lithocarpus pachyphylla Rehder	24.9	24.78	0.206	0.0538	0.006825
Litsea cubeba (Lour.) Pers.	2.98	3.8	0.055	0.01445	0.00016
Litsea monopetala (Roxb.) Pers.	7.07	7.93	0.096	0.02508	0.000698
Lyonia ovalifolia (Wall.) D.Don	2.64	1.62	0.028	0.00737	0.000029
Macropanax dispermus K.	3.79	3.04	0.047	0.01217	0.000103
Magnolia campbelli Hk. f.	76.76	16.81	0.161	0.04218	0.00314
Michelia velutina DC.	27.37	6.15	0.08	0.02081	0.00042
Phoebe hainesiana Brandis	7.1	2.77	0.043	0.0113	0.000085
Prunus cerasoides D.Don	23.9	6.19	0.08	0.02091	0.000426
Quercus lamellosa Sm.	107.57	28.55	0.224	0.05847	0.009058
Rhododendron arboreum Sm. Subsp. *delavayi* (Fran.) Chm.	9.02	3.14	0.048	0.01246	0.000109
Rhododendron macabeanum Watt ex I.B. Balf.	6.72	30.93	0.234	0.06119	0.010633
Rhododendron maddenii Hk f. subsp. *crassum* (Fran.) Cul.	1.4	12.33	0.131	0.03425	0.001688
Saurauia nepaulensis DC.	6.51	2.16	0.035	0.00927	0.000052
Schima Khasiana Dyer	3.41	2.27	0.037	0.00965	0.000058
Schleffera shweliensis W.W. Sm.	11.45	3.81	0.055	0.01448	0.000161

Sorbus foliolosa (Wl.) Spc.	5.24	4.94	0.068	0.01765	0.000271
Sorbus insignis (Hk.f.) Hedl.	9.8	2.58	0.041	0.01069	0.000074
Symplocos dryophila D.Don	15.15	11.73	0.127	0.0331	0.001528
Symplocos thaefolia D.Don	2.23	5.3	0.071	0.01861	0.000312
Symplocos sp.	1.27	1.15	0.021	0.00558	0.000014
Sterculia villosa Roxb.	2.61	2.11	0.035	0.00912	0.000049
Taxus wallichiana Zucc.	12.51	3.1	0.047	0.01234	0.000107
Trevesia palmata (Rb.) Vs.	5.33	1.73	0.03	0.00775	0.000034
Turpina pomifera DC.	4.47	3.18	0.048	0.01258	0.000112
Vitex quinata (Lr.) F.N. Wil.	3.68	7.28	0.09	0.02356	0.000589
Zanthoxyllum acanthopodium DC.	10.19	4.48	0.063	0.01639	0.000223
Species 1	2.11	2.02	0.034	0.00879	0.000045
Species 2	2.74	2.55	0.041	0.01058	0.000072
Species 3	2.53	3.92	0.057	0.0148	0.000171
Species 4	16.49	3.86	0.056	0.01464	0.000166
	522.34	**300**	**3.433**	**0.89668**	**0.045128**

Table 3.19 : Shannon Wiener index, Pielou index and Simpson's index of shrub species in Mt. Japfü.

Shrubs	Shannon Wiener index, H	Pielou index, E	Simpson index, D
Aonogonum molle (D.Don) H. Hara	0.064	0.016	0.000234
Ageratina adenophora (Spreng) R.M. King & H. Rob.	0.046	0.0114	0.000097
Angiopteris evecta (Forst.) Hoffm.	0.022	0.0055	0.000016
Ardisia macrocarpa Wall.	0.007	0.0017	0.000001
Astragalus concretus Benth.	0.02	0.0049	0.000012
Berberis wallichiana DC.	0.051	0.0127	0.000129
Buddleja macrostycha Benth.	0.017	0.0043	0.000009
Callicarpa macrophylla Vahl	0.022	0.0055	0.000016
Caryopteris bicolor (Roxb. ex Hardw.) Mabb.	0.026	0.0066	0.000024
Cephalostachyum capitatum (Munro) Majumder	0.102	0.0255	0.000819
Chimonocalamus griffithianus (Munro) Chao and Renv.	0.292	0.0733	0.025235
Cotoneaster acuminatus Wall. ex Lindl.	0.034	0.0086	0.000048
Cotoneastera adpressus Bois	0.044	0.011	0.000088

Cotoneaster microphyllus Wall. ex Lindl.	0.051	0.0127	0.000129
Daphne papyracea Wall. ex Steud.	0.094	0.0236	0.000658
Dichroa febrifuga Lour.	0.024	0.006	0.00002
Edgeworthia gardeneri (Wall.) Meisn.	0.007	0.0017	0.000001
Ficus hederacea Roxb.	0.004	0.0009	0
Gaultheria hookeri Clarke	0.271	0.0679	0.018406
Gaultheria griffithiana Wight	0.026	0.0066	0.000024
Helwingia himalaica Hook.f. and Thom. ex Clarke	0.017	0.0043	0.000009
Hypericum hookerianum Wight and Arn.	0.053	0.0132	0.00014
Ilex sikkimensis Kurz	0.036	0.0091	0.000055
Leea asiatica (L.) Rids.	0.004	0.0009	0
Leptodermis kumaonensis R. Park.	0.015	0.0037	0.000006
Leucosceptrum canum Sm.	0.03	0.0076	0.000035
Mahonia manipurensis Takeda.	0.012	0.0031	0.000004
Myrsine semiserrata Wall.	0.01	0.0024	0.000002
Ophiorrhiza succirubra King ex Hook.f.	0.022	0.0055	0.000016
Persicaria campanulata (Hook.f.) Ronse Decr.	0.032	0.0081	0.000041

Phlomoides hamosa (Benth.) Mathi.	0.024	0.006	0.00002
Pieris formosa (Wall.) D.Don.	0.036	0.0091	0.000055
Polygala arillata Buch.-Ham ex D.Don	0.007	0.0017	0.000001
Rhododendron elliotti Watt.	0.034	0.0086	0.000048
Rhododendron johnstoneanum Watt ex Hutch.	0.032	0.0081	0.000024
Rhododendron triflorum Hook.f. var. *bauhiniflorum* (watt ex Hutch.) Cullen	0.082	0.0205	0.00045
Rosa sericea Lindl.	0.034	0.0086	0.000048
Rubus calophyllus Clarke	0.02	0.0049	0.000012
Rubus ellipticus Sm.	0.032	0.0081	0.000041
Rubus hirtus Heget.	0.026	0.0066	0.000024
Rubus lineatus var lineatus Reinw.	0.03	0.0076	0.000035
Rubus pedunculosus. D.Don.	0.028	0.0071	0.000029
Rubus sumatranus Miq.	0.015	0.0037	0.000006
Rubus sp.	0.02	0.0049	0.000012
Sambucus adnata Wall. ex DC.	0.038	0.0096	0.000062
Schisandra grandiflora (Wall.) Hook.f. & Thom.	0.01	0.0024	0.000002
Skimmia laureola Franch.	0.024	0.006	0.00002
Spiraea canescens D.Don	0.02	0.0049	0.000012

Strobilanthes pterygorrhachis Clarke	0.047	0.0119	0.000107
Vaccinium retusum Hook.f. ex Clarke	0.024	0.006	0.00002
Vaccinum sp	0.049	0.0123	0.000118
Viburnum erubescens Wall.	0.012	0.0031	0.000004
Wendlandia coriacea (Wall.) DC.	0.015	0.0037	0.000006
Yushania rolloana (Gamble) Chao and Renv.	0.368	0.0922	0.143554
	2.482	**0.6221**	**0.190982**

Table 3.20 : Shannon Wiener index, Pielou index and Simpson's index of herb species in Mt.Japfü.

Herb species	**Shannon Wiener's index, H**	**Pielou's index , E**	**Simpson's index, D**
Aconitum nagarum Stapf.	0.12	0.0247	0.001309
Achyranthes bidentata Blume	0.016	0.0034	0.000008
Ainsliaea aptera DC.	0.09	0.0185	0.000582
Anaphalis contorta(D.Don) Hook.f.	0.092	0.019	0.000627
Anaphalis margaritaceae(L.) Benth. and Hook.f.	0.025	0.0051	0.000021
Anemone rupestris Wall. ex Hook.f. and Thom.	0.021	0.0043	0.000014
Arisaema erubescens (Wall.)	0.012	0.0024	0.000004

Schott.			
Arisaema nepenthoides (Wall.) Mart.	0.025	0.0051	0.000021
Arundinella pumila (Hoch. Ex A. Rich.) Sterd.	0.077	0.0158	0.000380
Aster thomsonii Clarke	0.006	0.0013	0.000001
Astilbe rivularis Buch.-Ham. ex D.Don	0.016	0.0034	0.000008
Begonia thomsonii A.DC.	0.033	0.0067	0.000042
Begonia sp.	0.012	0.0024	0.000004
Biden pilosa Linn.	0.006	0.0013	0.000001
Boehmeria platyphylla D.Don	0.012	0.0024	0.000004
Bromus inermis Leyss.	0.047	0.0096	0.000104
Calanthe brevicornu Lindl.	0.04	0.0082	0.000069
Calanthe metoensis Z.H.Tsi and K.Y.Lang	0.006	0.0013	0.000001
Campanula pallida Wall.	0.006	0.0013	0.000001
Cardamine hirsuta L.	0.012	0.0024	0.000004
Cardiocrinum giganteum(Wall.) Makino	0.016	0.0034	0.000008
Carex polycephala Boott	0.087	0.018	0.000538
Carpesium cernuum L. var. *penduncolosum* Wall. ex Clarke	0.012	0.0024	0.000004
Cautleya gracilis (Sm.) Dandy	0.012	0.0024	0.000004

Chaerophyllum villosum DC.	0.09	0.0185	0.000581
Chirita pumila D.Don	0.016	0.0034	0.000008
Chrysoplenium nepalensis D.Don	0.033	0.0067	0.000042
Cicerbita macrorhiza (Royle) P.Beauv.	0.016	0.0034	0.000008
Circaea alpina L.	0.025	0.0051	0.000021
Cirsium falconeri (Hook.f.) Petr.	0.006	0.0013	0.000001
Clintonia udensis Trautv. and C.A.Mey.	0.033	0.0067	0.000042
Coniogramme affinis Wall. ex Hieron	0.025	0.0051	0.000021
Corydalis cornuta Royle	0.025	0.0051	0.000021
Corydalis leptocarpa Hk.f. & Thom.	0.016	0.0034	0.000008
Cyananthus inflatus Hook.f. and Thom.	0.012	0.0024	0.000004
Cyperus involucratus Rottb.	0.016	0.0034	0.000008
*Dichrocephala integrifolia (*Linn.f.)Kuntze.	0.025	0.0051	0.000021
Diphylax urceolata (Clarke) Hook.f	0.05	0.0103	0.000123
Diplazium esculentum (Retz.) Sw.	0.016	0.0034	0.000008
Dryopteris hirtipes (Bl.) Kunze	0.04	0.0082	0.000069
Dryopteris odontoloma (Bedd.) C.Chr.	0.131	0.0269	0.001665
Elatostema acuminatum Brongn.	0.05	0.0103	0.000123

Elatostema platyphyllum Wedd.	0.1	0.0205	0.000773
Elsholtzia strobilifera Benth.	0.04	0.0082	0.000069
Epilobium brevifolium D.Don	0.012	0.0024	0.000004
Euonymus echinatus Wall. ex Roxb	0.053	0.011	0.000146
Fagopyrum esculentum Moench.	0.047	0.0096	0.000104
Fragaria nubicola Lindley ex Lacaita	0.159	0.0328	0.002992
Galeola lindleyana (Hook. f. and Thom.) Reich.f.	0.016	0.0034	0.000008
Galium elegans Wall. ex Roxb	0.033	0.0067	0.000042
Galium aparine L.	0.025	0.0051	0.000021
Galium asperuloides Edgew.	0.053	0.011	0.000146
Gentiana quadriferia Bl.	0.036	0.0075	0.000055
Geranium nepalense Sweet	0.012	0.0024	0.000004
Girardinia heterophylla Decaisne	0.033	0.0067	0.000042
Globba racemosa Sm.	0.016	0.0034	0.000008
Goodyera schlechtendaliana Rchb.f.	0.114	0.0234	0.001116
Goodyera vittata (Lindl.) Benth. and Hook.f.	0.016	0.0034	0.000008
Gynura bicolor (Roxb. ex Willd.) DC.	0.006	0.0013	0.000001
Habernaria arietina Hook. f.	0.006	0.0013	0.000001

Hedychium coccineum Buch.-Ham. ex Sm	0.006	0.0013	0.000001
Hemiphragma heterophyllum Wall.	0.006	0.0013	0.000001
Heracleum wallichii DC.	0.029	0.006	0.000031
Himalaiella deltoidea (Cand.) Raab-Strau	0.025	0.0051	0.000021
Houttuynia cordata Thunb.	0.006	0.0013	0.000001
Hydrocotyle javanica Thunb.	0.025	0.0051	0.000021
Impatiens bracteolata Hook.f.	0.043	0.0089	0.000086
Impatiens dolichoceras Pritz. ex Diels	0.082	0.0169	0.000454
Impatiens graciliflora Hook.f.	0.033	0.0067	0.000042
Impatiens radiata Hook.f.	0.021	0.0043	0.000014
Impatiens siculifer Hook.f.	0.033	0.0067	0.000042
Inula cappa (Buch.-Ham. ex D. Don) DC.	0.006	0.0013	0.000001
Juncus thomsonii Buch.	0.047	0.0096	0.000104
Laportea bulbifera (Siec. & Zucc.) Wedd.	0.029	0.006	0.000031
Ligularia fischeri (Ledeb.) Turcz.	0.029	0.006	0.000031
Lobelia doniana Skottsb.	0.033	0.0067	0.000042
Lycopodium pseudoclavatum Ching.	0.053	0.011	0.000146
Maianthemum fuscum (Wall.)	0.012	0.0024	0.000004

LaFrankie			
Monotropa uniflora L.	0.021	0.0043	0.000014
Myriactis wallichi Less.	0.012	0.0024	0.000004
Oenanthe thomsonii Clarke	0.012	0.0024	0.000004
Ophiopogon intermedus D.Don	0.114	0.0234	0.001116
Osbeckia sp.	0.025	0.0051	0.000021
Oxalis corniculata Linn.	0.025	0.0051	0.000021
Paris polyphylla Sm.	0.029	0.006	0.000031
Parochetus communis Buch.-Ham.ex D.Don.	0.173	0.0356	0.003869
Pedicularis curvipes Hook.f.	0.012	0.0024	0.000004
Persicaria nepalensis (Meisn.) H.Gross	0.025	0.0051	0.000021
Persicaria runcinata (Buch.-Ham. ex D.Don) H.Gross	0.016	0.0034	0.000008
Pilea bracteosa Wedd.	0.077	0.0158	0.000380
Pilea scripta (Buch.-Ham ex D.Don) Wedd.	0.021	0.0043	0.000014
Plantago erosa Wall.	0.012	0.0024	0.000004
Platenthera leptocaulon (Hook.f.) Soo'	0.025	0.0051	0.000021
Pollia japonica Thunb.	0.021	0.0043	0.000014

Polygonatum kingianum Coll. and Hem.	0.016	0.0034	0.000008
*Polypodiodes amoena (*Wall. ex Mett.) Ching	0.021	0.0043	0.000014
Polystichum semifertile (Clarke) Ching	0.012	0.0024	0.000004
Potentilla lineata Trev. ex Reich.	0.047	0.0096	0.000104
Pouzolzia sanguinea (Bl.) Mr.	0.016	0.0034	0.000008
Primula geraniifolia Hook.f.	0.006	0.0013	0.000001
Pseudognaphalium affine (D. Don) Ander.	0.016	0.0034	0.000008
Ranunculus cantoniensis DC.	0.016	0.0034	0.000008
Rhodiola bupleroides (Hook.f. & Thom.) Fu	0.016	0.0034	0.000008
Rohdea wattii (Clarke) Yama. & M.N. Tam.	0.068	0.0141	0.000279
Rubia manjith Roxb. ex Flem.	0.053	0.011	0.000146
Rubus fockeanus Kurz J.	0.025	0.0051	0.000021
Rubus calycinus Wall. ex D.Don	0.006	0.0013	0.000001
Rumex nepalenis Spreng.	0.033	0.0067	0.000042
Satyrium nepalense D.Don.	0.029	0.006	0.000031
Saxifraga brachypoda D.Don	0.04	0.0082	0.000069
Saxifraga brunonis Wall. ex Ser.	0.056	0.0116	0.000169
Sedum linearifolium var ovatisepalum Raym.-Hamet	0.043	0.0089	0.000086

Sedum sp.	0.006	0.0013	0.000001
Senecio laetus Edgen	0.021	0.0043	0.000014
Senecio scandens Buch.-Ham. ex D.Don	0.016	0.0034	0.000008
Solanum nigrum Linn.	0.006	0.0013	0.000001
Streptopus simplex D.Don	0.006	0.0013	0.000001
Swertia franchetiana Hr. Sm.	0.071	0.0147	0.000310
Tectaria polymorpha (Wl. ex Hk.f.) Cp.	0.012	0.0024	0.000004
Thalictrum reniforme Wall.	0.016	0.0034	0.000008
Tiarella polyphylla D.Don	0.016	0.0034	0.000008
Tipularia josephi Rchb. f. ex Lindl.	0.006	0.0013	0.000001
Urtica mairei H. Lev.	0.053	0.011	0.000146
Valeriana hardwickii Wall.	0.012	0.0024	0.000004
Valeriana jatamansi Jones	0.016	0.0034	0.000008
Viola betonicifolia Sm.	0.05	0.0103	0.000123
Species 1	0.102	0.021	0.000829
Species 2	0.012	0.0024	0.000004
	4.286	**0.883**	**0.021161**

Life form classes	Code	No. of species	Percentage (%)	
Phanerophyte	**Ph**	**134**		45.11
Megaphanerophyte	MMM	3	1.01	
Mesophanerophyte	MM	30	10.1	
Microphanerophyte	M	37	12.46	
Nanophanerophyte	N	27	9.09	
Epiphyte	E	23	7.74	
Lianas	L	14	4.71	
Chamaephyte	**Ch**	**19**		6.40
Hemicryptophyte	**H**	**79**		26.60
Cryptophyte	**Cr**	**37**		12.46
Geophyte	G	37	12.46	
Therophyte	**Th**	**28**		9.42
Total		**297**		**100**

Table 3.21 : Life form composition of plants in Mt. Japfü.

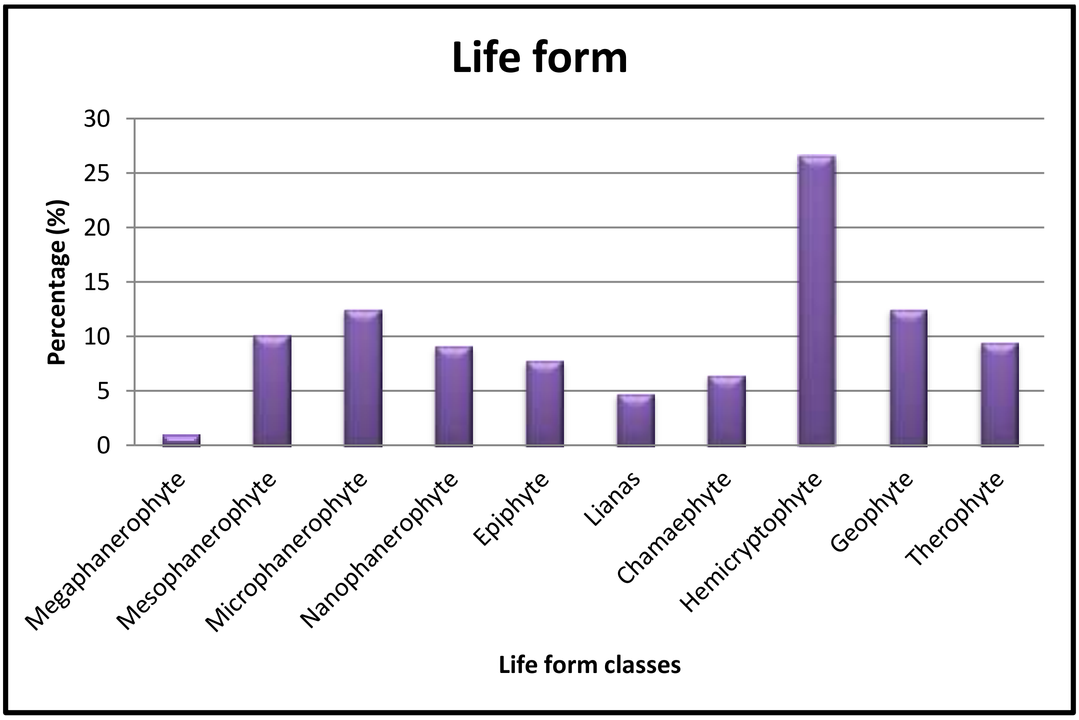

Fig. 3.15: Chart showing percentage (%) of different life forms in Mt. Japfü.

7. Remote sensing and GIS

For the present study, Indian satellite IRS-P6, LISS IV sensor data (Path 123 , Row 53) of 2nd November 2013 imagery was used. The satellite image has been obtain from NASTEC, Science and Technology Department, Government of Nagaland.

The richness of red colour in false colour composite image indicates the density of the vegetation in the region. Dense forests appear dark red tone with rough texture and open forest appear lighter red tone with smooth texture in the satellite image (Fig.3.13). The agricultural fields appears light pinkish tone and cleared or fallow land showed light cyan tones.

7.1 NDVI Image

Normalized Difference Vegetation Index was used to study the different spectral features of the vegetation in the remote sensed image of Mt. Japfü. NDVI value of zero means absence of green vegetation and the NDVI value close to +1 indicates high density of green vegetation. From the present study, the NDVI image shows that majority of the area represents NDVI value between 0.489 and 0.618 which indicates the dense temperate forest vegetation of Mt. Japfü. NDVI value ranging between 0.232 and 0.361 represents moderately densed forest and scrub vegetation. Shadow regions, agricultural fields and cleared or fallow lands has NDVI value <0.104 and are represented as red in colour in the NDVI image (Fig. 3.14).

7.2 Vegetation Map

With the use of spectral vegetation indices such as NDVI and texture of satellite image, the vegetation in an area can be classified into different types. Red coloured regions in the vegetation map signify agricultural fields and fallow lands in the study site. Light brown regions are Sub alpine scrub vegetations and light green parts represent the temperate forest areas which are moderately dense. Dark green regions in the map represent dense temperate vegetations in Mt. Japfü. Some of shadow regions are also shown as dark green colour in the map.

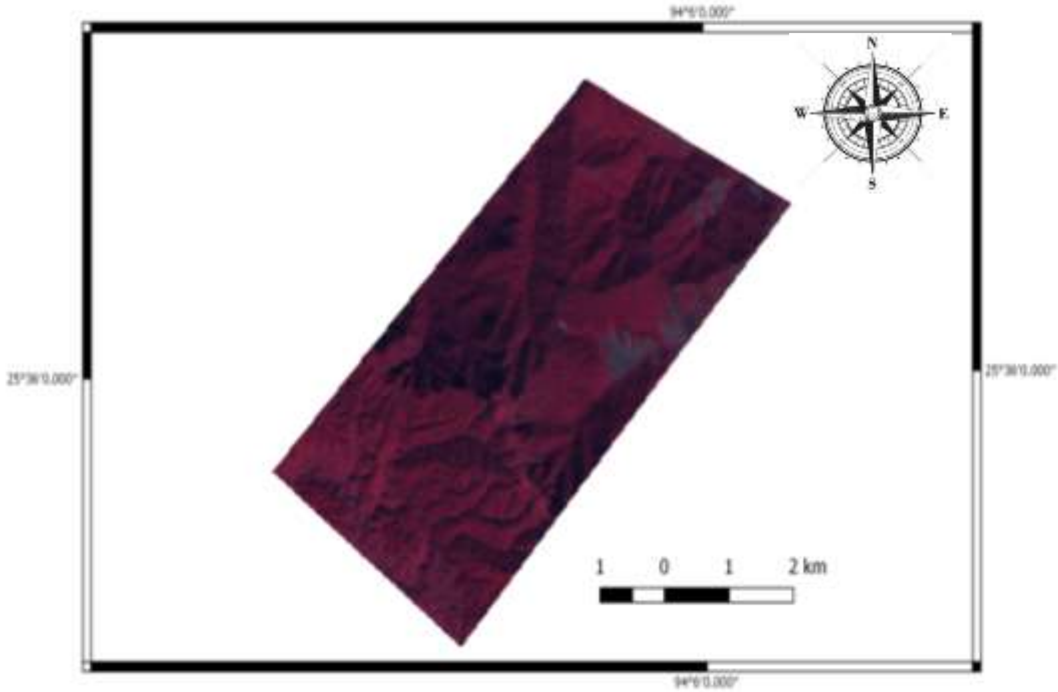

Fig. 3.16 : False colour composite image of Mt. Japfü.

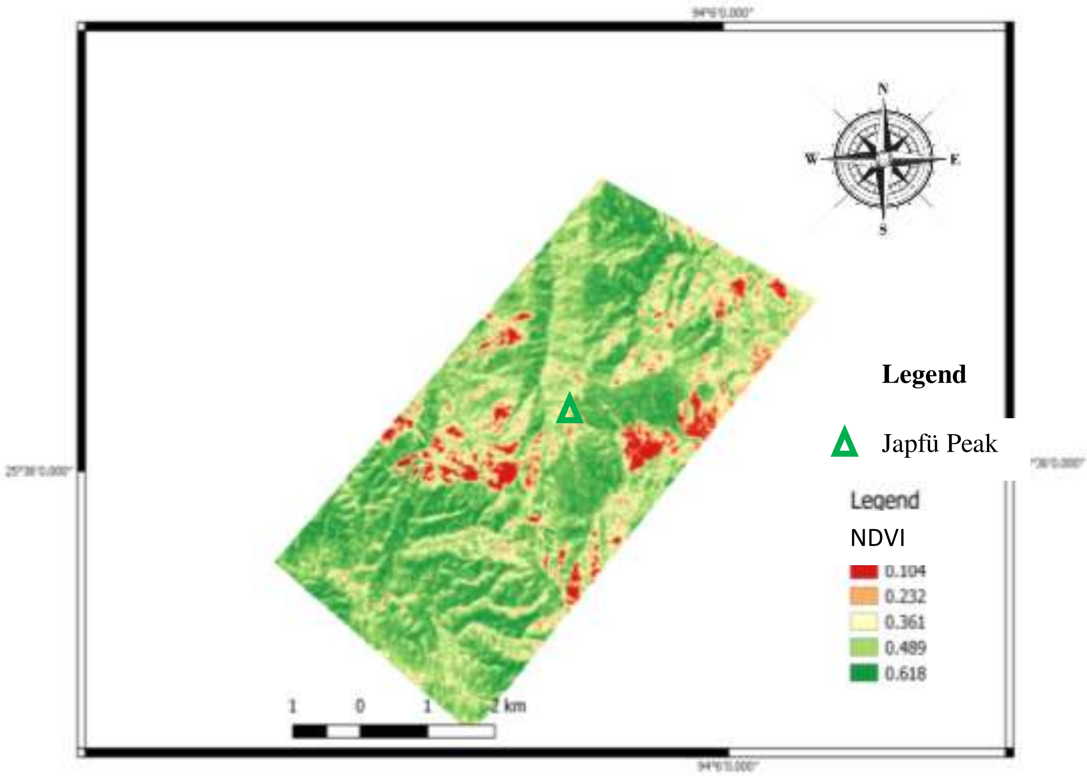

Fig. 3.17 : Generated NDVI image of Mt. Japfü.

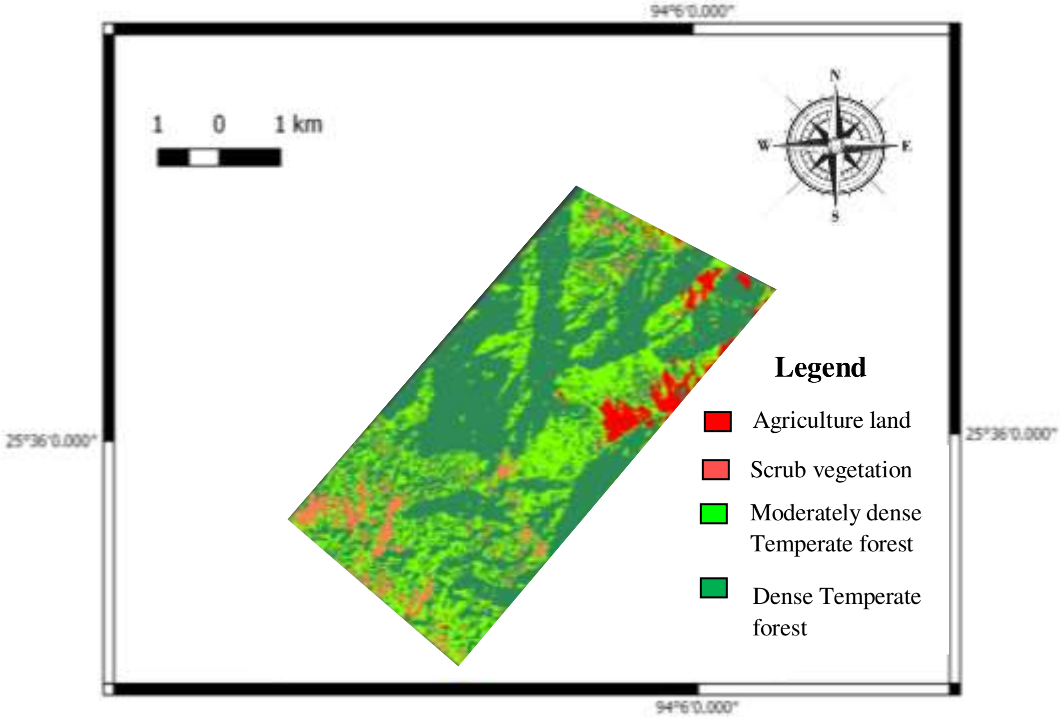

Fig. 3.18 : Satellite image showing different class of vegetation of Mt. Japfü.

CHAPTER IV

DISCUSSION

Mt. Japfü forest is a primary forest with Montane wet temperate forest at the slopes of the mountain and Sub alpine scrub vegetation at the peak. A total of 296 species belonging to 225 genera and 97 families were recorded from Mt. Japfü. Angiosperms with 278 species were found to the dominant group followed by Pteridophytes (18 species) and Gymnosperms (1 species). Dicotlyedons were the dominant components of Angiosperms. This finding is similar with other studies such as Balakhrishnan (1981-1983), Haridasan and Rao (1985-1987), Hynniewta (1999) and Mao *et al.* (2016).

The floristic components of the forest of Mt. Japfü exhibits close affinities with plants of Sikkim as reported by Clarke (1887). These affinities are represented by presence of some common species from genera such as *Acer, Agapetes, Alnus, Ardisia, Arisaema, Anemone, Begonia, Berberis, Betula, Brassiopsis, Chrysoplenium, Coelogyne, Euonymus, Eurya, Gentiana, Geranium, Helwingia, Ilex, Impatiens, Lithocarpus, Macropanax, Magnolia, Michelia, Ophiopogon, Pedicularis, Pleione, Potentilla, Quercus, Rhodiola, Rhododendron, Rosa, Rubus, Satyrium, Schefflera, Schima, Skimmia, Symplocos, Taxillus, Taxus, Vaccinium, Valeriana* etc.

Based on Champion and Seth (1968) the vegetation can be classified as montane wet temperate forest and sub alpine vegetation. The temperate elements recorded from the forest were *Acer campbelli, Acer caudatum, Acer pectinatum, Achyranthes bidentata, Aeschynanthes hookeri, Agapetes smithiana* var *major, Ainsliaea aptera Anemone rupestris, Begonia thomsonii, Berberis wallichiana, Betula utilis, Buddleja macrostachya, Carpesium cernuum, Chimonocalamus griffithianus, Circaea alpina, Clematis montana, Clintonia udensis, Dichrocephala integrifolia, Diphylax urceolata, Euonymus echinatus, Hedera nepalensis, Himalaiella deltoidea, Ilex dipyrena, Lithocarpus pachyphylla, Macropanax dispermus, Magnolia campbelli, Prunus cerasoides, Quercus lamellosa,* *Rhododendron elloitti, Rhododendron johnstoneanum, Rhododendron macabeanum, Rhododendron maddenii, Rhododendron triflorum* var *bauhiniflorum, Rohdea wattii, Rubia sikkimense, Skimmia laureola, Symplocos dryophila, Symplocos thaefolia, Taxillus vestitus, Taxus wallichiana, Vaccinium retusum* etc.

The Sub alpine elements included *Anemone elongata, Campanula pallida, Chrysoplenium nepalensis, Cicerbita macrorhiza, Cotoneaster acuminatus, Cotoneaster adpressus, Cotoneaster microphyllus, Cyananthus inflatus, Elsholtzia strobilifera, Fragaria nubicola, Gaultheria hookeri, Hemiphragma heterophyllum, Hypericum hookerianum, Impatiens dolichoceras, Impatiens radiata, Juncus thomsonii, Leucosceptrum canum, Ligularia fischeri, Lobelia doniana, Pedicularis curvipes, Pedicularis porrecta, Persicaria chinense, Persicaria runcinata, Potentilla lineata, Pseudognaphalium affine, Rhodiola bupleroides, Rhododendron triflorum* var *bauhiniflorum, Rosa sericea, Rubus sumatranus, Saxifraga brachypoda, Saxifraga brunonis, Seniocio laetus, Thalictrum reniforme* etc.

Primitive angiosperms belonging to 10 families viz. Fagaceae, Ranunculaceae, Lauraceae, Magnoliaceae, Piperaceae, Schisandraceae, Urticaceae, Juglandaceae, Lardizabalaceae, Saururaceae and genera viz. *Actinodaphne, Alnus, Betula, Boehmeria, Elatostemma, Engelhardtia, Girardinia, Hoebelia, Houttuynia, Lithocarpus, Magnolia, Michelia, Phoebe, Pilea, Piper, Poulzolzia, Quercus, Schisandra* and *Urtica* were recorded from the study area.

Presence of considerable number of species in the study area can be contributed to high rainfall (average mean rainfall 250 mm) in the study area. Environmental variables like climate and edaphic factors are considered to be primary determinants of change in species composition and community structure along the elevational gradient in montane areas (Whittaker, 1975). Studies have revealed that species richness tend to decrease with increase in altitude (Bruun *et al*., 2006). This is observed in the present study in case of trees, shrubs, epiphytes and lianas. As the elevation increased lianas and epiphytes decreased in number and toward the peak there is very few or no species present. Tree and shrub species are also less diverse at the higher altitudes.

Topography, inclination of slope and soil type also affect the forest composition (Shank and Noorie, 1950). Vegetation and soils are mutually associated with each other as both are the product of the same environmental variables (Hironaka *et al*., 1990). Changes in vegetation composition can produce substantial changes in carbon and nitrogen dynamic (Tilman *et al.,* 1997). Soil in the study area is strongly acidic in nature, Organic Carbon content was high, available N content was medium, available Phosphorus and Potassium content was low. Temperate forest soils usually have higher organic matter than the tropical forest because they have lower temperature which slows down the decomposition rate and they have less biodiversity so nutrient uptake from the soil is also less. Studies have suggested that low transpiration rates due to high relative air humidity, high soil acidity, limited litter decomposition and mineralization rates results in tree stunting at high elevation (Odum, 1970; Grubb and Tanner, 1976; Heaney and Proctor, 1989). Phosphorus availability is known to decline with altitude and this may contribute to slow growth at high altitudes (Coomes and Allen, 2006). Nitrogen is known to be the most limiting element for vegetation in temperate and boreal forest (Tamm, 1991; Vitonsek and Howard, 1991).

Biological spectrum is used to indicate the stratification of a plant community and the phytoclimate of the habitat. The standard deviation of the biological spectrum of Mt. Japfü from Raunkiaer's Normal biological spectrum (NBS) shows that Hemicryptophytes (-0.69) and Cryptophytes (-6.5) percentage were more than NBS whereas Phanerophytes (+1.07), Chamaephytes (+2.48) and Therophytes (+3.54) were found to be less (Table 4.1). Biological spectrum of the Mt. Japfü was found to be more similar with that of the Raunkiaerian temperate climate biological spectrum (Ennis, 1928). The biological spectrum of Mt. Japfü showed the dominance of Phanerophytes followed by Hemicryptophyte and Geophytes (Cryptophyte). This indicates that phytoclimate of the study area is Phanero-Hemicryptophytic type. The abundance of Phanerophytes is an expression of monsoonic climate and low biotic pressure in the study area. Hemicryptophyte and Geophytes exceeds the normal spectrum indicating better soil condition in the study.

Spectrum	Ph	Ch	H	Cr	Th
Normal spectrum	46	9	26	6	13
Present study	44.93	6.42	26.69	12.5	9.46
Deviation in %	+1.07	+2.58	-0.69	-6.5	+3.54

Table 4.1 : Comparison of biological spectrum of study area with Raunkiaer's Normal Biological spectrum.

Spectrum	Ph	Ch	H	Cr	Th	Phytoclimate
Normal spectrum	46	9	26	6	13	Phanerophytic
Arctic	1	22	61	15	1	Hemicryptophytic
Temperate	15	2	49	22	12	Hemicryptophytic
Tropical moist	61	6	12	5	16	Phanerophytic
Tropical arid	9	14	19	8	50	Therophytic
Present study	44.93	6.42	26.69	12.5	9.46	Phanerophytic

Table 4.2 : Comparison of biological spectrum of study area with Raunkiaerian life form spectra of certain major climates.

Ph = Phanerophytes, **Ch =** Chamaephytes, **H =** Hemicryptophytes,

Cr = Cryptophytes, **Th** = Therophytes

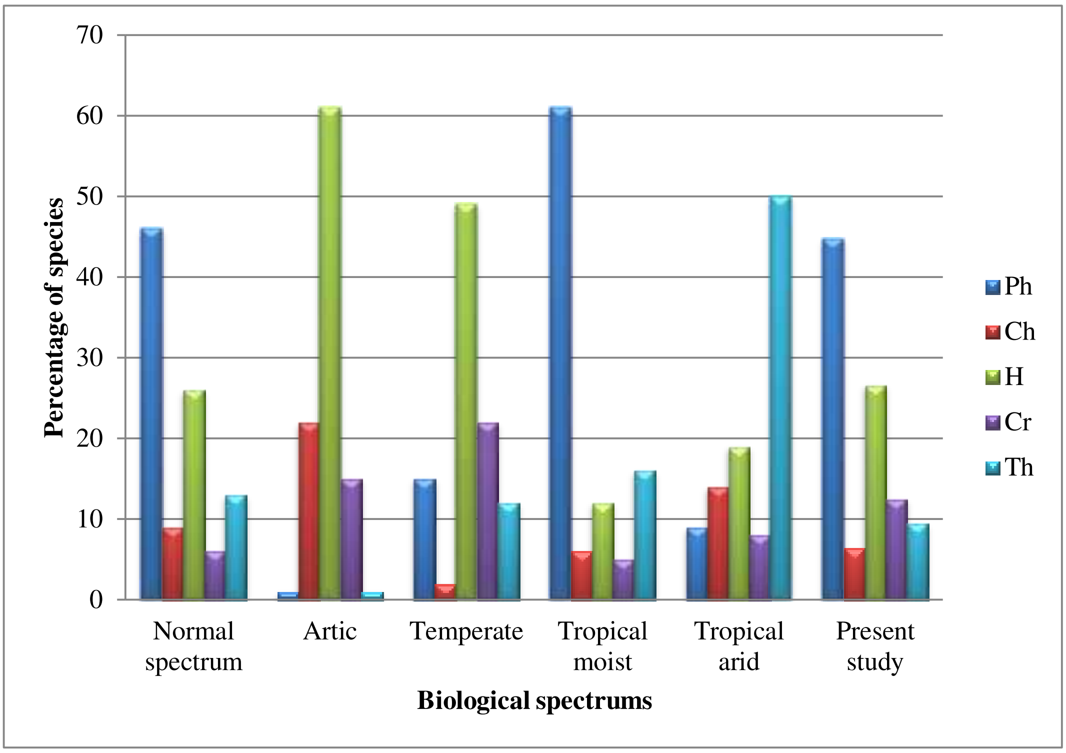

Fig. 4.1: Chart showing biological spectrum of study area in comparison with Raunkiaerian life form spectra of certain major climates.

area for underground growth. Chamaephytes were comparatively less in percentage than the normal spectrum due to the fact that the area receives sufficient rainfall which hampers their development. Biotic disturbances and low rainfall tends to increase the percentage of Therophytes (Daunbenmire, 1968), therefore the lower percentage of Therophyte in the present study may indicate low level of disturbance and high rainfall in Mt. Japfü.

Frequency is a measure of the uniformity of the distribution of a species; thus a low frequency indicates that a species is either irregularly distributed or rare in a particular stand or forest (Kharkwal and Rawat, 2010). In the present study maximum frequency of tree species was recorded in *Lithocarpus pachyphylla* and *Rhododendron macabeanum.* In shrub species it was found in *Daphne papyracea*, *Chimonocalamus griffithiana* and *Rhododendron triflorum* var *bauhiniflorum* and in herb species, *Daphne papyracea, Dryopteris odontoloma* and

Goodyera schlechtendaliana had the highest frequency values. This indicates that these species are the most wide spread and have the most uniform distribution in the study area . Raunkiaer's frequency class of trees, shrubs and herbs in the study area showed that 96.4% of the total plant species represents class A and only 3.6% represented class B. This is also another indication that the forest of Mt. Japfü is least disturbed.

Highest density of tree, shrub and herb species was documented in *Rhododendron macabeanum, Lithocarpus pachyphylla, Debregeasia longifolia, Yushiana rolloana, Chimonocalamus griffithiana, Gaultheria hookeri, Parochetus communis, Fragaria nubicola* and *Dryopteris odontoloma.* These species have most number of individuals and therefore most commonly found in the study site.

Abundance include both the numbers of individuals present and their frequency of occurrence in an area. In Mt. Japfü, tree species such as *Debregeasea longifolia, Rhododendron macabeanum*, *Casearia kurzii* and *Betula utilis* was found to be the most abundant. *Yushania rolloana, Gaultheria hookeri, Chimonocalamus griffithianus*, and *Cephalostachyum capitatum* are the most abundant shrub species. Herb species like *Chaerophyllum villosum*, *Parochetus communis*, *Fragaria nubicola, Viola betonicifolia* and *Aconitum nagarum* have the highest abundance in the area.

The above mentioned species having high frequency, density and abundance may have higher stress tolerance than other species of the region and therefore well established in the cold climatic condition of Mt. Japfü.

Presence of 488 individuals of trees in the samples studied from the study area reflects that the forest is quite dense. From the present study maximum number of species and individuals have been recorded in 10-20 cm DBH class and DBH class 21-30 cm and least number of species and individuals occur at 71-80 cm and 91-100 cm DBH classes. This shows that medium sized trees are more dominant than large trees in Mt. Japfü. Variation in tree size distribution in forest is the result of various factors such as competition for resources, regeneration pattern, disturbances, environment conditions, irregular or seasonal climatic events (Coomes *et al*., 2003; Webster *et al*., 2005). Diameter growth rates declines with altitude and this was associated with a shortening of growing season and reduction in mean summer temperature (Wardle, 1984).

Basal area refers to the ground area actually penetrated by the stems of plants. The higher the basal area greater is the dominance of the plant species in the area. *Quercus lamellosa* (107.57 m^2/ha) and *Magnolia campbelli* (76.6 m^2/ha) have the highest total basal area of tree species which also signify their dominance in the study site.

Importance value index of a species depicts the overall picture of its ecological importance in an area., *Rhododendron macabeanum* (30.93%), *Quercus lamellosa* (28.55%) and *Lithocarpus pachyphylla* (24.78%) has highest percentage of Importance Value Index (IVI) followed by *Magnolia campbelli* (16.81%), *Betula utilis* (13.13%), *Rhododendron maddenii* (12.33%), and *Symplocos dryophila* (11.73%). The higher values of IVI indicates that most of the available resources are being utilized by that species and the residual resources are used by the other associate species (Singh, 2014).

The dominance diversity curve in the study site showed the Log normal model of Preston (1948). This suggests highly mixed nature of the plant community in a stable environment. It is a result of existence of favourable environmental condition for a long period of time (Whittaker 1975).

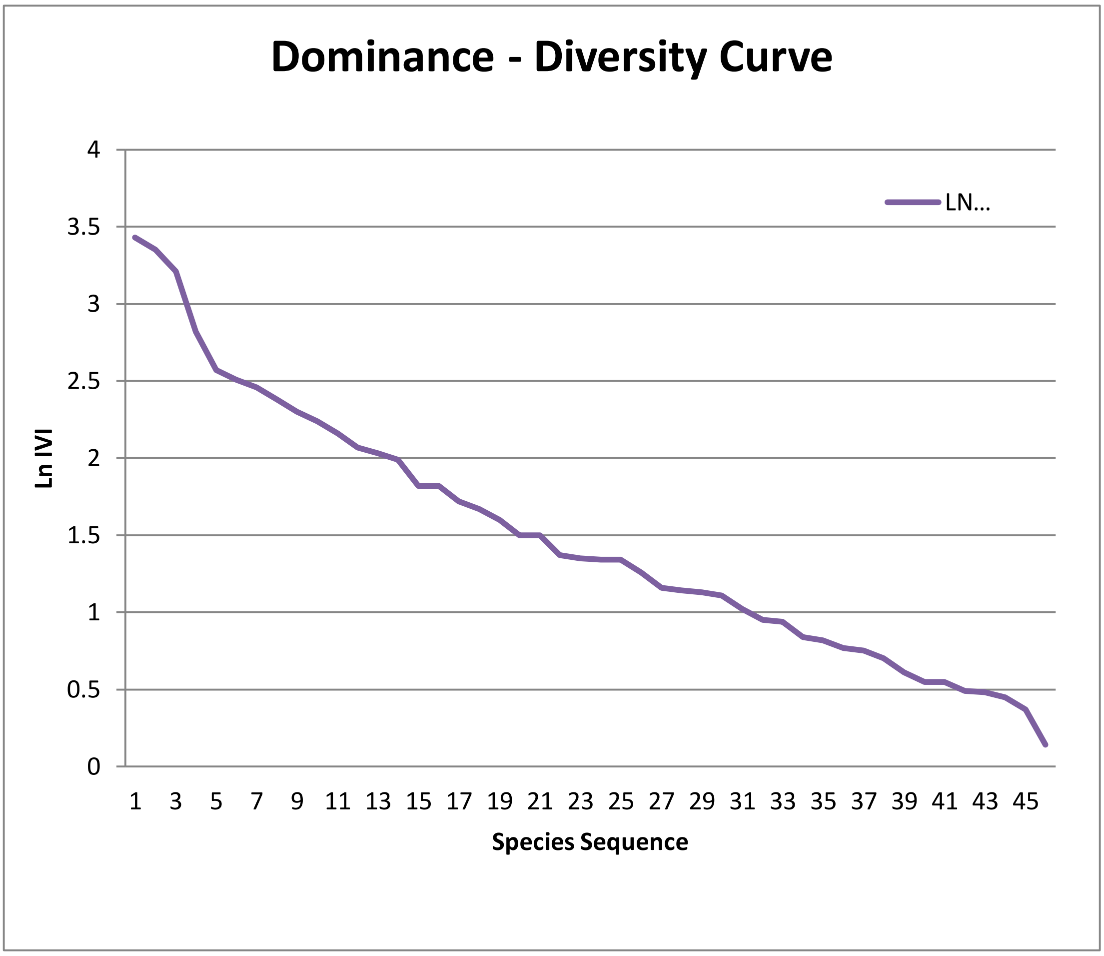

Fig. 4. 2: Dominance- diversity curve of tree species in Mt. Japfü.

Whittaker's species richness index was highest in herb species (42.21) followed by tree (17.11) and species (16.33). The high species richness of herb species is a common feature of a temperate forest. Studies have shown that the herbaceous layer of temperate forest especially ferns, can affect the establishment and growth of seedlings of over storey plants as herb species maybe superior competitors for soil nutrients than tree seedlings (Horsley 1993, Lyon and Sharpe 2003, George and Bazzaz 2003). This may be one of the reason for low tree species richness in the present study.

Shannon Wiener diversity index for shrubs and trees in Mt. Japfü were low (2.482 & 3.433) but herbs was high (4.286). Pielou's evenness index revealed greater equitable distribution of species dominance in case of herbs (0.883) and trees (0.897) but shrubs (0.622) showed less evenly distributed in the study area. Higher value of Simpson's dominance index was found in shrub (0.1909) but trees and herbs species has much lower values (0.0451 & 0.0211). The result of the present study was found to be similar with diversity study of cold temperate forest of Darjeeling Himalaya by Saurav and Das (2014). This study also reported high Shannon Wiener index in herbs (4.332) followed by shrubs (3.577) and trees (3.131), greater species evenness was observed in herbs (0.983) and shrubs (0.951) than trees (0.911) and Simpson's dominance index was higher in shrub (0.032) and trees (0.56) than herbs (0.014). The present study is also similar with other diversity studies of trees in temperate forests which range between 1.16 and 3.40 (Braun, 1950; Monk, 1967; Singh *et al.*, 1986; Pande *et al.,* 1996). Li *et al.* (2008) suggest that low diversity does not mean poor stability within the ecosystem rather it is those communities with simple structure and single dominance which have higher stability. Vegetation in high altitudinal zone mainly belongs to types that are cold-tolerant, so the species diversity is not high. Low values of Simpson's index has also been reported from other temperate forests which ranges from 0.10-0.99 (Ralhan *et al.*, 1982 ; Singh *et al.*, 1986; Pande *et al.*, 1996). Higher value of Simpson's index in shrubs indicates clumping of individuals in a few species whereas trees and herbs showed low values which means a more uniform distribution of individuals among the species in the study area.

Among the tree species, *Rhododendron macabeanum* (0.0106), *Quercus lamellosa* (0.0091) and *Lithocarpus pachyphylla* (0.0068) has the highest concentration of dominance (cd) at the present study. The dominance of these species could be because of their extensive root system and large canopy which makes the species able to absorb more resources and occupy larger space in the forest exerting their dominance over other species. In case of shrubs, *Yushiana rolloana* (0.1435), *Chimonocalamus griffithianus* (0.0252) and *Gaultheria hookeri* (0.0184) were recorded to have the most dominance in the plant community. The dominance of *Chimonocalamus griffithianus* inside the forest has caused a decline in ground vegetation resulting in poor herb and shrub diversity at certain areas. In herbs, *Parochetus communis* (0.00386), *Aconitum nagarum* (0.00131), *Goodyera schlechtendaliana* (0.00112) and *Ophiopogon intermedus* (0.0112) showed the highest dominance. In most temperate forests a single or few species dominate the area making the other species uncommon or rare.

The distribution pattern of the study area showed 99.1% contagious and 0.9% random distribution. Study of temperate forest in Garhwal Himalaya by Sharma *et al.* (2009) also showed contagious and random distribution pattern. Contagious distribution is the most common type of distribution found under natural condition and also reflects that individuals are aggregated in more favourable parts of the habitat. The clumping of individuals of a species may be due to insufficient mode of seed dispersal (Richards, 1996) or when death of trees create a large gap which encourages establishment and growth of numerous saplings (Armesto *et al.* 1986).

Remotely sensed imagery using NDVI can detect differences in spectral signature which is used to assess biodiversity of a region (Nagendra 2001, Pettorelli *et al.*, 2005). Majority of the vegetation in the study area showed high NDVI values ranging from 0.489 - 0.618, which represents healthy and dense vegetation. Lower NDVI values ranging from 0.232 - 0.361 represents sparse vegetation and 0.104 represents barren or cultivated lands. Studies have shown the positive correlation between NDVI and species richness (Bawa *et al.*, 2002). The use of GIS and vegetation classification systems in combination with computer-based automated field mapping techniques is an essential tool in creating an up-to-date vegetation map (Hasmadi *et al*., 2010). In the present study, the vegetation has been classified and mapped from remote sensing imagery according to their texture and unique spectral characteristics which has been verified by field visits. The vegetation map has been classified into four classes namely barren or cultivated area, very dense temperate forest, moderately dense temperate forest and sub alpine scrub vegetation. The dominant tree species in the dense temperate forest are *Litsea* spp., *Brassiopsis polycantha, Schima khasiana, Magnolia campbelli and Michelia velutina*. In the moderately dense forest the dominant species are *Lithocarpus pachyphylla, Rhododendron* spp*., Symplocos* spp*., Quercus lamellosa, Betula utilis and Acer* spp. The sub alpine vegetation is mostly dominated by the dwarf bamboo species (*Yushiana rolloana).* Similar study has also been done by Verma *et al*. (2016) where they used different vegetation indices and texture analysis for mapping the vegetation of Foloda village, Muzaffarnagar, India. Singh (2004) also studied and mapped the different vegetation types of Jiribam sub-division, Imphal, Manipur based on visual image interpretation technique supported by ground vegetation using Remote sensing and GIS. Many studies have been done on vegetation and land cover classes using Remote sensing and GIS to analyze the spatial distribution of plant species (Nagendra and Gadgi, 1999; Wagner *et al*., 2000; Li and Wu , 2004; Guisan and Thuiller, 2005).

From the present study *Tipularia josephi* Rchb. f. ex Lindl. (Orchidaceae) is reported as a new generic distributional record for the orchid flora of Nagaland which was found at an altitude of 2932m ASL from Mt. Japfü.

Growing on mountain peak associated with *Dryopteris odontoloma*, *Ophiopogon intermedus* and *Platanthera leptocaulon* etc. Only three individuals were observed during field survey.

Disturbances in Mt. Japfü

The study area Mt. Japfü comes under the community forest of Jotsoma, Phesama and Kigwema villages. Majority of the land falls under Kigwema village who have also marked the area as a Biodiversity Reserved Area. Therefore, the area is protected by certain rules like ban on hunting, fishing, logging and exploitation of forest bioresources. Regardless of these protective measures many disturbances have been observed in Mt. Japfü in the past 3 to 4 years. One of the major disturbances is deforestation because of road access inside the forest. There are several boundary issues between these villages, therefore in 2013 Jotsoma village constructed a road inside the forest marking their boundary. This has led to felling of many large trees of the forest which has also resulted in landslides in many areas. These activities has largely disturbed the local flora of the region. Another major disturbance of the study site is potato farming practised at the lower altitudes on the edge of the forest. Many weed species like *Artemissia nilagirica, Ageratina adenophora, Boehmeria platyphylla, Bidens pilosa* etc. has been introduced because of this practice. In spite of prohibition of exploitations of forest resources, excess extraction of forest resource for food, medicine, ornamental value and fodder has been observed. In certain areas this resulted in loss of medicinal plants like *Paris polyphylla* at lower altitudinal zones. Mt. Japfü is also a well known destination for mountain trekkers in Nagaland. In January 2014, a group of visitors caused a forest fire at the peak which led to devastation of majority of the flora at the peak. Regeneration of species like *Yushiana rolloana, Impatiens* spp.*, Aconitum nagarum, Parochetus communis, Saxifraga* spp. etc. have been observed but certain species such as *Leycestra* sp. and *Cynoglossum* sp. were not observed in the following 3 years. Littering by visitors has also been observed inside the forest. Rearing of mithun (*Bos frontalis*) at the lower elevations of the forest have also disturbed the vegetation of the forest. These animals are allowed to freely roam inside the forest which leads to over grazing of herbaceous plants.

CONCLUSION

Mt. Japfü forest area belongs to three Angami tribe villages namely Kigwema, Jotsoma and Phesama. Majority of the area falls under the community forest of Kigwema village. The word "Japfü" originates from the local dialect "Ja" which means a protective barrier. This name was given by Kigwema villagers as Japfü mountain range act as a protective barrier against harsh wind. Japfü mountain range is important to many cultural and traditional practice of the villagers. The villagers believe that if a person planned to visit the forest in Japfü but fails to go, that person will be cursed in such a way that his/her hair will fall off and die. The villagers practice a ritual called "asie" before plantation so that they will receive sufficient rainfall for their crops. In this ritual, the offspring's from the two lineage of 'thevo ü' and 'thepa' brings one of their best cocks and free them near the Japfü river 'Nezie rü'.

From the present study a total of 297 species have been recorded from Mt. Japfü out of which herbs has the highest species richness with 154 species. Shrubs and trees are poorly in the area represented by 54 and 45 species. The plants of Mt. Japfü showed close affinity with the flora of Sikkim (Hajra *et al.,* 1996). High rainfall and rich organic matter of the soil in the study site support the diverse flora. The present study also revealed that lower elevations have higher species richness in case of trees, shrubs, epiphytes and climbers but herb species were found to have higher number of species at the peak. This may be due to the climatic variables at the peak where trees are normally less or not found. The low temperature and accumulation of snow for few months in winter i.e. December to February, may also be the reason for lower species diversity at higher altitude.

Results of the present study showed high Shannon Wiener diversity index in herbs species and low diversity in tree and shrub species. This is a common trait of temperate forest which is due to the fact that herbs species are well adapted to cold and harsh climate by presence of structures tuber, bulb, corm and rhizome. Shrub species was found to be more evenly distributed than herbs and trees in the study area. The lower concentration of dominance in Mt. Japfü is because of shared dominance between many species while higher value of Simpson's dominance index of some species indicates their dominance in the plant community. The diameter at breast height (DBH) class of the forest showed the presence of large number of medium sized trees in the region. This could be due to the arrested growth of trees because of cold climatic condition and high acidity of the soil. The log normal distribution of dominance of tree species in Mt. Japfü suggest the plant community is of stable environment and it is least disturbed.

Life form study showed the dominance of woody species in the study area . High species composition of Phanerophyte is an indication of monsoon type climate of the area. The study showed that the phytoclimate of Mt. Japfü is of Phanero-Hemicryptophytic type.

The study of Raunkiaer's frequency class of the vegetation revealed that frequency class A is greater than class B. This is a characteristic of natural and undisturbed vegetation according to Raunkiaer (1934). The distribution pattern of species in the study site indicates mostly contagious and a few random type of distribution. The forests is highly heterogeneous due to contagious distribution pattern of species which is an attribute of natural vegetation.

In the present study, satellite imagery and GIS along with the spatial vegetation index (NDVI) has been used to map the species richness pattern in the study site. Results demonstrate that maximum of the NDVI values of the region are close to +1 which indicates a healthy vegetation and that the area has high species richness. Vegetation map shows different types of vegetation namely very dense temperate forest, moderately dense temperate forest, sub alpine scrub vegetation and barren or cultivated areas.

The study revealed that the rich and diverse flora of Mt. Japfü holds many medicinal plants (92 species). 31 endemic species, 11 rare species and 8 vulnerable, endangered and threatened species were recorded from the study area. High altitudinal plants are more vulnerable to climate change as they are restricted in distribution therefore fails to migrate or adapt to warmer climatic conditions. Japfü mountain biodiversity provides a number of ecosystem services to the villages at the foothills such as fuel wood, medicinal plants, wild vegetables, fodder, ornamental plants, timber etc. Wild birds and animals found in the forest are Antelope, Bear, Deer, Squirrels, wild Cat, Porcupine, Monkey, Jackal, Falcon, Owl, Cuckoo, wild Pigeons, wild fowl and Tragopan blyth. The practice of terrace cultivation by the villagers have helped to conserve the biodiversity of the forest. Jhuming is a common agricultural practice used in many districts of Nagaland but it not practiced by the villages living in and around the Japfü mountain this has also contributed in conservation of biodiversity in the area. Understanding the importance of biodiversity conservation of Mt. Japfü, Kigwema village council has marked the region as a Biodiversity Reserved Area. Restrictions and bans have been implemented on hunting, logging, fishing, exploitation of bio resources from the community forest and fines are imposed to the defaulters. Hunting is allowed only during the winter months of December and January. Despite taking all these measures, the region is still vulnerable to anthropogenic activities. The problem of logging, over grazing, excess extraction of medicinal plants, edible plants, fodder and ornamental plants observed in the periphery of forest should be regulated and checked. Sustainable use of bioresources and proper management of biodiversity is essential. In order to successfully conserve the biodiversity of the region active participation of the local community is necessary.

The present study of plant diversity assessment and mapping using both field studies and Remote sensing & GIS provides useful data of species diversity which can be used for formulating plans for conservation strategy.

Further research studies can be done on the important medicinal plants found in Japfü such as *Paris polyphylla, Taxus wallichiana, Aconitum nagarum* and *Dicentra scandens.* Studies using RS and GIS for mapping of rare and other important species for conservation can be explored in Mt. Japfü.

Plate 1.*Rhododendron arboreum* Sm. subsp. *delavayi* (Frn.) Chm.

Plate 2. *Rhododendron elliotti* Watt.

Plate 3.*Rhododendron formosum*Wall. var.*inequale* (Hut.) Cull.

Plate 4.*Rhododendron macabeanum* Watt. ex I.B. Balf.

Plate 5.*Rhododendron triflorum*Hk.f. var.*bauhiniflorum* (Watt. ex Hut.) Cull.

Plate 6.*Rhododendron maddenii*Hk .f. subsp. *crassum* (Fr.) Cl.

Plate 7.*Rhododendron johnstoneanum* Watt. ex Hut.

Plate 8.*Symplocosthaefolia*D.Don

Plate 9.*Symplocosdryophila*D.Don

Plate 10.*Euryaacuminata*DC.

Plate 11.*Pierisformosa* (Wall.) D.Don.

Plate 12.*Polygala arillata* Bch.-Hm. exD.Don

Plate 13.*Litseamonopetala* (Roxb.) Pers.

Plate 14.*Trevesiapalmata* (Roxb.)Vis.

Plate 15.*Vitexquinata*(Lour.)F.N. Will.

Plate 16.*Taxuswallichiana*Zucc.

Plate 17.*Debregeasialongifolia* (Burm.f.) Wedd.

Plate 18.*Skimmialaureola*Fran.

Plate 19.*Rosa sericea*Lindl.

Plate 20.*Hypericumhookerianum* Wight &Arn.

Plate 21.*Daphne papyracea* Wall. ex Steud.

Plate 22.*Buddlejamacrostachya* Benth.

Plate 23.*Sambucusadnata*Wall. ex DC.

Plate 24.*Gaultheria griffithiana* Wight

Plate 25.*Strobilanthespterygorrhachis* Clarke

Plate 26.*Cotoneasteraadpressus*Bois

Plate 27.*Cotoneaster acuminatus* Wall. exLindl.

Plate 28.*Vacciniumretusum*Hk.f. ex Clarke

Plate 29.*Astilberivularis*Bch.-Hm. ex D.Don

Plate 30.*Persicariacampanulata*(Hk.f.) Ron. Decr.

Plate 31.*Aconogonummolle*(D.Don) H. Hara

Plate 32.*Gynurabicolor* (Roxb. ex Wil.) DC.

Plate 33.*Dichroafebrifuga* Lour.

Plate 34.*Ophiorrhizasuccirubra*King ex Hk.f.

Plate 35.*Leptodermiskumaonensis* R. Park.

Plate 36.*Spiraeacanescens*D.Don

Plate 37.*Edgeworthiagardeneri* (Wall.) Meisn.

Plate 38.*Helwingiahimalaica*Hk.f. &Thm. ex Cl.

Plate 39.*Viola betonicifolia* Sm.

Plate 40.*Phlomoideshamosa*(Benth.) Mathi.

Plate 41.*Campanula pallida* Wall.

Plate 42.*Cardiocrinumgiganteum*(Wall.) Mak.

Plate 43.*Lobelia doniana*Skottsb.

Plate 44.*Cyananthusinflatus*Hk.f. & Thom.

Plate 45.*Anemone elongata*D.Don

Plate 46.*Streptopus simplex*D.Don

Plate 47.*Senecioscandens*Buch.-Ham. exD.Don

Plate 48.*Fagopyrumesculentum* Moench.

Plate 49.*Rubuscalycinus* Wall. exD.Don

Plate 50.*Paris polyphylla* Sm.

Plate 51.*Impatiens siculifer*Hk.f.

Plate 52.*Neohymenopogonparasitus* (Wall.)Benn.

Plate 53.*Gaultheria hookeri* Clarke

Plate 54.*Arisaemaconcinnum*Schott.

Plate 55.*Gentiana quadriferia* Bl..

Plate 56. *Clintonia udensis*Tra. & C.A.Mey.

Plate 57.*Begonia thomsonii* A.DC.

Plate 58.*Achyranthes bidentata* Blume

Plate 59. *Tiarella polyphylla* D.Don

Plate 60. *Elatostema obtusum* Wedd.

Plate 61. *Thalictrum reniforme* Wall.

Plate 62. *Anemone rupestris* Wall. ex Hk.f. & Thom.

Plate 63. *Theropogon pallidus* (Wall. ex Kun.) Max.

Plate 64. *Ainsliaea aptera* DC.

Plate 65. *Urtica mairei* H. Lev.

Plate 66. *Chirita pumila* D.Don

Plate 67. *Ophiopogon intermedus* D.Don

Plate 68. *Corydalis cornuta* Royle

Plate 69. *Rubus hirtus* Heget.

Plate 70. *Persicaria chinense* (L.) H. Gross

Plate 71. *Carex baccans*Nees

Plate 72. *Juncus thomsonii* Buch.

Plate 73. *Anaphalis contorta* (D.Don) Hk.f.

Plate 74. *Rubus sumatranus* Miq.

Plate 75. *Impatiens radiata* Hook.f.

Plate 76. *Persicaria nepalensis* (Meisn.) H.Gross

Plate 77. *Himalaiella deltoidea* (Cand.) Raab-Strau.

Plate 78. *Circaea alpina* L.

Plate 79. *Polygonatum kingianum* Coll. and Hem.

Plate 80. *Dichrocephala integrifolia* (Linn.f.) Kun.

Plate 81. *Monotropa uniflora* L.

Plate 82. *Aster thomsonii* Clarke

Plate 83. *Pilea scripta* (Buch.-Ham ex D.Don) Wedd

Plate 84 .*Hydrocotyle javanica* Thunb.

Plate 85.*Aconitum nagarum* Stapf.

Plate 86. *Parochetus communis* Buch.-Ham.ex D.Don.

Plate 87.*Sedum linearifolium* var *ovatisepalum* Ray.-Ham.

Plate 88. *Aeshynanthus hookeri* Clarke

Plate 89. *Agapetes smithiana* var *major* Sleum

Plate 90. *Vaccinium vacciniaceum* (Roxb.) Sleum.

Plate 91. *Clematis montana* Buch.-Ham. ex DC.

Plate 92. *Hoya lanceolata* Wall. ex D.Don

Plate 93. *Crawfurdia speciosa* Clarke

Plate 94. *Cyphostemma auriculatum* (Roxb.) P. Sin. & B.V. Shet.

Plate 95. *Passiflora jugorum* W.W.Smith

Plate 96. *Hoeboelia latifolia* Wall.

Plate 97. *Pleione praecox* (Sm.) D.Don

Plate 98. *Pleione humilis* (Sm.) D.Don

Plate 99. *Dendrobium longicornu* Lindl.

Plate 100. *Oberonia pyrulifera* Lindl.

Plate 101. *Coelogyne corymbosa* Lindl.

Plate 102. *Coelogyne punctulata* Lindl.

Plate 103. *Pholidota articulata* Lindl.

Plate 104. *Otochilus lancilabius* Seidenf.

Plate 105. *Neottianthe secundiflora* (Hk.f.) Sch.

Plate 106. *Tipularia josephi* Rchb. f. ex Lindl.

Plate 107. *Diphylax urceolata* (Clarke) Hk.f

Plate 108. *Goodyera vittata* (Lindl.) Benth. & Hk.f.

Plate 109. *Galeola lindleyana* (Hk. f. &Thm.) Rch.f.

Plate 110. *Corybas himailaicus* (King & Pant.) Schl.

Plate 111. *Satyrium nepalense* D.Don.

Plate 112. *Pholidota imbricata* (Roxb.) Lindl.var *coriaceae* Hk.

Plate 113. *Calanthe metoensis* Z.H.Tsi & K.Y.Lang

Plate 114. *Agrostophyllum callosum* Reichb.

Plate 115. Rules and regulation sign board in Kigwema village Biodiversity Reserve area.

Plate 116. Rules and regulation sign board in Jotsoma Community Forest area.

Plate 117. Snowfall in winter at the peakof Mt. Japfü.

Plate 118. Snowfall in winter inside the forest of Mt. Japfü.

Plate 119. Flowering season at the peakof Mt. Japfü.

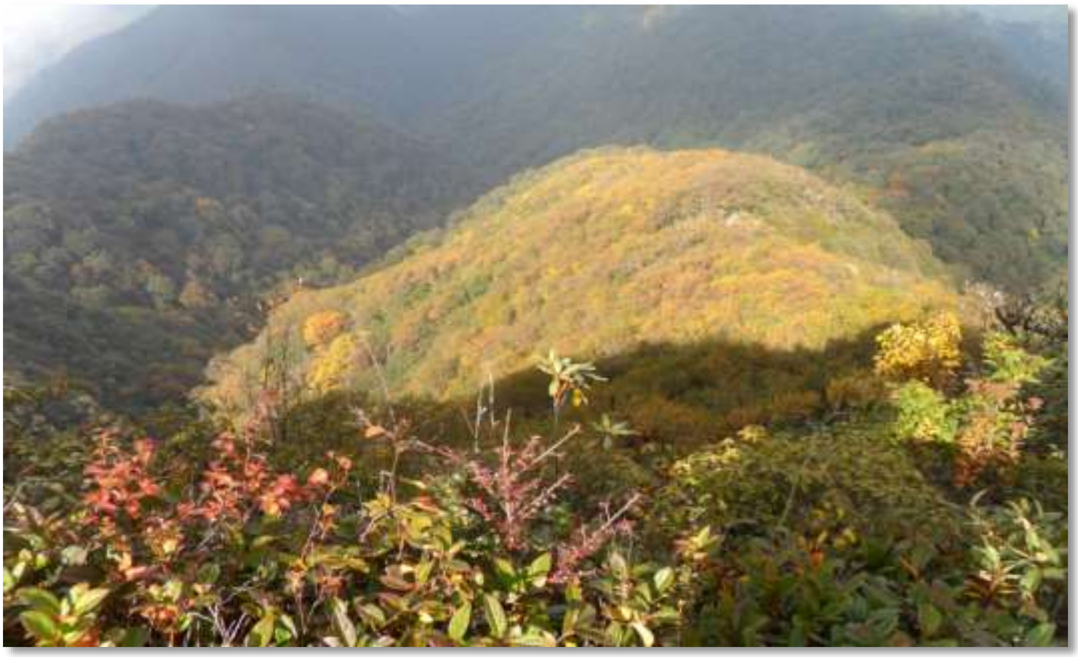

Plate 120. Autumn season in Mt. Japfü forest.

Plate 122. Temperate forest cover in the northern slope of Mt. Japfü.

Plate 123. Temperate forest cover in the southern slope of Mt. Japfü.

Plate 124. Sub alpine vegetation at the peak of Mt. Japfü.

Plate 125. Sub alpine vegetation at the southern slope of Mt. Japfü.

Plate 126. Vegetation at 2000m ASL in the northern slope.

Plate 127. Vegetation at 2600m ASL in the northern slope.

Plate 128. Vegetation at 2900m ASL in the northern slope.

Plate 129. Vegetation at 2800m ASL in the southern slope.

Plate 130. Forest fire at the peak in 2014

Plate 131. Construction of road inside the forest.

Plate 132. Logging observed at the edge of the forest in Kigwema

Plate 133. Potato farming below the forest of Mt. Japfü.

Plate 134. Mithun found in the forest.

Plate 135. Laying quadrat at the peak of Mt. Japfü.

Plate 136. Laying quadrat in the forest.

Plate 137. Measuring DBH of trees in the forest.

Plate 138. Collection of soil samples in the field.

REFERENCE

Acharya KP, Vetaas OR and Birks HJB. 2011. Orchid species richness along Himalayan elevational gradients. *J Biogeo*. 38(9): 1821-1833.

Ahmed M, Husain T, Sheikh AH, Hussain SS and Siddiqui MF. 2006. Phytosociology and structure of Himalayan forests from different climatic zones of Pakistan. *Pak J Bot.* 38(2): 361-383.

Ahmedullah M and Nayar MP. 1999. *Red Data book of Indian Plants*.Vol.4. Botanical Survey of India.

Allen SE, Grimshaw MH, Parkinson JA and Quarmby C. 1974. *Chemical Analysis of Ecological materials.* Blackwell's Scientific Publications, Oxford.

Anderson JM and Ingram JSI. 1993. *Tropical soil biology and fertility: A handbook of Methods*, 2nd ed. CAB International.

Armesto JJ, Mitchell JD and Villagran C. 1986. A comparison of spatial patterns of trees in some Tropical and Temperate forests. *Biotropica.* 18(1):1-5.

Austin MP, Pausas JG and Nicholls AO. 1996. Patterns of tree species richness in relation to environment in south- eastern New South Wales. *Aust J Ecol.* 21: 154-164.

Baishya AK and Rao RR. 1982. *Ferns and fern allies of Meghalaya State*. Scientific Publishers, Jodhpur.

Balakhrishnan NP. 1981-83. *Flora of Jowai and Vicinity Meghalaya*. Botanical Survey of India, Calcutta.

Baniya CB. 2010. Species richness patterns in space and time in the Himalayan area. PhD Thesis. University of Bergen, Norway.

Barret EC and Curtis LF. 1982. *Introduction to Environmental Remote Sensing*, 2nd edn. Chapman and Hall, London.

Batalha MA and Martins FR. 2002 Life form spectra of Brazilian cerrado sites. *Flora*. 197: 452-460.

Bawa R, Rose J, Ganeshaiah KN, Barve N, Kiran MC and Umashaanker R. 2002 . Assessing Biodiversity from Space: an Example from the Western Ghats. India. *Conserv. Ecology.* 6(2):7

Bhandari MM. 1978. *Flora of the Indian Desert*. Scientific publishers, Jodhpur.

Bhattacharya SC and Dutta S. 1956. Classifications of Citrus fruit of Assam. *ICAR Sci Monograph.* 20: 1-110

Bhattarai KR and Vetaas OR. 2003. Variation in plant species richness of different life forms along a sub tropical elevation gradient in the Himalayas, east Nepal. *Global Eco Biogeo*. 12: 327-340.

Bhatti AA, Bhat RA and Pandit AK. 2014. Phytosociological study of herbaceous plant community in Yusmarg forest: a developing Hill Resort in Kashmir valley. *Int J Env Bioen.* 9(3): 217-235.

Biswas K. 1941. The flora of Aka hills. *Indian For Rec (N.S) Bot*. 3: 1-62.

Biswas S. 1988. Studies on Bamboo distribution in Northeastern region of India. *Indian For*. 114: 514-531.

Bor NL. 1942. The relict vegetation of the Shillong Plateau, Assam. *Indian For Rec*. 3: 152-195.

Bor NL. 1960. *The grasses of Burma, Ceylon, India and Pakistan: excluding Bambuseae.* Pergamon Press, London, Vol.i-xvii.

Brandis D. 1906. *Indian Trees*. Bishen Singh Mahendra Pal Singh. Dehradun, India.

Braun EL. 1950. *The Ecology of the Forest of Eastern North America, their development, composition and distribution. Deciduous Forest of Eastern North America.* McGraw Hill, New York - Blakiston.

Braun-Blanquet J. 1932. *Plant sociology.* McGraw-hill, New York, London.

Brossard T and Joly D. 1994. Probability models, remote sensing and field observation: test for mapping some plant distributions in Kongsfiord area, Svalbard. *Polar Res*. 13: 153-161.

Brossark T and Joly D. 1994. Probability models, remote sensing and field observation: test for mapping some plant distributions in the Kongsfjord area, Svalbard. *Polar Research*. 13: 153-161.

Brunet J and von Oheimb G. 1998. Migration of vascular plants to secondary woodlands in Southern Sweden. *J Ecol*. 86: 429-38.

Bruun HH, Moen J, Virtanen K, Grytnes JA, Osaken L and Angerbjorn. 2006. Effects of high altitude and topography on species richness of vascular plants, bryophytes and lichens in alpine communities. *J Veg Scie*. 17: 37-46.

Cadisch G and Giller KE. 1997. *Driven by nature: plant litter quality and decomposition.* CABI, Wallingford.

Cain SA. 1931. Concerning certain phytosociological concepts. *Ecol Monogr.* 2: 475-508.

Cain SA. 1950. Life forms and phytoclimate. *Bot Rev.* 16: 1-32.

Carlson KM, Asner GP, Hughes RF, Ostertag R and Martin RE. 2007. Hyperspectral remote sensing of canopy biodiversity in Hawaiian lowland rainforests, NY, Print. *Ecosystems*. 10: 536-549.

Carpenter C. 2005. The environmental control of plant species density on a Himalayan elevation gradient. *J Biogeo*. 32: 999-1018.

Castillo CG, Haffter G and Moreno CE. 2008. Primary and secondary vegetation patches as contributors to floristic diversity in a tropical deciduous forest landscape. *Bio and Conserv*. 17: 1701-1714.

Chakraborty R, De B, Devanna N and Sen S. 2012. Northeast India an ethnic storehouse of unexplored medicinal plants. *J Nat Prod Plant Resour*. 2(1): 143-152.

Champion HG and Seth SK. 1968. Revised Survey of Forest types of India, Delhi.

Changkija S and Kumar Y. 1996. Ethnobotanical folk practices and beliefs of the Ao Nagas in Nagaland, India. *Ethnobotany*. 8: 26-30.

Changkija S. 1999. Folk medicinal plants of the Nagas in India. *Asian Folk Lore Stud*. 58: 205-230.

Chankija S, Ajungla L, Rongsensashi and Mozhui R. 2010. *Medicinal and Aromatic Flora of Nagaland*. Creative printers.

Chankija S. 1992. *Ethnobotanical studies of Mokokchung and Tuensang districts of Nagaland.* Ph.D. Thesis (unpublished), North Eastern Hill University, Shillong.

Chase P and Singh OP. 2013. Ethnomedicinal plants used by Angami tribe of Nagaland, India. *Indian J Trop Biodiv* 21(1&2): 29-42.

Chase P and Singh OP. 2016. Bioresources of Nagaland: A case of wild edible fruits in Khonoma village forest. In: Purkayastha J (Ed.), Bioprospecting of Indigenous Bioresources of Northeast India. Springer Science Business Media, Singapore.

Chase P. 2016. Environmental and socio economic benefits of Khonoma village forest Nagaland. Ph.D Thesis. NEHU, Shillong.

Chatterjee S. 2008. Biodiversity conservation issues of Northeast India. *Int For Rev*. 10(2): 315-324.

Chettri N, Shercham U, Chaudhary S and Shakya B. 2012. *Mountain biodiversity conservation and Management*. ICIMOD, Kathmandu, Nepal.

Chettri N, Shrestha AB, Zhaoli Y, Bajracharya B, Sharma E and Hua Q. 2012. Real world protection of the 'third pole' and its people. In: *Huettmann (Ed.), Protection of the three poles.* Springer, Japan. 113-133.

Chiarucci A and Bonini I. 2005. Quantitative floristics as a tool for the assessment of plant diversity in Tuscan forests. *For Eco Manag*. 212: 160-170.

Chiarucci A, Bacaro G and Scheiner SM. 2011. The old and new challenges in using species diversity for assessing biodiversity. *R Soc Lond B Biol Sci.*

Chiarucci A, Dominicis D and Wilson J.B. 2001. Structure and floristic diversity in permanent monitoring plots in forest ecosystems of Tuscany. *For Eco and Manag*. 141: 201-210.

Chowdhery HJ. 2009. Orchid diversity in North Eastern states of India. *J Orchid Soc India.* 23(1-2): 19-42.

Cihlar J, St Laurent L and Dyer JA. 1991. The relation between normalized differences vegetation index and ecological variables. *Remote Sensing of Environment.* 35: 279-298.

Clarke GB. 1983. *Plants of Kohima and Muneypore*. Bishen Singh Mahendra Pal Singh, Dehra Dun.

Cohen WB, Spies TA and Bradshaw GA. 1990. Semivariogram of digital imagery for analysis of conifer canopy structure. *Rem Sens of Env*. 34: 167-178.

Collet H. 1902. *Flora Simlensis: a handbook of the flowering plants of Simla and the neighbourhood.* Bishen Singh Mahendra Pal Singh. Dehradun, India.

Cooke T. 1958. *Flora of the Presidency Bombay*.Vol.3. Botanical Society of India, Calcutta.

Cooke T. 1958. *The Flora of the Presidency of Bombay*. Vol 3. Botanical Survey of India.

Coomes DA and Allen RB. 2006. Mortality and tree size distributions in natural mixed age forests. *Journal of Ecology*. 95(1) : 27-40

Coomes DA, Duncan RP, Allen RB and Truscott J. 2003. Disturbances prevent stem size-density distributions in natural forests from following scaling relationships. *Ecol. Lett*. 6: 980-989.

Coomes, D. A. and Allen, R. B. 2007. Mortality and tree-size distributions in natural
` mixed-age forests. *J Ecol*. 95: 27-40.

Csaplovics E. 1998. High Resolution space imagery for regional environmental monitoring status quo and future trends. *International Archives of Photogrammetry and Remote Sensing*. 32(7): 211-216.

Curran PJ. 1989. Remote sensing of foliar chemistry. *Remote Sens Env*. 30: 271-278.

Currie DJ. 1993. Energy and large scale patterns of animal and plant species richness. *The American Naturalist*. 137: 27-49.

Curtis JT and Mc Intosh RP. 1951. An upland forest continuum in the Prairie forest border region of Wisconsin. *Ecology*. 32: 476-496.

Curtis JT. 1959. *The vegetation of Wisconsin*: An ordination of plant communities. University of Wisconsin Press, Madison, USA.

Dabgar YB, Solanki HA, Mali MS and Khokhariya BP. *Plant Archives*. 10(2): 589-593.

Dar JA and Sundarapandian S. 2016. Patterns of plant diversity in seven temperate forest types of Western Himalaya, India. *J Asia-Paci Biodiv*. 9(3): 280-292.

Das S and Deori NC. 1983. A census of endemic orchids of North eastern India. In: Jain SK and Rao RR (eds.), An assessment of Threatened plants of India. *Botanical Survey of India, Howrah, India.* 104-109.

Dash MC. 1988. *Fundamentals of Ecology*. McGraw Hill Publishing Company, New Delhi, India.

Daubenmire RF. 1968. *Plant communities*. Harper and Row, New York. 366(1576): 2426-2437.

Deb CR and Imchen T. 2008. *Orchid Diversity of Nagaland*. Sci Chem , Udiapur.

Deb DB. 1960. Forest type studies in Manipur. *Indian For.* 86: 94-111.

Deb DB. 1975. Economic plants of Tripura state. *Indian For*. 101: 328-336.

Deb DB. 1981, 1983. *The flora of Tripura state.* Vol. 1,2. Today and Tomorrow's Printers and Publishers, New Delhi, India.

Dengler J. 2017. Phytosociology. In: Richardson D, Castree N, Goodchild ME, Kobayashi A, Liu W and Marston RA (Eds.), The International Encyclopaedia of Geography. John Wiley and Sons, Ltd.

Denslow JS. 1995. Disturbance and diversity in tropical rain forests: The density effect. *Ecol Appl*. 5: 962-968.

Deorani SC and Naithani HB. 1995. *Orchids of Nagaland*. Oriental Enterprises, Dehra Dun.

Deorani SC and Sharma GD. 2007. *Medicinal plants of Nagaland.* Bishen Singh Mahendra Pal Singh, Dehra Dun.

Devi SL and Yadava PS. 2006. Floristic diversity assessment and vegetation analysis of tropical semi evergreen forest of Manipur, north east India. *Tropical Ecology*. 47(1): 89-98.

Dey S, Jamir NS, Gogoi R, Kikon ZP and Chaturvedi SK. 2014. *Musa nagalandiana* sp. nov. (Musaceae) from Nagaland, northeast India. *Nordic J Bot*. 32(5):51-53.

Dhaliwal DS and Sharma M. 1999. *Flora of Kullu district, Himachal Pradesh*. Bishen Singh Mahendra Pal Singh, Dehradun, India.

Dolezal J, Dvorsky M, Liancourt P, Hiiesalu I, Macek M, Altman J, Rehakova K, Capkova K, Mudrak O and Wild J. 2016. Vegetation dynamics at the upper elevational limit of vascular plants in Himalaya. *Scientific Reports.* 6.

Dufour A, Gadallah F, Wagner HH, Guisan A and Buttler. 2006. Plant species richness and environmental heterogeneity in a mountain landscape: effects of variability and spatial configuration. *Ecography*. 29: 573-584.

Ennis B. 1928. The life forms of Connecticut plants and their significance in relation to climate. C*onn State Geol Nat Hist Surv Bull*. 43.

Everitt JH, Escobar DE, Villarreal R, Noriega JR and Davis MR. 1991. Airborne video systems for agricultural assessment. *Rem Sens Env*. 35: 231-242.

Foody GM. 2002. Status of Land Cover Classification Accuracy Assessment. *Remote Sensing of Envi*. 80: 185-201.

Forest Survey of India. 2015. *Indian State Forest Report*. MoEF, Govt. of India.

Fuller RM, Groom GB, Mugisha S, Ipulet P, Pomeror D, Katende A, Bailey R and Ogutu-Ohwayo. 1998. The integration of field survey and remote sensing for biodiversity assessment: a case study in the tropical forests and wetlands of Sango Bay, Uganda. *Biol Conserv*. 86: 379-391.

Gamble JS and Fischer CEC. 1915-1936. *Flora of the Presidency of Madras*, Vol.1-3. Adlard & Sons, Ltd. London.

Gazal S and Raina AK. 2013. Life form composition and biological spectrum of Ramnagar Wildlife Sanctuary, J&K, India. *Int J Scie and Res*.4(4):161-163.

George LO and Bazzaz FA. 2003. The herbaceous layer as a filter determining spatial pattern in forest tree regeneration. In Gilliam FS, Roberts MR, eds.

Gibson JP and Gibson TR. 2006. *Plant Ecology. In: The Green World* (eds) Hopkins WG. Chelsea House Publishers.

Gilbert B and Lechowicz MJ. 2004. Neurality, niches and dispersal in a temperate forest understory. PNAS. 101 (20): 7651-7656.

Gilbert GS, Howard E, Ayala-Orozco B, Bonilla-Moheno M, Cummings J, Langridge S, Parker IM, Pasari J, Schweizer D and Swope S. 2010. Beyond the tropics: forest structure in the temperate forest mapped plot. *J Veg Scie.* 21: 388-405.

Gould WA. 2000. Remote sensing of vegetation, plant species richness and regional diversity Hotspots. *Ecol Appl.* 10: 1861-1870.

Griffiths BS, Ritz K, Bardgett RD, Cook,R, Christensen S, Ekelund F, Sorensen S, Baath E, Bloem J, de Ruiter PC, Dolfing J and Nicolardot B. 2000. Ecosystem response of pasture soil communities to fumigation-induced microbial diversity reductions: an examination of the biodiversity-ecosystem function relationship. *Oikos*. 90:279–294.

Grime JP. 1979. *Plant strategies and vegetation processes*. Wiley and Sons, Chichester.

Grubb PJ and Tanner EVJ. 1976. The montane forests and soils of Jamaica: a r eassessment. *J Arnold Arboret*. 57: 313-368.

Guisan A and Thuiller W. 2005. Predicting species distribution: offering more than simple habitat models. *J Eco Lett.* 8(9): 993-1009.

Gurung PB and Tripathi RS. 2004. Orchids of Mokokchung district of Nagaland, India. In: Manilal KS and Kumar CS (Eds.), Orchid Memories- A tribute to Gunnar Seidenfaden. Mentor Books and Indian Association for Angiosperm Taxonomy. 111-116.

Hajra PK, Verma DM and Geri GS. 1996. *Materials for the flora of Arunachal Pradesh,* Vol.1. Ranunculaceae-Dipsaceae. Botanical Survey of India, Calcutta.

Hall JB and Swaine MD. 1981. *Distribution and ecology of vascular plants in a Tropical rainforest. Forest vegetation in Ghana*. Junk W, The Hague.

Handique R. 2004. *British forest policy in Assam.* Concept Publishing Company, New Delhi, India.

Hanway JJ and Heidel H. 1952. Soil analysis methods as used in Iowa state college soil testing laboratory. *Iowa Agriculture*. 57: 1-31.

Haridasan K and Rao RR. 1986. *Forest flora of Meghalaya.* Vol.1-2. Bishen Singh Mahendra Pal Singh, Dehradun, India.

Hasmadi M, Zaki MH, Adnan IAM, Pakhriazad HZ and Fadlli MAY. 2010. Determining and Mapping of Vegetation using GIS and Phytosociological approach in Mount Tahan, Malaysia. *J Agri Scie.* 2(2): 80-87.

Hattenschwiler S, Tiunov A and Scheu S. 2005. Biodiversity and litter decomposition in terrestrial ecosystems. *Ann Rev Eco Evo Syst*. 36:191-218.

Heany A and Proctor J. Chemical elements in litter in forests on Volcan Barva, Costa Rica. In: Proctor J (Ed.) *Mineral nutrients in Tropical forest and savannah ecosystems*. Blackwell Scientific Publications, UK.

Hector A, Schmid B, Beierkuhnlein C, Caldeira MC, Diemer M, Dimitrapoulos PG, Finn JA, Freitas H, Giller PS, Good J, Harris R, Hogberg P, Huss-Danell K, Joshi J, Jumpponen A, Korner C, Leadley PW, Loreau M, Minns A, Mulder CP, O'Donovan G, Otway SJ, Pereira JS, Prinz A and Read DJ. 1999. Plant diversity and productivity experiments in european grasslands. *Science*. 286(5442): 1123-7.

Hedge SN. 2000. Conservation of Northeast flora. *Arunachal For News*. 18:1-2.

Hironaka M, Fosberg MA and Neiman KE. 1990. The relationship between soils and vegetation. In Proceedings of Management and productivity of western-montane forest soils. https://forest.moscowfsl.wsu.edu/smp/solo/documents/GTRs/INT_280/Hironaka_INT-280.php

Holdridge L, Grenke W, Hatheway W, Liang T and Tosi J. 1971. *Forest Environment in Tropical Life Zones: A pilot study.* Oxford Pergamon Press, Oxford, UK.

Hooker JD. 1872-1897. *The Flora of British India.* Vol.7, London.

Horsley SB. 1993. Mechanisms of interference between hay scented fern and black cherry. *Canadian J of Forest Res.* 23: 2059-2069.

Humbolt A. 1805. Memoire sur une nouvelle espece de pimelode, jetee par les volcans du Royaume de Quito. In : Voyage de Humboldt et Bonpland, Deuxieme partie. Observations de Zoologie et d' Anatomie comparee. Paris. Humboldt and Bonpland's Voyage v.1 (Title page 1811): 21-25, Pl.7. (See Sherborn 1899, *Ann Mag Nat Hist* . 3(7): 428.

Huston MA. 1994. Biological diversity: the co-existence of species on changing landscape. Cambridge University Press, Cambridge.

Hynniewta TM, Kataki SK and Wadhwa BM. 2000. *Orchids of Nagaland*. BSI.

Hynniewta TM. 1999. Nagaland. In: Mudgal V and Hajra PK. (edits.) *Floristic diversity and conservation strategies in India*, BSI, Dehra Dun.

Imchen K and Jamir NS. 2011. Ethnomedicinal plants used by the Phom-Naga tribe in Longleng district of Nagaland, India. *Pleione* 5(1): 77-82.

Jain SK and Rao RR. 1977. *A Handbook of Field and Herbarium methods*. Today and Tommorow, New Delhi.

Jain SK. 1986. The grass flora of India- a synoptic account of uses and Phytogeography. *Bull Bot Surv India*. 28: 229-240.

Jamir AN, Jamir NS and Deb CR. Three new distributional records of orchid from Intanki National Park, Nagaland, India. *Int J Res Stud Bioscie*. 3(6): 7-9.

Jamir HK, Tsurho K and Zhimomi A. 2015. Some indigenous medicinal plants and its uses in Zunheboto district, Nagaland. *Int J Dev Res* 5(8): 5195-5200

Jamir N. 2011. Characterization of Plant Biodiversity and Phytosociological analysis of some community forests of Nagaland. Ph.D. Thesis, Nagaland University, Lumami, Nagaland, India.

Jamir NS and Rao RR. 1985. A contribution towards a pteridophytic flora of Nagaland. *J Econ Taxon Bot*. 7(2): 277-297.

Jamir NS and Rao RR. 1988. *The Ferns of Nagaland*. Bishen Singh Mahendra Pal Singh, Dehra Dun .

Jamir NS and Rao RR. 1990. Fifty new or interesting medicinal plants used by the Zeliang of Nagaland , India. *J Soc Ethnobot* 2: 11-18

Jamir NS, Jungdan and Deb MS. 2008. Traditional knowledge of medicinal plants used by the Yimchunger Naga tribes in Nagaland. *Plieone* 2(2):223-228

Jamir NS, Lanusunep and Pongener N. 2012. Medico-herbal medicine practiced by the Naga tribes in the state of Nagaland, India. *Ind J Fund Appl Life Scie* 2(2): 328-333

Jamir NS, Takatemjen and Limasemba. 2010. Traditional knowledge of Lotha-Naga tribes in Wokha district, Nagaland. *Indian J Trad Know* 9(1): 45-48.

Jamir NS. 1997. Ethnobotany of Naga tribe in Nagaland -1. *Med Herb J Soc Ethnobot.* 9(1) : 101-104.

Jamir NS. 2006. Indigenous knowledge of medicinal plants in the state of Nagaland. *In proceeding on Horticulture for sustainable income and protection*. 2:677-683.

Jamir SA, Upadhaya K and Pandey HN. 2006. Life form composition and stratification of montane humid forests in Meghalaya, northeast India. *Trop Eco*. 47(2):183-190.

Jamir SA, Upadhaya K and Pandey. 2006. Life form composition and stratification of montane humid forests in Meghalaya, Northeast India. *Trop Eco*. 47: 183-190.

Jayakumar S, Kim SS and Heo J. 2011. Floristic inventory and diversity assessment – a critical review. *Proc of the Intl Acad of Eco and Env Sci.* 1(3-4): 151-168.

Jenny H. 1980. *The soil resource. Ecological Studies* No. 37, Springer- Verlag, New York.

Joshi NK and Tiwari SC. 1990. Phytosociological analysis of woody vegetation along an altitudinal gradient in Garhwal Himalaya. *Indian J of For*. 13: 322-328.

Joshi P, Pande HC and Pande PC. 2004. Uttarachal mein paaye jaane wale adhipadaptya fern. *Vigyanvan*. 10(1): 28-32.

Joshi, Pragya, Pande HC and Pande PC. 2004. Fern flora of Mandal and adjoining localities in Chamoli district of Garwhal Himalayas. *Indian J For*. 27(4): 397-403.

Jost L. 2006. Entropy and diversity. *Oikos*. 113(2): 363-375.

Kanjilal UN, Kanjilal A, Das RN and Bor NL. 1934-40. *Flora of Assam*. I-V. Government Press, Shillong.

Karthikeyar S and Kumar A. 1993. *Flora of Yavatmal District Maharastra*. Botanical Survey of India, Calcutta.

Kataki SK, Jain SK and Sastry ARK. 1984. Distribution of orchids in Sikkim and North- Eastern India. *Plant Conserv Bull.* 5:1-38.

Kerr J and Ostrovsky M. 2003. From space to species: ecological applications for remote sensing. *Trends Eco Evol*. 18: 299-305.

Kershaw KA. 1973. *Quantitative and dynamic plant ecology*. Edward Arnold-Science.

Kharkwal G and Rawat YS. 2010. Structure and composition of vegetation in sub tropical forest of Kumaun Himalaya. *Afr J Plt Scie*. 4(4): 116-121.

Kharkwal G, Mehrotra P, Rawat YS and Pangtey YPS. 2005. Phytodiversity and growth form in relation to altitudinal gradient in the central Himalayan (Kumaun) region of India. *Curr Scie*.89(): 873-878.

Kidwai Z. 2013. Vegetation structure and composition in Core area of Sariska National Park , Rajasthan. *Ind For*. 139(7): 636-644.

Kimmins JP. 1997. *Forest Ecology. A foundation for sustainable management*. 2nd Edit. Prentice Hall, NJ, USA.

Knight RS, Crowe TM and Siegfried WR. 1982. Distribution and species richness of trees in southern Africa. *J S Afr Bot*. 48: 455-480.

Kriegler FJ, Malila WA, Nalepka RF and Richardson W. 1969.Preprocessing transformations and their effect on multispectral recognition. Published in the *Proceedings of the sixth International symposium on Remote sensing of Environment,* held at the University of Michigan, Ann Arbor, MI. 97-131.

Kristensen HL, Gundersen P, Callesen I, and Reinds GJ. 2004. Throughfall nitrogen deposition has different impacts on soil solution nitrate concentration in European coniferous and deciduous forests. *Ecosystems*. 7(180): 180-192.

Kromer T, Kessler M, Gradstein SR and Acebey Amparo. 2005. Diversity patterns of vascular epiphytes along an elevational gradient in the Andes. *J Biogeo*. 32: 1799-1809.

Kumar A, Marcot BG and Saxena A. 2006. Tree species diversity and distribution patterns in tropical forests of Garo Hills. *Current science*. 91(10): 1370-1381.

Langley JA and Hungate BA. 2003. Mycorrhizal controls on below ground litter quality. *Ecology*. 84(9): 2302-2312.

Lanusunep and Jamir NS. 2010. Folk medicinal herbs used by the Sumi-Naga tribes of Zunheboto district, Nagaland. *Plieone* 4(2) : 215-220.

Leathwick JR, Burns BR and Clarkson BD. 1998. Environmental correlates of tree alpha diversity in New Zealand primary forests. *Ecography*. 21:235-246.

Levin N, Shmida A, Levanoni O, Tamari H and Kark S. 2007. Predicting mountain plant richness and rarity from space using satellite derived vegetation indices. *Div Distri.* 13: 692-703.

Li H and Wu J. 2004. Use and misuse of landscape indices. *Landscape Eco*. 19(4): 389-399.

Li XR, He MZ, Jia RL. 2008. The response of desert plant species diversity to the changes in soil water content in the middle lower reaches of the Heihe River. *Advances in Earth Science*. 23(7): 685-691.

Liu Y, Wang C, He N, Wen X, Gao Y, Li S, and Yu G. 2017. A global synthesis of the rate and temperature sensitivity of soil nitrogen mineralization: latitudinal patterns and mechanisms. *Global change biology*. 23(1): 455-464.

Llorkar VM and Khatin PK. 2003. Phytosociological study of Navegon National Park. *Ind For.* 129:377-387.

Lobo JM, Castro I and Moreno JC. 2001. Spatial and environ- mental determinant of vascular plant species richness distribution in the Iberian Peninsula and Balearic Islands. *Biol J Linn Soc.* 73:233-253.

Longman KA and Jenik J. 1987. *Tropical forests and its environment*. Singapur: Longman Publishers.

Lyon J and Sharpe WE. 2003. Impacts of hay-scented fern on nutrition of northern red oak seedlings. *J of Plant Nutri*. 26: 487–502.

Ma Y, Dam RLV and Jayawickreme D. 2014. Soil moisture variability in a temperate deciduous forest: insights from electrical resistivity and throughfall data. *Env Earth Scie*. 72(5): 1367-1381.

Magurran AE. 2004. *Measuring Biological Diversity*. Blackwell Science Ltd.

Majumdar RB. 1979. Flora of Rajasthan, East of the Aravall. *Bull Bot Surv India*. 19(1-4): 23-24.

Majumdar RS. 1979. Synoptic flora of the Kota division (SE Rajasthan). Part II. *Bull Bot Surv India*. 18: 49-79.

Mao AA and Gogoi R. 2010. Floristic study of Dzükou valley and surrounding hills, Manipur and Nagaland, India. *Indian For*. 136(1): 57-68.

Mao AA and Gogoi R. 2012. Rhododendrons of Manipur and Nagaland, India. *NeBio*. 3(1):1-10.

Mao AA, Odyuo N and Verma D. 2016. *Checklist of Flora of Nagaland* Vol.I. BSI, Kolkata. bsi.gov.in

Mao AA, Yumnam JY, Gogoi R and Pinokiyo A. 2009. Status and distribution pattern of Rhododendron species in Temperate and Sub Alpine hill ranges of mount Esii and surrounding in Manipur and Nagaland, India. *Indian For*. 880-890.

Martin ME and Aber JD. 1997. Estimation of canopy lignin and nitrogen concentration and ecosystem processes by high spectral resolution remote sensing. *Ecol Appl.* 7: 431-443.

Master JW. 1848. Extract from a memoir of some of the natural productions of the Angami Naga Hills and other parts of upper Assam. *J Asiat Soc Bengal*. 17(1): 57-59.

Master JW. 1844. Observations on the flora of Naga hills. *J Asiat Soc Bengal*. 13(2): 707-734.

McGraw JB, Warner TA, Key TL and Lamar WL. 1998. High spatial resolution remote sensing of forest trees. *Trends in Eco and Env*. 13: 300-301.

Medhi P, Kar A and Borthakur SK. 2013. Medicinal uses of wild edible plants among the Ao-Nagas of Mokokchung and its vicinity of Nagaland, India. *Asian Reson.* 2(4):64-67

Megoneitso, Rao RR. 1983. Ethnobotanical studies in Nagaland- sixty two medicinal plants used by Angami Nagas. *J Eco Tax Bot* 4:167-172.

Ministry of Environment and Forests, Government of India. 2014. India's fifth National report to the Convention on Biological Biodiversity.

Mishra BP, Tripathi RC and Laloo. 2005. Community Characteristics of a climate Sub tropical humid forest of Meghalaya and Population structure of ten important species. *Tropical Eco*. 46: 241-251.

Misra R. 1968. *Ecology Work Book*. Oxford and IBH Publishing Company, New Delhi.

Misra S. 1990. An enumeration of the orchids of Similipal hills in Orissa, India. *Pl Sci Res.* 11(2): 73-84.

Misra S. 1990. Orchid flora of Orissa. *J Orch Soc India*. 3: 61-72.

Moaakum and Chaturvedi SK. 2015. A checklist of angiospermic flora of Zunheboto district of Nagaland, India. *Pleione*. 9(1): 82-94.

Moaakum. 2015. Flora of Zunheboto district, Nagaland. PhD Thesis, Nagaland University, Lumami, Nagaland, India.

Monk CD. 1967. Tree species diversity in Eastern deciduous forest with particular reference to North Central Florida. *American Naturalist.* 101: 173-187.

Morris EK, Caruso T, Buscot F, Fischer M, Hancock C, Maier TS, Meiners T, Muller C, Obermaier E, Prati D, Socher SA, Sonnemann I, Waschke N, Wubet T, Wurst S and Rillig MC. 2014. *Eco Evol.* 4(18): 3514-3524.

Mozhui R. 2016. Studies on floristic diversity of Dimapur district, Nagaland. Ph.D. Thesis. Nagaland University, Lumami.

Mueller- Dombois D and Ellenberg H. 1974. *Aims and methods of vegetation ecology.* John Wiley and Sons, New York.

Mukherjee A and Sarma K. 2014. Community structure of plant species in Okhla Bird Sanctuary, Delhi, India. *Int J Conser Scie.* 5(3): 397-408.

Muller RN and Bormann FH. 1976. Role of *Erythronium americanum* Ker. in energy flow and nutrient dynamics of a northern hardwood forest ecosystem. *Science*. 193: 1126–1128.

Murti SK. 2001. *Flora of Cold deserts of Western Himalaya*. Vol. I. Monocotyledons. Botanical Survey of India, Calcutta, India. 8: 452.

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB and Kent J. 2000. Biodiversity hotspot for Conservation priorities. *Nature*. 403: 853-858.

Nad Karni NM, Matelson TJ and Haber WA. 1995. Structural characteristic and floristic composition of Neotropical cloud forest, Monteverde, Costa Rica. *J of Trop Ecology*. 11: 481-497.

Nagendra H and Gadgil M. 1999. Biodiversity assessment at multiple scales: Linking remotely sensed data with field information. *Proc Natl Acad Sci USA*. 96: 9154-9158.

Nagendra H and Rocchini D. 2008. High resolution satellite imagery for tropical biodiversity studies: the devil is in the detail. *Biodiver Conserv.* 17: 3431-3442.

Nagendra H. 2001. Using remote sensing to assess biodiversity. *Intl J Rem Sens*. 22(12): 2377-2400.

Naithani HB. 2011. *Bamboos of Nagaland*. NEPED, NBDA.

Nakashizuka T. 2001. Species coexistence in temperate, mixed deciduous forests. *Trends in Ecology and Evolution*. 16: 205-210.

Nayar MP. 1996. 'Hot spots' of endemic plants of India, Nepal and Bhutan. Tropical Botanical Garden and Research Institute, Palode, Trivandrum.

Nayar PH and Sastry ARK. 1990. *Red data sheet. In: Red Data Book of Indian Plants Vol. 3*. The Director Botanical Survey of India, Calcutta, India.

Neufeld HS, Young DR. 2003. Ecophysiology of the herbaceous layer in temperate deciduous forests. In Gilliam FS, Roberts MR, eds. *The Herbaceous Layer in Forests of Eastern North America*. New York: Oxford University Press. 38–90.

Noss RS. 1996. Conservation of Biodiversity at landscape level. In: Szaro RC and Johnston DW (Eds.), Biodiversity at Managed landscape: Theory and Practice. Oxford, New York, USA. 574-589.

Odum EP. 1971. *Fundamentals of Ecology*. WB Saunders Company, Philadelphia, PA.

Odyuo N, Roy DKR and Averyanov LV. 2017. *Gleadovia konyakianorum* (Orobanchaceae), a new species from Nagaland, India. *Phytotaxa*. 326(4): 274-278.

Ojeda F, Maranon T and Arroyo J. 2000. Plant diversity patterns in the Ajibe mountains (S.Spain): a comprehensive account. *Biodiv Conserv*. 9(9): 1323-1343.

Pala NA, Negi AK, Gokhale Y, Shah S and Kumar M. 2016. Community structure and plant diversity of community based religious conserved forests of Garhwal Himalaya, India. *J Earth Sci Clim Change*. 7(2): 1-12.

Panda S. 2012. Checklist of Ericaceae in Tuensang district of Nagaland, India with special reference to Mt. Saramati. *J Threatn Taxa*. 4(15): 3454-3461.

Pande PK, Negi JDS and Sharma SC. 1996. Plant species diversity and vegetation analysis in moist temperate Himalayan forests. Abstracted in First Indian Ecological Congress, New Delhi. 27-31.

Pant S and Samant SS. 2007. Assessment of plant diversity and prioritization of communities for conservation in Mornaula Reserve Forest. *Appl Eco Env Res*. 5(2): 123-138.

Paramathma M, Ezumalai R, Luanglath K and Parthiban KT. 2002. Floral diversity of Eastern Ghats of Western Tamil Nadu- a case study. In: *Proceedings of National Seminar on Conservation of Eastern Ghats.* 27-33.

Parviainen M, Luoto M and Heikkinen RK. 2010. NDVI- based productivity and heterogeneity as indicators of plant species richness in boreal landscapes. *Bor Env Res*. 15: 301-318.

Pausas JG and Austin MP. 2001. Patterns of plant species richness in relation to different environments: An appraisal. *J Veg Scie.* 12(2): 153-166.

Pearce N and Cribb PJ. 2002. *The Orchids of Bhutan.* Edinburgh: Royal Botanic Gardens, Edinburgh and Royal Government of Bhutan.

Perakis SS and Sinkhorn E. 2011. Biogeography of a temperate forest nitrogen gradient. *Ecology*. 92(7): 1481-1491.

Petorelli N, Vik JO, Mysterud A, Gaillard JM, Tucker CJ and Stenseth NC. 2005. Using A Satellite derived NDVI to assess ecological responses to environmental change. *Trends in Ecology & Evolution*. 20: 503-510.

Pfoze NL, Kehie M, Kayang H and Mao AA. 2014. Estimation of ethnobotanica plants of the Naga of North East India. J Med Plt Stud 2(3) 92-104.

Phillips EA.1959. *Methods of Vegetation Study*. Henry Halt and Co. New York Inc.

Pielou EC. 1966. The measurements of diversity in different types of biological collections. *J Theoret. Biol.*13:131-144.

Prescott CE, Chappell HN and Vesterdal L. 2000. Nitrogen turnover in forest floors of coastal Douglas-fir at sites differing in soil nitrogen capital. *Ecology.* 81:1878-1886.

Preston FW. 1948. The commonness and rarity of species. *Ecology.* 29: 254-283.

Qian Y, Zhang H, Wu Z and Wang Z. Vegetation composition and distribution on the northern slope of Karlik Mountain to Naomaohu basin. 2011. *J Arid Land*. 3 (1): 15-24.

Rahlan PK, Saxena AK and Singh JS. 1982. Analysis of forest vegetation at and around Nainital in Kumaon Himalaya. *The Proceeding Indian National Science Academy.* 348: 121-137.

Rahman MH, Bahauddin M, Khan MASA, Islam MJ and Uddin MB. 2012. Assessment of soil physical properties under plantation and deforested sites in a biodiversity conservation area of north eastern Bangladesh. *Int J Env Scie*. 3(3): 1079-1089.

Raina AK and Kumar R. 2011. Floristic composition, life form classification and biological spectrum of the catchment of Ratle H.E. project, distric Kishtwar-Jammu and Kashmir, India. Env Conserv J. 12(3):1-6.

Ramaswamy SV and Razi BA. 1973. *Flora of Bangalore District*. Prasaranga. University of Mysore, Mysore.

Rao DS, Murthy PP and Kumar OA. 2015. Plant biodiversity and phytosociological studies on tree species diversity of Khamman district , Telangana state, India. *J Pharm Sci Res.* 7(8): 518-522.

Rao RR and Haridasan K. 1991. An ethnobotanical survey of medicinal and other useful plants of Northeast India. *J Econ Taxon Bot*. 15(2): 423-435.

Rao RR and Jamir NS. 1982. Ethnobotanical studies in Nagaland-1. *Medicinal plants. Econ Bot* 36: 176-181.

Rao RR. 1981. Ethnobotany of Meghalaya- Medicinal plants used by Khasi and Garo tribes. Econ Bot. 35:4-9.

Rao RR. 1994. *Biodiversity in India.* Bishen Singh Mahendra Pal Singh, Dehradun, India.

Rao RR. 2006. *Biodiversity in India: Floristic Aspect.* Bishen Singh Mahendra Pal Singh, Dehra Dun.

Rashid A, Swati MF, Sher H and Al-Yemni MN. 2011. Phytoecological evaluation with detail floristic appraisal of the vegetation around Malam Jabba, Swat, Pakistan. *Asian Pacific J Trop Biomed*. 1: 461–467.

Raunkiaer C. 1934. *The life forms of plants and statistical plant geography*. Clarendon Press, Oxford.

Rawal RS, Bankoti NS, Samant SS and Pangtey YP. 1991 Phenology of tree layer species from the Timberland around Kumaun in Central Himalaya, India. *Vegetation*. 93: 109-118.

Reddy CS, Jha CS, Diwakar PG and Dadhwal VK. 2015. Nationwide classification of forest types of India using remote sensing and GIS. *Env Mon Assess*. 187:777

Richerson PJ and Lum KL. 1980. Patterns of species diversity in California: relations to weather and topography. *Am Nat*. 116: 504-536.

Riofrio-Dillon G, Gegout JC and Betrand R. 2017. Eutrophication impacted temperate forest vegetation recently.

Risser P and Rice EL. 1971. Diversity in tree species in Oklahoma upland forest. *Ecology*. 52: 876-880.

Rocchini D. 2007. Effects of spatial and spectral resolution in estimating ecosystem α- diversity by satellite imagery. *Rem Sens Envi.* 111: 423-434.

Rongsensashi, Mozhui R, Changkija S and Limasenla. 2013b. Medicinal plants diversity of Fakim Wildlife Sanctuary, Nagaland, India. *Pleione* 7(1) :110-126

Rongsensashi, Mozhui R, Limasenla, Changkija S and Ajungla L. 2016. Ethnobotanical studies on Yimchunger-Naga tribe living in and around Fakim Wildlife Sanctuary in Nagaland, India. *Pleione* 10(1): 53-65.

Rongsensashi. 2015. Studies on the floristic diversity of Fakim Wildlife Sanctuary, Nagaland. Ph.D. Thesis. Nagaland University, Lumami.

Rouse JW, Haas RH, Schell JA and Deering DW. 1973 . Monitoring vegetation systems in the Great Plains with ERTS. *Third ERTS Symposium*, NASA SP-351 1, 309-317.

Roy PS and Behera MD. 2002. Biodiversity assessment at landscape level. *Trop Eco.* 43: 151-171.

Roy PS, Saran S, Ghosh S, Prasad N, Karnatak H and Talukdar G. 2002. *Development of Biodiversity Information System for Northeast India using internet GIS*. IIRS, Dehra Dun, India.

Sahu SC, Dhal NK, Reddy CS, Pattanaik C and Brahmam M. 2007. Phytosociological study of tropical dry deciduous forest of Boudh District, Orissa, India. *Res J For*. 1(2):66–72.

Sakai A. 1975. Freezing resistance of conifers in Japan with special reference to their distribution. *Jap J Eco*. 25: 101-111.

Salam S, Kumar PK and Jamir NS. 2010. Wild edible plants used by the Tangkhul Naga tribe of Ukhrul district of Manipur, India. *Pleione* 4(2) : 284-287.

Sangtam TL, Jamir NS and Deb CR. 2012. A study on the medicinal plants used by the Sangtam Naga tribe in Kiphire district, Nagaland, India. *Int J Ayur Herb Med* 2(2): 267-275.

Saurav M and Das AP. 2014. Plant species richness and phytosociological attributes of the vegetation in the cold temperate zone of Darjiling Himalaya, India. *Int Res J Env Scie.* 3(10): 47-57.

Scheiner SM and Benayas JM. 1994. Global patterns of plant diversity. *Evol Ecol*. 8: 331-347.

Shankar R and Devalla RB. 2012. Conservation of folk healing practices and commercial medicinal plants with special reference to Nagaland. *Int J Biodiv Conserv* 4(3): 155-163

Shannon, CE and Wiener W. 1963. *The Mathematical Theory of Communication*. University of Illinois Press, Urbana.

Sharma CM, Ghildiyal SK and Gairola S. 2009. Vegetation structure, composition and diversity in relation to the soil characteristics of temperate mixed broad leaved forest along an altitudinal gradient in Garhwal Himalaya. *Ind J Scie Techno*. 2: 39-45.

Sharma E, Chettri N and Oli KP. 2010. Mountain biodiversity conservation and Management: Paradigm shift in policies and practices in the Hindu Kush-Himalayas. *Int J of Ecol Res.* 25: 909-923.

Sharma PD. 2012. *Ecology and Environment*. 11th Edit, Rastogi publications, Meerut.

Sheikh MA, Sharma S and Tiwari A. 2017. Phytosociological characters and biodiversity of sacred grove a preliminary study. *Int Res J Env Scie.* 6(1): 67-69.

Shimwell DW. 1971. *The description and classification of vegetation*. Sedgwick and Jackson, London.

Simpson EH.1949. Measurement of diversity. *Nature.* 163:688.

Singh AB and Teron R. 2015. Diversity of wild edible plants used by the Angami-Nagas in Kohima district of Nagaland, India. *Pleione* 9(2) : 311-324

Singh KHR, De A and Reddy CS. 2013. Spatial patterns of forest fragmentation in Manipur , Northeast India: A case study using RS and GIS technique. *Int J Earth Sci and Eng*. 6(6): 1713-1717.

Singh KHR. 2014. Spatial patterns of forest fragmentation in Manipur, Northeast India: A case study using RS and GIS technique. PhD Thesis.

Smith WW and Cave GH. 1911. The vegetation of Zemu and Llonakh Valleys of Sikkim. *Rec Bot Surv India*. 4: 141-260.

Sobuj NA and Rahman M. 2011. Assessment of plant diversity in Khadimnagar National Park of Bangladesh. *Int J Env Scie.* 2(1):79-91.

Somsundaram S and Vijayan L. 2010. Plant diversity and phenology in the montane wet temperate forests of the southern Western Ghats, India. *For. Stud. China.* 12(3): 116-125.

Subbiah BV and Asija GL. 1956. A rapid procedure for the determination of available nitrogen in soil. *Curr Scie*. 25: 259-260.

Sumitra S, Jamir NS, Singh PK. 2009. Traditional uses of medicinal plants used by the Tankhul-Naga tribe in Manipur, India. *Pleione* 3(2): 157-162

Swift MJ, Heal OW and Anderson JM. 1979. *Decomposition in terrestrial ecosystems.* Blackwell Scientific Publications, London, UK.

Tablot WA. 1894. *Forest flora of the Bombay Presidency and Sind*. Bishen Singh Mahendra Pal Singh. Dehradun, India.

Tambe S and Rawat GS. 2010. The alpine vegetation of the Khangchendzonga landscape, Sikkim Himalaya: Community characteristics, diversity and aspects of Ecology. Mount Res Dev. 30(3): 266-274.

Tamm CO. 1991. Nitrogen in terrestrial ecosystems, Vol.81 of *Ecological Studies*. Springer-Verlag, Berlin, Germany.

The Herbaceous Layer in Forests of Eastern North America. New York: Oxford University Press. 265–282.

Tilman D and Pacala S. 1993. The maintenance of species richness in plant communities. In: Ricklefs RE and Schluter D (Eds.), Species diversity in ecological communities: historical and geographical perspectives. University of Chicago Press, Chicago, Illinois, USA. 13-25.

Tilman D, Knops J, Wedin D, Reich P, Ritchie M and Siemann E. 1997. The influence of functional diversity and composition on ecosystem processes. *Science*. 277: 1300-1302.

Tilman D. 1982. Resource competition and community structure. Princeton University Press, NJ.

Tripathi SP. 2005. Status of joint forest management in Nagaland. *The Indian For*. 131(9): 1158-1170.

Tucker CJ. 1979. Red and Photographic infrared linear combinations for Monitoring Vegetation. *Remote Sensing of Environ*. 8: 127-150.

Upadhaya K, Pandey HN, Law PS and Tripathi RS. 2003. Tree diversity in sacred groves of Jaintia hills in Meghalaya, northeast India. *Bio and Cons*. 12:583-597.

Verma AK, Garg PK, Prasad KSH and Dadhwal VK. 2016. Classification of LISS IV imagery using Decision Tree methods. *Int Arch Photo Rem Sen Spat Info Scie*. 23: 1061-1066.

Vesterdal L and Raulund-Rasmussen K. 1998. Forest floor chemistry under seven tree species along a soil fertility gradient. *Can. J. For. Res*. 28, 1636–1647.

Vetaas OR. 1997. The effect of canopy disturbance on species richness in central Himalayan oak forests. *Plant Ecology*. 132: 29-38.

Vijayarahavan R and Sundaramoorthy S. 2004. Hyperspectral analysis of some trees and shrubs species in semi arid region. In: *ISRS National Symposium*, Jaipur, India. 142-143.

Vijayarahavan R and Sundaramoorthy S. 2012. Mapping *Prosopis juliflora* using satellite data in a part of Indian Thar desert. *Int J of Eco and Env Sci*. 38(1): 9-18.

Vitousek PM and Howarth RW. 1991. Nitrogen limitation on land and in the sea: How can it occur? *Biogeo- chemistry*. 13:87-115.

Wagner HO, Wildi O and Ewald KC. 2000. Addictive partitioning of plant species diversity in an agricultural mosaic landscape. *Landscape Eco.* 15: 219-227.

Walkely A and Black IA. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Scie.* 37: 29-38.

Walker RE, Stoms DM, Estes JE and Cayocca KD. 1992. Improved modelling of biological diversity with multi temporal vegetation index data. Technical paper of the 1992 annual meetings of ASPRS / ACSM. 3-7.

Wang R, Gamon JA, Montgomery RA, Townsend PA, Zygielbaum AI, Bitan K, Tilman D and Cavender-Bares J. 2016. Seasonal variation in the NDVI-species richness relationship in a Prairie grassland experiment (Cedar Creek). *Rem Sens*. 8(128): 1-15.

Wang S, Fu BJ, Gao GY, Yao XL and Zhou J. 2012. Soil moisture and evapotranspiration of different land cover types in Loess Plateau, China. *Hydro Earth Syst Scie.* 16: 2883-2892.

Ward-Kingdon F. 1949. Plant Hunting in Manipur. *J Roy Hort Soc*. 74: 288-295.

Wardle J. 1984. *The New Zealand beeches. Ecology, utilisation and management*. New Zealand Forest Service, Wellington.

Warming E. 1909. *Oecology of Plants*. Oxford.

Watt G. 1890. Forests of Manipur. *Ind For.* 14:291-339 & 387.

Webster PJ, Holland GJ, Curry JA and Chang HR. 2005. Changes in tropical cyclone number, duration, and intensity in a warming environment. *Science.* 309: 1844-1846.

Whitford PB. 1949. Distribution of woodland plants in relation to succession and clonal growth. *Ecology*. 30:199-288.

Whittaker RH. 1956. Vegetation of the Great Smoky Mountains. *Ecol. Monogr*. 26:1-80.

Whittaker RH. 1972. Evolution and measurement of species diversity. *Taxon,* 21:213-251.

Whittaker RH. 1975. *Communities and Ecosystem*. 2nd ed. MacMillan Publishing Co., New York.

Wilson EO. 1992. *The diversity of life.* Cambridge, MA: Belknap.

Wright SJ. 1992. Seasonal drought, soil fertility and species density of tropical forest plant communities, *Trends Ecol Evol.* 7: 260-263. www.http://dx.doi.org/10.1101/103721

Xie Y, Sha Z and Yu M. 2008. Remote Sensing Imagery in Vegetation Mapping : a Review. *J Plant Ecology*. 1 (1): 9-23.

Yacouba D, Guangdao H and Xingping W. 2010. Assessment of land use cover changes using NDVI and DEM in Puer and Simao Counties, Yunnan Province, China. Report and Opinion. 2(9).

Yoshioka K. 1963. The northern limits of the natural forest of Shiia sieboldii. *Scie Rep Tohoku Univ Ser.* 4(29): 327-336.

Zeven AC and Zhukovsky PM. 1975. Dictionary of cultivated plants and their centres of diversity. Pudoc, Wageningen, the Netherlands. 9-26.

PAPERS PUBLISHED

Sachu K and Puro N. 2017. *Tipularia josephi* Rchb. f. ex Lindl. (Orchidaceae): A new generic record for Nagaland. *Plieone*. 11(2): 529- 531.

Sachu K and Puro N. 2018. Plant diversity assessment of Mt. Japfü , Nagaland. *Annals of Plant Sciences*. 7 (3) : 2110-2113.

PAPERS UNDER COMMUNICATION

Sachu K and Puro N. 2018. A Checklist of plants found in Mt. Japfü , Nagaland.

Accepted for the proceedings of National Seminar on 'Globalization, Development and Environment with special reference to Northeast region' (March 19-20, 2015) organized by Nagaland University Teachers Association (L), Nagaland University.

SEMINAR, CONFERENCE AND WORKSHOP ATTENDED

Poster presented at the National Seminar on Recent Trends in Bioresource Management and Biodiversity Conservation (17-19 October, 2013) organized by Center with Potential for Excellence in Biodiversity (CPEB-II), Rajiv Gandhi University, Itanagar, Arunachal Pradesh and Sponsored by UGC & DBT, New Delhi.

Attended a National Seminar organized by Young Ecologist Talk and Interact (YETI) on 16th-19th December 2013, Nagaland University.

Participated in National Workshop on 'Scientific Writing, Research Communication & IPR Issues' (28th-29th August 2014) organized by Institutional Biotech Hub & Department of Botany, Nagaland University, Lumami, Nagaland.

Participated in the National Workshop on 'Database Designing for Biologists' (9th-11th September 2014) organized by DBT sponsored Bioinformatics Infrastructure Facility Centre, Nagaland University , Lumami, Nagaland.

Paper presented at a National Seminar on ‘Globalization, Development and Environment with special reference to Northeast region’ (March 19-20, 2015) organized by Nagaland University Teachers Association (L), Nagaland University, Lumami, Nagaland.

Attended Second Meet of Himalayan Young Researchers' organized by G.B. Pant Institute of Himalayan Environment & Development (GBPIHED) and Indian Himalayas Climate Adaptation Programme (IHCAP), Swiss Agency for Development & Cooperation (SDC), from 15-17 September, 2015 in Almora, Uttarakhand.

Participated in Conservation Assessment and Management Prioritisation (CAMP) Workshop (22-25 September 2015) organized by State Forest Department, Nagaland in association with Foundation for Revitalization of Local Health Tradition (FRLHT), Bangalore.

Presented a paper in the National Seminar on 'Inventory, Sustainable Utilization & Conservation of Bioresources' (February 26-27, 2016) organized by Department of Botany, Nagaland University and Institutional Biotech Hub, Nagaland University, Lumami, Nagaland.

Presented a paper in the International Conference on Natural Resources Management and Technology Trends (27^{th} -29^{th} March , 2017) organized by Centre of Advanced Study, Department of Life Sciences, Manipur University, Imphal in collaboration with SLNA for Watershed Management, Planning Department, Govt. of Manipur.