SPECIES RICHNESS AND PRODUCTIVITY PATTERN ALONG ALTITUDINAL GRADIENTS IN EAST DISTRICT OF SIKKIM, INDIA

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Declaration

I declare that the thesis entitled "***Species Richness and Productivity Pattern along Altitudinal Gradients in East District of Sikkim, India***" has been prepared by me under the guidance of **Dr. A. P. Das,** Professor, Taxonomy and Environmental Biology laboratory, Department of Studies in Botany, University of North Bengal and **Dr. M. D. Behera,** Associate Professor, Indian Institute of Technology, Kharagpur. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

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Abstract

The present work **"Species Richness and Productivity Pattern along Altitudinal Gradients in East District of Sikkim, India"** is based on the field data collected from the different altitudinal gradient of East district of Sikkim. The elevation of East district of Sikkim is ranging from 340 m at Rangpo to 4649 m near Nathula and the total geographical area is 954 sq km. Within the very short distance the all kind of climatic zones *viz.* tropical, sub-tropical, temperate, sub-alpine, alpine and permanent snow line area were cover within this district. For the present work, field data were collected through nested quadrats within an altitudinal range of 500 – 3300 m elevation gradient located within the district. The field data collected mostly from the undisturbed vegetation tracts including reserve forest (RF), wildlife sanctuary, khasmal and gorucharan (rangeland), located at least 500 m away from the human habitat areas. Altogether there are 224 nested quadrats of 20 x 20 m size laid out in the field for trees. The data from two 5 x 5 m quadrats [located within 20 x 20 m] for shrubs and five 1 x 1 m [also within 20 x 20 m] for herbs/ ground cover were collected. The field data was collected in the designed field format and the voucher specimens were collected for identification. A total of 664 species of vascular plants were recorded through such sampling, which include almost all habit groups like herbs, shrubs, climbers, lianas, trees and epiphytes. Major part of the natural vegetation, especially in the tropical to warm temperate belt is dominated by trees. Out of the recorded 664 species 34 species are found to be endemic to different sections of the Himalayan region.

Slope, aspect, climatic elements and soil were also taken into consideration during the analysis.The field data was divided in three elevation categories (grain size) *viz*. 100 m elevation steps, 200 m elevation steps and 300 m elevation steps with three taxonomic spectra (i.e., species, genus and family). As much as 159 species of trees, 121 shrub species, 302 herbaceous species and 82 epiphytes and lianas were recorded from the field. *Schima wallichii* Choisy is found to be occurring with highest abundance in sub-tropical belt of the district with recorded 1246 counts. A minimum of 60 and maximum of 155 species were noted in 3200 – 3300 m and 2200 – 2300 m elevation bands respectively. *Castanopsis hystrix* Hook.f. & Thomson ex A.DC., *Engelhardtia spicata* Hook.f. & Thomson ex A.DC., *Ostodes paniculata* Blume, *Alnus nepalensis* D.Don and *Schima wallichii* Choisy are the dominant tree species of tropical and temperate forests.

Schima wallichii Choisy contributed highest IVI score of 12.19 followed by *Ostodes paniculata* Blume with 4.64 in phytosocological analysis.

Pteridium quilinum (L.) Kuhn is found in all the elevation bands indicating maximum tolerance and adaptability with its extremely broad ecological amplitude. On the other hand, 190 species were found with single appearance in one elevation band and have very narrow tolerance and adaptability ranges. The Margalef diversity index showed very high values at all elevation bands with the highest 19.33 reaching at 2200 – 2300 m; whereas Shannon Weiner Diversity Index values varied between 3.4 and 4.4 (except at the highest elevation band, where the value was the lowest, 1.9) with the highest value of 4.4 recorded at 2200 – 2300 m.

The species richness pattern along the altitude analysis became prominent when adjudged from 100 m to 200 m and 300 m elevation bands with R^2 values of 0.502, 0.553 and 0.743 respectively. The species richness showed a gentle mid-elevation peak with a fast declining trend beyond mid-elevation. The pattern became prominent when adjudged from 100 m to 200 m and 300 m elevation bands with R^2 values of 0.502, 0.553 and 0.743 respectively; indicating realisation of scale effect. Similarly, the genus and family richness pattern followed the mirror image of species with mid-elevation peak. The R^2 values increased when plotted from100 m to 200 m and 300 m elevation bands for genera (0.657, 0.764 and 0.862) and families (0.765, 0.875 and 0.907). Though, the species richness pattern along elevation gradient showed non-linear polynomial relationship, it clearly confirmed the pattern of mid-elevation peak across the taxonomic spectrum (i.e., species, genera and families), and grain size (100 m, 200 m and 300 m elevation bands).

The above ground (AG) biomass distribution pattern showed alternate increasing and decreasing pattern along the elevation gradient in the study area. In general, the AG biomass showed a smooth increase up to mid-elevation and then decreases further. The R^2 values increased (i.e., 0.28, 0.41 and 0.58) when plotted from 100 m to 200 m and 300 m elevation bands. Species richness and AG biomass along elevation gradient shows strong positive relationships.

Species richness and above ground biomass vary in similar direction along the elevation gradient showing strongly positive relationships. The relationship became prominent with increasing elevation and grain size of different elevation bands i.e. from 100 m to 200 m and 300 m (along with the increase of R^2 values i.e., 0.31, 0.53 and 0.80).

Satellite remote sensing data, in the form of imageries, provide consistent and systematic observations on vegetation and ecosystems. So, as a proxy of biomass NDVI and EVI were calculated using the Landsat data of different dates, where the R^2 at 0.322 has been observed in second order polynomial in 100 m elevation band. But the field derived biomass and MODIS productivity was not showing the good relationship.

The multivariate analysis was also performed using the GLM model, to understand the correlation between species richness and other variables *viz*. temperature, rainfall, slope, soil, elevation, aspect and biomass. The good relationship between species richness with temperature and elevation were observed through such analysis.

Finally, it was suggested that more research in different scale is required to know the better relationship between species richness and productivity pattern along the altitudinal gradient in the biodiversity rich mountainous regions like Sikkim.

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Chapter 1

INTRODUCTION

INTRODUCTION

The term "species" is the identity of each living things. There are different types of living organism in the earth. It is broadly divided into plant and animals, present studies are attempted to know the plant species richness and its relation with biomass along the altitude using the field data of East district of Sikkim

1.1 Biological Diversity

Biodiversity entails all forms of biological entities inhabiting the globe, including prokaryotes and eukaryotes, wild plants and animals, microorganisms, domesticated animals and cultivated plants and even genetic materials like seeds and germplasm (Kothari, 1992). Biodiversity refers to the variability among the living organisms like plants, animals and microbes from all sources including terrestrial and aquatic ecosystems and ecological complexes of which they are the parts. In brief, it refers to the versatilities within the species, among the species of plants, animals and micro-organisms, ecosystems and the ecological complexes on the earth. Biodiversity is the assemblage of different life forms. It can also be defined as the number of different organisms and their relative frequency in an ecological system. Diversity is composed of two elements: *richness* and *evenness*, it decrease and its endemic subset increased along the gradients (Behera & Kushwaha, 2007). India has about 2,00,000 species of living organisms (Agrawal *et al*., 2002). Vegetation zones along the altitudinal gradient showed interesting differences in species richness (Hegary *et al*., 1998). Species diversity is measured as the total number of individual species habited in a study area (Pianka, 1966).

The world has at least 5 – 7 million different species of plants, animals and micro-organisms, out of these only about 1.7 million is known to humans (Subba, 2002). The Himalayas which is the largest and youngest mountain ranges in the world stretches across the north of sub-continent from Myanmar in the east to northern Pakistan in the west. On the north, they border the Tibetan plateau and on south by Indo-Gangetic low land. The rich biodiversity of the Himalayan states have not been studied so far upto the level of satisfaction (Subba, 2002). Only superficial studies of ferns and fern-allies, Gymnosperms, Angiosperms (including special groups like orchids, medicinal and Aromatic plants), Butterflies, Fishes, Amphibians, Reptiles, Aves (Birds) and Mammals have been attempt so far. There is an urgent need to study the rich and vulnerable biodiversity of the entire Himalayan range and their distribution pattern, especially in respect to elevation gradient in its different parts.

To understand the ecological phenomena like environmental disturbance of the species, the term species diversity is used. The understanding of species richness pattern is important for the management of species diversity in the world that may become warmer owing to the human impact (Grytnes, 2003). To understand the common cause of species distribution species in various environmental gradients, researchers are working in different environment using various factors, the commonly known are latitudinal and altitudinal. Pianka (1966) reviewed a concept of latitudinal gradient in species diversity. Gaston (2000) and Rahbek and Graves (2001) studied the spatial patterns of latitudinal gradient in species richness.

To understand the distribution pattern of species along the elevation gradient, Kreft and Jetz (2007) observed the global pattern and determinants of vascular plant diversity. Liberman *et al*. (1996) studied the species pattern along the altitudinal gradient of Costa Rica. Among the various patterns of species richness along the altitude, the monotonic decline of hump-shaped patterns are most commonly recognized (Bhattarai & Vetaas, 2003; Grytnes, 2006; Acharya *et al.,* 2011).

Many factors, such as climatic variables like rainfall, temperature, soil conditions, moisture, nutrients, historic events, palaeo-climatic changes, interaction with fauna, competition between tree species for crown and root space as well as human influence have been considered as responsible for the elevational pattern and distribution of species richness. (Odland & Birks, 1999; Kharkwal *et al.,* 2005; Veenendaal *et al*., 2005; Brown, 2001)

High mountains offer a variety of steep environmental gradients over a relatively short distance (Peterson *et al.,* 1997; Korner, 2003; Becker *et al.,* 2005). The large environmental variation within a small geographical area makes altitudinal gradients ideal for investigating several ecological and biogeographical hypotheses (Korner, 2000). The Himalayan elevation gradient is the longest bio-climatic gradient in the world (Grytnes & Vetaas, 2002). Several studies has been carried out in plant community and in altitudinal gradient in the Himalayan region (Grytnes & Vetaas, 2002; Bhattarai & Vetaas 2003;Shapoo *et al*., 2004; Kharkwal *et al*., 2005; Bhatnagar *et al*., 2006;) on variation of plant species richness composition along the altitudinal gradient.

Behera and Kushwaha (2007) analyzed trees along an elevational gradient covering a 2000 m elevation range (200 to 2200 m) in the Eastern Himalaya. Achraya *et al.* (2011) studied in Sikkim to analyse the tree diversity using the transects for sampling keeping the 150 m elevation distance between the two transects from the elevation range of 300 – 4700 m, i.e. from tropical forests to alpine meadows.

The species diversity generally decreases with the increase in altitude (Odland & Birks, 1999; Lieberman *et al.,*1996; Grytnes & Vetaas, 2002); Achraya *et al.,* 2011). The distribution of the species richness in the Himalayan region mostly depends on the altitude and climatic variables. The climatic conditions and the geography of the area are changes along the altitude (Kharkwal *et al.,* 2005). The altitude, slope, aspect, rainfall and humidity had to play sole information of community composition. Besides, vertical canopies also play vital role in forest ecosystems (Kharkwal *et al.,* 2005).

Species richness along the elevation gradient and underlying factors for the pattern are not properly explored and understood. Understanding elevational distribution pattern of species and the factors governing the same would help to understand biodiversity and aid in their conservation (Battarai *et al*., 2004; Hunter & Yonzon, 1993). Elevation is an important factor in habitat diversity because it present changes in the availability of resources, to know correspondence between the physical conditions and natural communities that are found along a gradient of increasing elevation and those are found along a gradient of increasing elevation. Many researchers have explored biodiversity distribution pattern of plants and clarified that elevation has a role in regulating species richness patterns (Grytnes 2003; Oommen & Shanker 2005).

A simple rule says that the species richness and altitude relationship follows the same principle as the analogous latitudinal pattern (Stevens, 1992; Colwell & Hurtt, 1994). Species richness of various taxonomic groups decreases towards the poles or higher altitudes . It was long believed that a monotonic decrease of species richness with increasing elevation was the universal pattern (Stevens, 1992). The plants and animal diversity is the lowest near the poles and increases towards tropics, reaching its peak in tropical rain forests and slowly decrease towards the sub-alpine and alpine regions.

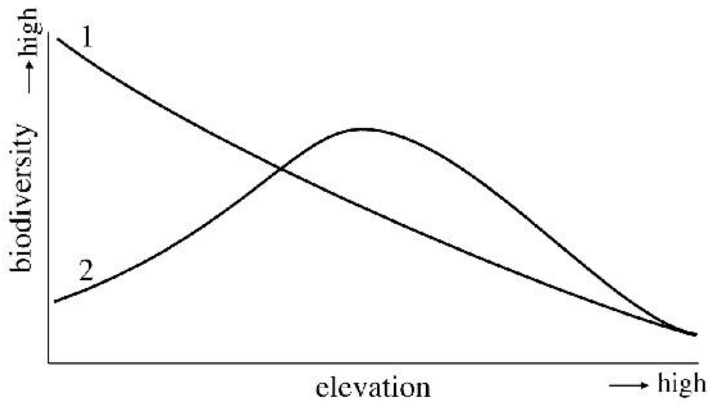

Fig. 1.1. Biodiversity distribution pattern along the elevation gradient. Curve '1' shows that the biodiversity levels decrease with elevation and the maximum is at low elevations and curve '2' indicates that most diverse zones are in the mid-elevation (*Adapted from*: Weng *et al*., 2007)

Species richness generally decreases with elevation (Stevens, 1992; Brown & Lomolino, 1998; Rahbek, 1995). Relationship between richness patterns and various ecological, geographical and other factors have been dealt in by many workers. Among the various patterns, monotonic decline and hump-shaped pattern of species richness are most commonly recognized (Vetaas & Grytnes, 2002; Rahbek, 2005 Acharya *et al.*, 2011; Bhattarai & Vetaas, 2003).

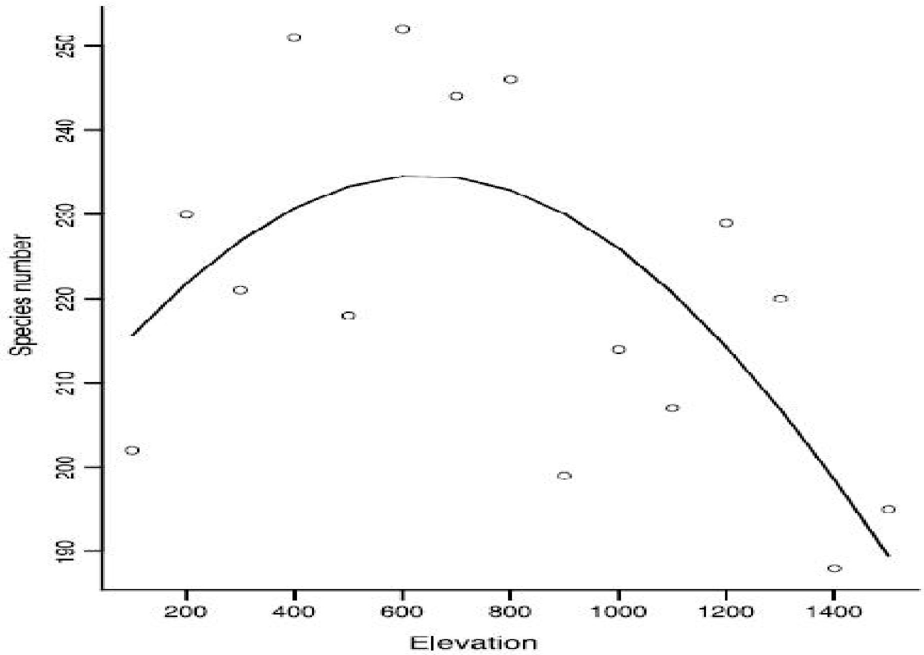

Fig. 1.2. Relation between tree species richness and elevation in central Nepal (*Adapted from*: Bhattarai & Vetaas, 2003)

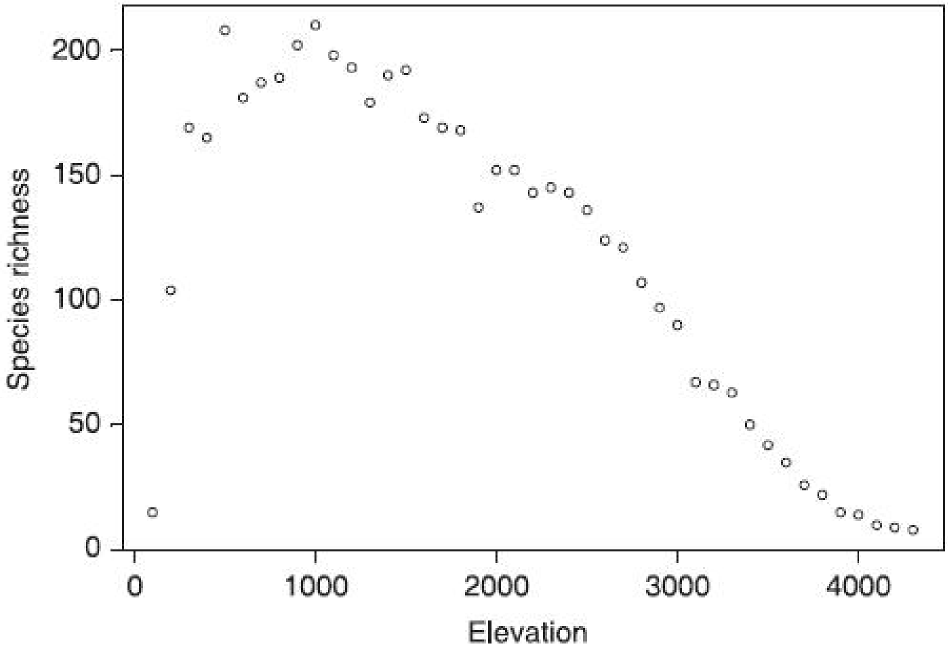

Fig. 1.3. Relation between tree species richness and elevation in central Nepal (*Adapted from*: Bhattarai & Vetaas, 2006).

Many factors such as climate (Hawkins *et al*., 2007; McCain, 2007), productivity (Mittelbach *et al*., 2001), historic events (Brown, 2001; Hawkins *et al*., 2007) and isolation (Lomolino, 2001) have been considered as responsible for the elevational pattern of species richness. Vetaas and Grytnes, (2002) studied the distribution of vascular plant species richness along the elevation gradient of Nepal Himalaya, between 1000 to 5000m and found a hump-shaped pattern (Fig. 1.2 – 1.3). Acharya *et al*., (2011) have examined the relation between tree species richness along the elevation gradient of eastern Himalaya using the field data collected from different altitudinal range of Sikkim in 1km transects using sample size 20x10m (Fig. 1.4).

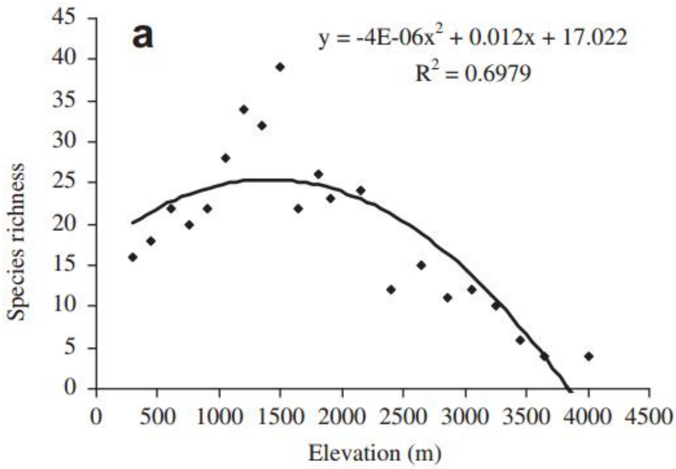

Fig. 1.4. Observed species richness of trees along the elevation gradient of Sikkim, Eastern Himalaya (Adapted from: Acharya *et al*., 2011)

The altitudinal/ latitudinal decrease in species richness has been known for over a century, species diversity as a whole and its distribution along the altitudinal gradient had been a subject of ecosystem (Hubbell *et al*., 1999; Kharkwal *et al*., 2005). Himalaya is one of the Hotspots of biodiversity in India, this region comprises several species of plants, with many of them being indigenous (Kharkwal *et al*. 2005). Lamolino (2001) studied the gamma diversity for the species richness for each elevation zone which is interpolating species presence between known elevation range limits has commonly been used to investigate species richness pattern along the elevation gradient. In tropical and subtropical latitudes, profound differences in climatic regime ranging from tropical to high-tundra, may occur within latitudinal distances of less than 100 km in mountainous region (Lacoul & Freedman, 2006). Such large and steep altitudinal gradients have a great influence a biodiversity in mountainous region (Ormered *et al*., 1994).

Studies to establish relation between species richness and the altitude are lacking in the Sikkim Himalayan region which has a highest altitudinal gradient in India. In the present study, attempt has been made to understand the relationship between the plant species (trees, shrubs, herbs and epiphytes) richness along the altitudinal gradient of East Sikkim. Further, such kind of study will be helpful for the future research as it provide a comparative study of the change in species and species composition of plant community along the altitudinal gradient in the East district of Sikkim.

The number of species present, i.e. the “species richness” and species evenness with which the individuals are distributed among these species has also studied to understand the diversity of the species along the elevation gradient (i.e. species evenness, species equitability, or abundance of each species) by some workers (Margalef, 1958; Lloyd & Ghelardi, 1964; Pielou,1966; Spellerberg, 1991).

1.2. Plant community structure

Diversity of a community can be assessed by the proportional species abundance data either by using statistical sampling theory (Preston, 1948; 1962) or by a variety of nonparametric measures (Simpson, 1949; Shannon, 1963). Owing to the complex nature and lack of theoretical justification for statistical sampling theory, the nonparametric measures have gained a great deal of popularity in the recent past (Magurran, 1988; Krebs, 1989). McNaughton and Wolf (1970) opined that dominance is an expression of ecological inequalities arising out of different exploitation strategies. The growth form or life-form composition of a community is the manifestation of the adaptation of its component species to the climatic condition of the area. Raunkiaer (1934) described plant communities in terms of life-form composition. Richards (1952) used the word ‘Synusiae’ to describe a group of plants having similar life-form, which play similar role in the community to which they belong.

1.3. Topographical description

Topography is a field of geoscience and planetary science comprising the study of surface shape and features of the Earth. It also deals with the description of earth surface such as shape and features. Topography is widely related with the biodiversity; the topography of an area could also mean the surface shape and features, some commonly use topography for the biodiversity study are; elevation, slope, aspect, drainage, road etc. Relationship between biodiversity with topography is highlighted below.

1.3.1. Elevation: Elevation gradient provides the well-known correspondence between the physical conditions and natural communities those are found along a gradient of increasing latitude and those which are found along a gradient of increasing elevation (Huston, 1994), it is not surprising that species diversity generally decreases with increasing elevation. General rules of thumb is for air temperature is that an increase in elevation of 1000 m results in a decrease in temperature (6^0C) equivalent to that associated with an increase in latitude corresponding to linear distance of 500 km to 750 km (Holdridge 1967; Whittaker & Niering 1965). Many physical conditions in addition to mean temperature, such as the seasonal variability of those conditions also change along the altitudinal and latitudinal gradients.

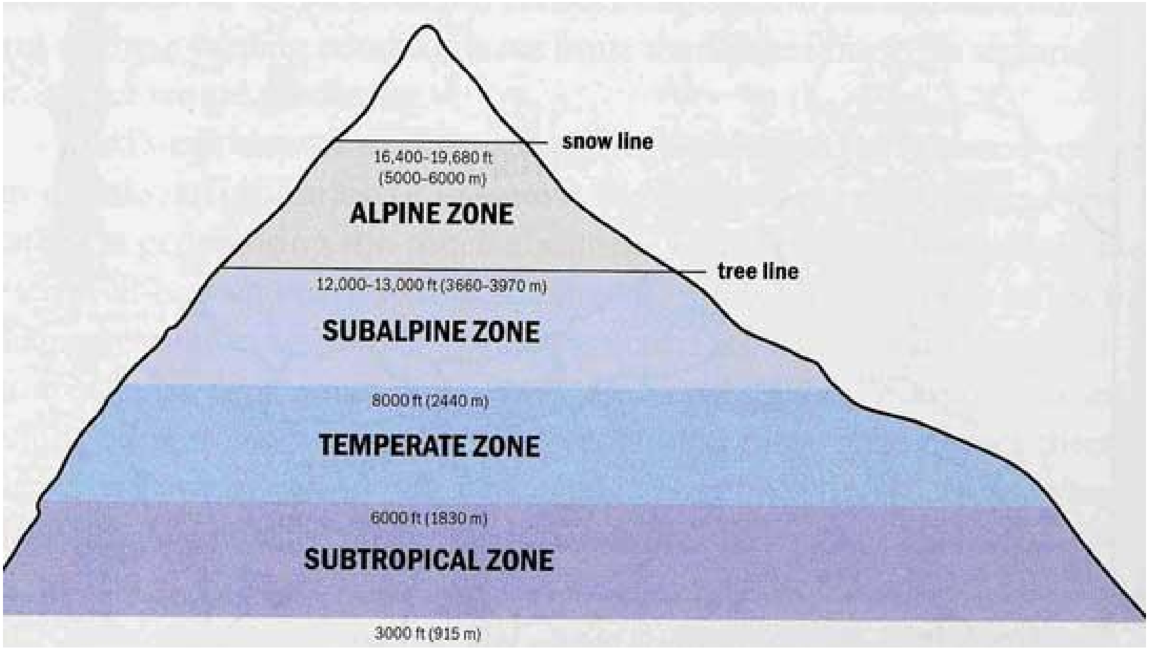

Fig.1.5. Vegetation zones in the Himalayas as adapted from http://blog-yard-garden-news.extension.umn.edu/2009/02/in-rhododendron-fairyland-fantasy-of.html

The study of altitudinal gradient does not influence species diversity, but the explanatory mechanism must be related to some of the many physical and historical factors that changes along the altitudinal gradient, such as sun angle, day length, seasonality, temperature means and extremes, rainfall amount and timing, winds and storms, glacial history, etc. each of these, and other factors can interact with organism and their physical environment in complex way that could potentially influence species diversity. To understand the many reasons why diversity changes along this dramatic gradient, it is necessary to examine the effect of diversity of simpler gradients, and if possible for single factor (Huston, 1994). So, there are several factors which correlate the species diversity along the altitudinal gradient.

Moisture is also considered as one of the factors, when moisture (Relative Humidity) increases with the increasing elevation, but the greatest number of plant species of all growth form together per 0.1ha sample was found at intermediate to low elevations and intermediate moisture level in open oak woodlands grasslands and in the Sonoran desert.

1.3.2. Slope and aspect: Slope is a characteristic feature of the mountains. Steepness of slope affects the amount of solar radiation received during the day and soil characteristics primarily through its effect on the rate of water flow. In the northern hemisphere, at higher Elevations, steepness of the slope increases the exposure of the surface to sun on the southern slope, whereas the northern slopes remain cooler. This is due to the fact that the steep southern slopes receive the rays of the mid-day sun almost at right angles, whereas the northern slopes receive only oblique rays during morning and evening hours and sometimes none at all except for a short period during summer. This difference in solar radiation and consequent temperature values bring about changes in vegetation on the two slopes. Thus, northern slopes support virgin forest with hygrophilous ground vegetation. The local climatic differences on two slopes can play vital role in the health of the vegetation.

1.3.3. Drainage: Drainage has a major role to promote the development of new vegetation types with a dense ward of grasses, from which characteristic species of wet meadows disappear at different rates (Grootjansa, 2005). The presence of perennial rivers and turbulent streams in the region has helped in the luxuriant growth of forest in the region.

1.3.4. Road: Road is the lifeline of the civilizations it connecting the small towns and the capital city pass through the middle of the reserved forests small settlements. The expansion and construction of road networks is destroying the forests cover in the entire Himalayan region as it triggers small and large landslides during south west monsoon seasons as well as destroy the springs and catchments.

1.3.5. Edaphic conditions: Soil and vegetation has a complex interrelationship. Soil properties influence the vegetation and vice versa. Soil is one of most important ecological factors. Plants depend on it for the nutrient, water supply, and for anchorage. Soil is a natural body that exists as part of the pedosphere and which performs four important functions: it is a medium for plant growth; it is a means of water storage, supply and purification; it is a modifier of the atmosphere of Earth; and it is a habitat for organisms all of which modify the soil. Similarly, Selective absorption of nutrients by different tree species and their capacity which is return to the soil brings about changes in the soil properties. The temperature of soil is one of the most important factors for the growth of plants particularly that of the surface layers by its effects during germination (Richardson, 1958).

1.4. Biodiversity pattern

In order to monitor and conserve biological diversity, it is important to have ways of measuring it and documenting the levels of diversity in different parts of the world. We have to consider diversity at different levels. E.O. Wilson, 1988 was first used the term biodiversity in the literature, the concept of biological diversity from which it arose had been developing since the nineteenth century and continues to be widely used.

The major biological diversity pattern is discussed as below;

1.4.1. Latitudinal pattern: The latitudinal gradient was the pattern that first attracted scientific attention to species diversity. For most of the groups, the terrestrial plants and animals, diversity is lower near the poles and increases towards the tropics, reaching its peak in tropical rain forest.

There are many factors correlated with this gradient that could potentially affect species diversity, such as an average temperature and precipitation, the variability in temperature and precipitation, annual net primary productivity, and geological history. Some of the factors are positively correlated with latitude while others are negatively correlated. The latitudinal gradient in species diversity has been reported in a wide variety of taxa. The most dramatic and biologically important latitudinal diversity gradient is that of plant species. Diversity of trees increases from the nearly non-specific boreal forests of the subarctic, to the overwhelming diversity of tropical rain forests. The same pattern of increasing diversity with decreasing latitude is also found in the nature (Monk, 1967; Glenn-Lewin, 1977; Currie, 1991; Silvertown, 1985). Diversity increases with decreasing latitude in most groups of plants.

1.4.2. Life-form composition pattern: Life-form plays the major role in the biological pattern, there are several types of plant growth forms or life-forms, the higher plants are trees and lower growth forms of plants are moss and lichen which are easily found in the field, the life-form of a plant species is usually a constant characteristic. The same species, however, may assume a different life-form when growing under very different environmental set-up. The life-form was originally developed for non-taxonomical comparison of vegetation types in different regions of the world. Klimes (2003) stated that many basic elements of life history of plants are strongly affected or even largely determined by the life-form, species pools and other associated environmental (soil texture nutrient substrate stability etc.) factors.

Plants of the same life-form growing together are likely to compete directly for the same space or niche (ecological role of a species in an environment). Their similarity in structure and form indicates a similarity in adaptation to the utilization of the environmental resources offered in a given space. The most extreme form of life-form similarity is shown among individuals of the same species. Wherever they grow close together, they are also the strongest competitors, because they are adapted to use the environmental resources in the same manner. Species of much unrelated families may also be of the same life-forms e.g., similar stem-succulents evolved in the families Cactaceae, Euphorbiaceae, Asclepiadaceae, and Agavaceae.

1.4.3. Factors correlated with diversity: Describing the variety of biodiversity patterns on the earth is relatively simple in comparison with understanding and explaining those patterns, some properties of the environment will be positively correlated with diversity and some negatively correlated with each other. Statistical analyses can never demonstrate causal relationships, but can often show strong correlations of diversity with factors that are marginally, if at all, related to the mechanisms responsible for the diversity gradient.

1.4.4. Ecotone zone: Ecotone is the transition zone between two adjacent ecological communities, such as forest and grassland. It has some of the characteristics of each bordering community and often contains species not found in the overlapping communities. An ecotone may exist along a broad belt or in a small pocket, such as a forest clearing, where two local communities blend together. The influence of the two bordering communities on each other is known as the edge effect. An ecotonal area often has a higher density of organisms and a greater number of species than are found in either flanking community.

1.4.5. Forest type variation: Different forest types may also play an impotent role for the diversity of plant species. Tropical, temperate and boreal forests offer widely due to the presence of diverse habitat conditions for plants, animals and micro-organisms.

1.4.6. Species distribution range: Even today, the number of plant species currently in existence in the world is not clear, but there are number of plant species distributed in different part of the world.

About 8.7 million living thing exist in the world out of which about 3.90 lakh plant species have been estimated in the world.

1.4.7. Biodiversity scale factor; Biodiversity patterns can be studied at three levels viz., global, focal and local. By studying spatial patterns of biodiversity we can identify some distinct spatial gradients in biodiversity. The description of each of those is given below:

A. *Grain size:* There is different scale to study the biodiversity. Grain size is one of those, in landscape ecology, grain describes the size of the smallest homogeneous unit of study and determines the resolution at which a landscape is studied.

B. *Local scale:* On a local scale, changes in the abundance of species in plant communities, be it fluctuations or trends, can be indicative of the fate of the local populations.

C. *Global scale:* The most striking gradient is a global one; there is an increase in species richness as one move from high latitudes at the poles to the lower latitudes of the tropics. A similar pattern is seen for higher taxonomic groups (genera, families). Various hypotheses have been raised to explain the greater species.

1.5. Community

Community analysis was carried out for further study of frequency, density, abundance and finally Importance Value Index (IVI)

1.5.1. Frequency and Relative Frequency:

Frequency: Various species of the community are recorded by different phytosociological methods by taking any sampling unit like quadrat transect and point, Frequency is the number of sampling units (as %) in which a particular species occurs.

Relative Frequency: The relative frequency of an event is defined as the number of times that the event occurs during experimental trials, divided by the total number of trials conducted

1.5.2. Density and Relative Density: Density is an expression of the numerical strength of a species, where the total number of individuals of each species in all the quadrats is divided by the total number of quadrats studied is the density of the population.

Relative density: The Relative density is the study of numerical strength of a species in relation to the total number of individuals of all the species and can be calculated.

1.5.3. Abundance and Relative Abundance (Dominance):

Abundance: This is the number of individuals of any species per sampling unit of occurrence. Abundance may not be expressed generally in quantitative terms. Organisms, particularly plants are not found uniformly distributed in an area. They are found in smaller patches or groups depending upon the number of plants and degree of evenness of the neche.

Relative Abundance (Dominance): Ecological dominance is the degree to which a taxon is more numerous than its competitors in an ecological community, or makes up more of the biomass. Most ecological communities are recognized and defined by their dominant species.

1.5.4. Importance Value Index: This index is used to determine the overall importance of each species in the community structure. In calculating this index, the percentage values of the relative frequency, relative density and relative dominance are summed up together and this value is designated as the Importance Value Index or IVI of the species (Curtis, 1959).

1.6. Diversity Indices

Determining which community has greater species diversity is easy when either species richness or evenness is held constant while the other parameters vary, but often communities will vary in both richness and evenness. Scientists have developed a variety of mathematical equations (or indices) that incorporate both species richness and evenness into a single measure of species diversity (e.g., the Shannon-Wiener Index and Simpson's Index). Different diversity indices assign different weightings to species richness and evenness, so the most useful index to choose depends on the circumstances. In ecology, it is often used to quantify the biodiversity of a habitat. It takes into account the number of species present, as well as the large quantity of each species. It measures the probability that two individuals randomly selected from a sample will belong to the same species. Different indices have been used for the diversity (*viz*., Simpson's Index of Diversity 1- D, Shannon-Wiener index (H') [Diversity] (1949), Shannon's diversity index, Margalef index, etc.). The units of these indices differ greatly, making comparisons difficult and confusing.

1.7. Plant Biomass

Plant biomass is defined as the mass of living plant materials as per unit area; it is divided into two parts, above ground biomass and below-ground biomass. It can also be defined as the mass of living plant materials per unit area. Biomass assessment is necessary because forest is affected by various factors such as deforestation, fire, harvest, pests, silviculture and climatic change (Schroeder *et al*., 1997; IPCC, 2006), which cause changes in the forest ecosystem. However, the quantification of forest biomass becomes difficult due to different approaches, based on field measurements as well as remote sensing and GIS are available for biomass estimations (Lu, 2005).

Measurement of biomass is carried out mainly by the following four techniques:

· Destructive sampling technique or Harvest mapping technique (Husch et al. 2003)

· Non-destructive sampling technique (Chave et al. (2005)

· Measurement based on remotely sensed data taken from airborne/spaceborne systems (Kale et al., 2002), and

· Semi-empirical modelling -estimation using models (Mette et al., 2003; Lee et al., 2003).

1.7.1. Destructive sampling technique or harvest mapping technique: This method involves felling of trees, the individual's trees can be harvested and separation into different components like branches, leaves, and stems finally the fresh and dry weights are taken. The ratio between dry and fresh weight used to calculate for the entire sample. Destructive approach is most accurate among all the other methods of biomass estimation, but this method cannot be used for the large forests because of destructive and high cost involved.

1.7.2. Non-destructive sampling technique: Non-destructive technique for biomass estimation is one widely used technique. In this method tree specific regression equation were involve viz. Tree diameter/circumference, tree height and basal area are used as independent variables. Brown *et al*. (1989) used non-destructive sampling technique to estimate the volume of the tree and then converted into biomass using the specific gravity of individual species. Sampling of tree to develop an equation has been carried out by several authors (Overmen *et al*., 1994). Day *et al*. (2013), used sampled tree >10cm dbh to calculate biomass of Central African rainforests. The non-destructive technique for estimation of biomass is time and cost effective, as compared to destructive method, but this method is generally used for the estimation of biomass for large forests.

1.7.2.1. The biomass assessment using the field data: To estimate the biomass the volumetric equations and the specific gravity of respective tree species is required. For remote sensing based biomass estimation we need remote Sensing data of the particular time frame.

Plants those dominate a site, in terms of biomass, is a reflection of the plants which are controlling the nutrient, water, and solar resources on the site. Therefore, biomass is often measured to assess the ecological status of a site.

1.7.3. Measurements based on remotely sensed data taken from airborne/ spaceborne systems: Satellite based estimation of biomass is the technique to estimate Above Ground Biomass. Rauste (2005) was mapping the forest biomass using Multi-temporal JERS SAR data, Ferrazoli and Guerriero (1995) use radar sensitivity to investigate tree geometry and wood volume. Pandey *et al*. (2010) used the Envisat ASAR data for biomass estimation in Dudhwa National Park of Lakhimpur-Kheri district in Uttar Pradesh state of India. Eriksson *et al*. (2003) also use Multitemporal JERS data for growing-stock volume estimation of Siberian forest. Kale *et al*. (2002) also used remote sensing and Geographic Information System (GIS) to estimate the NPP at the patch level, which takes Intercepted Photosynthetically Active Radiation (IPAR). There are several studies conducted for the estimation of biomass using optical remote sensing data (Zheng *et al*., 2004; Schlerf *et al*., 2005; Foody *et al*., 2003; Devagiri *et al*., 2013).

The continuous nature and synoptic coverage of remotely sensed data have led to their increased application for AGB estimation over large areas, although the use of these data remains challenging in complex forest environments.

1.7.3.1. Satellite derived NPP Products: Forest productivity and biomass are expected to change drastically as global climate change (Singh *et al*., 1994). Average ecosystem productivity as a function of ecosystem redundancy can be greatly affected by both the species responses and the degree of synchronicity of their responses in the ecosystem (Yachi & Loreau, 1999). Productivity of ecological system, community or any point there, is defined as the rate at which radiant energy is stored by photosynthetic and chemosynthetic activities of the producer organism in the form of organic substances which can be used as food material by the consumers. The relationship between bio-diversity and ecosystem functioning focused upon the effect of losses of plant diversity and productivity often declined with the diversity loss (Ruijven & Berendse, 2005). The values of Net Primary Productivity (NPP) are much higher than in the natural forests of India (Singh & Toky, 1995).

Vegetative productivity is the source of all food, fibre and fuel available for human consumption and therefore improves the habitability of this planet. The rate of conversion of light energy to plant biomass is termed as primary productivity. The sum total of the converted energy is called gross primary productivity (GPP). NPP is the difference between GPP and energy lost or used during respiration of plants (Campbell, 1990).

Global productivity can be estimated by combining remote sensing technique with carbon cycle processing. The U.S. National Aeronautics and Space Administration (NASA) Earth Observing System (EOS) currently "produces a regular global estimate of gross primary productivity (GPP) and annual net primary productivity (NPP) of the entire terrestrial earth surface at 1-km spatial resolution, 150 million cells, each having GPP and NPP computed individually" (Thornton *et al.*, 2002; Running *et al.*, 2004). For the estimation of GPP/NPP across the Earth's entire vegetated land surface. MOD17 algorithm-MODIS project has been launched to provide continuous estimates of MOD17 GPP/NPP outputs that are useful for natural resource and land management, global carbon cycle analysis, ecosystem status assessment, and environmental change monitoring. MOD17 is part of the NASA's Earth Observation System (EOS) program and is the first satellite-driven dataset to monitor vegetation productivity on a global scale. Additionally, user guide for GPP and NPP (MOD17A2/A3) Products NASA MODIS Land Algorithm had been developed in and around 2000 by Heinsch *et al.* (2002). The MOD17A2/A3 User's Guide provides description of the GPP and NPP algorithms (MOD17A2/A3) designed for the MODIS sensor aboard the Aqua and Terra platforms. The resulting 8-day products are archived at a NASA DAAC (Distributed Active Archive Center). The document is intended to provide both a broad overview and sufficient detail to enable the successful use of the data in research and applications.

1.7.4. Semi-empirical modelling – Estimation using models: Semi-empirical methods are simplified versions of Hartree-Fock theory using empirical (= derived from experimental data) corrections in order to improve the performance. These methods are usually referred to through acronyms encoding some of the underlying theoretical assumptions.

On the other hand the relationship between species richness and above-ground biomass is emerging as a central theme in diversity studies (Peet & Christensen, 1988). A critical challenge for ecology is to understand the mechanisms linking ecosystem functions and community dynamics (Loreau *et al*., 2001)

1.8. Relation between productivity and species richness

The relationship between the productivity and species richness (biodiversity) in plant community has two different perspectives (Bishoff *et al*., 2005), first one is the effect of species richness and productivity as a particular ecosystem function (Tilman *et al*., 2001), and the next perspective is the effect of the productivity and diversity of the plant communities. The relationship between species richness and NPP has been particularly controversial, with disagreement over whether productivity controls or is controlled by species richness (Waide *et al*., 1999; Loreau *et al*., 2001; Bond & Chase, 2002). Species richness and productivity pattern is a function of various disturbance gradients. Although numerous empirical studies have been conducted to examine the effects of resource additions or disturbance regimes on species richness (Huston, 1999), difficulties arise in applying generalized theoretical models to patterns in natural environments because patterns may be scale-dependent (Waide *et al*., 1999). A few studies of productivity-species richness patterns in extremely species-rich communities were conducted across natural resource gradients, particularly at scales intermediate between small plots and continents or within vegetation types (Abrams, 1995). Owing to scanty information on the mechanistic explanations of the relationship between species richness and productivity and predictions of conditions that produce monotonic or unimodal patterns remain unresolved (Huston, 1994; Abrams, 1995). Waide *et al*. (1999) and Weiner (1995) argued that examination of patterns at a local level is an essential first step in generating testable hypotheses regarding the basis of a species diversity gradient.

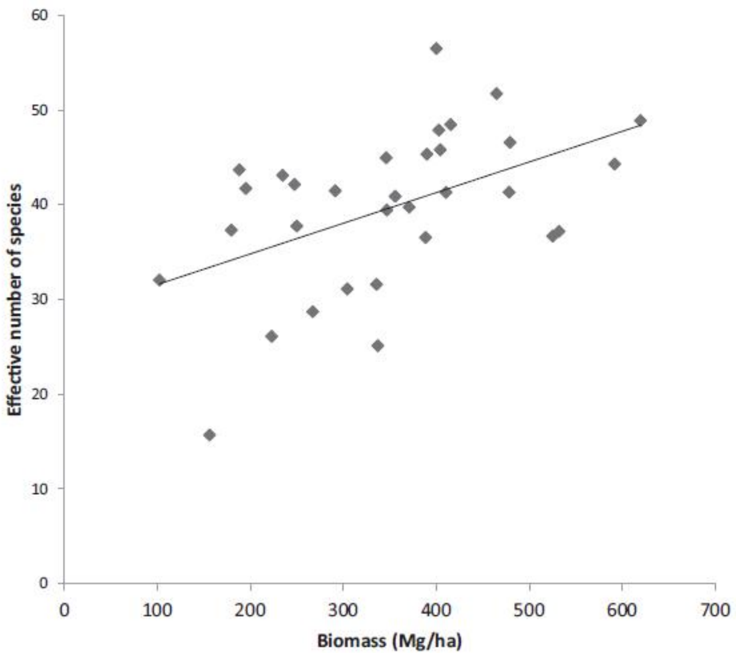

Fig. 1.6. Plot of effective number of species calculated from the Shannon Wiener index against AGB estimates; (Adapted from Day et. al, 2013).

1.9. Relationship between species richness with biomass along the elevation

The relationship between species richness and biomass has become a central issue of community and ecosystem ecology; there is no reason to expect any general relationship between species richness and productivity (Mouquet *et al*., 2002). There are many cases in which biomass are negatively correlated with species diversity. Some authors have predicted a positive relationship between productivity and species richness (Tilman *et al*., 1997; Loreau, 1998b) based on niche complementarily.

The difference between situations with positive versus negative correlations and diversity and biomass is an important step in understanding how diversity is regulated. The productivity can be either negatively or positively correlated with species diversity. In fact, in many systems a unimodal pattern is found with highest species diversity at intermediate levels of productivity and diversity decreasing with either an increase or decrease in productivity. In General, the productivity is either remaining constant or decrease as the number of locally coexisting species increases (Loreau & Mouquet, 1999). The species richness and productivity relationship mainly depend upon the environmental context (Mouquet *et al*., 2002). There is no relationship between species richness and biomass under constant conditions but, when communities were exposed to experimental drought, biomass increased with species richness (Mulder et al., 2001).

1.9.1. Positive correlations of diversity and productivity: As per Reichle (1970), on the global scale, the primary productivity of terrestrial vegetation is positively correlated with plant species diversity. Productive forest ecosystems generally have more species than less-productive deserts or grasslands. The studies carried out in North America and America by Currie and Paquin (1987), Adams and Woodward (1989), and Currie (1991) on species richness and climatic conditions have shown strong correlations between the species richness of major taxonomic groups and simple climatic parameters. Similarly, positive correlation of seed-eating ants and rodents in North American desert has been reported by Brown and Davidson (1977).

Conversely, diversity does not always increase with productivity or the environmental conditions that influence productivity. Abramsky and Rosenzweig (1985) reported that in the desert of Israel, the species richness of desert rodent's first increases with increasing rainfall, then decreases at higher levels of rainfall with a maximum at intermediate levels.

Similar patterns of diversity have been noticed by Whittaker and Niering (1975) among the vascular plants in Arizona mountains.

In forests the primary productivity is positively correlated with plant species diversity, as compared with deserts and grasslands the productive forest ecosystems have more species as well as more productivity (Huston, 1994). Potential evapotranspiration is also correlated with plant productivity, but diversity does not always increase with productivity or the environmental conditions that manipulate productivity.

1.9.2. Negative correlation of diversity and productivity: A few studies have documented negative correlation of species diversity with productivity. This unexpected phenomenon was sometimes referred as 'the paradox of enrichment' (Rosenzweig, 1971; Riebesell, 1974). They opined that diversity often decreased when nutrients or other resources that increases productivity were added to a system. Additionally, oceanic ecosystem shows a similar phenomenon along the natural gradients of productivity. Thus, productivity can be either negatively or positively correlated with species diversity. In fact, in many systems a unimodel pattern is found with highest species diversity at intermediate levels of productivity, and diversity decreasing with either an increase or a decrease in productivity (Grime, 1973, 1979; Al-Mufti *et al.*, 1977).

The diversity often decreases if increased amount of nutrients or other resources that increase productivity were added to the system. In aquatic system, though the addition of fertilizer to herbaceous plant communities often results in sharp decrease in species diversity, some pattern was found along the natural gradients of soil fertility (Huston, 1994). The central region of the open ocean is characterized by low productivity and a low density of individuals. However, the species diversity remains high in such areas. But in high productivity area there is high concentration of individuals though shows low species diversity. The productivity is either negatively or positively correlated with the species diversity (Huston, 1994). Total rate of photosynthesis, including the organic matter used up in respiration during the measurement period (Shukla & Chandle, 2006). If plant growth continues then only the NPP is available for harvest by man and other animals. The Himalayan region is biologically extremely diverse and the efforts for conservation are somehow successful with both local global implications.

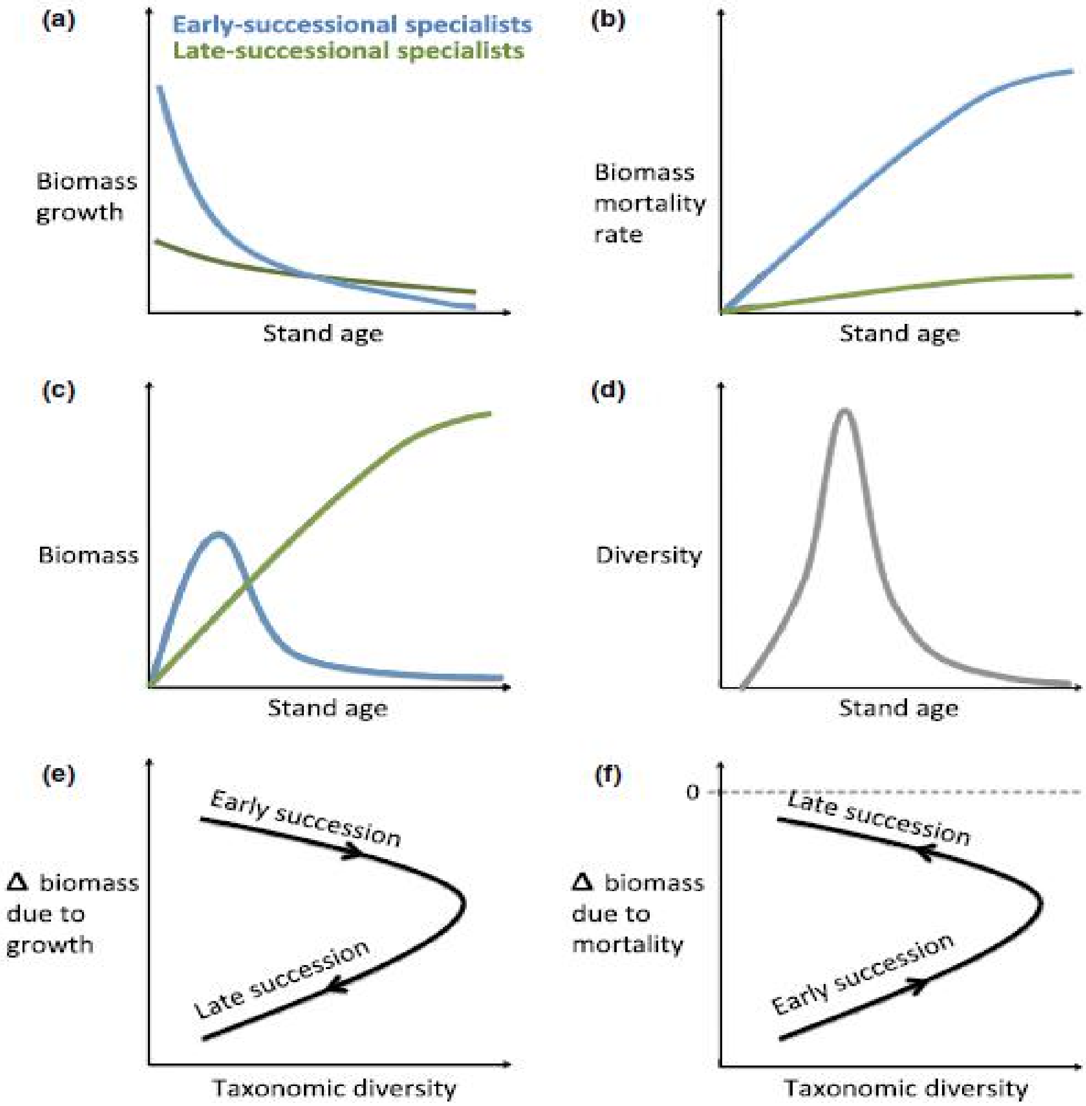

Fig.1.7. Qualitative predictions of growth–mortality trade-offs (a–b), biomass (c), diversity (d) and resulting BEF relationships (e–f) based on a successional niche model with only early- and late-successional specialists (e.g. two species, Kinzig and Pacala 2001). (a) Biomass growth declines with stand age. Early-successional specialists have higher productivity under abundant resources early, but cannot maintain productivity as stands age. (b) As resources decline with stand age, biomass mortality increases. Increased mortality is higher for early-successional species. (c) As a result, early-successional species biomass peaks early in succession but is supplanted by late-successional species. (d) Under the successional niche hypothesis, the highest diversity occurs in middle-aged stands transitioning from early to late-successional species. (e) Diversity relationship with biomass dynamics (Dbiomass) due to growth shifts from negative to positive across succession. (f) Diversity relationship with Dbiomass due to mortality shifts from positive to negative, due to dominance late in succession by low mortality species. [Adapted from: Lasky *et al.*, 2014]

1.10. Summary of some related studies around the globe

There are several literature on the study of species richness along the altitudinal gradient in the globe some of them is as presented in 1.1.

Table 1.1. Summary of some related studies around the globe

Title	Site	Location	Elevation (amsl)	Important Result	Authors	Methodology
Phytodiversity and growth form in relation to altitudinal gradient in the Central Himalayan (Kumaun) region of India	Central Himalaya	23:43:45 – 30:20:12 N and 78:44:30 – 80:18:45 E	200 m to 5800 m	Distribution of the Species Richness in the central Himalayas depends on altitudinal and climatic variation	Kharkwal *et al.*, 2005	Field sampling
Relationship between plant species richness and Biomass in an arid sub-alpine grassland of the Central Himalayas, Nepal	Central Himalaya Nepal	28:40 N & 88: 01 E	3500 m to 7000 m	The hump shaped relationship in arid Himalayan grassland in linear model.	Bhattarai *et al.*, 2004	200 sample were plots (1x1m) in two grassland site (site I and II), through random sampling, it followed a subjectively transect line, the central plots were made along the transect line
Density may alter Diversity–Productivity relationships in experimental plant communities				Aboveground, belowground and total biomass increased significantly with species richness and community density. However, a significant interaction between species richness and community density occurred for both total and aboveground biomass, indicating that the diversity – productivity relationship was complementary at higher than at lower density.	He *et al.*, 2005	Conducted a factorial experiment in which plant functional group richness was held constant at three, while plant species richness increased from three to six to 12 species and community density from 440 to 1050 to 2525 seedlings. Response variables included density, evenness and above- and belowground biomass at harvest.

Title	Site	Location	Elevation (amsl)	Important Result	Authors	Methodology
Relationships between aquatic plants and environmental factors along a steep Himalayan altitudinal gradient	Himalayan altitudinal gradient	26:36 – 28:13 N and 88:57 – 87:30 E	077m to 4980m	Arcto-tertiary floristic elements of the highest altitudinal region from the more widely distribution temperature and tropical species of lower regions.	Lacoul & Freedman 2006	Environmental variables were sampled in all seasons and the sampling was done using 10–20 (depending on lake size) quadrates of $1m^2$, stratified according to the approximate area of obvious communities present. Total cover could not exceed 100%. Finally, the Species diversity was calculated using the Shannon index.
An analysis of altitudinal behaviour of tree species in Subansiri district, Eastern Himalaya	Eastern Himalaya	26:55 – 28:42 N and 92:41 – 94:37 E	200m to 2200m	Detailed floristic studies to determine the break of changes between adjacent forest type and details of local species richness in high diversity area.	Behera & Kushwaha 2007	Field data was collected by randomly laid quadrants of 20x20m for tree species(> 15cm cbh) was considered as tree in every 200m steps with 8-quadrats per step
Altitudinal Pattern of Plant Species Diversity in Shennongjia Mountains, Central China	Shennongjia mountains central china	31:15 – 31:57 N and 109:59 – 110: 58 E	470m to 3080m	The relationship between the altitudinal pattern of plant diversity and the vegetation type in eastern china has been discussed	Zhoa *et al*., 2005.	Four main transects two in each southern and northern watershed, plots are in every 100m asl, size of the plots was 20x20m, 10x10m and 5x5m for forest (tree), shrubs and meadow respectively. 160 plots were laid
Anthropogenic pressure on tree structure and biomass in the temperate forest of Mamlay watershed in Sikkim	Temperate forest o Mamlay watershed in Sikkim	27:10:8 – 27:14:10 N and 88:19:3 – 88:24:23 E	300m to 2650m	Forest resource will become more desirable and many species are likely to disappear in due course of time.	Sundrial & Sharma 1996	Tree sampling was done using 10x10m quadrants listed CBH and DBH separated in four categories, seedling, samplings, small trees and big tree and the tree height is measured with bamboo stick. Finally, Diversity index was measured following Shannon and weaver (1949).
Distribution of vascular plant species richness and endemic richness along the Himalayan elevation gradient in	Himalayan elevation gradient in Nepal	Not available	1000m to 5000m	The dynamic hard boundary may have cause an increase in the extinction rate above 4000m the endemic species increase steadily from low to high	Vetaas & Grytnes 2002	Compare different null models of species richness pattern paper and based on over 1,00,000 herbarium specimen in addition field experience. The elevation gradient between sea

Title	Site	Location	Elevation (amsl)	Important Result	Authors	Methodology
Nepal				elevation		level and 6000m was divided into 60 and 100m vertical bond.
Biomass, Productivity, Leaf Longevity, and Forest Structure in the Central Himalaya	Central Himalaya	29:7 – 30:41 N and 79:15 – 79:40 E	300m to 3600m	To summaries data on forest characteristics from foothills to timberlines in the Indian central Himalayas. The data base for forest properties especially for broad leaved evergreen forest.	Singh *et al.*, 1994	Compilation of separate studies of forest structure, leaf phonology biomass and production.
Plant biodiversity patterns on Helan Mountain, China	Helan Mountain, China	38: 21 – 39:22 N and 105:49 – 106:41 E	1000m to 3556 m	The number of species initially increased and then declined, and the curve was markedly 'humped'. Richness was the highest between 1800 and 2000m a.s.l. Similar pattern in the relationship between α - diversity and environmental factors the variation of the Shannon–Weiner index highest at 1700m a.s.l.	Jiang *et al*,. 2007	Sampled all major vegetation communities, using quadrates, the size of which was 10 x10 m, 4 x 4m and 2 x2m and the field data were analyzed through CCA (Canonical Correspondence Analysis), and through Shannon–Weiner index for α-diversity and Sorensen index for β-diversity.
Plant diversity in the threatened sub-tropical grasslands of Nepal	sub-tropical grasslands of Nepal	26:35 – 28:57 N and 80:07 – 87:04 E	75m to 1441 m	In total 246 species from 48 families were recorded from the four protected areas. Changes in the impact of these disturbances, for example as a result of dam building or a change in the fire regime, will alter the diversity and distribution of the plant assemblages together with their associated fauna.	Peet *et al.*, 1999	A total of 200 plots were randomly located in the grasslands, 50 in each of the four protected areas. Plot sizes of 8.5x8.5 m, In each plot all plant species were recorded and the percentage cover of each species was estimated approximately.
Relationship between plant species richness and	Central Himalaya, Nepal	Not available	-	A significant unimodal relationship between species richness and biomass only in	Bhattarai *et al.*, 2004	Sampled two hundred plots (lm x lm) in two different types of pastures: common pasture and old field, which

Title	Site	Location	Elevation (amsl)	Important Result	Authors	Methodology
Biomass in an arid sub-alpine grassland of the Central Himalayas, Nepal				the common pasture. The turnover was lower in the old field than in the common pasture.		both have similar grazing practices. DCA2 (detrended correspondence analysis) used.
Development of a two-band enhanced vegetation index without a blue band		Not available		Demonstrate that the differences between EVI and EVI2 are insignificant (within ±0.02) over a very large sample of snow/ice-free land cover types, phenologies, and scales when atmospheric influences are insignificant, enabling EVI2 as an acceptable and accurate substitute of EVI. EVI2 can be used for sensors without a blue band,	Jiang *et al*., 2008	A linearity-adjustment factor β is proposed and coupled with the soil-adjustment factor L used in the Soil-adjusted vegetation index (SAVI) to develop EVI2.
Advantages of a two band EVI calculated from solar and photosynthetically active radiation fluxes	-	Not available	-	EVI2 performed slightly better than NDVI when comparing tower derived vegetation indices to MODIS and spectroradiometer derived vegetation indices.	Rocha & Shaver 2009	Calculated VIs from solar and photosynthetically active radiation fluxes, and validated these calculations against Vis derived from the Terra MODIS and ground-based spectroradio-meter measurements.
Higher levels of multiple ecosystem services are found in forests with more tree species	different parts of the country	Not available	8 (in the north) to 4 (in the south)	Reported that tree species richness in production forests shows positive to positively hump-shaped relationships with multiple ecosystem services. Soil carbon storage and understory plant species richness increased with tree species richness	Gamfeldt *et al*., 2013	Used a nationwide forest data set from the Swedish National Forest Inventory and the Swedish Survey of Forest Soils and Vegetation. The inventory uses a randomly planned regular sampling grid in a data set with a total of 4,335 sample plots distributed across 1,401 tracts

Title	Site	Location	Elevation (amsl)	Important Result	Authors	Methodology
Seasonal changes in the relationship between plant species richness and community biomass in early succession	Central German chernozem region, 15 km southwest of Halle.	Not available	--	This study demonstrated the importance of temporal dynamics and regional processes in understanding species richness productivity patterns. Between-species differences in individual number–community biomass relationships and their seasonal dynamics revealed ‘‘interspecific competitive exclusion’’ even though the species richness–biomass relationships were not negative or hump-shaped	Bischoff *et al.*, 2005	Sampling (10x10m) plots was conducted in three times, in May, June and July, all vascular plants were harvested in a circular area of 0.25m2 positioned at random within each plot. Care was taken that harvested areas were not sampled a second time. Plant species richness was determined and after drying at 80 ^{0}C for 48 hr. the biomass of each species was determined.
Life-forms and clonality of vascular plants along an altitudinal gradient in E Ladakh (NW Himalayas)*	East Ladakh (NW Himalaya)	32:26 – 33:36 N and 77:18 – 78:30 E	4180m to 6622m	404 species of vascular plant were recorded in which maximum species was found in 4500-4750m, the six different Raunkiaer life-form were distinguished among the total vascular flora in between 4200-4900m	Klimes Leos. 2003	The species number recorded in particular altitudinal intervals was randomly selected from a species pool which was defined as the set of species recorded in the whole study area.
Species richness of vascular plants, bryophytes, and lichens along an altitudinal gradient in western Norway	western Norway	60:13 N and 6:15 E	310m to 1135m	1. Bryophytes species richness has no statistically significant trend. 2. Lichen richness increased from the lower point and up to the forest limit. 3. The vascular plant species richness peaked immediately above the forest limit. 4. bryophytes and lichen species richness responds local scale and shading from forest tree respectively	Grytnes *et al.*, 2006	42 quadrates was laid each measuring 25m2, placed along the transect at intervals of approximately 20 vascular meters, very dry and wet area were avoid when placing the plots.

Title	Site	Location	Elevation (amsl)	Important Result	Authors	Methodology
Vegetation, species diversity and floristic relations along an altitudinal gradient in south-west Saudi Arabia	south-west Saudi Arabia	Not available	0 m to 3000m	Species richness increase from lower elevation to higher elevation up to 2000m highest in 2000-2500m, then the species diversity decreased while increasing elevation there is a remarkable change in vegetation species diversity and floristic relation	Hegazy *et al*., 1998	The 15 sampling site was studied, the quadrats size was $10x10m^2$ which is placed 300m away from the motorable road, the sampling site was divided in six altitudinal belt in between 0-3000m Elevation.
Predictive relations of tropical forest biomass from Landsat TM data and their transferability between regions		Not available		The relationship between predicted and measured biomass derived from vegetation indices differed markedly in both strength and direction between sites. Although the incorporation of test site location information into an analysis resulted in an increase in the strength of the relationship between predicted and actual biomass, considerable further research	Foody *et al*., 2003	Three types of predictive relation, based on vegetation indices, multiple regression and feedforward neural networks, were developed for biomass estimation at each site. For each site, the strongest relationships between the biomass predicted and that measured from field survey was obtained with a neural network developed specifically for the site
Tropical Forest Structure and Composition on a Large-Scale Altitudinal Gradient in Costa Rica	Costa Rica.	10:24 N and 88:00 W	30m to 2600m	Species richness, species diversity was highest in 300m, decreased both above and below this latitude the range of lowland species was similar to that of montane species; the species of high-diversity assemblages were similar in altitudinal niche breadth to species of low-diversity assemblages.	Lieberman *et al*., 1996	14 plots was placed with the total area 23.4h; tree >10Cm dbh were tagged, identified, mapped and measured in diameter and height.

Title	Site	Location	Elevation (amsl)	Important Result	Authors	Methodology
Altitudinal distribution of alien plant species in the Swiss Alps	Swiss Alps	Not available	200m to 2470m	155 species were recorded at 232 sites, the number of alien species per site declined strongly with increasing Elevation and there was no difference in species richness between road and railway sites, but there was a significant interaction with elevation.	Becker *et al*., 2005	Plant species are recorded from 232 sites of railways station and road sites, author recorded all alien vascular plant species.
Distribution pattern of trees along an elevation gradient of Eastern Himalaya, India	Eastern Himalaya	27 :30 – 28 :70 N and 88 :03 – 88: 57 E	300 to 4700 m	Recorded 3874 individual trees belonging to 171 species and 58 families no trees were observed above 4000 m. Species richness of trees followed a hump-shaped relationship with elevation showing a peak at around 1500 m.	Acharya *et al*., 2011	Laid five transects each in four vegetation types keeping a minimum of 150 m elevational distance between any two transects. Quadrats at every 100 m interval, 10 quadrats were laid per transect. Sampled 230 quadrats covering 4.6 ha area (0.2 ha per transect).
What drives elevationa patterns of diversity? A test of geometri constraints, climate and species poo effects for pteridophyte on an elevational gradient in Costa Rica	Costa Rica	Not available	100 m - 3400 m	The species richness of the 484 recorded species showed a hump shaped pattern with elevatio with a richness peak at mid elevations at 1700 m) strongly with climatic variables especially humidity and temperature. Area and specie pool were associated les strongly.	Kluge *et al*., 2006	Analysed species richness on 156 plots of 20x20 m and measured temperature and humidity at four elevations (40, 650, 1800 and 2800 m). Species richness patterns were regressed against climatic variables (temperature, humidity, precipitation and actual evapotranspiration).
Biomass and diversity of dry alpine plant communities along altitudinal gradients in the	Ladakh, western Himalaya	Not available	4,500 to 5,500 m asl	Observed unimodal relationship between plant species-richness and Elevation between 5,000 and 5,200 m, while it peaked between 3,500 and 4,000 m at	Namgail *et al*., 2012	Vertical transect at every 200 m alternatively on either side of a valley, starting at the valley-bottom. Along each of the vertical transects, we sampled phytomass in 2 x 2 m plots at

Title	Site	Location	Elevation (amsl)	Important Result	Authors	Methodology
Himalayas				entire Ladakh level. Reported a hump shaped relationship between aboveground phytomass and Elevation.		50-m elevational intervals
Forest vegetation patterns along an altitudinal gradient in sub-alpine zone of west Himalaya, India	west Himalaya	Not available	2800 - 3600 m asl	In all the sites, the mid Elevation stratum (3000 – 3200 m) showed high species diversity for all the life forms.	Gairola *et al*., 2008	
Variation in plant species richness of different life forms along a subtropical elevation gradient in the Himalayas, east Nepal	South-Eastern part of Nepal	26:42 N; 87:16-E), to (26:59-N; 87:21E)	100 - 1500 m asl	Herbaceous species, including herbaceous climbers, was unrelated to any of the climate variables. PET was strongly negatively correlated with elevation, and the following relationships were found between increasing PET and richness: (i) shrubs, trees and total species (sum of all life forms) showed unimodal responses (ii) ferns decreased monotonically, and (iii) woody climbers increased monotonically	Bhattarai & Vetaas, 2003	The number of species was counted in six plots (50x20m) in each of the 15 100 m elevation bands covering the main physiognomic structures along an imaginary transect. Potential evapotranspiration (PET, i.e. energy), mean annual rainfall (MAR), and their ratio (MI = moisture index) were evaluated as explanatory variables by means of generalized linear models (GLM)
Structure and regeneration dynamics of dominant tree species along altitudinal gradient in a dry valley slopes of the Bhutan Himalaya	Bhutan Himalaya	27:30 N - 89 : 52 E to 27:28N - 89:45E	1250 m - 3550 m asl	recorded 83 tree species comprising of 37 evergreen broad-leaved, 40 deciduous broad-leaved and six coniferous species belonging to 35 families. regeneration pattern of major dominant species shifted from inverse-J (lower altitudes), to sporadic (mid-altitudes), and	Wangda & Ohsawa, 2006	Fifteen sampling plots (P1–P15) were established along the altitudinal gradient from lower, warm, dry pine forest to upper, cool, humid conifer forest. Plot size varied from 400 m^2 to 800 m^2 due to difficulties in setting up equally large plots in a complex topography.

Title	Site	Location	Elevation (amsl)	Important Result	Authors	Methodology
				to uni-modal type (upper altitudes) corresponding to three regeneration trends.		
Diversity increases carbon storage and tree productivity in Spanish forests	Continental Spain.			A consistent positive effect o functional diversity on carbo storage and tree productivity wa observed in all seven forest type studied. This relationship was no linear, and the largest changes i carbon storage and tre productivity were observed a low levels of functional diversity Found a generally positive effec of diversity on carbon storag and tree productivity, supporte by both complementarity an selection mechanisms	Benito *et al*., 2014	Used 54,000 plots of the Spanish Forest Inventory and maximum likelihood techniques to quantify how climate, stand structure and diversity shape carbon storage and tree productivity
Altitudinal patterns illustrate the invasion mechanisms of alien plants in temperate mountain forests of northern China	Mount Tai and Mount Lao, Shandong Province, China.	Mount Tai, (N36:05 – N36:15 and E117:5– E117:24) and Mount Lao (N36:05 – N36:19, and E120:24 – E120:42).	Mount Tai 1532.5 m, Mount Lao 1132.7 m.	Two different richness patterns along the elevation gradient on Mount Tai and Mount Lao, alien species richness presented a consistent decreasing tendency with increasing elevation, suggesting that mechanisms driving native and alien species richness may be different. While native plants had many specialists at high altitudes and presented an obvious change of chorological groups along the elevation gradient.	Zhang *et al*., 2015	In Mount Tai and Mount Lao, the altitudinal gradient was systematically divided into thirteen and nine 100 m-wide elevation bands, respectively. A total of 38 plots were sampled in Mount Tai and 25 plots in Mount Lao.

1.11. Hills, Mountain and biodiversity

Mountain regions cover nearly one third of the earth's land-area and the Himalaya Hindu-Kush mountain regions comprised half of this area radiating from the Pamir knot. The Hindu-Kush mountain are rich in forest, flora and fauna, including biodiversity and vast natural recourses, which including the glaciated region and water recourse which remain still untapped (Dang & Mamgain, 2003)

Himalayan range covers the entire northern part of India passing through five major states of the country and the biodiversity of this entire region need to study intensively. Biodiversity is the variety of all forms of life, from plant and animal species to ecosystems. Earth's biodiversity provides food, shelter, fresh water, medicines, and spiritual solace. The abundance of life is unevenly distributed around the world with the highest concentrations of species in the tropics. Biodiversity losses can upset ecological cycles and adversely affect people's quality of life. The life-form of both, plants and animals, that characterize these bio-geographical regions is unique and unparallel, perhaps in the whole world, ranging from streaming hot foothills to ice cold alpine meadows.

1.12. The Sikkim Himalaya

Sikkim is located in the Eastern Himalayas and is globally renowned for its biological diversity and the traditional knowledge associated with it. Sikkim is a part of the global biodiversity hotspot. The unique terrain, climate and biogeography of the state have resulted in the sustenance of varied eco-zones in close proximity. Also the harmonious presence of several ethnic groups having their distinct identity and practising their traditional livelihood adds to the treasure house of knowledge related to this biodiversity. (Arrawatia & Tambe, 2011). Sikkim encompasses within its narrow belt a luxuriant floristic composition encountered nowhere else in a similar situation (Anonymous, 1994). Within the 75 km of aerial distance in Sikkim, the elevation is ranging from 284 m – 8598 m (Fig. 2.2) and covers all type of vegetation zones viz. tropical, sub-tropical, temperate, sub-alpine, alpine meadow and permanent snow-covered region. Keeping in view of above facts, Sikkim Himalayas is considered as an ideal site for studying the biodiversity pattern along the altitude.

1.13. The Hypothesis

Productivity of the bio-diversity of Sikkim Himalaya must be based on accumulated bio-geographical knowledge about species distribution and its treasured uniqueness. This requires knowledge about variation in plant richness in relation to human use that points to the core questions in the current biodiversity debate; does species richness increase with productivity and increased biomass? Or, is species richness highest under intermediate productivity and intermediate biomass? Does controlled disturbance through utilization of vegetation reduce biomass and enhance species richness? This study would also aim at evaluating such research questions at local scales focussing upon the East district of Sikkim.

Chapter 2

OBJECTIVES

Objectives

The biological diversity of the Sikkim part of the Himalayas is well-known for its extremely rich biological diversity, both plants and animals. Anonymous, 1994 Sikkim Himalaya is one unique region for the study of different physical and environmental gradients. (Acharya, et al., 2011) . However, till date, no such well-defined work has been conducted in this region. The present work is one such attempt to understand the patterns of biodiversity, the species richness and the production of biomass in the East District of Sikkim.

For the present study following three are the basic objectives:

1. To analyze the species diversity pattern along the elevation gradient
2. To estimate the biomass productivity pattern along the elevation gradient; and
3. To establish a relationship between species diversity and productivity pattern along the elevation gradient

The entire work will be done using the tools of Remote Sensing using suitable satellite imageries along with intensive ground trouthing to correlate and to explain the imagery and the actual vegetation condition

Chapter 3

STUDY AREA

STUDY AREA

The present study the small Himalayan state of India (Sikkim) was taken for the collection of field data, after analysis the collected field data was correlated with satellite product of the same area.

3.1. The Himalayan State of Sikkim

Sikkim, a small Himalayan state of India, with total area of 7096 km^2 lies in geographical coordinates between 27° 002 46² to 28° 072 48² N latitudes and 88° 002 58² to 88° 552 25² E longitudes. The location of Sikkim state in India is shown in Figure 3.1.

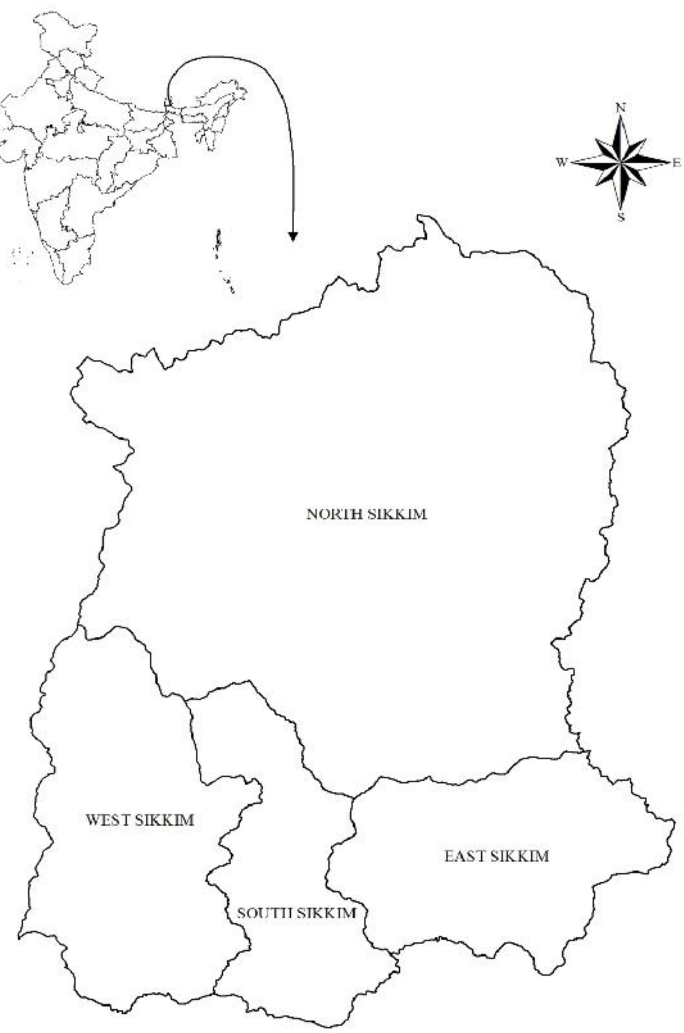

Fig. 3.1. Location map of Sikkim

It is located north of the Darjeeling-hills of West Bengal, and shares international border with Nepal in the west, China in the north and north east and Bhutan in the east. The state is extending approximately 114 km from north to south and 64 km from east to west. The entire part of it is interlaced with jungle clad ridges and deep ravines created through major mountain peaks and the river valleys and extremely dense forests (Champion & Seth, 1968). Sikkim is also referred as the "Abode of snow" by Risley, (1894) and it is also known as landform of resplendent floral and faunal aggregation. The state is predominantly mountainous virtually with no plain land. The altitudes Sikkim above mean sea level (amsl) varies between 284 m (at Melli) to 8598m (summit of Mt. Kanchandzonga). Within the 75km along the elevation one can cross the tropical to snowline area in the state figure 3.2.

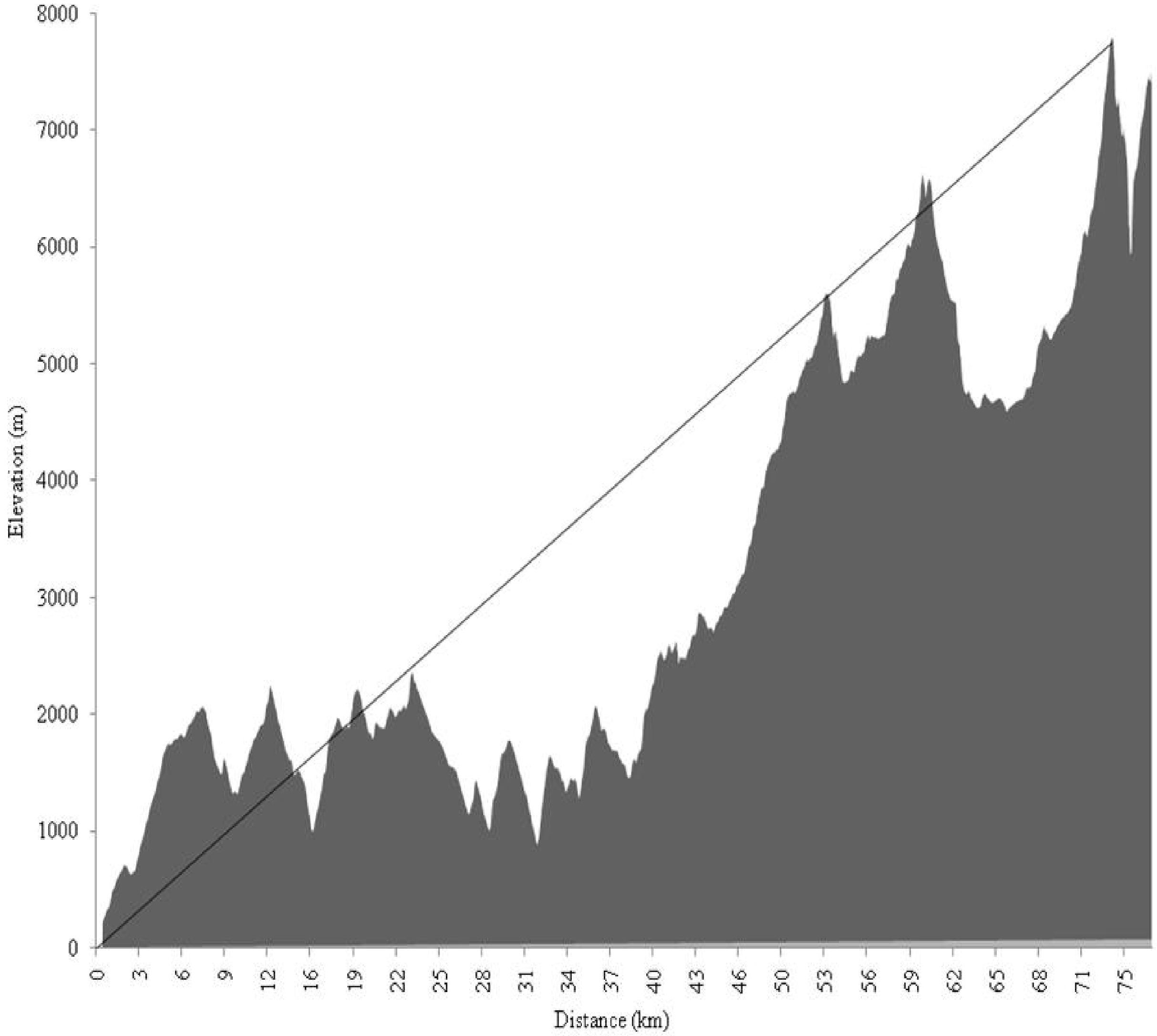

Fig. 3.2. Profile along the altitude of Sikkim with the distance in Kilometers

The highest mountain Mt. Khangchendzonga (8598 m) adorns the state with its beautiful snow covered mountain range. Sikkim Himalaya is the drainage basin of mighty rivers Tista and Rangit. The variation in altitude from south to north within a short distance has resulted in too much of micro-climatic variations. Sikkim can be divided into three botanical zones *viz.*, tropical, temperate and alpine, depending on the elevation and characteristics of the vegetation. The foothills of Sikkim are covered with forests consisting of the species of *Shorea, Haldina, Dalbergia, Dillenia, Artocarpus, Ficus, Bauhinia, Litsea; Lagerstroemia, Terminalia* etc. In the lower hill ranges (600 – 1500 m) the forests chiefly include the species of *Schima, Syzygium, Duabanga, Engelhardtia, Ficus, Castanopsis, Pandanus, Cyathea, Magnolia, Quercus, Saurauia, Photinia, Juglans, Leucosceptrum*, etc. (ISRO, 1994).

The temperate vegetation comprises of forests dominating with the species of *Alnus, Acer, Betula, Magnolia, Rhododendron, Larix, Berberis, Salix, Cotoneaster, Vaccinium, Daphne, Sorbus, Rubus* and the herbaceous species of *Aconitum, Anemone, Potentilla* etc. *Abies densa, Larix griffithiana, Tsuga dumosa, Picea spinulosa* and *Taxus wallichiana* var. *chinensis* represents the coniferous belt in the altitudinal range of 2700 – 3900 m. The Rhoddendron-Conifer forests comprise of the several species of *Rhododendron, Daphine, Betula* etc. mark the timberline at the altitude of 4000 m. The alpine vegetation which occurs above 4500 m and up to a limit of 5500 m is confined to moorlands of coarse meadows with many stunted and dwarf shrubby species of *Rhododendron,* prostrate plants of *Juniperus squamata*, and cushion-like herbaceous species of *Arenaria, Androsace, Aconitum, Cassiope, Saxifraga, Primula, Pinguicula, Sedum, Rheum, Saussurea, Gentiana, Kobresia, Carex* etc. (ISRO, 1994).

3.2. Distribution of Forest Vegetation vis-à-vis Elevation

Based on altitude, the vegetation of Sikkim is classified into following categories:

3.2.1. Low Hill Forests (tropical to sub-tropical, up to 900 m): From the base (244 m) to 900 m, semi-evergreen broad-leaved forests with trees, 24 – 36 m high are the main vegetation structure. The rainfall is heavy, even up to 500 cm annually. Epiphytes like orchids, aroids etc. are abundantly represented. The undergrowth is luxuriant and varied. *Shorea robusta* is very common, covering large tracts especially along the Tista and Rangit rivers. *Schima wallichii, Bauhinia purpurea, Toona ciliata*, *Stereospermum tetragonum, Bombax ceiba, Dillenia pentagyna, Lagerstroemia parviflora, Sterculia villosa, Terminalia myriocarpa, Terminalia tomentosa* and *Albizia* spp. are prominent components of these forests. Similarly, other trees occasionally met with includes *Garuga pinnata, Aglaia spectabilis, Amoora rohituka, Chukrasia tabularis, Evodia meliifolia, Ailanthus integrifolia* subsp. *calycina, Duabanga grandiflora, Tetrameles nudiflora, Celtis tetrandra, Castanopsis indica, Syzygium formosum* and *Magnolia champaca* together with laurels like *Ocotea lancifolia, Phoebe hainesiana, Phoebe attenuata, Litsea monopetala* and *Cinnamomum bejolghota*. Several species of *Artocarpus* such as *Artocarpus integer* and *Artocarpus chama* together with *Bischofia javanica* also occur. Large planted trees of *Ficus elastica* are often seen along the banks of the river Tista, alongside Pakyong road, and near Dickchu. Occasionally interspersed in the forest are *Ficus semicordata* and *Pandanus furcatus* Tree-ferns are not uncommon in the low-land forests of Sikkim (ISRO, 1994; Hajra & Verma 1996).

3.2.2. Middle Hill Forests (subtropical, 750 – 1500 m): These are largely dominating with many evergreen species. The trees are usually 20 – 30 m height in this zone. Epiphytes and climbers occur in large numbers. The undergrowth is not usually dense and consists of numerous herbaceous and shrubby species. *Castanopsis tribuloides, Castanopsis indica, Schima wallichii*, and *Phoebe* *hainesiana* are the commonest tree species between 750 m and 1200 m. *Magnolia champaca* and *Stereospermum tetragonum* may also seen in this region. Other prominent components of the forests of this region are *Drimycarpus racemosus*, *Juglans regia*, *Engelhardtia spicata*, *Spondias mombin*, *Exbucklandia populnea*, *Magnolia cathcartii*, *Magnolia hodgsonii*, *Saurauia napaulensis*, *Ficus auriculata*, *Ficus semicordata*, *Betula alnoides*, *Alnus nepalensis*, *Terminalia* spp., *Macaranga* sp., *Litsea monopetala*, *Ocotea lancifolia*, *Phoebe attenuata*, and members of Meliaceae. Large evergreen trees of *Quercus glauca*, Lithocarpus elegans, *Quercus serrata* and *Quercus griffithii* grow in dense formations between 1200 and 1600 m or above. Bamboos may also be found near human settlements in these hills. It will not be out of place to mention that *Cryptomeria japonica* is being extensively cultivated in this zone and that is creating problems with the survival of local species. It covers large areas and forms dense forests in areas between 1200 m and 2400 m. The ground vegetation underneath these forests is very little due to lack of sun light and unsuitable substratum. Only a few ferns are known to grow in the periphery these forests (ISRO, 1994; Hajra & Verma 1996).

3.2.3. Upper Hill forests (Wet temperate, 1500 – 2700 m):

The forests are evergreen with medium-sized trees, rarely over 24 m height. There are a number of deciduous tree species but those form only a small proportion. Oaks and laurels form large patches in otherwise mixed forests. The oaks have branched spreading crowns and are abundantly covered with mosses and other epiphytes. The forests are extremely thick and the requisite amount of moisture is available for the ground growing as well as epiphytic vegetation. The shelter of trees provided shade and prevents rapid air movements to a considerable extent. This results in a prolific growth of small herbs, shrubs and ferns on the forest floor. Woody climbers are frequent but not conspicuous. Several altitudinal zones may be distinguished by the preponderance of certain species such as laurels between 1800 and 2100 m, *Quercus lamellosa* between 2100 and 2400 m and *Lithocarpus pachyphyllus* between 2400 and 2700 m, though freely overlapping. *Magnolia cathcartii*, *Magnolia campbellii*, *Machilus edulis*, *Lithocarpus fenestratus* and *Castanopsis hystrix* are quite common in all the forests up to 2100 m. Between 2100 and 2400 m of altitudes *Quercus lamellosa*, *Castanopsis tribuloides*, *Acer campbellii*, *Magnolia doltsopa* and *Magnolia cathcartii* are dominant species. *Quercus lineata*, *Betula alnoides* and *Symplocos lucida* are also frequently met with former being quite prominent species. The oaks constitute the greater part of the trees of top canopy and Lauraceae is usually relegated to the second storey, though numerically predominant. Laurels like *Machilus gammieana*, *Machilus gamblei*, *Machilus edulis*, *Litsea sericea*, *Litsea elongata*, *Litsea kingii*, *Neolitsea zeylanica* and *Cinnamomum bejolghota* Sweet are not uncommon. *Alnus nepalensis* grows mainly along water courses and is the chief colonizer of new landslip areas. *Magnolia doltsopa* is one well known timber tree of this zone (ISRO, 1994; Hajra & Verma 1996).

Still higher up, between 2400 m and 2700 m or so *Quercus lamellosa*, *Lithocarpus pachyphyllus*, *Castanopsis tribuloides*, *Acer campbellii*, *Magnolia campbellii*, *Symplocos lucida* and *Taxus wallichiana* are the prominent elements of these forests. Above 2700 m in this zone *Lithocarpus pachyphyllus* occurs in pure formations. Under the shade of these trees *Rhododendron griffithianum* finds a favourable place. Dwarf bamboos, *Arundinaria* spp. are common as undergrowth at higher altitudes (ISRO, 1994; Hajra & Verma 1996).

3.2.4. Rhododendron-Conifer Zone (cold temperate or sub-alpine, 2700 – 3600 m):

The forests of this zone are also evergreen, mainly composed of Rhododendrons and conifers. Quite often *Lithocarpus pachyphyllus* and *Quercus lineata* formations are extending above 2700 m altitude and *Acer campbellii*, *Acer caudatum*, *Betula utilis* and *Magnolia campbellii* may also be met with though very infrequently. As one proceeds higher up, there is a gradual replacement of oaks by *Rhododendron arboreum*, *Rhododendron campanulatum*, *Rhododendron grande* and other species of the genus. *Betula utilis* is occasionally found in the high level *Rhododendron* forests at the head of Lachen valley near or above Yumaysamdong (3300 m). *Taxus wallichiana*. grows in the forests as one proceeds above Lachung. At about 2700m – 3000 m in northen valley, *Tsuga dumosa* grows in abundance and is the dominant tree. It also grows at Tsokha, West Sikkim. *Picea spinulosa* grows abundantly on all the hills around Lachen intermixed with *Tsuga dumosa* but are not extended above 3000 m. The bamboo, *Thamnocalamus spathiflorus* forms dense undergrowth in silver-fir forests, especially where fire has destroyed the tree canopy. *Abies densa* also occurs almost in pure formations between Karponang and Chhangu (East Sikkim), and Yumaysamdong to Thangu (North Sikkim) extending upto 3600 m or a little above. Few trees of *Salix disperma* are also seen growing near Thangu along the streams. *Rhododendron arboreum* forms scrub on steeper slopes at about 3000 m. Above the tree-line, the vegetation is a sort of mosaic of *Rhododendron campanulatum, Rhododendron wightii*, *Rhododendron thomsonii*, *Rhododendron cinnabarinum* and *Rhododendron decipiens* scrubs on slopes near Tsomgo (3900 m) and near Thangu (4000 m). *Rhododendron anthopogon*, *Rhododendron setosum* and *Rhododendron barbatum* may also be occasionally met with in such formations. Grasslands are frequent at 2700 m altitude and above. Some species of *Arisaema* may be found in open places. Various species of *Aconitum* grows abundantly on the forest-floor underneath Rhododendrons at high altitudes especially around Thangu (ISRO, 1994; Hajra & Verma 1996).

3.3. Occurrence and distribution of forest types

The forested vegetation of Sikkim, which is located entirely within the Eastern Himalaya, is with wide range of variations. The details of forest types in Sikkim are presented below in Table 3.1.

Table 3.1. Details of forest types found in Sikkim, Eastern Himalaya, India [Adapted from: Grierson & Long, 1983; Champion & Seth, 1968].

S. No.	Forest type as per Grierson & Long (1983)	Characteristic species	Altitud e range	Forest type as per Champion & Seth (1968)	
1	Sal (*Shorea robusta*) forest	*Shorea robusta* *Terminalia myriocarpa* *Schima wallichii* *Phyllanthus emblica* *Mallotus philippensis* *Bombax ceiba*	300 – 900	3C/Ci a	East Himalayan sal forests
2	Chir pine (*Pinus roxburghii*) forest	*Pinus roxburghii* *Woodfordia fruticosa* *Phoenix acaulis*	500 – 900	$9/C_{1b}$	Himalayan chir pine forests

S. No.	Forest type as per Grierson & Long (1983)	Characteristic species	Altitude range	Forest type as per Champion & Seth (1968)	
3	Subtropical forest	*Terminalia myriocarpa* *Tectona grandis* *Duabanga grandiflora* *Tetrameles nudiflora* *Dillenia pentagyna* *Ailanthus integrifolia*	300 – 900	3C/C_{3b}	East Himalayan moist deciduous forest
4	Warm broad-leaved forest	*Schima wallichii* *Engelhardtia spicata* *Macaranga nepalensis* *Castanopsis indica* *Choerospondias axillaris* *Ostodes paniculata*	900 – 1700	8B/C_1	East Himalayan sub-tropical wet hill forest
5	Alder forest	*Alnus nepalensis*	1500 – 2000	12/IS_1	Alder forest
6	Evergreen Oak forest	*Castonopsis* sp., *Quercus* sp., *Magnolia* sp., *Juglans regia* *Symplocos* sp., *Acer campbellii*	1700 – 2800	11B/C_1	East Himalayan wet temperate forests
7	Dwarf bamboo thicket	*Arundinaria maling* *Thamnocalamus spathiflorus*	2600 – 3100	12/DS_1	Montane bamboo brakes
8	Mixed conifer forest	*Tsuga dumosa* *Lithocarpus pachyphyllus* *Larix griffithii* *Picea smithiana*	2700 – 3100	12/C_{3a}	East Himalayan moist temperate forest
9	Conifer forest	*Abies densa* *Tsuga dumosa* *Sorbus macrophylla* *Prunus cornuta*	2800 – 3700	13/C_6, 14/C_2	East Himalayan dry temperate coniferous forest, Larch forest, East Himalayan sub-alpine forests
10	Alpine thicket	*Rhododendron* spp., *Betula utilis*, *Acer* spp., *Juniperus* sp.	3500 – 4500	15/C_1	Birch/Rhododendron scrub
11	Alpine scrub	*Juniperus* sp., *Rhododendron* spp., *Caragana* sp., *Ephedra gerardiana*	4000 – 5500	15/C_2, 16/C_1, 16/E_1	Dwarf *Rhododendron* scrub, Dry alpine scrub, Dwarf Juniper scrub

3.3.1 Forest Type Distribution as per Champion and Seth (1968)

Champion & Seth (1968) characterized the forests of Sikkim also and the forests of east district of Sikkim were divided as under:

3.3.1.1. Tropical Semi-Evergreen Forests-3C/C1 (300 – 900 m):

The vegetation of tropical semi-evergreen zone, located between 300 - 900 m altitudes, consisting of mainly tropical dry deciduous to semi-evergreen species with *Shorea robusta* as a dominant species. Sal is mainly found upto Tista valley. Some of the common tree species are *Terminalia myriocarpa*, *Dalbergia sissoo*, *Albizzia lucida*, *Haldina cordifolia*, *Callicarpa arborea* and *Anogeissus latifolia* with certain bamboo species as undergrowth. In the East division, this forest type is restricted to the low elevation areas of Singtam Range, Rongli Range and Pakyong Range. This forest type is also found in Amba Reserved forest (RF), Pacheykhani RF, Bhasme RF, Dhanuke RF, Burdang RF, Ralep RF, Khamdong RF, Tinek RF, Burung RF, Song RF Salingay RF, Tumlabong RF, Linku RF, Dikling RF Khani RF, Sitey RF, and Tarpin RF.

3.3.1.2. Sub-Tropical Mixed Broad Leaved Hill Forests-8B/C1 (900 – 1800 m):

Some tall evergreen species like *Schima wallichii* Choisy, *Alnus nepalensis*, *Prunus cerasoides*, *Engelhardtia spicata* var. *integra* are associated with other trees including species of *Macaranga*, *Castanopsis*, *Syzygium*, *Sapium* etc, are also seen in this altitude zone. This forest type is mostly found in tree clad areas (area outside forest). In the forest areas it is found restricted in areas like Karthok RF and Sumin RF of Singtam and Pakyong Range.

3.3.1.3. Upper Hill-Himalayan Wet Temperate Forests-11B/C1 (1800 – 2400 m):

This is a transitional zone between sub-tropical mixed broad leaved to sub-temperate zone with species ranging from *Machilus*, *Alnus*, *Quercus* and *Symplocos*. The evergreen tree dominates this region and the undergrowth is mainly of species of bamboos. This is the most broadly distributed forest type in the Sikkim state and is occupying about 221.19 km^2 of forest land, which is nearly half of the total forest area of 512 km^2 (WPR, 2013). This forest type is found in 43 compartments in Gangtok Block, Pangthang Block, Pathing Block, Rangpo Block, Pakyong Block, Kyongnosla Block, Assam Block and Rongli Block.

3.3.1.4. Sub-alpine Forests (2400 – 3000 m):

The typical temperate forests consists of species of *Abies* and *Pinus* mixed with *Picea*, *Tsuga* and *Juniperus* covering broad areas intermixed with species of *Quercus*, *Rhododendron*, *Machilus*and *Betula*. This forest type is distributed in Zuluk area and Kyongnosla area of East district of Sikkim.

3.3.1.5. Moist Alpine Forests (2700 – 3700 m):

The Moist alpine forest zone mainly consists of *Rhododendron* species intermixed with temperate evergreen species of plants. The forest cover becomes sparse as altitude increases and often restricted to grooves of the hills. This forest type is mainly found in Kyongnosla Block and Phadamchen Range in East Sikkim.

3.3.1.6. Dry Alpine Forests (3700 – 4500 m):

The vegetation of dry alpine vegetation is practically of scattered scrubs, often barren. Most of the species are of stunted thorny scrubs because of unfavorable conditions of a lesser amount of soil cover and severe frost. The species of *Juniperus*, *Berberis* and *Salix* are commonly available in this region. The forest type was divided into two zones. One is Alpine barren (without vegetative cover) and Alpine scrub (with bushes). This forest type is found in Tsomgu, Kupup, and Gnathang of East district Sikkim.

3.4. Location of East District

East district Sikkim lies at the south-eastern part of Sikkim. Geographical coordinate of the district is 27° 08'2.88" N to 27°25'32.28" N latitudes and 88°26'26" E to 88°54'25" E longitudes (Figure 3.3). The administrative jurisdiction of the East district of Sikkim spreads over a geographical area of 954 km^2. The total area comprises of 512.09 km^2 of reserved forest, 63.29 km^2 of *Khasmal* and *Gorucharan* forest land. A total area of 378.62 km^2 is under non-forestry areas which include Agricultural land, roads and urban areas, etc.

The whole tract is very mountainous and consists of series of ridges and valleys. The general topography of the district is highly undulating. Slopes ranged from moderately steep to very steep. Due to the abrupt rise of mountains and ridges form the drainage channels which often flow through deep gorges, there is conspicuous absence of flat land within the slope range of 1 % to 15 %. The tract dealt with is drained by river Tista, Rangpo Chhu, Ratey Chhu and Reshi Khola ('chhu' & 'khola' = river). The river Tista and Rangpo Chhu are the main rivers which have a number of perennial and seasonal tributaries. The famous Tsomgo and Mememcho lakes are the main sources of Rangpo Chu in the up-stream. The detailed of forest range of East district Sikkim is in Table 3.2.

Table 3.2. Detailed of Forest Range of East Sikkim *(Source:* FEW&MD, 2010)

Administrative unit	Forest Range	Area (ha)
East District	Gangtok	10408.97
	Kyongnosla	17980.97
	Pakyong	6452.09
	Pathing	3422.10
	Phadamchen	15733.12
	Rongli	12641.50
	Singtam	13873.72
	Tumin	5650.96
	Ranipool	9236.66
	Total	95400 ha

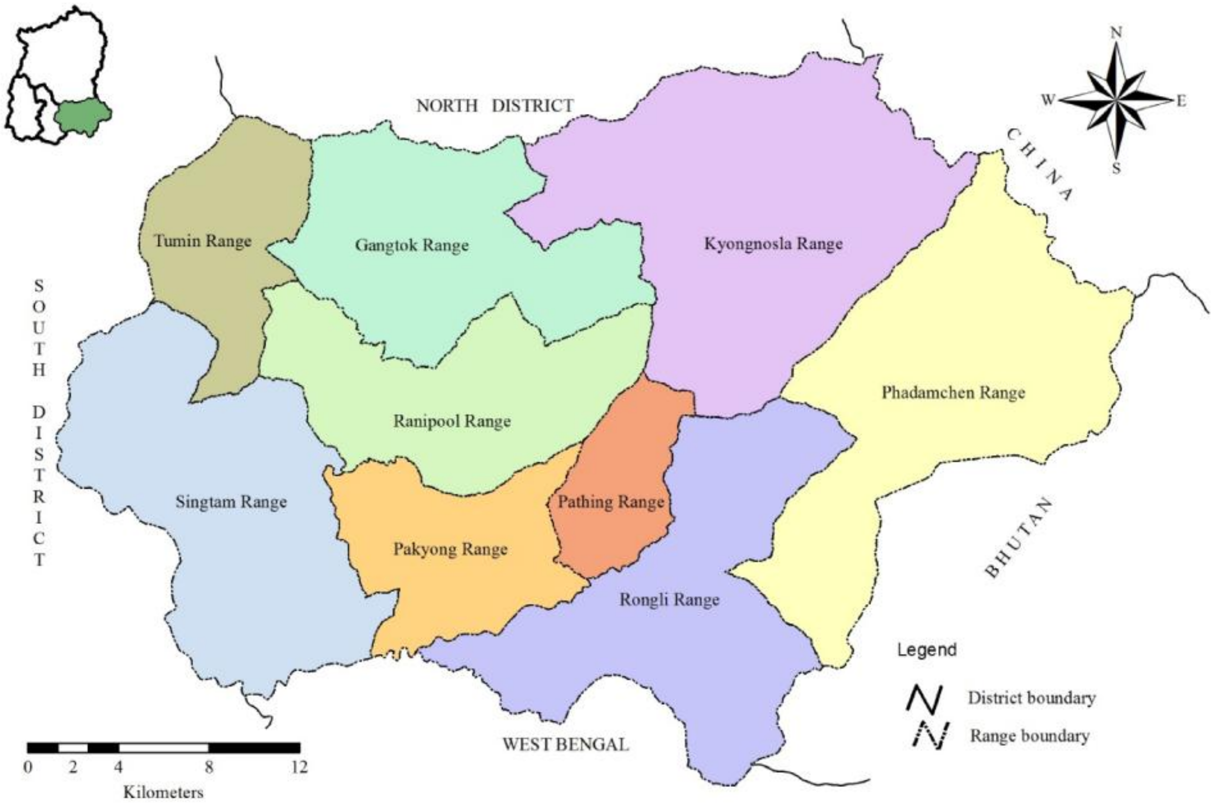

Fig. 3.3. Forest Range map of East Sikkim

East district of Sikkim shares the border with Bhutan, China and the state West Bengal. The border between China and Bhutan has several passes which had been used as the trade routes in the past. Important passes are Chola, Yak La, Nathula, Jelep La, Dong Chul La, and Batang La lying with China border and Dokala, Kephyak La, and Pangolakha with Bhutan border. In 2006 Nathula pass has been reopened for the trade related activities with China.

Recently, East district of Sikkim has been divided into four sub divisions *viz.,*

i. Gangtok sub-division with Gangtok Range, and Ranipool Range.
ii. Pakyong Sub-division with Pakyong Range and Pathing Range
iii. Rongli Sub-division with Rongli Range, Phadamchen Range; and
iv. Rangpo sub-division with Singtam Range and Rangpo forest block

The area of the reserved forest (RF) after excluding the RF of the protected areas is 301.33 km^2. As per the records available from the Land Revenue Department, Government of Sikkim, the division has nine forests range and fifteen forest blocks (Fig.3.3). The concept of compartmentalization of reserved blocks into separate compartments has been initiated recently. There are a total of 90 compartments in the division. The average area of each compartment is approximately 335 ha.

The human population of the district is 2, 45,040 s (DESM&E, 2013) with diverse climate, topography and rich biodiversity. East district of Sikkim is bounded by river Tista in west, river Dichu and Rathechu in North, river Reshi and Rangpo with Darjeeling district of West Bengal in South and Chola range in the north-east and Bhutan in south-east.

3.4.1. Protected areas in East District: Sikkim holds 31% of the geographical area under the Protected Area Network (PAs), much higher than country's national average. In the east district of Sikkim, a network of protected area is pervasive. There are three PAs located within the boundary of East district and are Fembong Lho Wildlife Sanctuary, Kyongnosle Alpine Sanctuary and Pangolakha Wildlife Sanctuary (Lepcha & Das 2012).

In East district of Sikkim elevation varies between 340 m at Rangpo to about 4649 m near Nathula. The lower part of the district has the tropical and sub-tropical evergreen forest (Rangpo, Singtam) followed by temperate forest and in the higher elevation the sub-alpine and alpine in (Gnathang, Nathula, Kupup and Chhangu). The landscape of the sub-alpine and alpine region being hilly terrain, rocks, covered with scrubs to thick forests in different areas, which ultimately turns out to be practically unfavorable for human settlements.

The vegetation of tropical and sub-tropical region of East district is consisting of the species of *Shorea, Haldina, Dalbergia, Dillenia, Artocarpus, Ficus, Bauhinia, Litsea; Lagerstroemia, Terminalia,* etc. In the lower hill ranges (600 – 1500 m) the forests chiefly include the species of *Schima, Syzygium, Duabanga, Engelhardtia, Ficus, Castanopsis, Pandanus, Cyathea, Magnolia; Quercus, Saurauia, Photinia, Juglans, Leucosceptrum* etc . The temperate vegetation comprises forests consisting of the species of *Alnus, Acer, Betula, Magnolia, Rhododendron, Larix, Berberis, Salix, Cotoneaster, Vaccinium, Daphne, Sorbus, Rubus* and the herbaceous species of *Aconitum, Anemone, Potentilla,* etc. *Abies densa, Larix griffithii*, *Tsuga dumosa*, *Picea spinulosa* and *Taxus wallichiana* represent the coniferous belt.

The vegetation of the alpine region of East district Sikkim is completely unusual. *Abies, Salix,* and *Rhododendron* scrubs are the most dominating type of vegetation supported by several minute spiny short herbs. Devoid of the predictable extremely harsh climate, it still supports a large number of animals including birds, mammals, fishes, etc. Perhaps it is also not wrong to say that it appears to be the home of some of the endemic animal species of Sikkim particularly of *Sikkim Stag, Blue sheep,* etc. Some notable places those fall under the region are Tsomgo lake, Kupup, Kyongnosla, Nathula, Memen Chho, Nathang, Padamchen, etc. As such, Tsomgo, Memen Chho, Bidang Chho, Lampokhkri etc. are some of the lakes those contribute substantially in terms of sustaining wildlife and promoting tourism. Most importantly, two important sanctuaries of Sikkim, namely Kyonglasha Alpine Sanctuary (31 Km^2) and Pangolakha Wildlife Sanctuary (128 Km^2) are located in this region. Some of the important nurseries of alpine medicinal plants are being developed in the nearby areas of these sanctuaries by the Forest Department, Government of Sikkim for *ex-situ* conservation of rare and endangered medicinal and other valuable plant species. Notable species under the conservation process includes *Aconitum ferox, Bergenia ciliata, Neopicrorhiza scrophulariiflora, Nardostachys jatamansi, Sinopodophyllum hexandrum, Panax pseudo-ginseng,* etc.

As elsewhere, floristic components representing here is entirely diverse from the one that appear in temperate and tropical regions. It upholds a majority of highly valuable economical plants including medicinal and aromatic, dye yielding, timber yielding etc. Different species of Rhododendrons, known for their medicinal and aesthetic values, are the major floristic components of this region. Interestingly, rare orchids of some genera e.g. *Orchis, Spiranthes, Habenaria* etc. are also nicely represented in the vegetation.

The alpine region of East district of Sikkim including the places like Nathula, Jalepla, Baba Mandir, Men-men Chho and Tsomgo lake have been already been identified as important tourist hubs by the government of Sikkim. Apart from these, the reopening of the trade center at Sherathang near Nathula between India and China further enriches the importance of the area.

Alpine and sub-alpine regions of East district of Sikkim covers an important strategic international border with China and kingdom of Bhutan. As such, the major areas of this region have been occupied for the national army and for their camps, etc. However, a negligible number of the highlanders including Sherpas, Bhutias, Tibetans and others in the form of laborers, supplier etc. partially inhabit the area.

3.5. Plant diversity in the Sikkim Himalaya

Sikkim Himalayan region is characterized by a rich floral diversity (Hajra & Verma 1996). This region is rich in floral diversity, housing many endemic elements and large number of species those have become rare, threatened or endangered (Pandey, 1991; Bhujel, 1996). Sikkim Himalaya is characterized by the rich forest cover and great drainage region of the rivers Tista and Rangit which constitutes the hills of Sikkim and Darjeeling district of West Bengal in the Eastern Himalaya. The area thus covers several ecological zones *viz.*, subtropical, temperate, sub-alpine and alpine. In such a small area sharp climatic differences in different ecological zones have promoted a rich flora (Rai *et al.*, 2000). Sikkim Himalaya together with Darjeeling hills of West Bengal has 577 species of trees, which come close to 20 species/km^2. The timber trees, fodder trees, fuel-wood trees, Drug/dye/fiber trees, other plants consisting the young formation of Sikkim Himalayan system.

Sikkim is also rich in medicinal and aromatic plant diversity, with well over 500 species of medicinal plants, many of them are reported to be endemic in Sikkim Himalaya (Lepcha 2011) Medicinal and aromatic plants make up the largest economic resource being tapped in the Himalayan region (Sharma & Sharma, 2010).

The Sikkim Himalaya is a synonym to Himalayan floral bounty and has the distinction of being recognized as one of the “Hotspots” in the Hindu Kush Himalaya for its high biological diversity (Arrawatia & Tambe 2011). It harbors 4000 species of flowering plants comprising of 38 species of Rhododendron, 450 species of Orchids, 9 Conifer species and 300 species of pteridophytes. With only 0.2% of total landmass of India it harbors more than 26 % of the total flowering plants of the country. This signifies the vast floral diversity of the state. The luxuriant forest cover also supports wide variety of non timber forest produces such as bamboos, canes, wild edible fruits and aromatic plants. The state is a repository of potential medicinal plants. Sikkim Himalaya is inhabited by three major ethnic communities Nepali, Lepcha and Bhutia each having distinct cultural heritage and excellent knowledge of the plant wealth in their environment. Initially, the Bhutia communities settled mostly in high mountains in alpine and sub alpine belts in north, the Lepchas restricted their settlement in dense forests in temperate and sub temperate forests of Dzongu, North Sikkim where as the majority of Nepalese lived in temperate and sub tropical belts. These ethnic groups lived in perfect harmony with nature worshipping high mountains, forests, rivers and lakes as their guardian deities to sustain their livelihood and protect themselves from famine, disease and other natural calamities. They made judicious use of the forests resources and forest produce for their basic necessities *viz.*, food, fuel, fodder and timber (Verma, 2009)

3.5.1. Endangered plants

The flora of Sikkim in the last 10 – 15 years were under great pressure due to biotic factors, mostly anthropogenic, like various developmental projects viz., construction activities, heavy deforestation by burning, tree-felling and clearing land for the preparation of agricultural fields. Landslides, forest fires, climate change, etc. are also partially due to anthropogenic activities and are increasing quite fast that is easily visible. These activities have destroyed many rich diversity centres. They led to environmental degradation due to which a large number of precious rare plants have been lost or endangered within a very short spell of time. These include: *Acer sikkimense, Pimpinella tongloensis, Pimpinella wallichii, Pternopetalum radiatum, Tibetoseris depressa, Arenaria thangoensis, Dendrobium treutleri, Cymbidium eburneum, Cymbidium hookerianum, Cymbidium whiteae, Cymbidium elegans, Cypripedium himalaicum, Tipularia cunninghamii, Diplomeris hirsuta, Paphiopedilum venustum, Zeuxine pulchra, Aconitum ferox, Cotoneaster simonsii, Picrorhiza kurrooa, Acronema pseudotenera, Angelica bulbigena, Ceropegia hookeri, Ceropegia lucida, Codonopsis affinis, Rhopalocnemis phalloides, Carex sahnii, Lloydia himalensis, Neottia acuminata, Calanthe alpina, Ophiorrhiza lurida, Nardostachys jatamansi, Dennstaedtia elwesii, Hymenophyllum levingei, Panax pseudoginseng, Calamus nambariensis, Livistona jenkinsiana, Begonia tenuifolia, Begonia satrapis, B. sanctata, Lagerstroemia minuticarpa, Cyclogramma squamaestipes* Tagawa, *Oreopteris elwesii, Christiopteris tricuspis, Rhynchospora rugosa* subsp. *brownii* etc. (Hajra & Verma 1996).

3.5.1.1. Number and status of endangered plants

The lists of some of endangered and endemic flowering plants of the area has been provided in Table 3.3.

Table 3.3. Endangered and endemic flowering plants known to grow in the East district of Sikkim *(Source:* FE&WLMD; *WPR. 2013)*

Species	**Family**	**Altitude (m)**	**Habit**
Anemone demissa	Ranunculaceae	3200-4600	Herb
Clematis andersonii	Ranunculaceae	-	Herb
Ranunculus brotherusii var. tanguticus	Ranunculaceae	3000-4300	Herb
Ranunculus sikkimensis	Ranunculaceae	ca 4800	Herb
Arenaria thangoensis	Caryophyllaceae	ca 4500	Herb
Stellaria decumbens var. *acicularis*	Caryophyllaceae	Above 3300	Herb
Uvaria lurida var. *sikkimensis*	Annonaceae	Upto 800	Climber
Berberis concinna	Berberidaceae	3350-3950	Shrub
Berberis umbellata	Berberidaceae	2000-3500	Shrub
Sinopodophyllum sikkimensis	Berberidaceae	3000-3500	Herb

Species	**Family**	**Altitude (m)**	**Habit**
Mahonia napaulensis	Berberidaceae	ca 2500	Shrub
Corydalis cavei	Papaveraceae	2700-4300	Herb
Corydalis changuensis	Papaveraceae	3660-3900	Herb
Draba humillima	Brassicaceae	4500-5000	Herb
Draba stenobotrys	Brassicaceae	4000-5000	Herb
Solms-laubachia platycarpa	Brassicaceae	2000-3000	Herb
Viola placida	Violaceae	2500-3000	Herb
Hypericum monanthemum subsp. *filicaule*	Hypericaceae	3500-4000	Herb
Hypericum williamsii	Hypericaceae		Shrub
Sabia campanulata var. *kingiana*	Sabiaceae	800-1600	Climber
Astragalus zemuensis	Fabaceae	ca 3600	Herb
Brachycaulos simplicifolius	Rosaceae	ca 4575	Herb
Cotoneaster sikkimensis	Rosaceae		Shrub
Potentilla saundersiana var. *subpinnata*	Rosaceae	4000-4900	Herb
Spiraea subrotundifolia	Rosaceae	3000-4300	Shrub
Saxifraga coarctata	Saxifragaceae	ca 4570	Herb
Saxifraga melanocentra	Saxifragaceae	ca 4400	Herb
Saxifraga pulvinaria	Saxifragaceae	4250-4570	Herb
Saxifraga inconspicua	Saxifragaceae	4265-5000	Herb
Saxifraga umbellulata	Saxifragaceae	3600-5300	Herb
Epilobium gouldii	Onagraceae	3600-4300	Herb
Trichosanthes cucumerina	Cucurbitaceae	Up to 2500	Climber
Begonia satrapis	Begoniaceae	ca 3600	Herb
Acronema nemaefolia	Apiaceae	ca 3600	Herb
Acronema pseudotenera	Apiaceae	3000-4000	Herb
Pimpinella sikkimensis	Apiaceae	1000-2600	Herb
Acronema hookeri	Apiaceae	2600-3600	Herb
Pimpinella tongloensis	Apiaceae	-	Herb
Pternopelalurn radiatum	Apiaceae	ca 3600	Herb
Pleurospermopsis sikkimensis	Apiaceae	4300-5300	Herb
Angelica nubigena	Apiaceae	ca 3800	Herb

3.5.2. Endemic plants

Endemics constitute another important element of biologically interesting plants. Being confined to narrow and restricted ecological niches, they are quite prone to extinction due to prevailing adverse biotic and/ or natural factors. Sikkim as such has comparatively less number of endemics because many of them range from Nepal to Bhutan. It is estimated that the total number of endemics truly confined to Sikkim may be 2 % of the total number in the floral elements. These include *Calamagrostis debilis*, *Calamagrostis tripilifera*, *Catabrosa aquatica*, *Cyathopus sikkimensis*, *Drepanostachyum intermedium*, *Poa gammieana*, *Trisetum flavescens*, *Carex sahnii*, *Rhynchospora rugosa* subsp. *brownii*, *Dendrobium treutleri*, *Anaphalis cavei*, *Anaphalis hookeri*, *Anaphalis subumbellata*, *Artemisia thellungiana*, *Blumea sikkimensis*, *Cremanthodium decaisnei*, *Cremanthodium palmatum*, *Youngia stebbinsiana*, *Gentiana glabriuscula*, *Gentiana recurvata* subsp. *prainii*, *Gentiana pluviarum*, *Gentiana recurvata*, *Inula macrosperma*, *Jaeschkea microsperma*, *Ligularia dux*, *Ligularia hookeri*, *Ligularia pachycarpa*, *Saussurea fastuosa*, *Saussurea laneana*, *Saussurea nimborum*, *Saussurea obscura*, *Saussurea pantlingiana*, *Swertia ramosa*, *Swertia rex*, etc. (Hajra & Verma 1996)

To conserve the depleting resources of this region, several attempts have been made in the recent past by the Government of Sikkim. Kanchanjanga National Park, Fambonglo Wildlife Sanctuary, Kyonglasa Wildlife Sanctuary and Kabi Sacred Groove are good examples where several endangered taxa have been conserved. A few botanical gardens viz. Jawaharlal Nehru Botanical Garden, Saramsa Botanical Garden in East district of Sikkim wherein exist and insist conservation of many species. But, at present, the main emphasis is to relocate or recollect the threatened taxa and attempts should be made for their *in situ* conservation. However, in some cases the help of advance technologies *viz.*, tissue culture, cryopreservation etc. can be used with advantage. In addition to this, the areas of diversity centres like Pangolakha Wildlife Sanctuary, Kyonglasa Alpine Sanctuary etc. should be brought under full protection with high level of restriction for the visitors (Lepcha & Das 2012).

3.5.3. Medicinal plants

Sikkim Himalayan region is the abode of a large variety of medicinal plants. *Prezwalskia tangutica*, *Nardostachys jatamansi*, *Picrorrhiza kurrooa*, *Aconitum luridum*, *Sinopodophyllum hexandrum*, *Dactylorhiza hatagirea*, *Taxus wallichiana*, *Ephedra gerardiana* and *Lycopodium clavatum* constitute the most important medicinal plants of the alpine zone. Several medicinal plants like *Dichroa febrifuga*, *Houttuynia cordata*, *Artemisia vulgaris*, *Rubia cordifolia*, *Panax pseudoginseng*, *Dioscroea deltoidea*, *Digitalis purpurea*, *Bergenia ciliata* are quite common in temperate and sub-temperate zones.

Tropical zone is also quite rich in the medicinal flora wherein plants viz. *Chilocostus speciosus*, *Vitex negundo*, *Solanum viarum*, *Cissampelos pariera*, *Woodfordia fruticosa*, *Oroxylum indicum*, *Alstonia scholaris*, *Abroma augusta* and to some extent *Rauvolfia serpentina*, *Terminalia chebula*, *Holarrhena pubescens* etc. grow in good number (Hajra & Verma 1996).

3.6. Elevation

Elevation is one of the important parameter of this study. The elevation of East district Sikkim is ranging from 340 m at Rangpo to about 4649 m near Nathula. Aspect and slope are other important parameters of this study, during our study we see the vegetation types on different slope and aspect, most of the study area covered in between 10º to 45º slope, over 60º slope is very less within the study area NRIS, 2006.

3.7. Soil

Soil is another important parameter to study the vegetation. The organic material of the soil has powerful effects on its development, fertility and moisture availability. Soil is the outer skins of the earth were all living and nonliving things exist to support the biological elements. Soil is classified in different classes, texture and types as per requirement. In the present study we used the soil data produced by the Soil Survey of India NRIS, 2006.

3.8. Climate

Temperature and rainfall are the major factors to study the vegetation of the study area. In Sikkim Indian Meteorological Department (IMD) have only two Meteorological Stations in Sikkim, *viz*. Gangtok and Tadong. Recently Indian Space Research Organization (ISRO) installed 18 Automatic Weather Stations (AWS) in different parts of Sikkim. And, in the present study, both, IMD and ISRO-AWS data has been used.

3.9. Drainage System

There are two major river systems in the state of Sikkim. They are Tista and Rangit. The Singalila and the Chola Ranges of Eastern Himalaya determine the boundary of the two rivers. The 98 percent of the state is drained by Tista, Rangit and their tributaries and sub-tributaries. As per Geological Survey of India (GSI, 2012), on the eastern side of Tista valley water contributed by Rilli, Rongpo, Rani Chhu and Dickchu are spectacular. The Rongpo Chhu, the biggest eastern tributary is symmetric barring a small part constricted towards north which emanates from Memenchho Lake in the Rongli Sub-division. The other eastern tributaries are symmetric. The lengths of the eastern tributaries are smaller compared to the western tributaries. The drainage pattern in Tista and Rangpo Chhu is mostly a mixture of trellis and sub-dendritic and sub-parallel. However, in the northern part directional trellis type drainage pattern is observed. The important rivers and streams flowing through East district of Sikkim is given below in Table 3.4. Additionally, presence of 77 wetlands has been reported from the East district. The wetlands have been identified and mapped through satellite remote sensing. The lists of important wetlands are in Table 3.5.

Table 3.4. Important rivers of East district of Sikkim (*Source:* NRIS, 2006)

Name of the River/Stream	Name of the River/Stream	Name of the River/Stream
Rongli Khola	Hante Khola	Taksam Chu
Sukdang Khola	Khari Khola	Yalli Chu
Chhuba Khola	Khali Khola	Leh Khola
Chhungi Khola	Chunabhatti Khola	Ramitey/Mendu Khola
Sawa Khola	Simana Khola	Aksu Khola
Rishi Khola	Kue Khola	Rangchang Khola
Lingtam Khola	Rangpo Khola	Di-Chu

Name of the River/Stream	**Name of the River/Stream**	**Name of the River/Stream**
Rankey Chhu	Sage Chu	River Tista
Navey Chhu	Malten Chu	Rora Chu
Nathang Chhu	Chhange Chu	Reshi Khola
Byu Chhu	Sanu Chhange	Tsang Rang Chu/Kali Khola
Lungze Chhu	Rong Chu	Re Chu
Jaldhaka river (Di-Chhu)	Richu Khola	Chuba Khola
Danak khola	Ralong Khola	Samdong Chu
Pache Khola	Kali Khola	Ratey-Chu
Dikling Khola	Khani Khola	Lay Khola
Rangdu Khola	Sang Khola	Gop Chu
Martam Khola	Pagla Khola	Buthang Khola
Aho Khola	Namphe Khola	Setei Khola
Andheri Khola	Richu Khola	Thekabong Khola, etc.

The lakes are the important water bodies and are the major sources of drinking water for all the living beings existing under an ecosystem. As of now Sikkim has 534 wetlands and 104 rivers. They have been mapped at 1:50K scale including the smaller water bodies occupying less than 2.25ha, with total area of 7477 ha (Sharma *et, al.,* 2010; NWA 2011; Panigrahy *et, al.,* 2012). There are 77 wetlands with the total area of 905 ha in the East district (Figure 3.4). The wetland serves as source of water for the wild animals and human beings. Most of these high altitude lakes are often being snow fed and remain snow covered during winter. However, some lakes tend to remain snow covered almost round the year. The dimensions of these lakes vary from a few meters to around hundred meters in length, but most of these lakes appear to be shallow and deep as well. These are permanent water bodies and it seems to have formed through the continuous process of so-called “glaciations”. Although all these lakes have their own specific names, some are devoid of, especially those, which are situated in isolated region. The lakes are pronounced as *Pokhri* or *Jeel* in Nepali, *Chhoka* or *Tso* or *Chona* in Bhutia; *Chho* or *Dah* by Lepchas. (Verma, 2009)

Some of the fascinating lakes of the East district in the alpine region are Tsomgo Chho, Bidang Chho, Men-men Chho etc. The congenial climate, rich biodiversity, blooming flowers, panoramic view of mountains and valleys, pristine lakes and forests contribute the growth of tourism in the state. It has been estimated that approximately 3 – 4 lakh tourists have visited this area in the recent past. The simulation based on the trend of tourists visited in past are expected to be jump up from 7.6 – 10.4 lakhs of tourists would visits Sikkim during the year 2017 (Joshi & Dhyani, 2009).

Therefore, they have been considered as an important contributor for the tourism sector in Sikkim, These resourceful lakes will certainly play a crucial role for such steady rise in the inflow of tourists that may have direct or indirect impact on the economic growth of the state as well. The drainage/ stream map of east district of Sikkim is in Figure 3.5.

Table: 3.5. Lists of important lakes in East district Sikkim (Source NWA 2011)

Name of the Lake	Name of the Lake	
Aritar lake	Jelep Chho	Bitang Chho
Chumpo Chho (Jor Pokhari)	Nampo Chho	Lam Pokhari
Chhokhya Chho	Men-men Chho	Tsomgo Chho
Chham Chho	Namnang Chho	Rathechhungu Chho
Nangpo Chho	Sherathang	Kupuk Chho
Laba Chho	Syebiruka Chho	
Three Sister Chho		

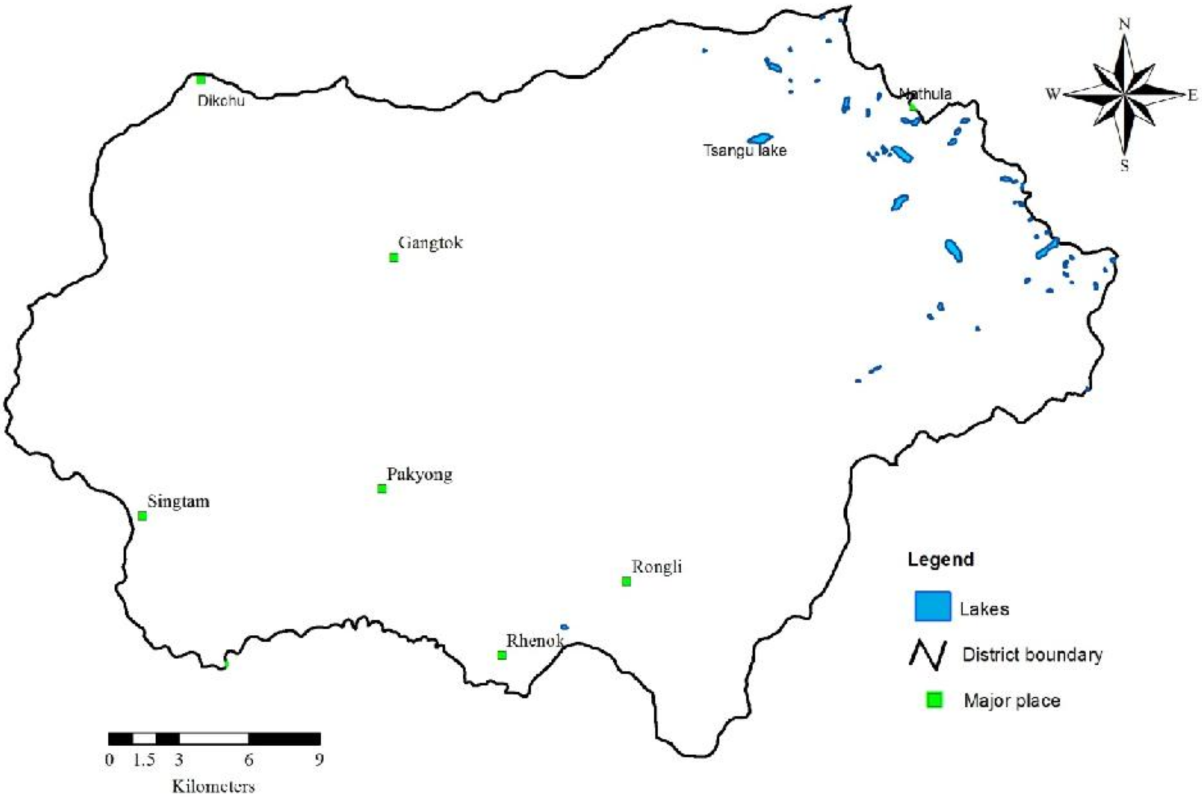

Fig.3.4. Wetlands in East Sikkim

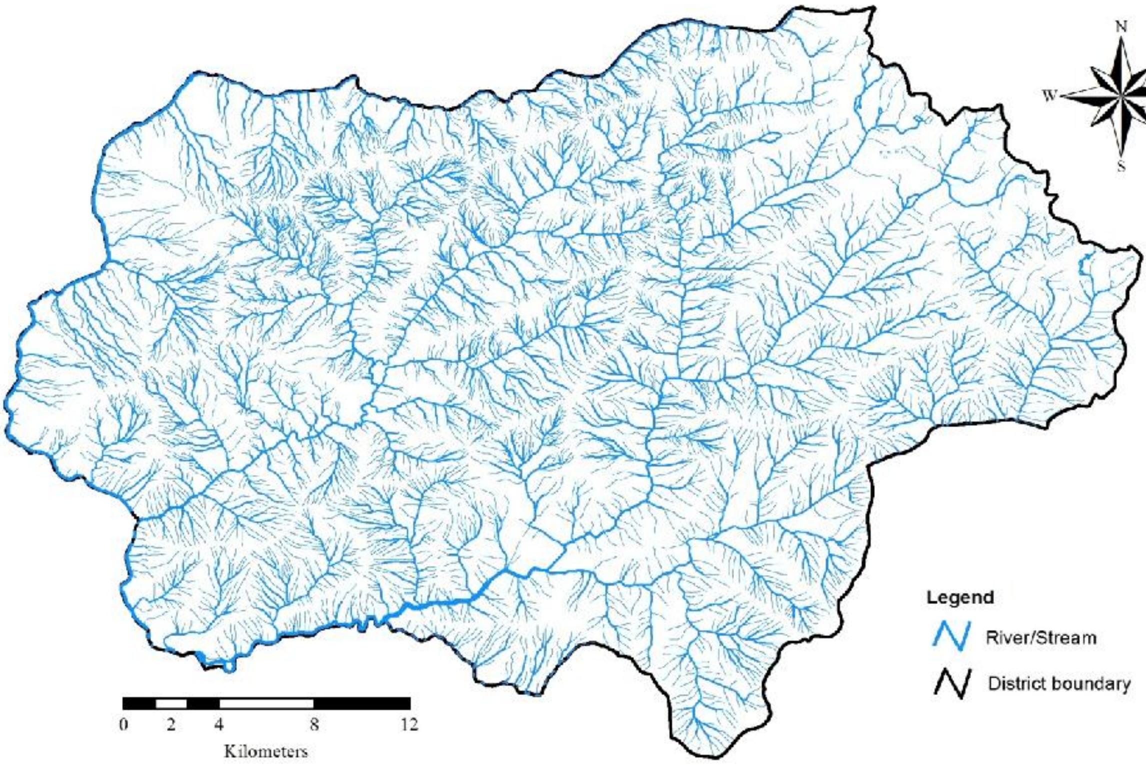

Fig. 3.5. Drainage/stream map of east district indicates very dense network

3.10. Communication network

Road is the most common and widespread among the modes of transportation. Roads are the arteries of a country and are most essential for progress. Roads of Sikkim are basically classified as national highways, state highways, district roads (major and minor) and village roads on their dimensions and functional status. Major roads of east district Sikkim along with NH-10 are shown in Figure 3.6.

Sikkim is one of the hilly states of the country under North East Region. There is only one National Highway linking the state with the other parts of India. NH- 10, along the bank of the River Tista, is the gateway to the rest of the world for Sikkim facilitating movement of goods and services. Thus, it may be considered as the lifeline of the state. The other important categories of roads in Sikkim are Border roads, State highways, district roads etc. Therefore, in Sikkim the roads affairs are being looked after by different organizations like Border Roads Organization, State PWD (Roads and Bridges), Rural Management and Development Department, etc. A part of the NH-10 falls within East district, between Rangpo and Gangtok, while Jawaharlal Nehru road connects the capital city Gangtok with Nathula on the Sino-Indian international boarder (Verma, 2009).

3.11. Socio-economic status

Sikkim, earlier a protectorate of India with a monarchy government came into existence as 22nd state of India in the year 1975. The population of the state is only 6, 07,688 as per the 2011census (DESM&E 2013). Sikkim being very rich in cultural heritage, many communities, cultures and customs of different

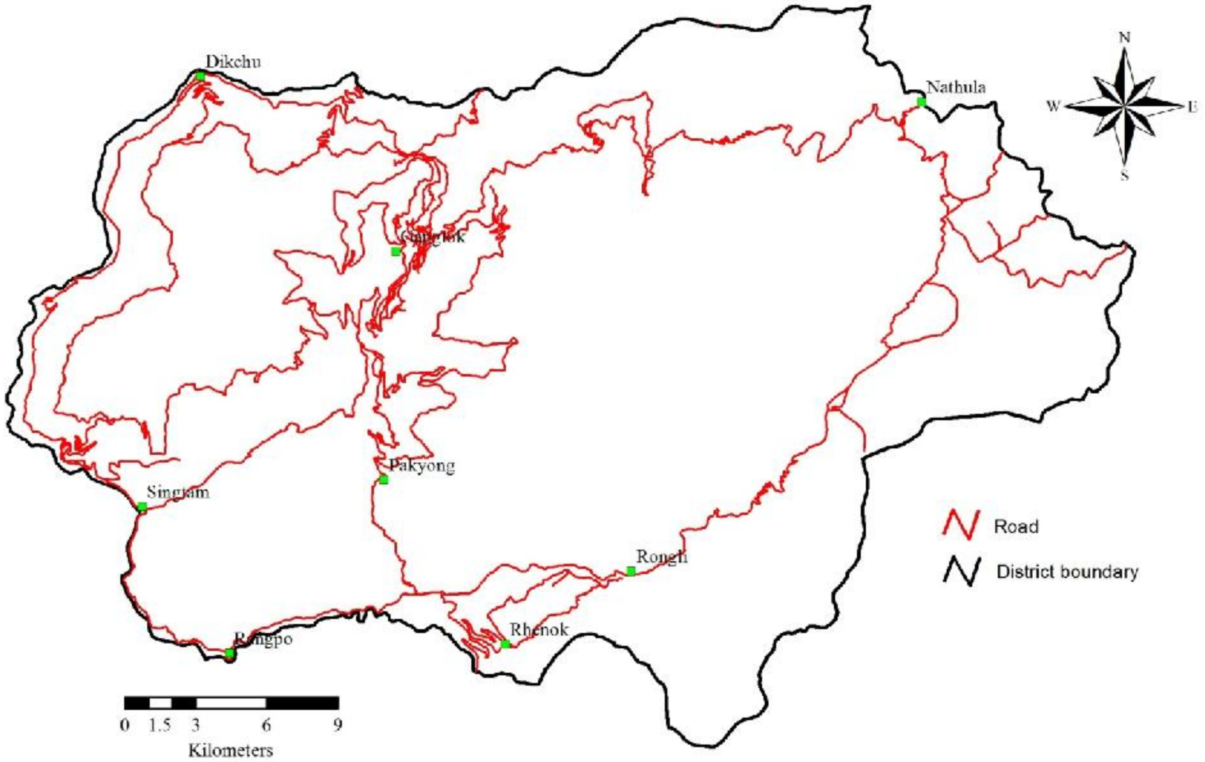

Fig. 3.6. Road network in east district of Sikkim shows less density

hues intermingle freely here in State, where majority (68 %) are Hindus, 28 % of the population are Buddhists and rest 4 % are others. In Sikkim, the predominant communities are Nepalis, Lepchas and Bhutias. In spite of many external influences, Sikkim has proved to be resilient accepting the benefits of progress while retaining their ethnic identity (Verma *et al.*, 2009).

The socioeconomic conditions of a place mostly depend upon the livelihood pattern and economic scenario of the region, which mostly comes from employment, agriculture as well as the business sector, which all are attributing to the socio-economic condition any region. Agriculture is the most important aspect of livelihood and healthy livelihood comes from healthy agricultural productivity. Many studies have confirmed that major crops of Sikkim now-a-days are in great threat and crop productivity is continuously going down during the last three decades. Drastic loss in productivity of many crops in the recent times are creating major problem for the farmers in Sikkim.

At the same time, productivity of the some crops viz., paddy, maize, ginger, potatoes have been declining as compared to the previous decades in the state. On the other hand, green vegetables which grow in the winter months are now-a-days susceptible to various kinds of pests and diseases. At present, the decreasing production in the agriculture sector is the key concern in Sikkim.

The present study in Sikkim Himalaya covers the elevation range of 500 – 3300 m, that is from the tropical forests (upto 900 m) to temperate conifer forests (above 2800 m) of East district (Champion & Seth, 1968). The Eastern Himalayan Mountain are part of IUCN recognized Himalaya Biodiversity Hotspot (Das *et. al* .,2013). With altitudinal range from the foot hills of the Himalaya, plains to the

Mount Everest, the climatic condition of these region is tropical hot to cold which cause wide distribution of verities of animals and vegetation types. In Sikkim within the 75 km distance one can cross the foot hills of Himalayas (284 m) to 8598m (Mt. Kanchandzonga) (Figure 3.2). Within this very small extend of the geographical area all vegetation zone started from tropical to cold alpine meadows can be accessed easily. So, this is an ideal region to study the species richness along the elevation gradient.

We studied the diversity pattern of trees, shrubs, herbs and epiphytes along an elevation gradient in East district of Sikkim Himalaya in India. The aim of the present study was to determine the species richness and to analyze species composition of plant as well as the distribution pattern of life-forms along the altitudinal gradient in the Sikkim Himalayas.

3.12. Fauna

The forests of East Sikkim is one of the reservoir for the numerous faunal species including mammals, birds, butterflies, beetles, snakes etc. This district also supports a large number of species, which have been enlisted for highly vulnerable and volatile mammalian species. The Indian Bison, Takin, Serow, Goral, Barking Deer, Himalayan Langur, Red Panda, Leopard Cat, Large Indian Civet, etc. and Pheasant, Tragopan and flock of partridges as well as large numbers of migratory birds like ducks were reported from the area (Lachungpa, *et al.*,2011).

Interestingly, the study area has also recorded one of the noted establishments for the migratory route of tiger, through the Neora Valley National Park in West Bengal, which is situated in the southeast part of East district. The record reveals that the tigers have used this belt of forest for more than hundred years ago. The Red (Barking) deer in eastern Sikkim through the display of trophies and hunting records. The deer is identified as a sub-species of *Cervus elephus*, either *C. elephus* subsp. *wallichi* with the probable synonym *C. elephus* subsp. *affinis* . However, too little is been known about it probably now extinct in Sikkim (Dolan & Killmar, 1988), considered it "almost as a mythical animal". However, R.F. Peacock in the 'Larger Deer of British India' (JBNHS 43(3): 1942) quotes a note from Col. F.M. Bailey for their appearance and distribution in between Chumbi Valley and Bhutan. According to him, occasional anthropogenic interference in the forests of Chumbi region (TAR) might have been driving those rare species of Deer back into Bhutan through the Pangolakha forest which he once noted in the summer of 1921 at above Lingmotang in the Chumbi Valley. Red Panda, Musk deer and Bharal (blue sheep) are among the highly endangered animals very rarely sighted during the last decade.

Chapter 4

MATERIALS AND METHODS

MATERIALS AND METHODS

The entire work is based on the data collected from different aspects of vegetation and remote sensing, particularly the satellite imageries. Apart from the imageries, all other data collected from the ground status following different techniques or gathered from secondary sources. Details of methodology are provided below.

4.1. Physiognomy, Climate, Edaphic and Forest Cover Mapping:

4.1.1. Elevation: The Digital Elevation Model (DEM) derived from SRTM **(***Shuttle Radar Topography Mission***)** and ASTER **(**Advanced Space borne Thermal Emission and Reflection Radiometer**)** data sources have been used to extract the elevation map using ERDAS-Imagine and Arc-GIS softwares. The district boundary of Sikkim was prepared using topographic map and an area of interest (AOI) for the study area (East district, Sikkim) was created. The ASTER-derived DEM was retained for further analysis, where the elevation varies from 340 m at Rangpo to about 4649 m near Nathula pass in the district. The district was divided into 100 m, 200 m and 300 m elevation steps for field sampling and analysis. The area estimate of each elevation zone was done using the Arc-GIS software.

4.1.2. Slope and Aspect: Slope and aspect are other major components to study the vegetation of hilly terrain, so the slope and aspect maps of the study area were prepared using the ASTER derived DEM images.

4.1.3. Climate: The climate data are equally important for the study of forest vegetation, so the meteorological data collected from different official sources and was utilized to derive the following climatic layers.

4.1.3.1. Temperature and Precipitation: The location map of the automatic weather station (AWS) and other meteorological weather stations were prepared. Further, the minimum, maximum and average temperature and precipitation maps were generated using appropriate interpolation technique using Arc GIS software.

4.1.4. Soil: Considering the soil is also a major component of plant productivity and diversity, the soil map prepared by National Bureau of Soil Survey and Landuse Planning (NBSS&LUP) was used to subset the soil map of East district, Sikkim in Arc-GIS format.

4.1.5. Forest type and density: Initially the Land use Land cover map of NRIS (Natural Resource Information System) Project of SSRSAC (Sikkim State Remote Sensing Application Centre) used for the field survey. Later on, the forest type and density maps prepared by Tambe *et al*.(2011) was used during the field survey. Sharma & Das (2015) was used in final interpretation. Initially, Research permission for survey obtained from Forests Environment and Wildlife Management Department, Government of Sikkim, before leaving to the field.

4.2. Plant diversity

The forest diversity of East district of Sikkim is mainly divided into five major classes i.e. (i)lower hill tropical semi-evergreen forests (300 – 900 m), (ii) middle hill sub-tropical mixed broad leaved hill forests (900 – 1800 m), (iii) upper hill-Himalayan wet temperate forests (1800 – 2400 m), (iv) sub alpine forests (2400 – 3000 m), (v) alpine vegetation (above 3000 m).[ISRO 1994]

4.2.1. Sampling design: Fieldwork, conducted using the nested quadrat design (Peet *et al*,. 1998; Das & Lahiri, 1997; Rai. 2006). Each site comprises of 20 x 20 m size for trees, 2 x (5 x 5 m) for shrubs and 5 x (1 x 1 m) for the ground covering plants (Fig.4.1). The epiphytes, lianas and host plants occurring inside the nested quadrat were noted according to their habit groups. The field format was designed to collect information on name, number, CBH and height of the trees using a Range Finder. Number of individual shrubs from two corners and number of herbs from the four corners and from the center of the sampling nested quadrat were recorded. Voucher specimens were collected for identification.

The field survey initiated with the optimum plans and information of the ridge including methods of collecting plant samples in the field (Jain & Rao, 1977). Due to the location of study in a difficult terrain, the progress of the work was slightly slow in the beginning. Reserve forests of east district lie in the difficult terrains and practically inaccessible to its interior and it is almost impossible to explore without the help of local guides. Therefore, in every field trip the local field guides were trusted to assist in the field sampling. Villagers also informed us about the regular visit of Himalayan black bear in to their villages.

4.2.2. Sampling strategy: Sampling is an important component of any piece of field oriented research program as it involves data collection from nature. There are different types of sampling methods, amongst those stratified random sample (SRS) is the most used one. In the present studies, simple SRS method used for collection of field data (Hansen *et al*., 1953). SRS is a basic type of sampling, since it can be a component of other more complex sampling methods. The principle of SRS is that every object has the same probability of being chosen. The random sampling avoids the sources of bias. It has every chance of sampling a species within quadrats in use that normally consist of a square frame. The purpose of using a quadrat is to enable comparable samples to be obtained from areas of consistent size and shape. (Peet *et al*,. 1998 Sharma, 2005). Sampling was done across varied slope and aspect condition.

The choice of quadrat size depends largely on the type of survey being conducted and is generally determined experimentally in the field (Misra, 1968; Santra et al., 1989). But for the present work a standard and largely used quadrate sized used in the Eastern Himalayan region (Das & Lahiri, 1997; Rai, 2006) has been used.

Equipment and material used in the field includes: GPS (GARMIN), Range Finder, measuring tape (100 m), tailor's tape (1.5 m), field note book, polythen bags (as substitute to a Vasculum), nylon rope, colored flags, secator, bamfok (cutter),blotting sheets, tags, pen, pencil, sharpener, eraser, data sheet, etc.

4.2.3. Field data collection: Attempts were made to lay the field sampling quadrat in relatively less or undisturbed areas located between 500 – 3300 m elevations AMSL steps that covers as much as 2800 m distance from the elevation point of view. In the lower elevation of 500 – 600 m, 600 – 700 m the data was collected from the Sang Khola, and Sumin Lingey forest range in the elevation range between 700 – 800 m, 800 – 900 m and 900 – 1000 m. Data was also collected from 32 other places located near Namli, ninth mile and Namchebong forest block. In the elevation, range of 1000 – 1300 m, data was collected from Linding, Lower Ranka and Middle Barbing forest block. Similarly, data pertaining to forest density was collected from Bhusuk, Ray, Perbing and Berbing representing elevation steps of 1300 – 1500 m segment of the study area. Yalli, Bhusuk, Ranka, PangthangTakshi, Bulbulay, TsangeySenti, PakyongKarthok, Upper Luing forest area were selected for the collection of data representing elevation range of 1500 – 1800 m. The forest areas of Barapathing, Assam Lingzey, GokthangRongli, ChaureyKharka, KyonglasaLatui have been selected to collect the data for the 1800 – 2400 m segment. Similarly, for the higher elevation range of 2400 – 3300 m the survey locations include Kyonglasa, Latui, Assam Lingzey, Rongli, Yalli, Rachela, Padamchen, Bhusuk, and Pathing.

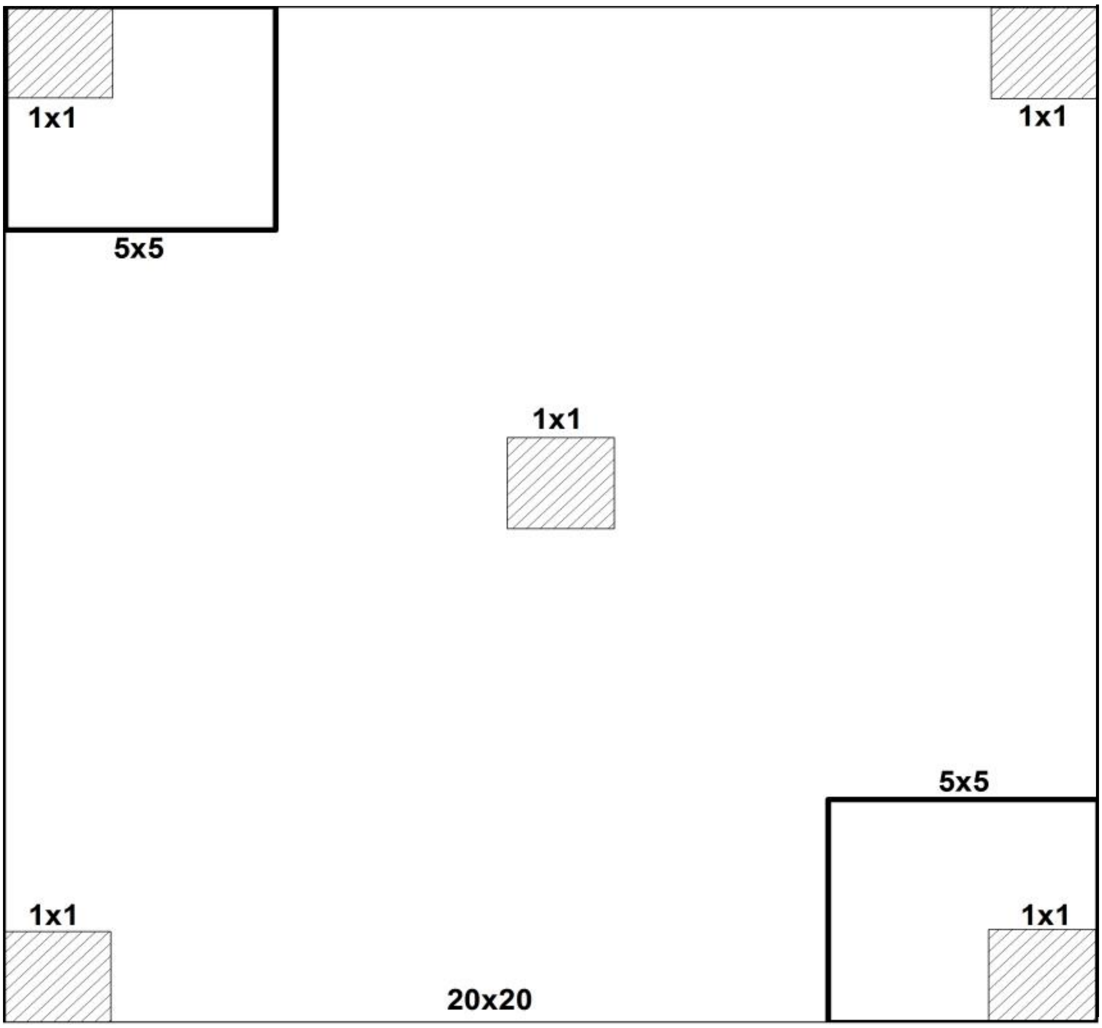

Fig. 4.1. Nested Quadrat design (20x20m for trees and lianas, 5x5m for shrubs and 1x1 m for herbs)

Fig. 4.2. Field photograph taking the CBH of tree in steep slope (left) counting of herb and noted in the prescribe format (Right)

4.2.3.1. List-Count Data: The field data like name (Local/botanical) and number of individuals of each species representing in each quadrate were recorded. CBH and height for each individual (with of 10 cm CBH) of trees were also recorded for the volume and productivity calculation. The unidentified plant sample specimens were collected in the poly-bags for identification.

Many of the species could be identified on field. Some could be identified through their local/ vernacular names that were further translated using nomenclature conversion literature. Further, the unidentified specimen were properly tagged and collected for identification in the herbarium of Botanical Survey of India (BSHC), Sikkim, Gangtok and in the Taxonomy and Environmental Biology Laboratory, Department of Botany, University of North Bengal (NBU) Siliguri. Collected specimens were processed into mounted Herbarium specimens and were deposited in the NBU-Herbarium.

Further, for the nomenclature and the family delimitation for each species <*http://www.theplantlist.org/*>was consulted.

3.2.4. Data entry and design: The Microsoft office excels software was used for the analysis of collected data. After data entry in tabular form, most of the statistical analysis also were made using this software. The entire data set of all life forms (tree, shrubs, herbs and lianas) of 28 elevation steps (each step has 8 quadrat) has been treated similarly.

3.2.5. Data analysis: For the calculation of species richness, data analysis was carried out in Microsoft excel. Collected field data was coded and tabulated into excel sheet. At first, data collected in the field targeting different elevation zone of the study area. Altogether, 224 (20 x 20 m) plots eight each in every 100 m elevation step up to 3300 m elevation of study area (28-elevation steps) is completed. The data includes tree species name, number and CBH. The shrubs species name and number from 5 x 5 m quadrat, herbs species name and number from 1 x 1 m quadrat as described above were entered into excel spread sheet. The epiphyte and lianas species and number data was collected as species name and total number of individual from each20 x 20 m quadrat. All 224 (20 x 20 m) quadrat for trees, 448 (5 x 5 m) quadrat for shrubs, 1120 (1 x 1 m) for herbs have been completed. After complete entry of about 16000 individual the data used for further analysis on biodiversity and biomass.

4.2.5.1. Dominance analysis: In order to assess the relative share of each species in plant community, Importance Value Index (IVI) for a total score of 300 has been calculated using the frequency, density, abundance, relative frequency, relative density and relative abundance. (Basistha *et. al.*, 2010)

4.2.5.1.1. *Frequency (F) and Relative Frequency (RF)*: Frequency(%)**:**The frequency refers to the degree of dispersion of individual species in an area and usually expressed in terms of percentage occurrence (Sharma, 2005, Basistha *et. al.*, 2010). It is calculated using the equation:

$$\text{Frequency (\%)} = \frac{\text{No. of quadrats in which the species occurred}}{\text{Total number of quadrats studied}} \times 100$$

Frequency does not give the correct idea of the distribution of any species, unless it is correlated with other character (Sharma, 2005).

$$\text{Relative Frequency} = \frac{\text{Frequency of the species}}{\text{Total frequency of all the species}} \times 100$$

4.2.5.1.2. *Density (D) and Relative Density (RD)*: Density is an expression of the numerical strength of a species where the total number of individuals of each species in all the nested quadrat divided by the total number of nested quadrat studied (Sharma, 2005). Density is calculated by the equation:

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

$$\text{Relative Density} = \frac{\text{Density of the species}}{\text{Total density of all the species}} \times 100$$

4.2.5.1.3. *Abundance (A) and Relative Abundance (RA)*: It is the study of the number of individuals of different species in the community per unit area. The quadrat method, samplings are made at random at several places and the number of individuals of each species was summed up for all the quadrat divided by the total number of quadrat in which the species occurred. It is represented by the equation (Sharma, 2005):

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

The relative frequency, relative density and relative abundance has been calculated to calculate the IVI value

$$\text{Relative Abundance} = \frac{\text{Abundance of the species}}{\text{Total abundance of all the species}} \times 100$$

4.2.5.1.4. *Important Value Index* (IVI): The concept of 'Important Value Index (IVI)' has been developed for expressing the dominance and ecological success of any species, with a single value (Mishra, 1968, Sharma, 2005). This index utilizes three characteristics, they are (i) Relative frequency,(ii) Relative density and (iii) Relative abundance. The three characteristics computed using frequency, density and abundance for all the species falling in all the quadrat by using the following formula.

IVI = Relative frequency + Relative abundance + Relative density [RF + RA + RD]

The IVI of all species, Genus, and Family has been calculated. The detail is given in (**Annexure I, II, III**).

4.2.5.2. Diversity Indices*:* For the assessment the species richness, diversity, evenness and dominance of the species different diversity indices like Shannon-Wiener diversity index (H), Margalef index species richness (M), Simpson's dominance index (D), and Pielou's index (E) (Evenness) were determined using following formulae.

4.2.5.2.1. *Margalef index (M)[Sp Richness]:* The margalef index (M) is study using the following formula

Margalef index (M)[Sp Richness] (Margalef, 1958) = M=n-1/lnN

Where: M = Margalef index

n = total number of species

N= total number of individual in the sample

ln= natural logarithm

The Margalef index has no limit value and it shows a variation depending upon the number of species

4.2.5.2.2. *Simpson's index (1/D)[dominance]:* The Simpson index calculated using following formula

Simpson's index (1/D)[dominance] = D= Σ (*p*i)2

Simpson Index (1/D): It measures the probability that two individuals are randomly selected from a sample will belong to the same species. Simpson gave the probability of any two individuals drawn from clearly large community belonging to different species. It has been measured by the given formula: D= Σ (*p*i)2

A value of D ranges from 0-1; zero represents no dominance and 1, for maximum dominance; viz: only one species in the sample data (Greenberg, 1956; Berger & Parker, 1970).

For representing diversity (D), Simpson index are subtracted from their maximum value of 1; i.e. 1- λ

The Simpson's reciprocal index 1/D values start with 1 as lowest possible figure. This figure would represent a community containing only one species. The higher the value the greater the diversity.

4.2.5.2.3. *Shannon-Wiener index (H')[Diversity] (1949)*

Shannon-Wiener index (H')[Diversity] = $H = -\sum_{i=1}^{s} \text{Pi} \log \text{Pi}$

Species evenness, richness, and diversity indices as Shannon-Weiner (Shannon & Weaver, 1949) and Simpson Index (Simpson, 1949) were used to evaluate the plant species diversity.

Shannon- Weiner Index assumes that individuals are randomly sampled from the independent large population and all the species are represented in the sample. Shannon diversity is very widely used index to compare diversity between various habitats (Clarke & Warwick, 2001). Shannon-Weiner diversity Index fall in between 0 to 5. It was calculated in order to know the species diversity in different habitat (Hutchison,1970) based on the abundance of the species by the following formula:

H´ = - [" Pi lnPi] Where, H´ = Diversity Index; Pi = is proportion to each species in the sample; lnPi = natural logarithm of this proportion. The presence of the one individual species is not necessarily indicative of the species being present in a large number.

4.2.5.2.4. *Pielou's index (e) [Evenness] (Pielou, 1966).*

Pielou's index (e) [Evenness] (Pielou, 1966) = (E=H/lnn)

For calculating the evenness of species, the Pielou's Evenness Index (e) was used (Pielou, 1966). Where e = H / lnn

H = Shannon – Wiener diversity index

n = total number of species in the sample (Muhammad, 2009). The values of evenness ranges form 0 to 1.

4.2.6. Species, Genera and Families richness along the altitude

The entire data sets has been divided into three different elevation bands for the analysis purpose, (i) 100m elevation band, (ii) 200m elevation band, (iii) 300m elevation band along the altitude of East district, Sikkim. In 100m elevation, 28 elevation steps identified; in 200 m elevation band 14 elevation steps were identified and in 300 m 10 elevation steps were identified. The entire data in different bands compared to see the effect of scale along the elevation bands between 100m, 200m and 300m, respectively.

4.2.6.1. Along 100 m 200 m and 300 m elevation step: The final dataset of excel spreadsheet used for analysis of the species richness along the altitude of 100 m elevation steps using excel pivot table. The species richness, genera and family richness along the 100m, 200m and 300m elevation steps were also calculated. The result so obtained from the analysis was highlighted in the results. It was tried to fit in the 1st order polynomials, but result was poor. Further, it then tried with second order polynomials (i.e. non-linear) that shows good fitness. Similar exercises were done in 200 and 300m elevation steps too.

4.3. Endemic species

The field data of the study area are taken for the selection of the endemic plant. The list of endemic plant species of this region were checked with Lepcha (2011). The final list of endemic plant species of this region was compared with our final list of plant species in the excel spreadsheet. Finally list of available endemic plants of study area was prepared.

4.4. Productivity (Biomass): There are several methods to estimate the biomass (Whittaker, 1966; Ovington, 1968).Some of the commonly employed methods can be divided into two categories, viz. (a) destructive and (b) non-destructive. In the present study, we used non-destructive method for biomass estimation. The height, Diameter at Breast Height (DBH) relationship to volume/biomass is well-formulated (Kira & Ogava, 1971) in the non-destructive method. Conventional methods have the limitations of extrapolation at large level and destructive in nature. The generation of algometric equations involve cutting of tree, though, this method is impractical in view of the current environmental problems (Rawat & Singh, 1988). So, non-destructive methods became clear with minimum or no damage to the trees.

Estimation of the total accumulated biomass any forest ecosystem is important for assessing the productivity and sustainability of the forest. The field data of excel spread sheet were used for further calculation of volume and biomass. First the trees above 10cm CBH were segregated as individuals below this size were treated as saplings and below 5cm CBH of tree species are considered as seedlings.

4.4.1. Name of the species: The first parameter recorded is the plant form, namely tree, shrub, herb or liana, followed by the name of the species. Among the trees, species differ in shape, size etc. It is also important to estimate the density of trees of each species in sample plots (20 x 20 m). Biomass for tree species estimated using the volume equation of FSI (1996).

4.4.2. Circumference at Breast Height*:* The second most important parameter of field data is circumference at breast height/diameter at breast height of the tree, this parameter used to calculate the volume or weight of the tree, which can converted to biomass per unit area (tonnes/hectare). The diameter and height can be used for estimating the volume by simple equations.

4.4.3. Height of trees: Next to DBH/CBH, height is the most important indicator of the volume or weight of a tree and used in many allometric functions along with DBH. To measuring the height of tall trees, 4 – 5 tall individuals were measured using the Range Finder and then for other tree species. Eye or ocular estimation was also practiced especially those with overlapping canopies.

4.4.4. Indicator parameters for non-tree species: Height and DBH are not measured for non-tree species such as herbs and grasses; where different data, such as species, total number individuals, etc. were recorded and were used for the calculation (Chaturvedi & Singh, 1987; Rawat & Singh, 1988; Singh & Singh,1991) and the biomass is estimated in terms contribution of percentage.

4.4.5. Basal area: the basal area of individual tree is also calculated in Microsoft-excel using the CBH with the formula:

Basal area = πr^2

4.4.6. Volume estimation: The volume of all vascular plants of the study area was estimated using the final dataset of species richness. More column, such as CBH/DBH, tree height, volume formula equation and biomass formula equation has been added in excel sheet for calculation of volume. To calculate volume, the tree diameter was first calculated. The available volume equation formula, tree volume equation (FSI, 1996)was used for total volume estimation. In most of the trees, the local volume equation has been used for those volume equation was not available. In the present work also the volume equation for the species of trans-Himalayan region like- Nepal, Bhutan, Darjeeling, Arunachal Pradesh and some part of the Garhwal Himalaya, Uttarakhand were used for some of the trees. The list of volume equation formulae is provided in **Annexure IV**.

4.4.7. Biomass estimation: the biomass of the individual tree calculated using the volume of the tree. In order to calculate the biomass the specific gravity of some available local species of trees has been used. Such basic data was collected from the Forest Department, Government of Sikkim. The' general' specific gravity is used for those trees whose specific gravity was not available. The volume equation and specific gravity used in this study listed in **Annexure IV.**

The above ground biomass (AGB) of each 100m and its multiples were plotted across the elevation to adjudge the relationship.

4.4.7.1. Biomass along 100 m elevation steps: The final dataset of excel spreadsheet of biomass estimated used for analysis of the biomass along the altitude of 100 m elevation steps using excel pivot table. The biomass pattern in the form of graphs and tables are highlighted in the results chapter section.

4.4.7.2. Biomass along 200 m elevation steps: The dataset of excel spreadsheet of biomass estimated further used for analysis of the biomass along the altitude of 200 m elevation steps using excel pivot table. The biomass pattern in the form of graphs and tables are highlighted in the results chapter section.

4.4.7.3. Biomass long 300 m elevation step: The biomass of the study area along 300 m elevation also estimated in the same manner and was presented in the form of graphs and tables and are properly highlighted.

4.5. Satellite based productivity:

To estimate the productivity of the study, MODIS MOD 17 data, Landsat-8, data product was used. Net Primary Product (NPP) estimated by using Normalised Difference Vegetation Index (NDVI) EVI2, which considered as a surrogate of NPP and vegetative growth of terrestrial ecosystem. MODIS data with a spatial resolution of 1km also used to estimate NPP and GPP (Gross Primary Productivity) of the study area.

4.5.1. MODIS Productivity: MODIS-Data, the Moderate Resolution Imaging Spectro- radiometer, or MODIS, sensor resides aboard the Terra and Aqua platforms, offering a view the Earth's surface every 1 – 2days. The MODIS sensor collects data within 36 spectral bands, ranging in wavelengths from 0.4 µm to 14.4 µm provides us with imagery at a nominal resolution of 250m at nadir for two bands, 500m resolution for 5 bands, and the remaining 29 bands at 1 km.

4.5.2. MODIS Algorithms: As such the Algorithm Theoretical Basis Documents (ATBD's) serve as useful background for understanding the development of the MODIS products and their application in the study of land, ocean, atmosphere and Level 1 characteristics of the Earth-atmosphere systems. Some of the Algorithm Theoretical Basis Documents (ATBD's) are the original documents for a MODIS product while others have been updated or supplemented by other approaches that help the user community to effectively use the MODIS products. MODIS Level 1B Product User's Guide was used to know about the product and data.

4.5.3. Landsat-8 NDVI and EVI: On the other hand, the Lansat-8 satellite imagery also use to calculate the EVI2 of the Sikkim Himalaya.

4.5.3.1. Data download and process: The cloud free Landsat satellite imagery of April, June, September and December 2013 has download from http://earthexplorer.usgs.gov/ in geo.tiff format. The image was further staked using Arc GIS software further using the ERDAS-Imagine software.

4.5.3.2. Normalised Difference Vegetation Index (NDVI): Using the cloud free satellite imageries of 6th December 2013, the NDVI of the study area was generated, using the *ERDAS-Imagine software and* further NDVI value was extracted using Arc-GIS software for further analysis.

4.5.3.3. *Enhanced Vegetation Index (EVI)*: EVI is often employed as an alternative to NDVI because it is less sensitive to some limitations. However, such data was not tested in EVI because of blue band issues. In this study it was decided to test the data in EVI2 because it needs only two bands (red and near-infrered).An index was generated as per the formula given by Jiang et al.(2008) to extract the EVI2 Value from Landsat imagery.

$$\mathbf{EVI\,2 = 2.5\ \frac{N - R}{N + 2.4\,R + 1}}$$

Where, N = NIR reflectance, and R = Red reflectance.

4.5.3.4. Data download and process: The website <http://modis.gsfc.nasa.gov/data/dataprod/dataproducts.php?MOD_NUMBER=17> has been accessed to download the MODIS NPP data of the study area and the NPP value has been extracted in csv format for further analysis. The values required for the correlation of the data with other parameters.

4.5.4. Relationship between MODIS productivity field biomass: Finally, MODIS NPP extracted using Arc GIS software from MODIS data product to see the relationship between field productivity (Biomass) and MODIS Productivity NPP using Microsoft Excel. Both maps also prepared to see the difference between field based NPP (Biomass) and MODIS based NPP.

4.5.5. Relation between field biomass Satellite EVI: Finally, the maximum EVI2 value from out of the four month Landsat-8 imagery has taken for further analysis. Landsat EVI values were compared with field based biomass productivity.

4.6. Relation between species diversity and Plant productivity (biomass) along the altitude:

In the present study, a relationship was established between species diversity and Plant productivity (biomass) along the altitude of Sikkim Himalaya utilizing the data of species richness and the biomass dataset. Finally, the significance test for 100 m, 200 m and 300 m elevation steps has been carried out using the second order polynomials.

4.7. Multivariate analysis:

Relation between species richness with other parameter (temperature, rainfall, aspect, slope elevation and soil) was done using the multivariate analysis using the R-software.

4.7.1. General Linear Model (GLM)

The relations between species richness environment relationships were tested using General Linear Model (GLM). The GLM usually refers to conventional linear regression models for a continuous response variable with respect to continuous and/or categorical predictors (McCullagh & Nelder, 1989). The GLM is mathematically identical to a multiple regression analysis, but stresses its suitability for both multiple qualitative and quantitative variables. It implements any parametric statistical test with one dependent variable, including any factorial ANOVA (Analysis of variance) as well as ANCOVA (covariance analysis) designs. Because of its flexibility to incorporate multiple quantitative and qualitative independent variables, GLM are a large class of statistical models for relating responses to linear combinations of predictor variables, including many commonly encountered types of dependent variables and error structures. In addition, GLM models for rates and proportions, binary, ordinal and multinomial variables and counts data were used. GLMs are frequently used by plant ecologists to model species response to environmental data (Yee & Mitchell, 1991; Franklin, 1995). GLMs quantify relationships between the dependent variables and the predictors (Austin *et al*., 1996), and are commonly used for macro ecological analyses or to forecast its geographic distribution (Austin *et al*., 1996; Lobo *et al*., 2001; Lobo & Martin-Piera, 2002). It is having great advantages for dealing with different error structures particularly the presence/absence data the common data type available for spatial modelling of species distributions (Rushton *et al*., 2004) and is commonly used in environmental research (Zimmermann & Kienast, 1999).GLMs are an extension of the linear (least-square regression) modelling that allows models to be fitted to data with errors following other than (only) Normal distributions, and for dependent variables following other than a Normal distribution, such as the Poisson, Binomial and Multinomial models (McCullagh & Nelder, 1989). GLMs of the binomial model family overcome this difficulty by linking the binary response to the explanatory covariates through the probability of either outcome, which varies continuously from 0 to 1 (Dobson, 2002). Other model families allow fitting response variables of different restricting characteristics (Poisson regression, etc.).

4.7.2. GLM Modelling in R

Maps have been extracted from each quadrat area by using the values of rainfall, temperature, elevation, slope, aspect and soil maps for each; and a csv file was prepared from Arc-GIS attribute table, as an input for modelling. GLM used to examine the relationships between species richness and elevation. The response variable, species richness, is a discrete data type (counts) may follow a Poisson error distribution with log link function (McCullagh & Nelder, 1989). Modelling was performed using R software (R Core Team).

The present study was based on the field data collected from different altitude range of East district of Sikkim. It was expected the hump shaped relation between species richness along the altitude. There are several studies around the globe; on species richness and biomass along the altitudinal gradients, where some projected the positive relationship and others projected the negative relationship. There are various ecological factors which directly and indirectly involve in the relationship between species richness and biomass accumulation along the altitude.

Chapter 5

RESULT:
SPECIES RICHNESS ALONG THE ALTITUDE

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It was expected that the species richness will change along with the increase or decrease of altitude. The altitude of the entire study area vary from 340 to 4649 m, which covers from tropical to alpine-snowline areas. This is also linked with the topography, aspects, etc. Present study covered all such conditions to understand the species richness at different localities.

5.1. Topography

Topography consists of elevation, slope, aspect soil etc of the study area.

5.1.1. Elevation: Elevation of east district, Sikkim ranges from 340 m at Rangpo to about 4649 m near Nathula pass, the highest point of the district. However, about 70 % area of the district is falling under the elevation range of 500 – 3300 m. Study designed at 100 m, 200 m and 300 m elevation steps helped in investigation and analysis across scale. An elevation zone map at each 200 m step has been shown in Fig.5.1; and their area statistics has been provided in Table 5.1.

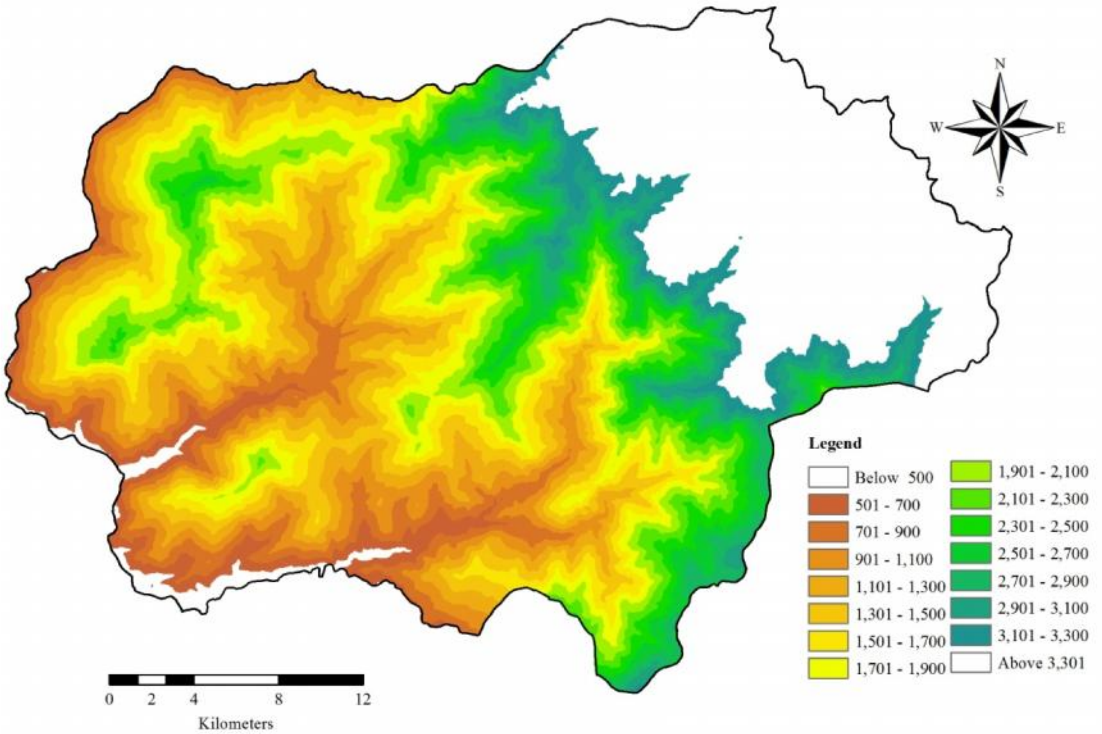

Fig. 5.1. 200 m elevation steps map of the study area showing over 70 % of the area of East district of Sikkim for the study

Table 5.1. Geographical area of each elevation band of study area

Elevation band, mid elevation value (m)	Area in ha.		
	100 m band	200 m band	300 m band
550	1284	3404	5581
650	2120		
750	2177	4707	
850	2530		9279
950	3437	6750	
1050	3313		
1150	4383	8264	13248
1250	3881		
1350	4983	8826	
1450	3842		11614
1550	4351	7771	
1650	3420		
1750	3284	7076	9977
1850	3792		
1950	2901	6127	
2050	3226		8012
2150	2300	4786	
2250	2485		
2350	1780	3456	5318
2450	1677		
2550	1862	3416	
2650	1554		4649
2750	1821	3096	
2850	1275		
2950	1329	2490	3848
3050	1161		
3150	1359	2442	
3250	1084		4067
3350	1247	2983	
3450	1736		

A maximum of 4983 ha area is available at 1300 – 1400 m elevation, whereas the minimum of 1084 ha area is available at 3200 – 3300 m elevation range. This followed the cumulative pattern of maximum area of 8826 ha and 13,248 ha at 1300 – 1500 m and 1100 – 1400 m respectively; and minimum area of 2442 ha and 3848 ha at 3000 – 3200 m and 2900 – 3200 m respectively (Table 5.1). In a mountainous area of East district, the available area at different elevation zones is important in the sense that the amount of area available for forest vegetation could have a direct bearing on species diversity content.

Fig. 5.2. Elevation step-wise area availability at 100 m elevation steps

It is found that Geographical area vary along the elevation with around 8000 ha, the highest, at the elevation of 1500 m. However, the geographic area then gradually decrease with the increase in elevation (Fig 5.2).

5.1.2. Slope and Aspect

Slope: Slope plays a key role in shaping the species diversity content. Slope of east district was classified as gentle (1^0 – 15^0), moderately steep (16^0 – 30^0), steep (31^0 – 45^0) and very steep (>46^0) categories. About 17 % of the total geographical area falls under gentle slope category, >50 % land falls under moderately steep slope, about 27 % falls under steep slope and around 3 % of the district falls under very steep slope categories (Fig.4.3).

Aspect: Aspect is also an important factor in vegetation characterization and aspect of east district was divided into four classes i.e., NE (northeast = 0 – 90°, SE (southeast = 90 – 180°), SW (southwest = 180 – 270°) and NW (northwest = 270 – 360°). The north-facing slope receives much less sunshine than the south-facing slope. The area increased from NE to SE, SW and NW while the southern slope

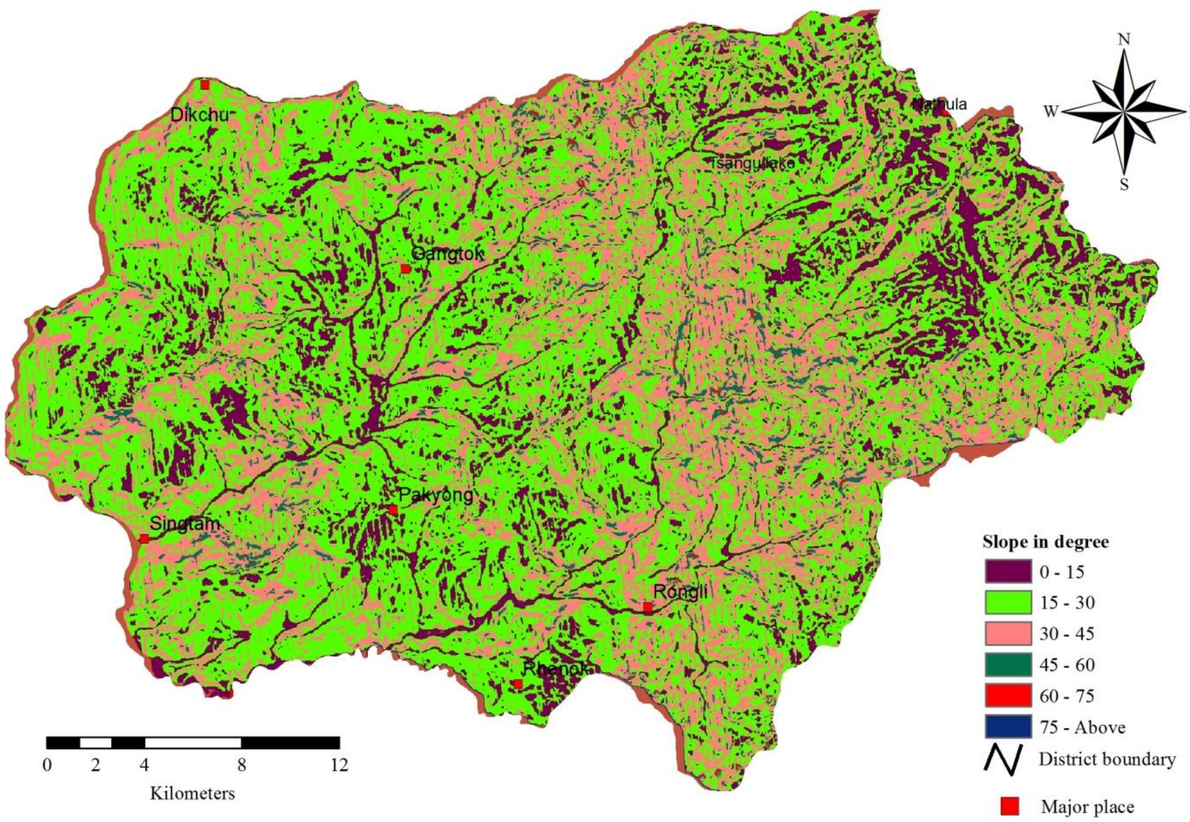

Fig. 5.3. Slope map of East district that indicates more area is under 15 – 30^{o} slope

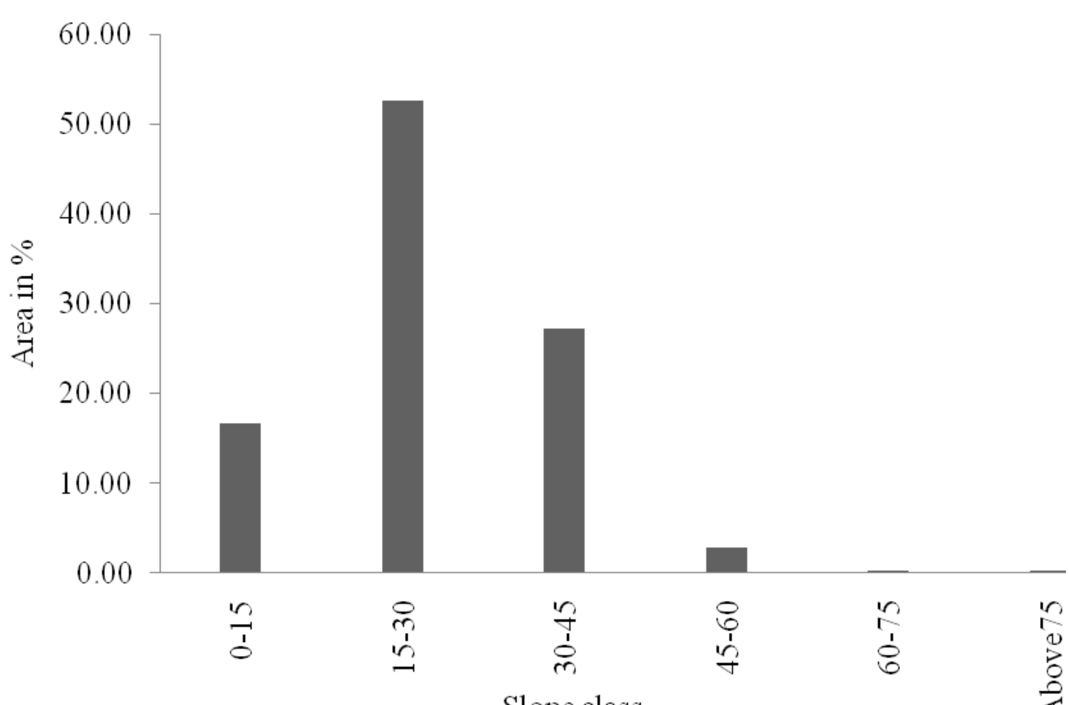

Fig. 5.4. Percentage-wise distribution of slope of East district of Sikkim

occupies 54 % area (Fig. 5.5 and Fig. 5.6). East Himalayan species tends to flourish in north or west aspect because they retain far more moisture and the vegetation on these aspects often merits attention in comparison to adjoining south or east aspects. The degree of moisture of a slope also controls the frequency of fire. Southern aspects with dry combustible under growth are often burnt, whereas northern aspect with damp undergrowth do not burn so easily. As a consequence, a southern aspect will frequently be treeless, while a neighbouring northern aspect will be forested. At higher altitudes, snow on north-facing slope exists for longer duration in spring season was shown to influence floral diversity due to higher snowfall. North facing area are mostly covered with fir trees (*Abies densa*).

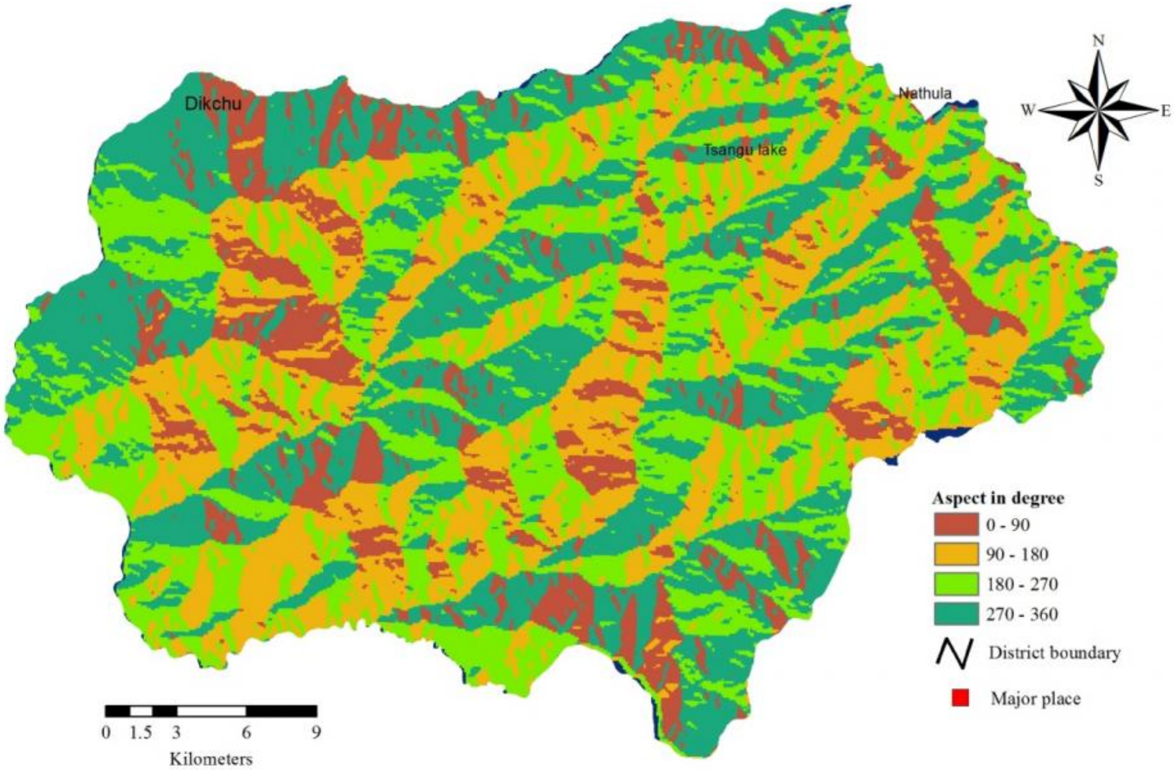

Fig. 5.5. Aspect map of East district indicates less area is under NE slope

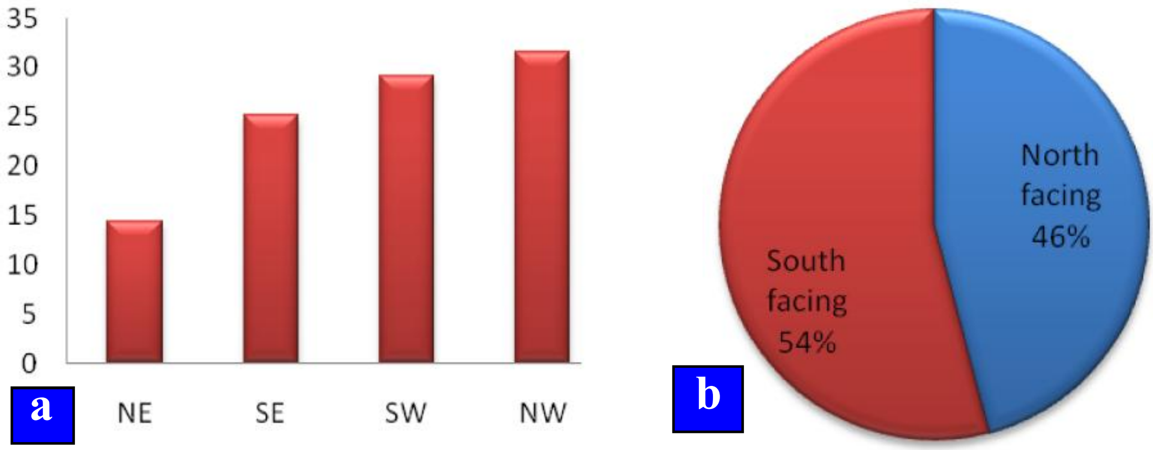

Fig. 5.6. (a) Percentage wise distribution of aspect; **(b)** distribution of northern and southern aspects of east district shown in a Pie diagram

5.1.3. Climate: Climate refers to conditions of the atmosphere at a particular location over a long period of time. The temperature and precipitation are the major component to understand the climate change.

5.1.3.1. Temperature*:* The climate changed from mid-hill temperate to severely cold alpine grassland. The climate was warm and humid during summer and monsoon season (June – October), and moderately cold during winter (December – February) at lower elevations. The winter months became severe as one goes up. Places like Nathula, Gnathang and Tsomgo remain almost snow covered during winter months. The perennial snowline, however, starts from 4500 m only. Most of the areas of the state are very wet during June to September with average annual rainfall ranged between 2000 mm – 4000 mm. The average minimum and maximum temperature varies between 4^{o} C – 17^{o} C in winter and 13° C - 24^{o} C in summer seasons respectively. The temperature at the lower belt of Rangpo, Singtam, Dikchu, Makha, Rorathang, Reshi and the places near Tista River and Rangpo Chhu begins to increase rapidly from the beginning of February and continues till the onset of monsoon in the late May to June. The maximum temperature is usually recorded during May and June and the minimum during the months of December and January. The field observations and from people's perception revealed that mountain range near Nathula, Zelepla and Tamzee remains under snow cover from December till late May. The average maximum and minimum temperature characteristics of Gangtok, the lone meteorology station for this study in east district of Sikkim is shown in (Fig.5.7).

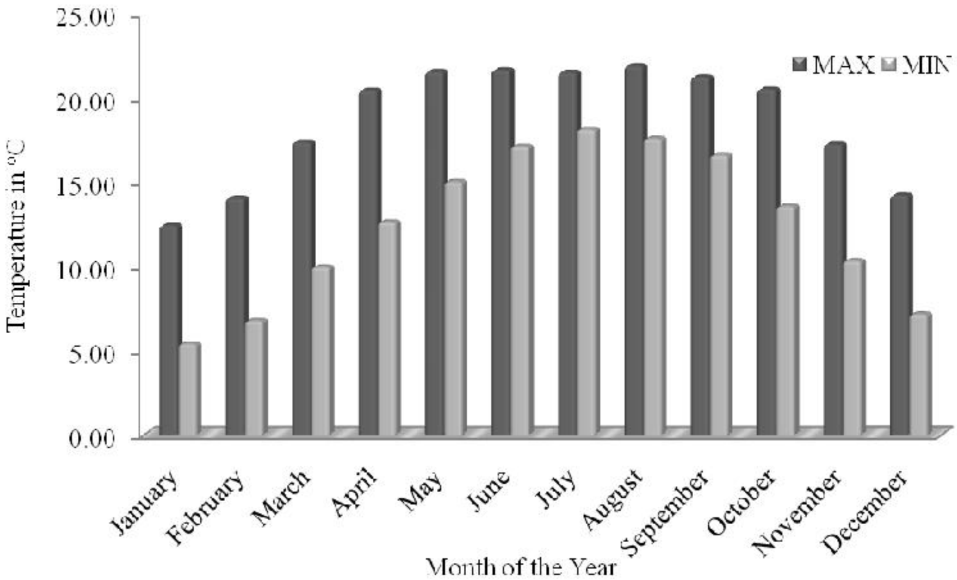

Fig. 5.7. Average Maximum and Minimum temperature between 2000 and 2010 of Gangtok in East district, Sikkim

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5.1.3.2. Precipitation

Precipitation is received mainly in two forms: Rainfall and snowfall. Snowfall does not occur in low altitude areas, i.e. below 2200 m, and increases with the increase of altitude.

Rainfall is heavy and well distributed during the months of May to September. Dikchu, Gangtok, Karponang, Rongli, Ganathang etc. are the maximum rainfall receiving areas, while the drought prone regions near Rangpo and Singtam get comparatively low rainfall. The intensity of rainfall may vary from drizzle to torrential. During the months of March to May, occasional hail-storms occur. Fog is quite common and dense during rainy season, ground frost can be observed during the winter months above 1800 m altitude. The rainfall data of Gangtok during the years 2000 – 2010 showed monthly variation of 40 mm in January to 700 m in June (Fig. 5.8). An isohyets map of East district revealed maximum rainfall in the mid elevation ranges and a decreasing pattern towards upper and lower reaches in the district (Fig.5.9).

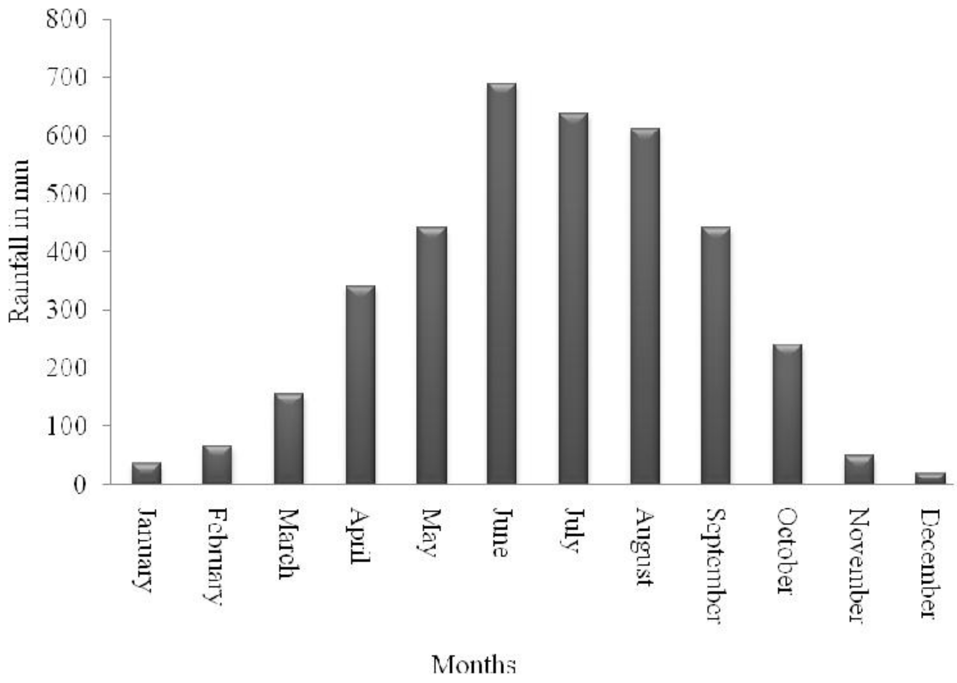


Fig. 5.8. Average rainfall at Gangtok during 2000 and 2010

5.1.4. Soil

Geologically, the area can be divided into six zones i.e., (i) the valley area, which is classified as lower glacio-fluvial valley and characterized by coarse-loamy Typic Haplumbrepts and coarse-loamy over fragmental Typic Udicorthents kind of soil family associations; (ii) the very steep side slope, moderately dissected with 40 % forest cover characterized by coarse-loamy Typic Haplumbrepts and loamy-skeletal Typic Udorthents family association; (iii) very steep side slope (33 – 50 %), highly dissected with 20 – 40 % forest cover characterized by coarse-loamy Pachic Haplumbrepts and fine-loamy Umbric Dystrochrepts; (iv) Periglaciated land, characterized by loamy-skeletal Lithic Cryorthents and coarse-loamy Cryumbrepts; (v) rocky cliffs, characterized by coarse-loamy Lithic Udorthents and solid rock; and (vi) very steep side slope (50 %), highly dissected with 20 % forest cover, characterized by coarse-loamy Typic Hapludolls and loamy-skeletal Typic Udorthents (NBSS & LUP, 1996). The soil map of east district, Sikkim is shown in Fig. 5.10.

The description of the soil class is shown in Annexure VI.

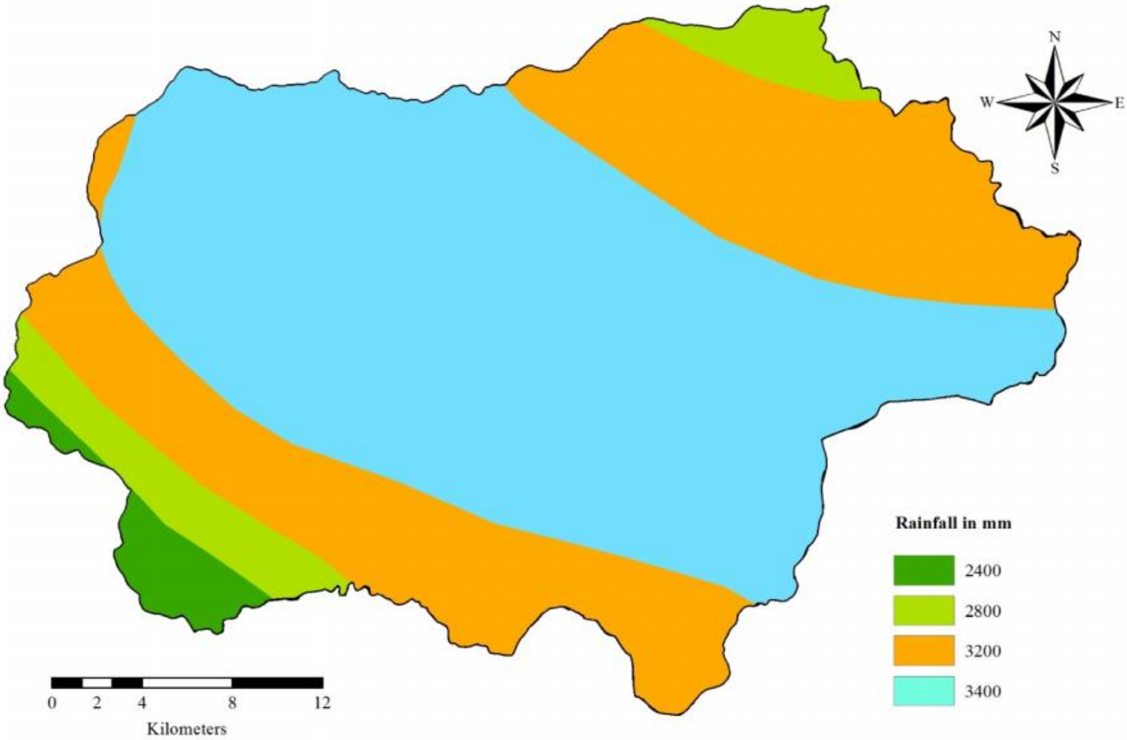


Fig. 5.9. Average Annual Rainfall map of east district, Sikkim showing Isohyets of rainfall

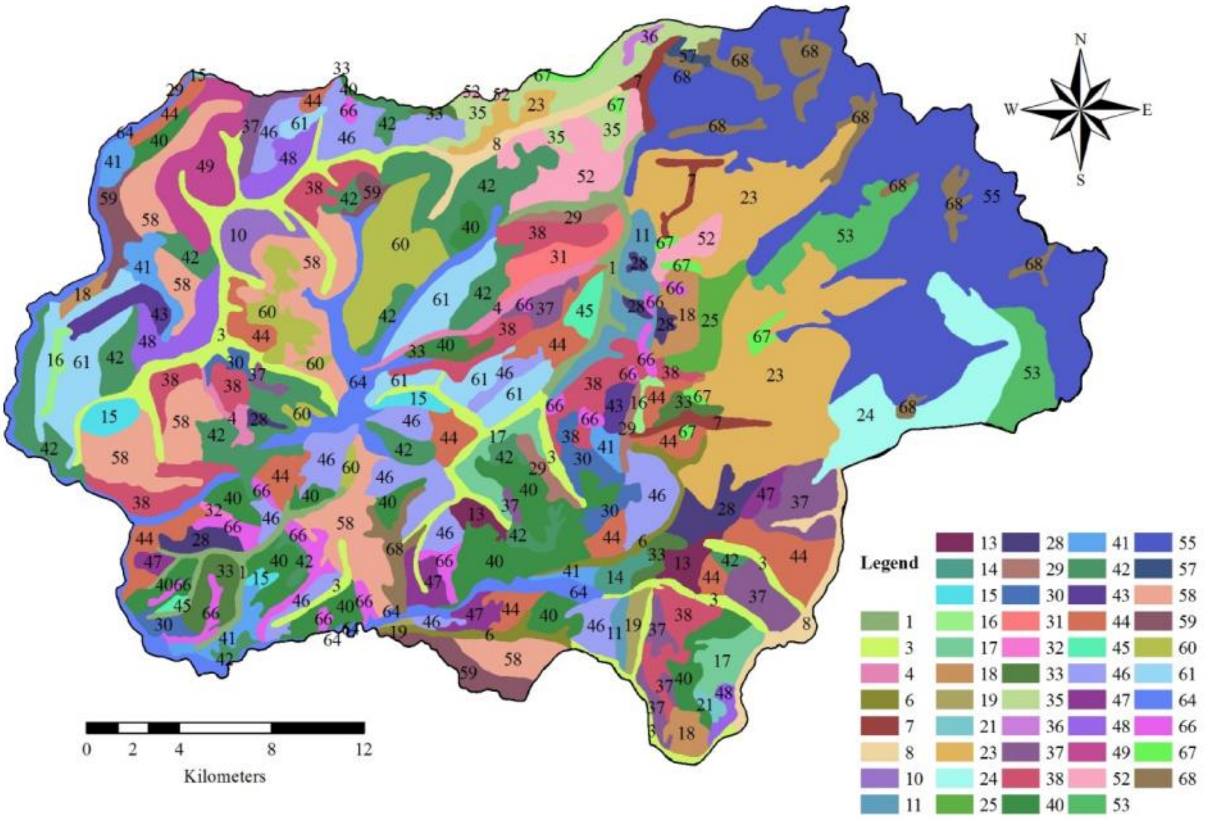


Fig. 5.10. Soil map of East district based on NBSS & LUP (1996) information

The soil developed from the gneissic group of rocks is brown clay, generally shallow and poor. The soil resulting from Daling group of rocks is dark grey, porous, rich and adaptable to most species. In the district forest soil is excellent, with adequate depth. The soil formation of valleys is due to decomposition of the Daling rocks. The resulting soil is sandy loam and dark grey with considerable amount of sand and is less acidic which supports sal and associated species. In higher reaches of steep slopes where the soil is predominantly of the gneissic group developed on the schist and humus podozols holds good for growth of numerous species of commercial importance. The greater portion of the East district, has gneissic rocks giving rise to different types of soil. The brown clayey soil is shallow and highly acidic, which supports the growth for the species of *Alnus*, *Engelhardtia*, *Macaranga*, etc. The dark brown soil is deep and more fertile and is usually found on the slopes and depressions. The soil on the ridges is shallow, poor and sticky and reddish yellow due to exposure of destruction of ground vegetation by natural calamities and anthropogenic interventions mainly through excessive grazing.

5.1.5. Forest type and density

The forest type zonation map of East district, Sikkim as per classification system is shown in figure 5.11. The forests of East District is broadly identified as Lower hill forests (Tropical and sub-Tropical), Middle hill forests (Temperate) and Upper hill forests (Alpine). The area covered by each forest types are presented in Table 5.2.

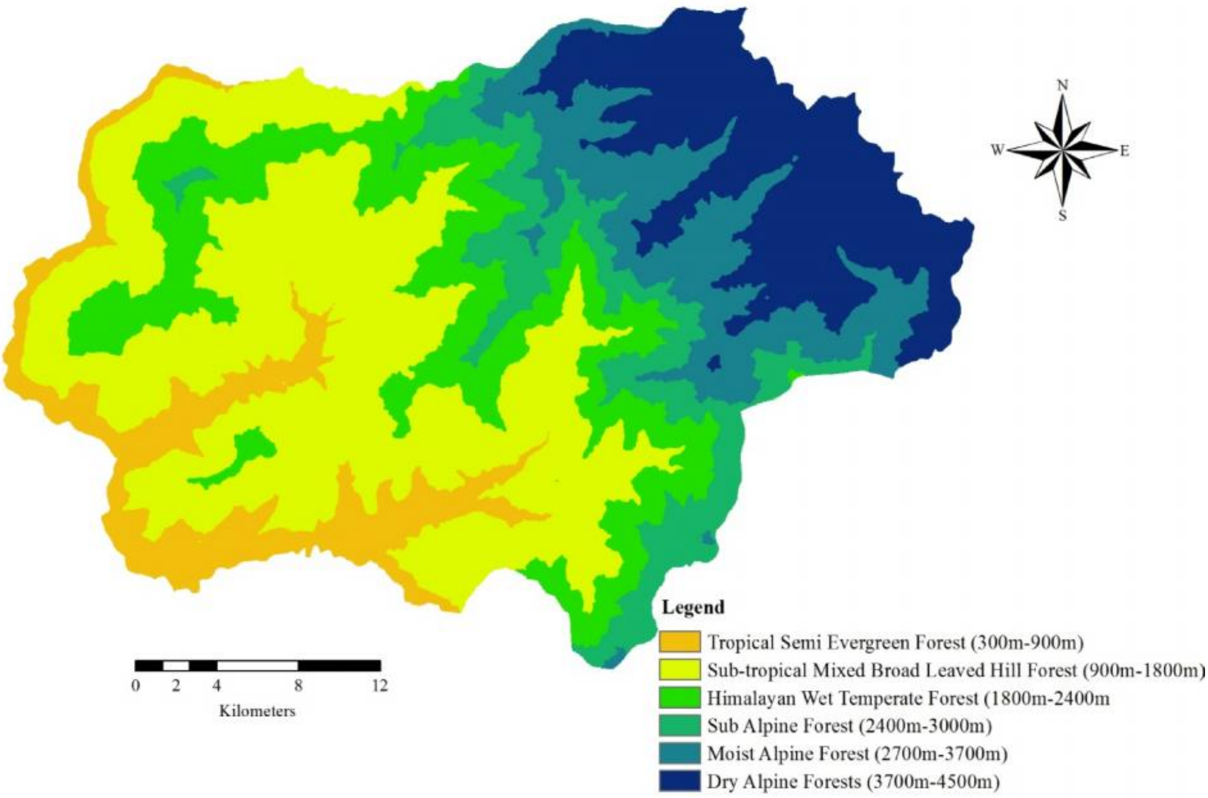


Fig. 5.11. Forest type zonation map of East district of Sikkim

Table 5.2. The area covered by each forest type in the East district of Sikkim

Forest type Zones	Area (ha)
300 – 900 (Lower Hill-Tropical Semi Evergreen Forest)	9800
900 – 1800 (Middle Hill-Sub-tropical Mixed Broad Leaved Hill Forest)	34600
1800 – 2400 (Upper Hill-Himalayan Wet Temperate Forest)	16300
2400 – 3000 (Sub Alpine Forest)	9400
3000 – Above (Alpine Forest)	25300
Total:	95400

5.2. Plant diversity

Plants were surveyed in the field using nested quadrate method, identified in the field and in the laboratory and was used for further analysis.

5.2.1. Data entry and design

The final data set of all, nested quadrat numbers, species, genus, family, locality, elevation, cbh, height etc. are entered into the excel sheet in a designed format which is used for further analyses.

5.2.2. Data analysis

First we see the distribution of plant species in different elevation, the average number of species, maximum number of species, minimum number of species, and the standard deviation of species in each of the eight plots in each elevation steps has been analysed (Fig. 5. 12)

There are 224 nested quadrats in 28 elevation steps, have been studied from each elevation steps. Eight quadrats of 20 x 20 m size (from nested quadrat layout) were used for the collection of trees and Lianas. A total 66314 tree individual recorded from the field survey between 500 to 3300 m

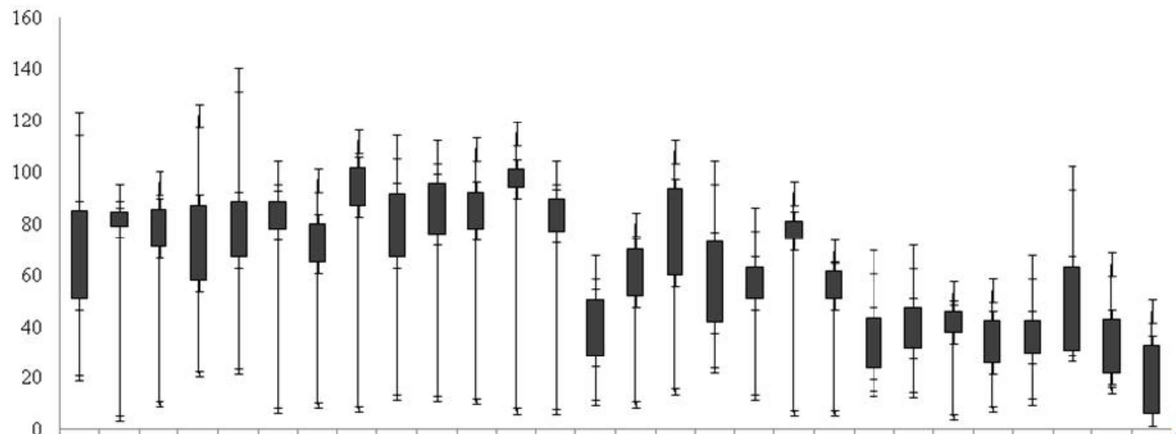
Table 5.3. List of 10 dominant tree species along with their total counts

Sl. No.	Tree Species	Total Count during the field study
1	*Schima wallichii*	1246
2	*Ostodes paniculata*	420
3	*Alnus nepalensis*	351
4	*Engelhardtia spicata*	313
5	*Castanopsis hystrix*	312
6	*Symplocos lucida*	209
7	*Macaranga indica*	138
8	*Acer campbellii*	131
9	*Rhododendron barbatum*	125
10	*Engelhardtia spicata*	123

elevation steps, accounting to 159 species covering 106 Genera and 61 families. *Schima wallichii* contributed maximum number of stands fallowed by *Ostodes paniculata*. The top ten dominant contributor trees are listed in Table 5.3. The lianas recorded from the 20 x 20 m plots, accounted to 3406 individuals with 13 families, 50 genera and 82 species.

Similarly shrubby species were collected from 448 (5 x 5 m) quadrats from 28 elevation steps, all together 14357 individual shrub with 121 species were recorded from the study area. *Yushania pantlingii* contributed more than 1000 individuals fallowed by *Dichroa febrifuga*, *Yushania maling*, *Boehmeria macrophylla*, *Arundinaria acerba*, *Mussaenda bevanii*. *Osbeckia crinita* and *Chimonocalamus griffithianus* contribute more than 500 individuals in the East district, Sikkim.

On the other hand the herbaceous ground cover species were also collected from 1120 (1 x 1 m) quadrats from 28 elevation steps. Altogether 66314 individual herbaceous plants covering 302 species were recorded from the study area. Amongst all herbs, *Cynodon dactylon* contributed more than 7000 individuals, followed by *Nephrolepis cordifolia*, *Selaginella ciliaris*, *Ageratina adenophora*, *Dryopteris sikkimensis*, *Elatostema obtusum* are other major contributor herbs of East district, Sikkim.



	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Average	85	85	86	87	88	89	80	102	92	96	92	101	89	51	70	93	73	63	81	61	43	47	46	42	42	63	43	33
Max	119	91	96	122	136	100	97	112	110	108	109	115	100	63	80	108	100	82	92	69	65	67	53	54	63	98	64	46
SD	20	4	10	22	22	7	10	8	12	12	11	7	7	10	10	15	23	12	7	6	14	13	5	8	11	28	15	13
Min	51	79	71	58	67	78	65	87	67	76	78	94	77	29	52	60	42	51	74	51	24	32	38	26	30	31	22	6

Fig. 5.12. Box plot of average maximum, minimum and standard deviation of every eight quadrat data in 28 elevation steps [5-32= (550 – 3250)]

A maximum of 136 species recorded in 900 – 1000 m fallowed by 122 species at 800 – 900 m and minimum 6 species were recorded from 3200 – 3300 m. The minimum standard deviation was 4 at 600 – 700 m and maximum slandered deviation 28 at 3000 – 3100 m elevation steps and the details are shown in figure 5.12.

The plant habit groups (trees, shrubs, herbs and lianas) were distributed in different altitudinal gradient. There is wide distribution of all habit groups within these regions. The herbaceous species are higher in the elevation between 1800 to 2900 m. The shrubby species decreased after 1800 – 1900 m. The highest peak of species richness has been seen at the elevation of 950 m between 900 – 1000 m, at 1,550m within 1500 – 1600 m and at 2,250 m within 2200 – 2300 m elevation zones. This is because

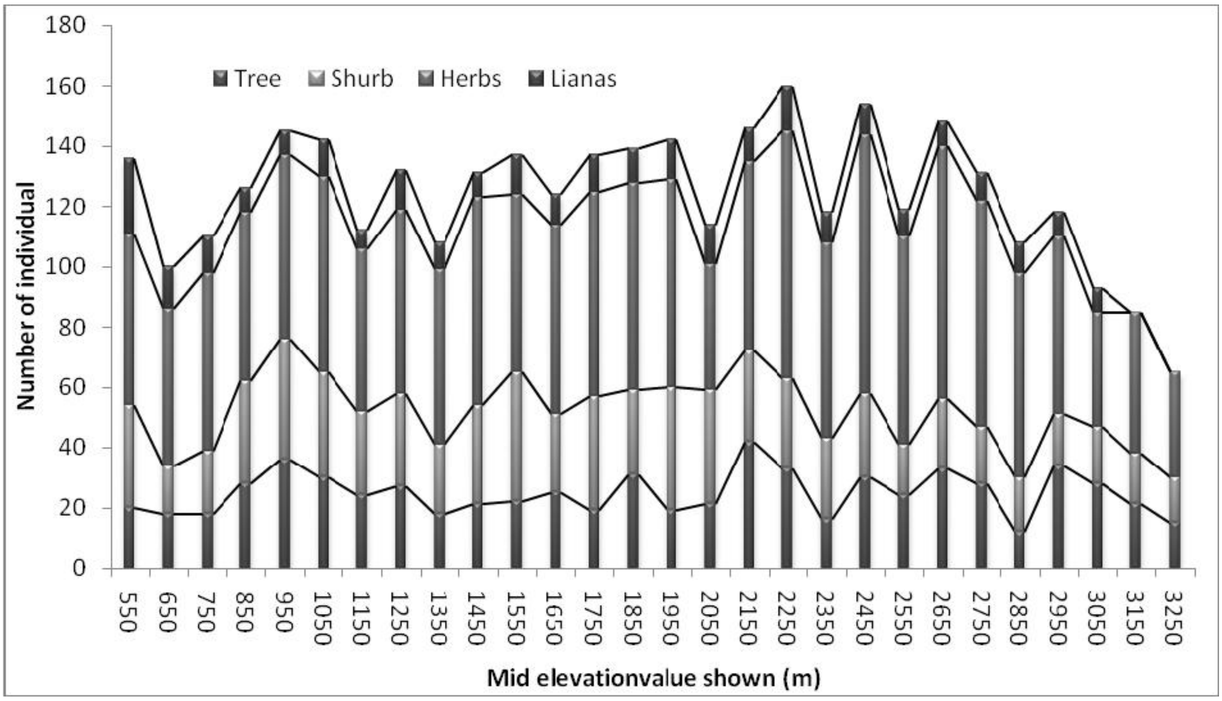


Fig. 5.13. Habit group richness along the 100 m elevation gradient

of ecotone region of tropical as well as sub-tropical, warm broad-leaved forest/ alder forest (Temperate) and temperate and sub-alpine forests of the East district.

The percentage of herbs along the elevation gradient is higher as compared to other habit groups. However, with an increase in altitude the number of all habit groups also decreases. Herbs decline from the elevation of 2400 – 2600 m. The major factor behind the decline of herb population could be attributed to the dense shrubby plants like *Arundinaria acerba*, *Chimonocalamus griffithianus*, *Arundinaria racemosa* etc., which does not allow other species to regenerate and grow up. All together, there are 664 plant species, 367 genera and 131 families have been recorded during the present study (*Annexures I, II & III*).

5.2.2.1. Dominance analysis

Only nine species has been found in more than 20 elevation steps in East district of Sikkim, *viz.,*. *Castanopsis hystrix, Dichroa febrifuga, Ageratina adenophora, Nephrolepis cordifolia, Polygonum runcinatum, Polystichum lentum, Pteridium aquilinum, Setaria palmifolia, Tectaria gemmifera* out of of them *Pteridium aquilinum* is found distribution in all elevation steps of the area studied. More than 190 species has been found in the single elevation gradient. The detailed list of herbs, shrubs and trees and epiphytes with every elevation steps are given in the Annexure- V.

Castanopsis hystrix, Engelhardtia spicata var. integra, Ostodes paniculata and *Schima wallichii* are the-dominant tree species of tropical forests. Similar species has reported by ISRO (1994) where as *Boehmeria macrophylla, Ficus hirta, Mussaenda bevanii* and *Osbeckia crinita* are the dominant shrub species of this region. *Achyranthes bidentata, Commelina paludosa, Drymaria cordata, Dryopteris sikkimensis, Eupatorium cannabinum, Nephrolepis cordifolia, Polygonum runcinatum, Polystichum lentum, Pouzolzia viminea, Pteridium aquilinum, Setaria palmifolia,* and *Tetrastigma rumicispermum* are found to be dominant species up to 1000 m i.e. in tropical forests. (*Annexure- II)*

In the sub-tropical region (1000 – 1800 m), *Alnus nepalensis Castanopsis hystrix*, *Engelhardtia spicata var. integra*, *Ostodes paniculata* and *Schima wallichii* are found to be dominant species of trees. The species like *Boehmeria macrophylla*, *Dichroa febrifuga*, *Ficus hirta*, *Mussaenda bevanii*, *Osbeckia crinita* are dominant in the sub- tropical forest between (1000 – 1800 m) elevation range. The species of *Digitaria ciliaris*, *Ageratina adenophora*, *Nephrolepis cordifolia*, *Polygonum runcinatum*, *Polystichum lentum*, *Pteridium aquilinum* and *Selaginella ciliaris* are observed to be dominant herbs in this region.

As it see the dominant species of the temperate forests (1900 – 2400 m) of East district, dominance of *Alnus nepalensis*, *Machilus edulis*, *Quercus lamellosa* and *Symplocos lucida* were found. The species of *Chimonocalamus griffithianus*, *Daphne papyracea*, *Dichroa febrifuga*, *Edgeworthia gardneri*, *Eurya japonica*, *Himalayacalamus hookerianus*, *Rubus ellipticus*, *Symplocos glomerata* are dominant shrubs found in this eco-region. The species like *Arisaema galeatum*, *Cissus repens*, *Elatostema obtusum*, *Elsholtzia flava*, *Eupatorium cannabinum*, *Fragaria rubiginosa*, *Lecanthus peduncularis*, *Polygonum runcinatum*, *Polystichum lentum*, *Pouzolzia viminea*, *Pteridium aquilinum*, *Setaria palmifolia*, *Tectaria gemmifera*, *Tetrastigma rumicispermum* are dominant herbaceous species found in the wet Himalayan temperate forest.

The sub-alpine and moist alpine regions of Sikkim lay between (2500 – 3700 m). In this study, data up to 3300 m has been collected. So, dominant species of trees found in this eco- region are *Acer campbellii*, *Magnolia campbellii*, *Rhododendron barbatum*, and *Viburnum cotinifolium*. The species like *Arundinaria acerba*, *Himalayacalamus falconeri*, *Polygonum molle*, *Viburnum cotinifolium*, *Viburnum erubescens* and *Yushania pantlingii* are dominant species of shrubs in this eco-belt. The herbaceous plants, *Cyperus distans*, *Cyperus tenuiculmis*, *Elatostema obtusum*, *Fragaria daltoniana*, *Nephrolepis cordifolia* and *Rubia wallichiana* are dominant species of herbs of this region.

5.2.2.1.1. *Frequency and Relative Frequency:* In order to know the diversity of species, genera and families, the Frequency (F) and Relative Frequency (RF) of different species, genera and families were calculated, using the formulae as described in methodology. **(***Annexures I, II & III***)**

Amongst all the 664 species, *Pteridium aquilinum* is recorded with 100 % frequency followed by *Polystichum lentum*, *Polygonum runcinatum*, and *Nephrolepis cordifolia* with 82 % and *Dichroa febrifuga*, *Ageratina adenophora* with 75 % frequency. However, more than 100 species were recorded with less than 4 % frequency.

5.2.2.1.2. *Density and Relative Density:* The Density (D) and Relative Density (RD) were also calculated in the excel sheet for the determination of Importance Value index (IVI) **(***Annexure I, II & III***)** among all species *Schima wallichii* contribute maximum value followed by *Ostodes paniculata* and *Alnus nepalensis*.

5.2.2.1.3. *Abundance and relative abundance*: Similarly as above we calculate the abundance and relative abundance species, genera and families **(***Annexure I, II & III***)**

5.2.2.1.4. Importance Value Index

The concept of Important Value Index (IVI) has been developed for expressing the dominance and ecological success of any species with a single value (Mishra, 1968). This index utilizes three characteristics, those are (1) Relative frequency, (2) Relative density and (3) Relative abundance. The three characteristics are computed using RF, RD and RA for all the species falling in all the quadrants by using the following formula.

$$IVI = RF + RA + RD$$

The IVI of all species, genus, and family has been calculated. The detail is in (*Annexure I, II, & III)*.

Among the species *Schima wallichii*, *Ostodes paniculata*, *Alnus nepalensis*, *Castanopsis hystrix*, *Engelhardtia spicata* var. *integra* and *Nephrolepis cordifolia* scored IVI value over 3 among all the recorded species. *Schima wallichii* scored the highest IVI 12.19, followed by *Ostodes paniculata* with 4.64.

At the generic level *Schima*, *Rhododendron*, *Ostodes*, *Engelhardtia*, *Castanopsis*, *Viburnum*, *Alnus*, *Cyperus*, *Eupatorium*, *Selaginella*, *Symplocos*, *Nephrolepis*, *Polygonum*, *Dryopteris* scored IVI more than 3 and among all *Schima* scored 14.33, followed by *Rhododendron* (6.12).

As it is observed, IVI at the family level, there are 32 families having the over 3 IVI score and 6 families viz. Theaceae, Poaceae, Euphorbiaceae, Urticaceae, Fagaceae, Ericaceae having the IVI value of more than seven, with Theaceae scored the highest (18.1).

5.2.2.2. Diversity Indices

The diversity of different groups of organism or different communities is useful not only to the extent that it contributes to the understanding of the process that structure those communities. The number of species in a sample is generally called species richness whereas the species in respect of the sample size of the area is species diversity. The diversity often described using statistical formula that combine both the components. The best known of these composite statistics is the Shannon-Wiener Index of 1949 and 1963. This index was selected for the analysis as it is widely used to express the species diversity and it is moderately sensitive to sample size (Castrezana & Markow, 2001).

5.2.2.2.1. Margalef Index (MI): In the present study the total species richness i.e. Margalef Index (MI) (Margalef, 1958) were recorded from 6.79 to 19.33 across the 550 – 3250 m elevation gradient. At the highest elevation, 3200 – 3300 m the minimum richness was 60 species and the MI calculated to 6.79, while the maximum values of 155 species and MI 19.33 were recorded at the elevation of 2250 m (Fig. 5.14).

Above 3000 m elevation, both the parameters, species richness and MI decreased from 86 to 60 species and 10.50 – 6.79 exponentially with increase in elevation and subsequently dropped to a minimum at 3250 m elevation.

5.2.2.2.2. Simpson's Index (Simpson, 1949): In this of species dominance were in between the range 2.48 to 54.60, higher the value more is the dominance. Recorded maximum value of 54.60 was from the 1850 m steps. The Simpson's Index 2.48 was recorded at 3250 m elevation. Shannon-Wiener Diversity Index (H') were recorded from 1.95 to 4.40 across the elevation gradient of 550 – 3250 m.

The minimum values of 1.95 was recorded at 3250 m and the maximum value of 4.40 at 2250 m elevations (Fig. 5.15).

5.2.2.2.3. Shannon-Wiener index (H'): In the present analysis the value of Shannon Weiner Diversity Index (1949) falls between 1.9 and 4.4, only. In the tropical and sub-tropical region the value falls in between 3.7 to 4.3 (Fig 5.16). It would indicate that the numbers of individuals are evenly distributed between all the species in tropical and sub-tropical forest.

5.2.2.2.4. Pielou's Index (J) **[Evenness] (Pielou, 1966)**: Evenness expresses how evenly the individuals in a community are distributed among the different species. It expresses the measurement of evenness pattern of species in the study area. It was recorded from 0.48 to 0.89 in 550 – 3250 m range with maximum of 0.89 at the 1850 m. The highest species richness has been observed in the elevation of 950 m. However, less evenness has been seen at the 950 m elevation plots (Fig. 5.17).

The details of the values of different Indices has been provided in Table 5.4.

Table. 5.4. Records of different diversity indices at different altitudinal steps in the East district of Sikkim.

Mid elevation Value	Total number of species (S)	Total number of individuals (N)	Natural log of species (lnS)	Natural log of Individual (lnN)	Margalef index (M)[Sp Richness]	Simpson's index (1/D)[dom-inance]	Shannon-Wiener index (H')[Diversity]	Pielou's index (J) [Evenn-ess]
550	127	2822	4.84	7.95	15.86	30.80	4.05	0.84
650	96	2736	4.56	7.91	12.00	32.63	3.90	0.86
750	106	3049	4.66	8.02	13.09	31.95	3.90	0.84
850	121	3094	4.80	8.04	14.93	34.36	3.99	0.83
950	134	3606	4.90	8.19	16.24	19.20	3.79	0.77
1050	134	3259	4.90	8.09	16.44	39.96	4.15	0.85
1150	109	2997	4.69	8.01	13.49	29.47	3.85	0.82
1250	126	3572	4.84	8.18	15.28	32.49	4.00	0.83
1350	106	2510	4.66	7.83	13.41	23.91	3.77	0.81
1450	128	4026	4.85	8.30	15.30	31.93	3.97	0.82
1550	133	4361	4.89	8.38	15.75	38.88	4.13	0.84
1650	122	4350	4.80	8.38	14.44	29.79	3.93	0.82
1750	130	3173	4.87	8.06	16.00	30.48	4.04	0.83
1850	134	1712	4.90	7.45	17.86	54.60	4.35	0.89
1950	140	2971	4.94	8.00	17.38	28.65	4.09	0.83
2050	109	4181	4.69	8.34	12.95	31.59	3.95	0.84
2150	143	3181	4.96	8.07	17.61	43.78	4.25	0.86

Mid elevation Value	Total number of species (S)	Total number of individu-als (N)	Natural log of species (lnS)	Natural log of Individual (lnN)	Margalef index (M)[Sp Richness]	Simpson's index (1/D)[dom -inance]	Shannon-Wiener index (H')[Dive rsity]	Pielou's index (J) [Evenn-ess]
2250	155	2883	5.04	7.97	19.33	52.42	4.40	0.87
2350	109	3435	4.69	8.14	13.27	31.37	3.93	0.84
2450	146	3189	4.95	8.07	17.97	41.69	4.24	0.85
2550	119	3082	4.78	8.03	14.69	18.42	3.69	0.77
2650	142	2667	4.96	7.89	17.87	36.57	4.18	0.84
2750	124	3540	4.82	8.17	15.05	12.57	3.36	0.70
2850	102	2143	4.63	7.67	13.17	26.49	3.82	0.83
2950	112	2404	4.72	7.79	14.26	13.86	3.47	0.74
3050	86	3268	4.45	8.09	10.50	12.19	3.81	0.74
3150	80	2549	4.38	7.84	10.07	21.82	3.56	0.81
3250	60	5930	4.09	8.69	6.79	2.48	1.95	0.48

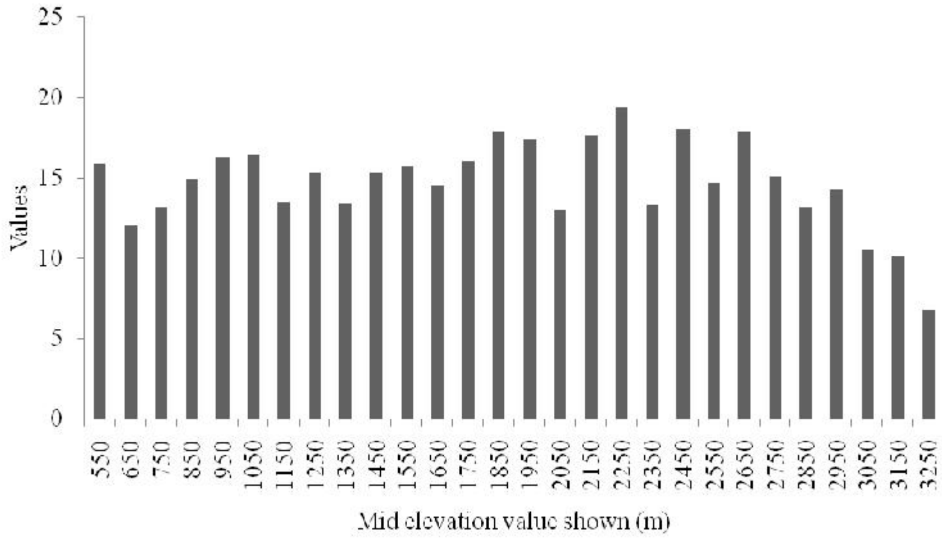


Fig. 5.14. Margalef index (MI) of Species Richness along100 m elevation gradients

5.2.2.3. Richness of Species, Genus and Family along the altitude

In the present study the richness of the species genus and family has been analysis using data from three elevation steps viz. 100 m, 200 m and 300 m.

5.2.2.3.1. ***Along 100 m elevation step***: A total of 224 quadrants have been laid down in 28 elevation steps along the altitudinal gradient of 500 – 3300 m. This has captured a variety of disturbed areas in the lower elevation, reserve forests, wildlife sanctuaries in the middle to higher elevation representing different slope and aspect in the East district of Sikkim (Fig. 5.18).

A total of 664 species, 367 genera and 131 families have been recorded in the present study, out of which 158 were tree species, 197 were shrubs, 91 epiphytic and 304 terrestrial herbs (*Annexure- I, II & III).*

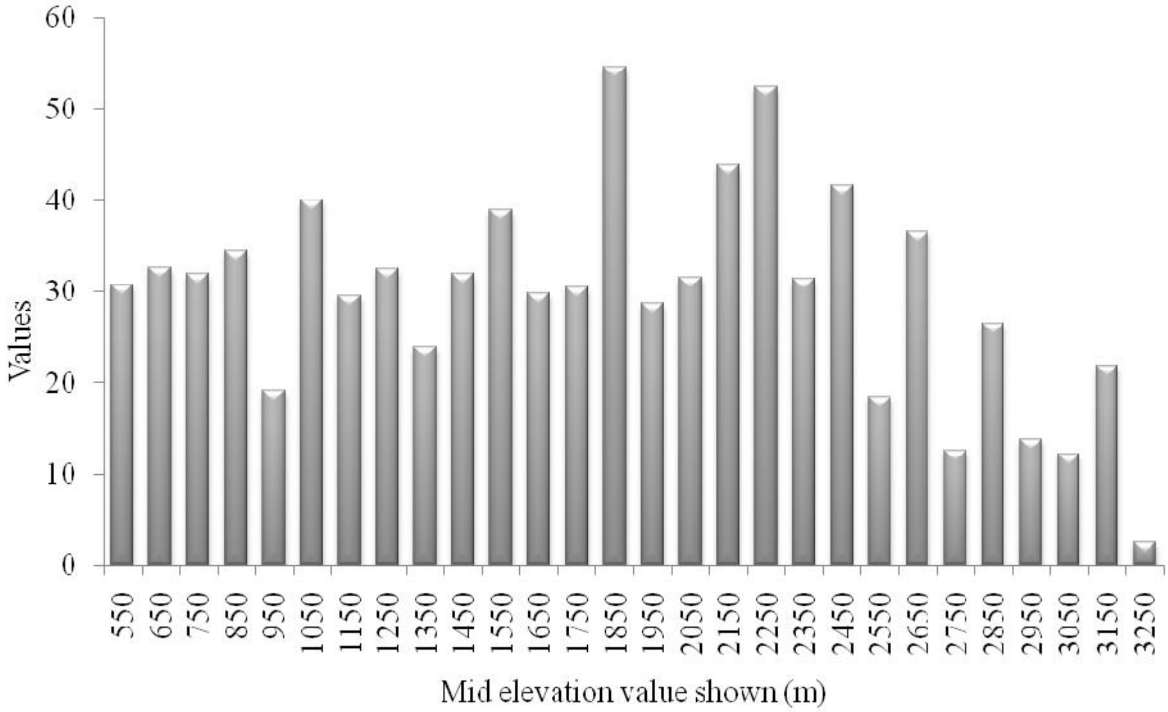


Fig. 5.15. Species dominance along the 100 m elevation gradients

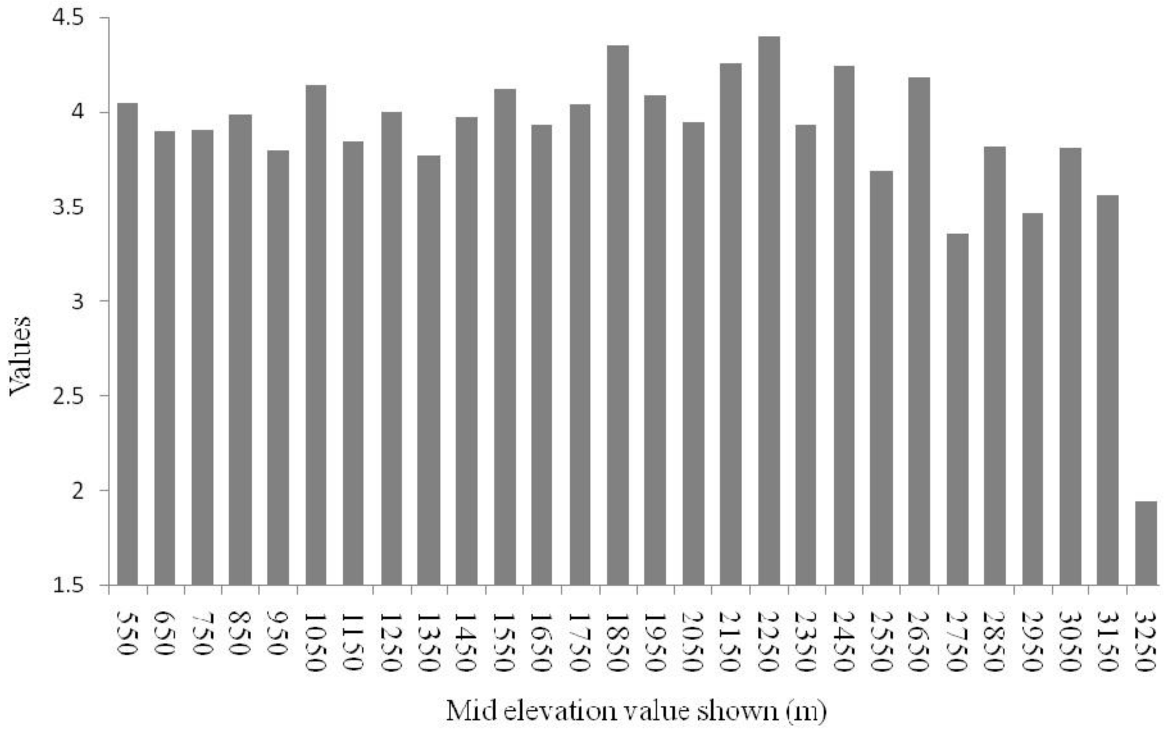


Fig. 5.16. Shannon-Wiener index of species diversity along the 100 m elevation gradients

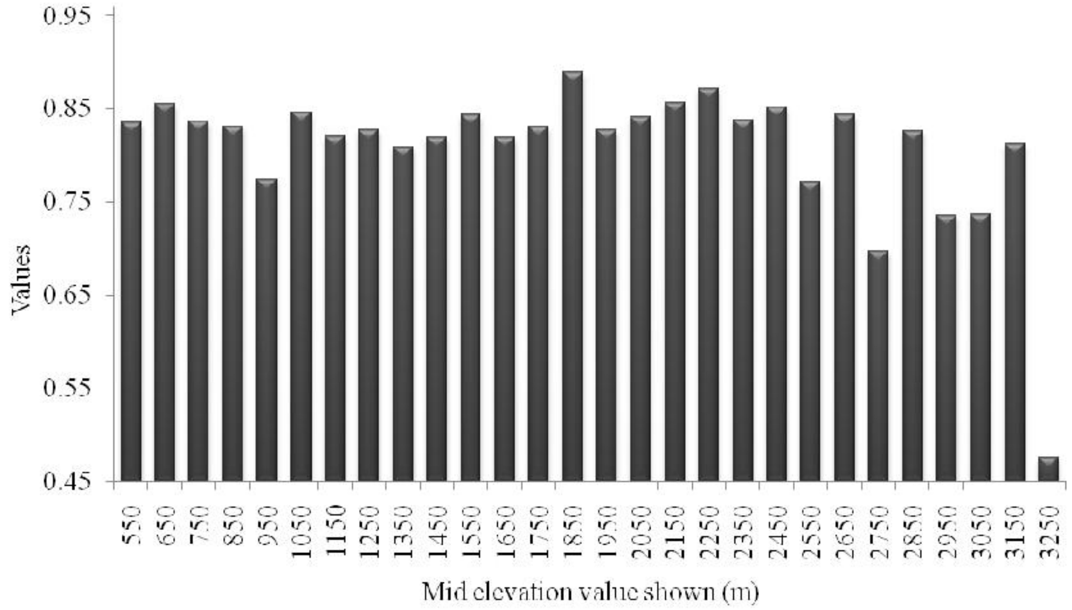


Fig. 5.17. Species Evenness along the 100 m elevation gradient

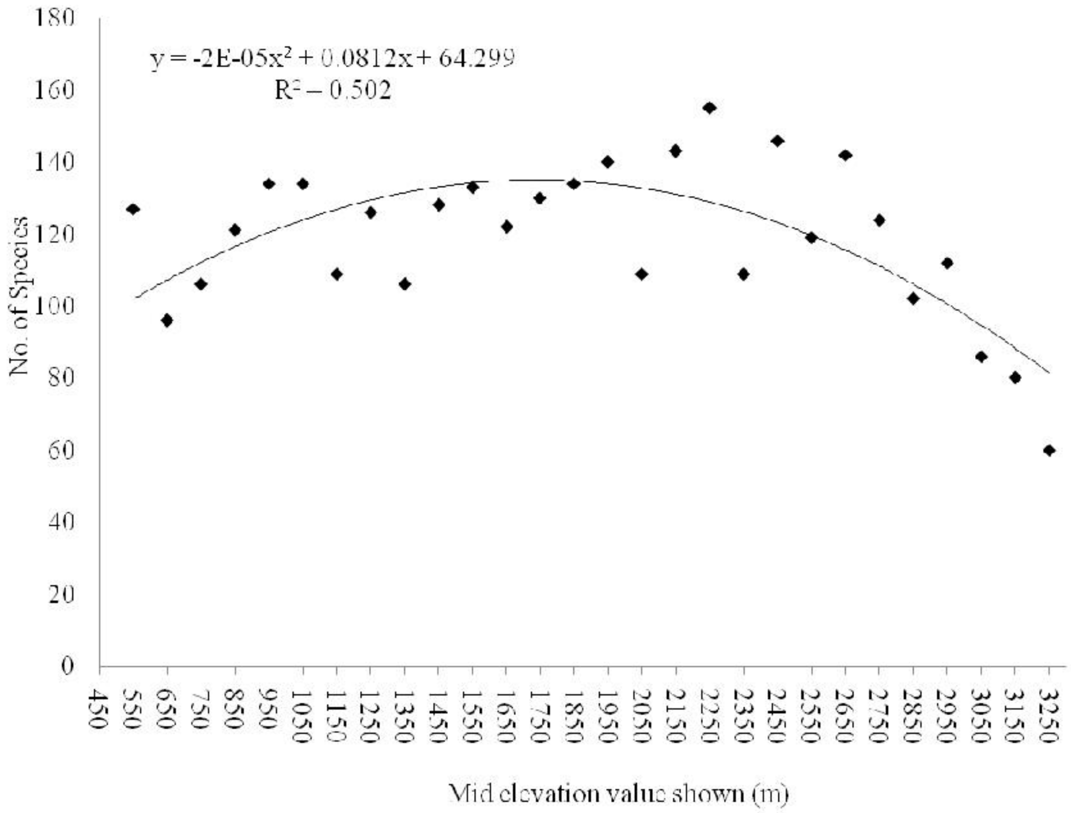


Fig. 5.18. Plant species distribution along the 100 m elevation gradient

Species: A total of 60 species only at the elevation of 3250 m and the maximum of 155 species at the elevation of 2250 m have been recorded. There is a gradual increase in the species upwards from the lower elevation and reach up to 134 species in the elevation between 950 – 1050 m representing ecotone zone of tropical and sub-tropical forests of Sikkim. The dominant species of these two zones are *Schima* *wallichii*, *Castanopsis hystrix*, *Alnus nepalensis*, *Engelhardtia spicata* var. *integra* etc. The species richness patterns, again, decreases slowly and again increases at the elevation between 1850 – 1950 m with the total number of species of 134 (at 1850 m) and 140 (at 1950 m), respectively. This zone corresponds to the ecotone zone of sub-tropical and template forests. The dominant species of ecotone zone are *Alnus nepalensis*, *Engelhardtia spicata* var. *integra*, *Mallotus* sp. *Ostodes paniculata* etc. The highest number of 155 species has been spotted at an elevation of 2250 m. In the ecotone of temperate and sub-temperate zones the dominant species were *Quercus lamellosa*, *Machilus kurzii*, *Symplocos lucida*, *Viburnum* sp. etc. The richness pattern gradually decreases upwards from the elevation of 2450 m.

Amongst the species richness pattern the contribution of *Schima wallichii* is the highest followed by *Ostodes paniculata*, *Alnus nepalensis*, *Castanopsis hystrix*, *Engelhardtia spicata* var. *integra* along the altitudinal gradient (*Annexure- I).*

For the 100 m elevation step data has been analysed and found statistically not significant (R^2 =0.502) (Fig.5.18), with a t-value of t=5.118.

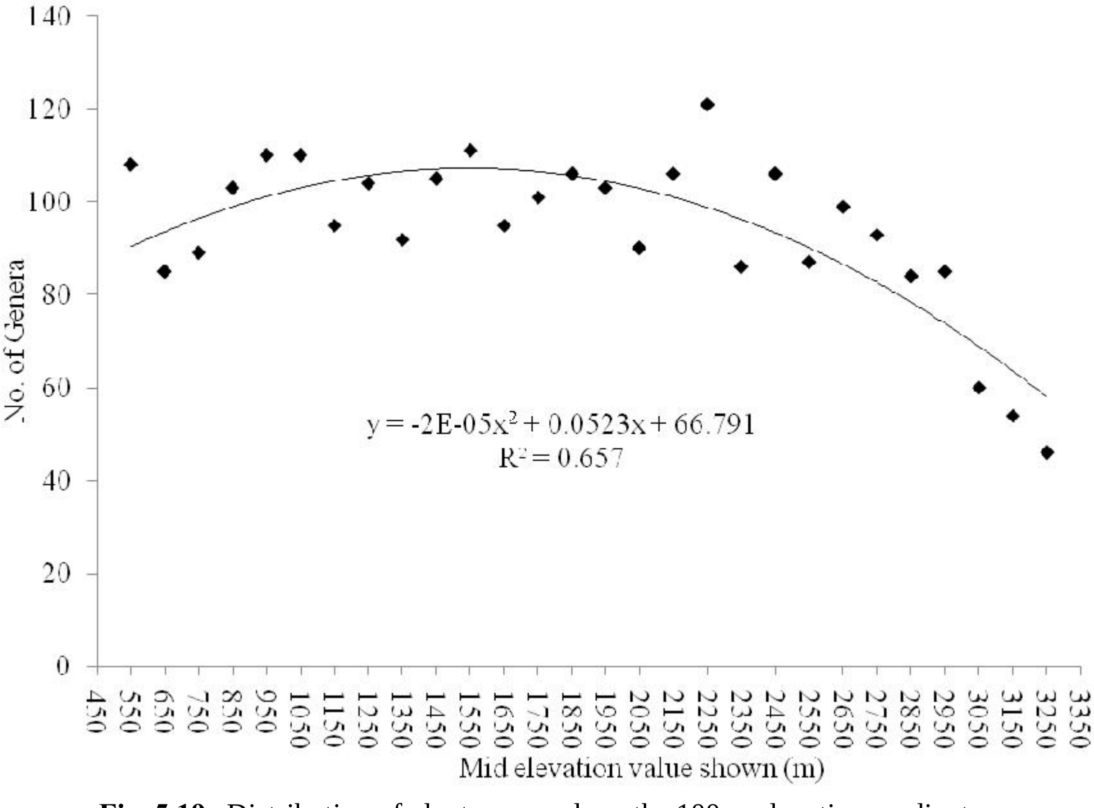


Fig. 5.19. Distribution of plant genera along the 100 m elevation gradient

Genus: Present study has recorded a total of 367 genera along the elevation gradient of east district, Sikkim. The *Schima* has contributed the highest Importance Value Index (IVI) followed by *Rhododendron*, *Ostodes* and *Engelhardtia* (*Annexure II*). In the elevation zone of 2250 – 2350 m the highest number of 121 genera has been recorded. In the ecotone of temperate and sub-temperate zones similar pattern has been observed. However, the least number of 46 genera has been located at 3,250 m. A hump-shaped relationship with the elevation showing peak at around 1750 – 1850 m is given in Fig 5.19. In the lower and middle elevation band, genera like *Schima*, *Alnus*, *Engelhardtia*, *Castanopsis Ostodes* etc. are dominating, while in the middle and higher elevation band *Rhododendron, Viburnum, Quercus* and *Acer* are dominants. However, in the second order polynomial regression ($R^2 = 0.657$) relation between genus along the 100 m elevation steps has been found insignificant with t=4.148.

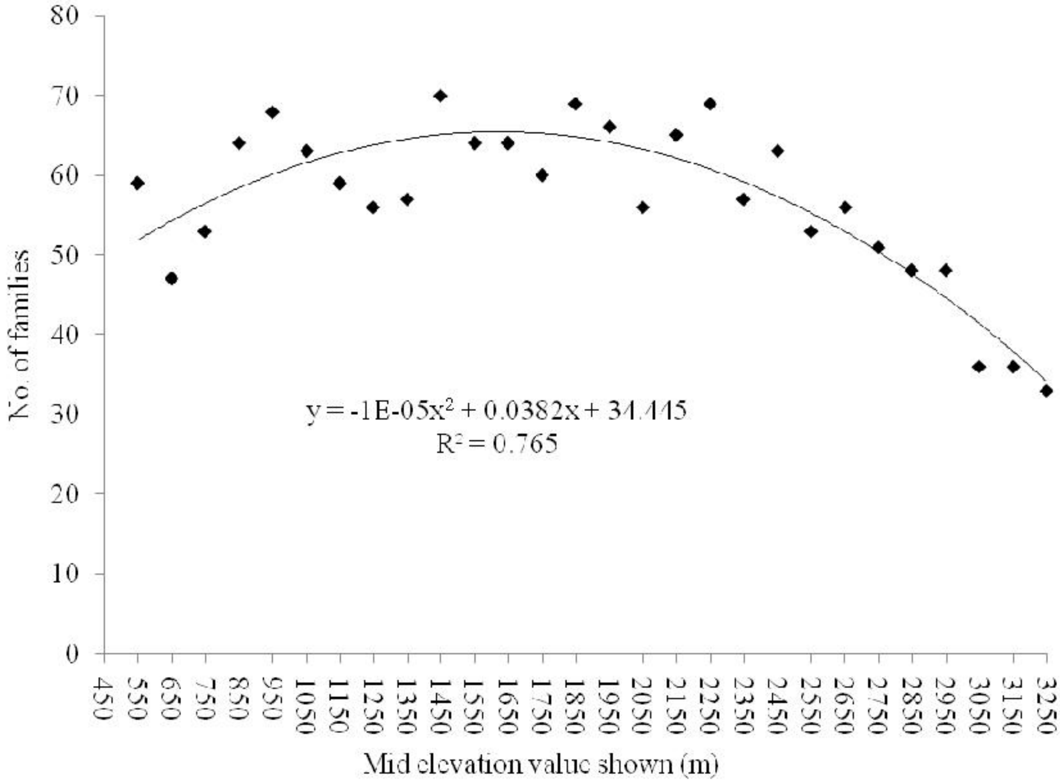


Fig. 5.20. Distribution of plant families along the 100 m elevation gradient

Family: Out of the recognized 131 families occurring in 28 elevation steps, maximum number of 70 families have been observed in the elevation band of 1400 – 1500 m and a minimum number of 33 families in the 3200 – 3300 m band. The number of individual families in each 100 m elevation steps have been plotted in figure 5.20, representing a hump- shaped relationship with a peak at around 1700 – 1800 m. However, the second order of polynomial regression ($R^2 = 0.765$, $p<0.02$) shows that the relation between the family and elevation in 100 m elevation step is statistically significant. Theaceae, Poaceae, Euphorbiaceae, Urticaceae, Fagaceae, Ericaceae, Juglandaceae etc. are the dominant families along the altitudinal gradient of 100 m in the East district of Sikkim **(***Annexure- III***).**

5.2.2.3.2. ***Along 200 m elevation step****:* The plot of the species richness along the elevation steps of 200 and 300 m elevation signify the relation between species richness along this elevation gradient. It was observed in the polynomial regression in 200 m elevation step with a $R^2 = 0.553$, the relationship between species richness along the 200 m altitudinal band is statistically significant at $p<0.01$ level (Fig.5.21) and in 300 m elevation the $R^2 = 0.743$, $p<0.01$ Fig.4.24. In 200 m elevation gradient, the highest peak occurred at around 1,800 m but in 300 m elevation the species richness gradually decrease upward from 1900 m elevation step.

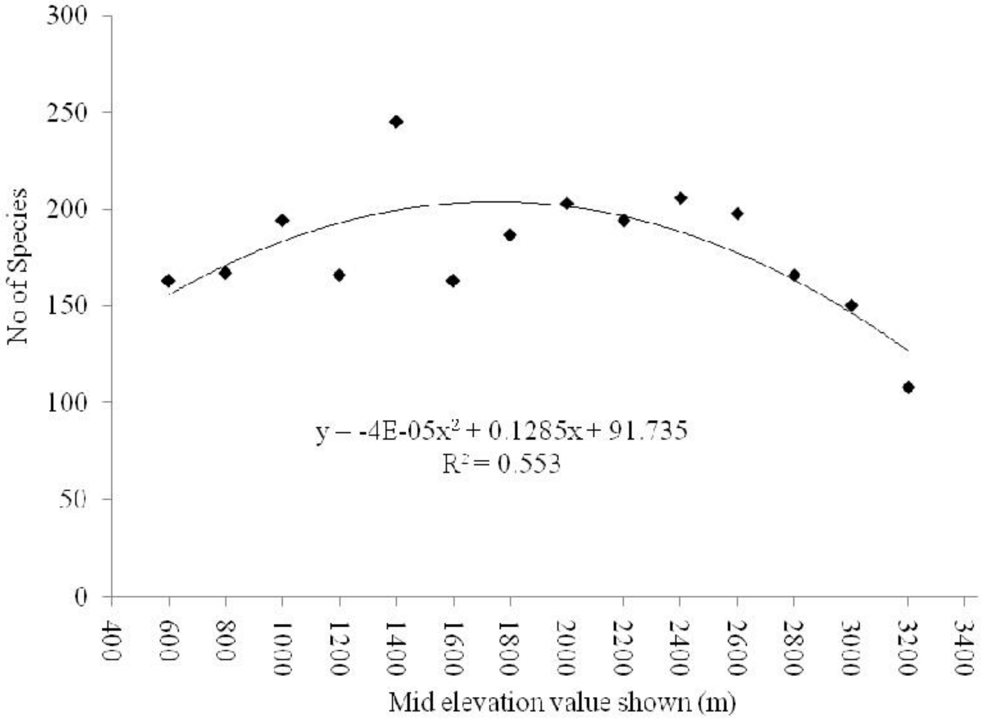


Fig. 5.21. Distribution of plant species along the 200 m elevation gradient

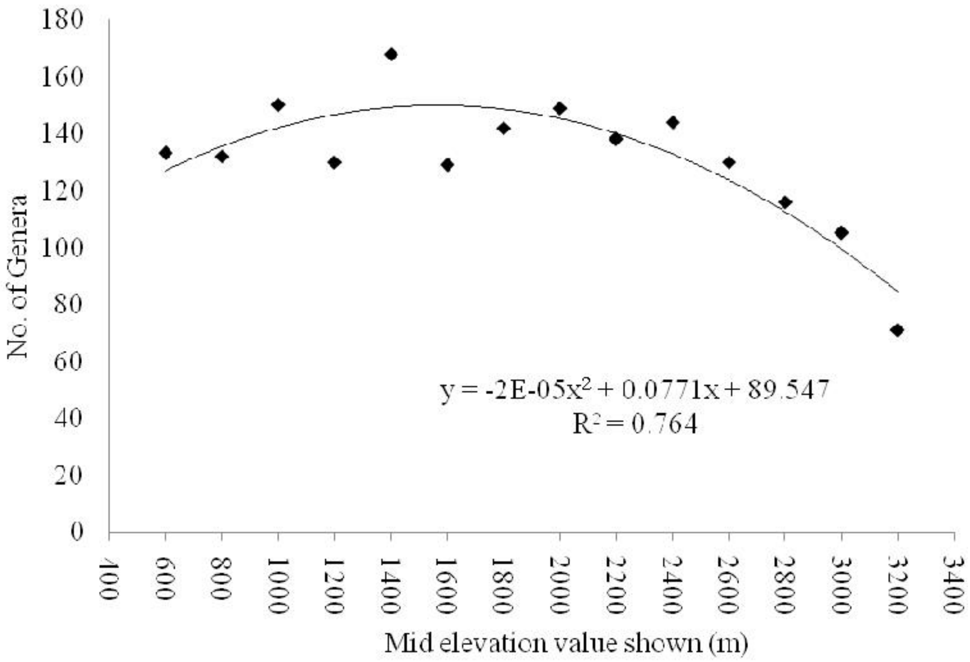


Fig. 5.22. Distribution of plant genera along the 200 m elevation gradient

5.2.2.3.3. *Along 300 m elevation step:*

The similar pattern was observed for the genera as it was noticed along the elevation gradient of 200 m and 300 m, where $R^2 = 0.764$, $p < 0.05$ and $R^2 = 0.8621$, $p < 0.05$ has been calculated in polynomial regression equation (Fig. 5.22 and Fig. 5.25) respectively.

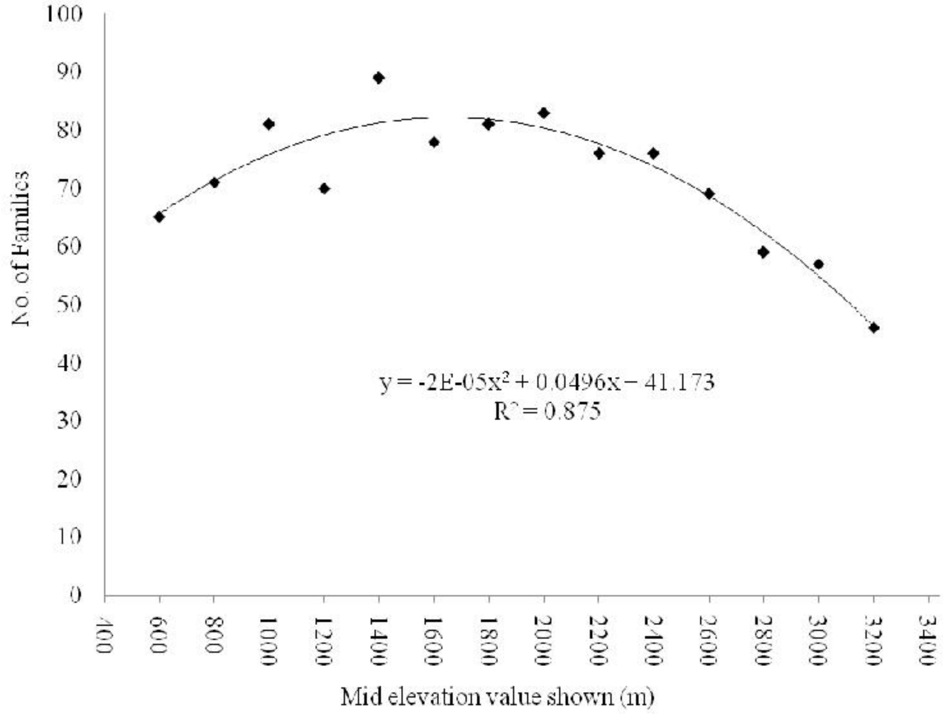


Fig. 5.23. Distribution of plant families along the 200 m elevation gradient

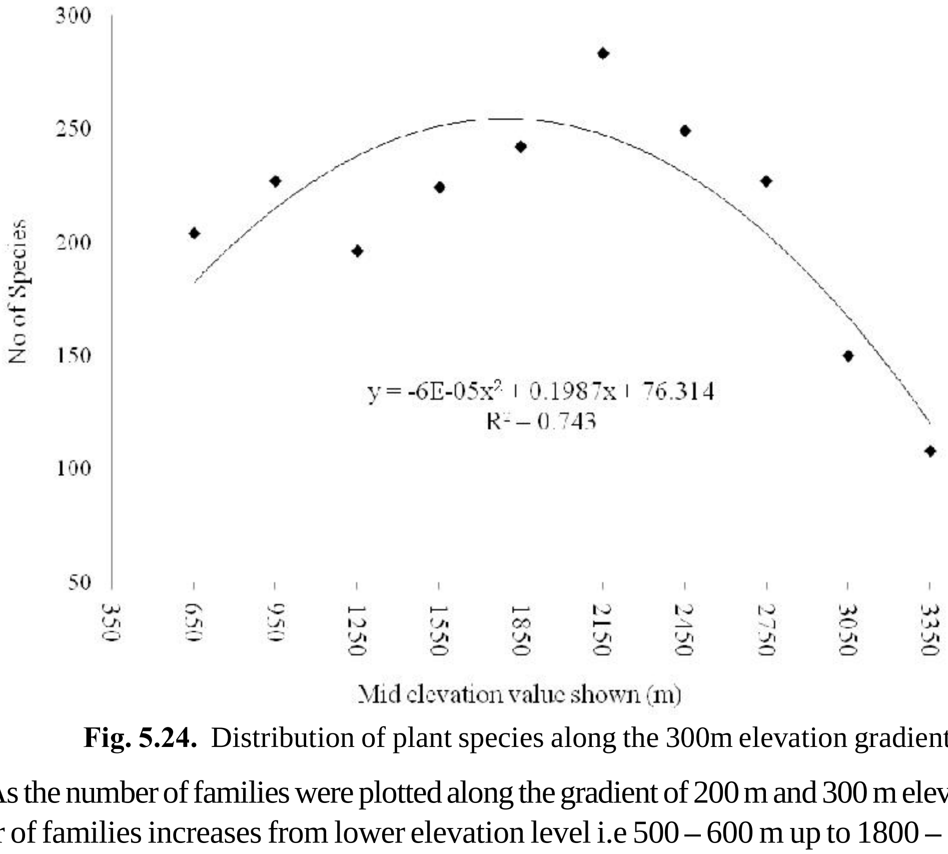


Fig. 5.24. Distribution of plant species along the 300m elevation gradient

As the number of families were plotted along the gradient of 200 m and 300 m elevation steps, the number of families increases from lower elevation level i.e 500 – 600 m up to 1800 – 1900 m. Afterwards the number of families decreases with the increase in elevation. In the polynomial regression equation the R^2 value of 200 m elevation band is $R^2 = 0.875$ and in 300 m elevation band $R^2 = 0.907$ (Fig.5.23 & Fig.5.26).

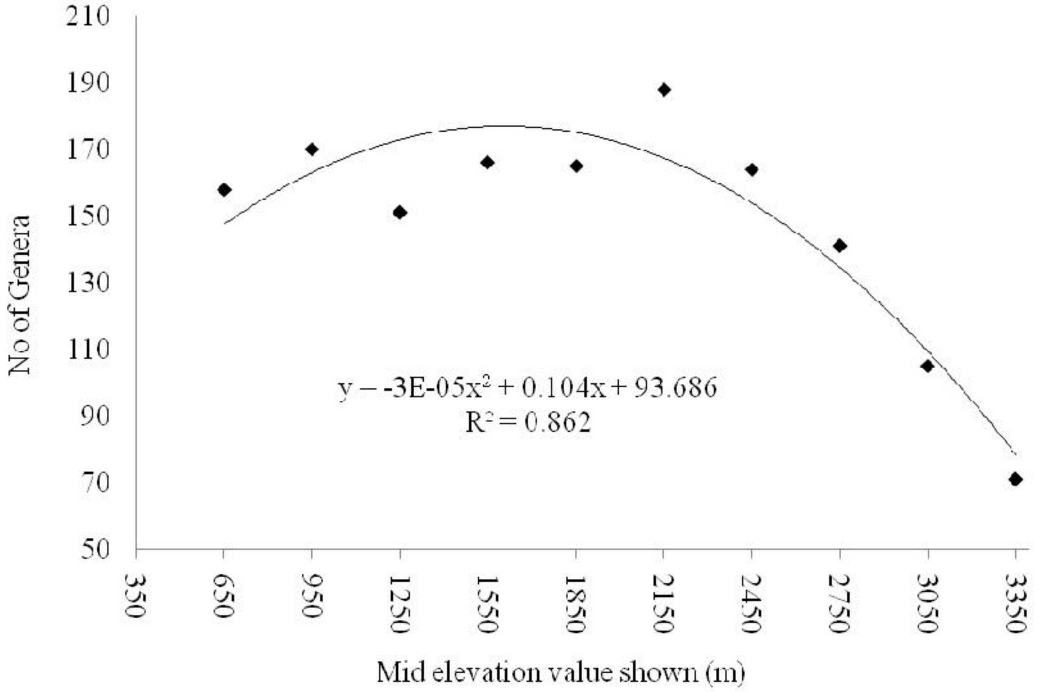


Fig. 5.25. Distribution of plant genera along the 300 m elevation gradient

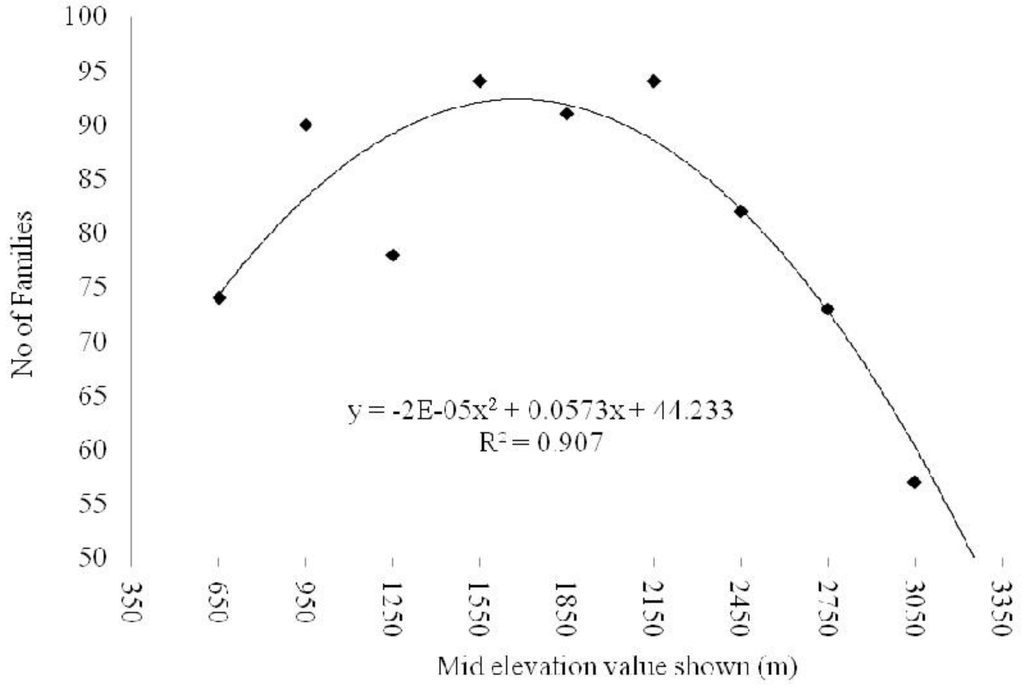


Fig. 5.26. Distribution of plant families along the 300 m elevation gradient

5.2.2.4. Endemic species

More than 200 species of plants are reported as endemic in the Sikkim Himalaya (Lepcha & Das 2011). The total number of individuals, species, genera and families observed were recorded from the East district during the present survey. A total of 224 plots were sampled randomly in various elevation

Table 5.5. List of endemic species recorded from the study area

Sl. No	Botanical Name	Family	Endemic for	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
1	*Ampelocalamus patellaris*	Poaceae	HR						√					√																		1000-1600
2	*Arisaema griffithii*	Araceae	NER											√				√		√												1500-2200
3	*Aucuba himalaica*	Garryaceae	EH																				√	√								2400-2600
4	*Begonia palmata*	Begoniaceae	C&EHR										√					√				√										1400-2400
5	*Beilschmiedia sikkimensis*	Lauraceae	SH																			√										2300
6	*Berberis angulosa*	Berberidaceae	HR											√																√		1500-3200
7	*Brassaiopsis hispida*	Araliaceae	HR																	√	√		√	√	√	√	√					2100-2900
8	*Brassaiopsis mitis*	Araliaceae	HR	√			√		√	√				√	√			√			√	√	√	√				√				500-3000
9	*Cephalostachyum capitatum*	Poaceae	EH																								√					2800
10	*Digitaria ciliaris*	Poaceae	HR		√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√						√					600-2900
11	*Drepanostachyum intermedium*	Poaceae	NER																						√							2600
12	*Heracleum wallichii*	Apiaceae	HR														√					√			√			√				1800-3000
13	*Himalayacalamus falconeri*	Poaceae	HR																						√	√	√	√	√		√	2600-3300
14	*Himalayacalamus hookerianus*	Poaceae	SH												√	√		√	√	√	√	√										1600-2400
15	*Holboellia latifolia*	Berberidaceae	HR																√													2000
16	*Liparis resupinata*	Orchidaceae	SH											√	√			√	√													1500-2100
17	*Maesa chisia*	Primulaceae	HR	√		√	√	√	√	√	√	√	√	√	√	√	√		√	√	√		√		√		√					500-2900
18	*Mahonia napaulensis*	Berberidaceae	HR											√							√							√				1500-3000
19	*Oberonia falcata*	Orchidaceae	SH									√	√	√																		1300-1600
20	*Pilea ternifolia*	Urticaceae	HR																						√					√	√	2600-3300
21	*Rhododendron anthopogon*	Ericaceae	EH																									√				2900
22	*Rhododendron barbatum*	Ericaceae	EH																	√			√		√	√	√	√	√	√	√	2100-3300
23	*Rhododendron dalhousieae*	Ericaceae	HR																												√	3300
24	*Rhododendron falconeri*	Ericaceae	EH																							√		√	√	√	√	2700-3300
25	*Rhododendron griffithianum*	Ericaceae	SH																					√				√	√	√	√	2500-3300

Sl. No	Botanical Name	Family	Endemic for	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
26	*Rhododendron thomsonii*	Ericaceae	HR																									√	√	√	√	2900-3300
27	*Rhododendron triflorum*	Ericaceae	HR																		√		√	√	√	√			√	√		2200-3200
28	*Rubus rugosus*	Rosaceae	HR					√																								900
29	*Satyrium nepalense*	Orchidaceae	HR									√				√																1300-1800
30	*Sorbus cuspidata*	Rosaceae	HR																						√		√	√				2600-3000
31	*Symplocos dryophila*	Symplocaceae	EH														√				√			√			√	√	√	√		1800-3200
32	*Symplocos glomerata*	Symplocaceae	NER														√	√	√	√	√	√	√									1800-2500
33	*Symplocos lucida*	Symplocaceae	HR														√	√	√	√	√	√	√	√	√		√		√			1800-3100
34	*Yushania pantlingii*	Poaceae	HR																					√	√	√	√	√	√			2500-3100

HR=Himalayan region; NER= North eastern region; EH= Eastern Himalayas; C&EHR= Central and Eastern Himalayan region; SH Sikkim Himalayas;

bands and has recorded 664 species of plants, out of which 34 species were found to be endemic. There are 14 families out of which Poaceae and Ericaceae contributed more number of species followed by Orchidaceae. Table 4.5 shows the list of endemic species found in the study area.

Total 34 endamic species of the Himalaya region are recorded from the study area out of which 6 species recorded from single elevation steps. *Brassaiopsis mitis* found the largely extended species which is recorded from 500 – 3000 m elevation steps fallowed by *Maesa chisia* and *Digitaria ciliaris* recorded from 500 – 2900 m and 600 – 2900 m elevation steps respective

Chapter 6

RESULT:

BIOMASS PRODUCTION ALONG THE ALTITUDINAL GRADIENT

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Biomass is defined as the total amount of dry weight of forest cover per unit area of land at any time, and is expressed in terms of tonnes (Lodhiyal & Lodhiyal, 2003). Also, it can be expressed as above ground biomass and below-ground biomass. It measures the change in forest structure (Schreuder *et al.,* 1997; Husch *et al.,* 2003). Several methods are in use to estimate forest biomass (Ovington 1968; Whittaker 1966): (1) Destructive and Non-destructive techniques (Foody *et al*., 2003; Zheng *et al*., 2004; Muukkonen & Heiskanen, 2005) and (2) Sampled data based using Satellite imagery (Brown *et al*., 1999). The former method is commonly used for biomass estimation.

Non-destructive technique for biomass estimation is widely used technique using field based data (Hunter *et al*., 2013; Garcia *et al.,* 1993). In this method tree specific regression equation were involve *viz*. Tree diameter/circumference, tree height and basal area are used as independent variables. Brown *et al*. (1989) used non-destructive sampling technique to estimate the volume of the tree and then converted into biomass using the specific gravity of individual species. Rana *et al*. (1989) used the field based method for the estimation of biomass for Central Himalaya. Bhattarai *et al*. (2004) performed field study of alpine grassland of the Central Himalayan part of Nepal for the estimation of biomass. Wang *et al*. (2014) saw the variations in the live biomass and carbon pools of *Abies georgei* Hand._Mazz. (*A. forestii* Coltm.-Rog.) along an elevation gradient on the Tibetan Plateau, China. There are several factors which directly control the biomass of the plants; some of those are climate (Wang *et al*., 2014) anthropogenic activities etc. Sundriyal and Sharma (1996) observed the impact of anthropogenic pressure on tree structure and biomass production in the temperate forest of Mamlay watershed in the South district of Sikkim.

The estimates of forest live biomass are still an important source of uncertainty in the carbon balance from local to regional scale, partly due to the scarcity of reliable estimates of live biomass and its variation across landscapes and forest types (Alves *et al*., 2010; Wang *et al*., 2014). Biomass assessment is necessary because forests are affected by various factors like deforestation, fire, uncontrolled harvest of different minor forest produces, pests, silviculture and climatic change (Schroeder *et al*., 1997; Change, I.P.O.C. 2006.) those bring considerable changes in the forest ecosystem.

Many studies have been analysed to understand the forest biomass patterns along elevation gradients in tropical mountains, The use of elevation gradients within the same biogeographic zone (tropical, temperate, boreal) is considered to be particularly powerful tool for improving biomass estimates across spatial variations and environment gradients (Wang *et al*., 2014).

Many environmental factors (e.g. rainfall, temperature, atmospheric pressure, solar radiation, wind velocity, etc.) change systematically with the change in elevation. Therefore, to test the ecological and evolutionary responses of biota to environmental changes the altitudinal gradients are among the most powerful techniques (Korner, 2007)

The above ground biomass and its dry weight decreases with the increasing elevation, and there are significant differences at different elevations (Jia *et al*., 2006). Goward and Dye (1987) opined that the integrated vegetation index can be related directly to the amount of vegetation (above ground phytomass) and primary productivity.

Chhabra *et al*. (2002) studied the average total growing stock volume density in India for the study years 1992 – 1993. Average total growing stock volume density in India was estimated as 74.42 m3 t/ha; with a range of 7.1–224.5 m3 t/ha. The mean biomass density in Indian forests was estimated at 135.6 t /ha and amongst the states it varied from 27.4 t /ha in Punjab to 251.8 t/ ha in Jammu & Kashmir. The total standing biomass (both, above and below ground) was estimated at 8683.7 Mt. The above ground and below ground biomass was estimated at 6865.1 and 1818.7 Mt; contributing 79 percent and 21 percent to the total biomass. The study has also highlighted state level differences in forest biomass density in India (Chhabra *et al*., 2002). The total above and below ground forest biomass in all states and union territories were estimated as 6865.1 and 1818.7 Mt, respectively. Sikkim contributes 48.1Mt. Total above ground biomass and below ground biomass has been calculated as 12.3Mt and 60.4Mt (Chhabra *et al*., 2002). Estimation of forest biomass is the key for understanding the exchange of energy flow, primary production and fluxes of nutrients in a forest ecosystem (Thakur, 2014).

Similarly, Sundriyal and Sharma (1996) recorded 8.32 t ha-1 for wood biomass and 1.80 t ha-1 for floor phytomass during their studies in the temperate forest of Mamlay watershed in South Sikkim.

The effect of adjusting plot placement to include large diameter trees over estimates forest biomass because biomass per tree increases geometrically with increasing diameter (Haripriya, 2002) The minimum diameter of sampled trees in India is more than 10 cm, reflecting the dominant interest in inventories of commercial volumes (Brown *et al.,* 1989). Though the smaller trees may have less volume than larger trees, they often contain relatively more trees than larger size classes and in certain cases they may contain important proportions of the total stand volume per biomass (Haripriya, 2002).

The above-ground biomass is mainly the largest carbon pool and it is directly affected by deforestation and forest degradation. Estimating the forest carbon stocks is mainly important to assess the magnitude of carbon exchange between the forest ecosystem and the atmosphere. Assessment of the amount of carbon sequestered by a forest will give us an estimate of the amount of carbon emitted into the atmosphere when this particular forest area is deforested or degraded. It will also help us to quantify the carbon stocks which in turn will enable us to understand the current status of carbon stock and also derive the near-future change in the carbon stock (Vashum & Jayakumar, 2012).

Sun *et al.* (2013) and Khan *et al.* (2014) studied the alpine meadow area, they found that elevation and soil moisture are strongly negative effects on above ground biomass (AGB) where as abundance, and soil nitrogen content was positively related to the AGB distribution. This study has confirmed that the average shrub biomass declined with increasing altitude.

This chapter records the estimation of biomass along the altitudinal gradient of Sikkim Himalayas. As has already discussed in the previous chapter the altitudinal range of the study area is spreading over from 500 m to 3300 m in the east district of Sikkim. The present study has estimated the total above ground biomass of this district using growing stock assessment field inventory method. Biomass was estimated using the tree volume formula and tree volume equation developed by FSI (1996). The methodology used for the calculation of biomass in East Sikkim has been detailed in the methodology chapter.

6.1. Biomass Productivity

Amongst others, the two type of non-destructive method for estimation of above Ground biomass is used in this study are (1) using the field sampled data like species number, tree height, CBH etc. and (2) Using the satellite based data.

6.1.1. Field data

Field productivity of East district of Sikkim Himalaya estimated, using the field sample plots data. There are 224 quadrats laid while collecting the field data from where a total 664 plant species collected from 28 elevation steps (500 – 3300 m). The biomass of the study area has been estimated using the volume equation of FSI (1996). The estimated biomass is ranging from 6.3 t/ha at 3150 m and 68.6t/ha at 2650 m in different elevation range in the East district. In an average 38t/ha biomass estimated from our field data.

6.1.1.1. Circumference at Breast Height (CBH): The CBH of above 10 cm of plants are taken as trees to estimate the biomass. *Lithocarpus pachyphyllus* is the biggest tree with CBH of 557 cm. The other big trees were *Castanopsis tribuloides*, *Quercus lineata*, *Quercus lamellosa* etc. Those contributed more than 500 cm CBH. The Diameter at Breast Height (DBH) is calculated using the recorded CBH, which, in turn, used for further volume calculation.

6.1.1.2. Tree height: the tree height collected from the field using range finder for 6 – 7 trees, than for other ocular estimation applied to estimate the tree height. The highest tree observe in the study area was *Artocarpus lacucha* and *Schima wallichii* with upto 37 m height followed by *Quercus lamellosa*, *Lithocarpus pachyphyllus* and *Magnolia lanuginosa*.

6.1.1.3. Basal area: It is similar to CBH and the *Lithocarpus pachyphyllus* found to possess the largest basal area in the study area.

6.1.1.4. Volume Estimation

Volume of the tree is a major component for the biomass/productivity estimation; first the individual tree volume was calculated in Microsoft excels using Volume equation formula of FSI, 1996 (*Annexure IV*). The volume is also correlated with CBH and basal area. *Lithocarpus pachyphyllus* found the largest one. The list of top 10 volume contributing trees are shown in Table 6.1.

Table 6.1. List of top ten volume contributor tree species from the East District of Sikkim

Sl. No	Plant Species	Volume contribution of the study area in M^3
1	*Castanopsis hystrix*	780.69
2	*Schima wallichii*	702.90
3	*Quercus lamellosa*	586.91
4	*Lithocarpus pachyphyllus*	507.66
5	*Alnus nepalensis*	350.93
6	*Acer campbellii*	328.92
7	*Engelhardtia spicata* var. *integra*	283.42
8	*Engelhardia aurifolia*	152.63
9	*Castanopsis tribuloides*	152.26
10	*Abies densa*	107.78

6.1.1.5. Biomass estimation

Biomass (Productivity) of the study area calculated using the volume and specific gravity of trees (*Annexure IV*), the *Quercus lamellosa* contributed the highest biomass followed by *Castanopsis hystrix* the detail of top 9 species is given in the Table 6.2.

Table 6.2. List of tree species as per their contribution of biomass

Sl. No.	Plant name	Contribution of Biomass by individual species t/ha.
1	*Quercus lamellosa*	410.249
2	*Castanopsis hystrix*	402.053
3	*Schima wallichii*	349.343
4	*Lithocarpus pachyphyllus*	261.446
5	*Acer campbellii*	163.471
6	*Engelhardtia spicata* var. *integra*	140.860
7	*Alnus nepalensis*	111.947
8	*Castanopsis tribuloides*	78.414
9	*Engelhardia aurifolia*	75.858

6.1.1.5.1. ***Along 100 m elevation step:*** It was seen in 100 m elevation gradient the biomass production increases with altitude up to the limit of tropical forests. The negative pattern was observed in sub-tropical forests between 900 – 1400 m elevation section, the major human habitation areas also fall in this region. Then, the biomass t/ha suddenly increase and reach to about 60 t/ha at around 1700 m elevation. It again decreased to about 30 t/ha at around 2000 m elevation. As we observed the overall pattern of biomass production along the altitude increases along the elevation in the temperate forest zone. After that, the production decreases with the increased elevation.

As shown in figure 6.1 the relation between biomass and elevation, as the elevation increases the tree biomass decreases. Similarly, the number of trees in the sample area also decreases with increased elevation.

Result was found significant at $p<0.10$, it shows that there was a poor relation of biomass along the elevation gradient of 100 m in the east district of Sikkim (Fig. 6.1).

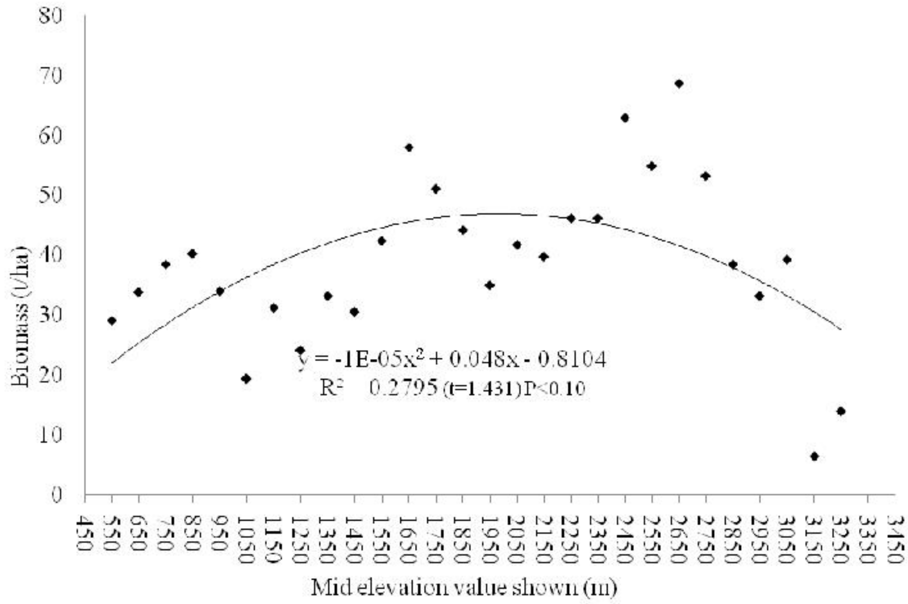

Fig. 6.1. Relationship between biomass and altitude along 100 m elevation step

6.1.1.5.2. ***Along 200 m elevation step*****:** The relation of biomass along the 200 m elevation gradient has been evaluated as shown in figure 6.2. In this step the relation of biomass and elevation R^2=0.410, it shows that there is 41 % chance to be a good relation of these two parameters.

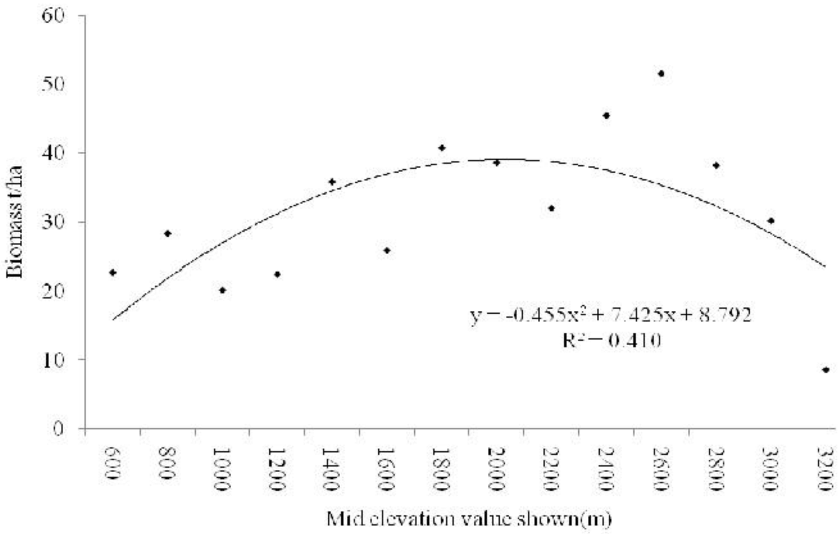

Fig. 6.2. Relationship between biomass and altitude along 200 m elevation step

6.1.1.5.3. ***Along 300m elevation step:*** The relation of biomass along the 300 m elevation gradient has been shown in figure 6.3. The R^2 at 0.58 is the expression of a good relation with altitude in 300 m elevation band. Here, a hump-shaped relation of biomass along the elevation gradient peak at around the 2500 m elevation is clearly visible.

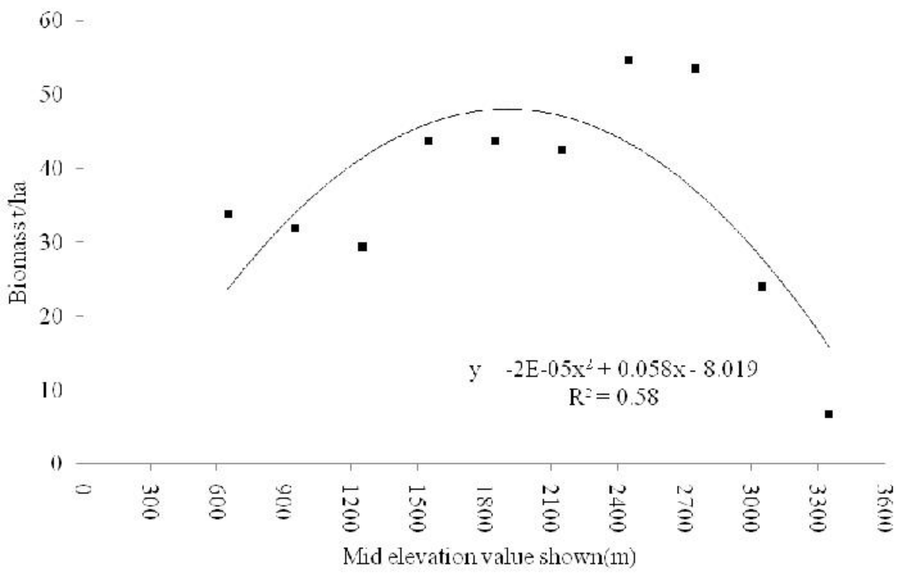

Fig. 6.3. Relationship between biomass and altitude along 300 m elevation step

6.2. Satellite based relation of Biomass

Several works has been conducted with remote sensing imageries and their utility in the field of plant biomass. The remote sensing satellites are equipped with sensors looking down to the earth. They are the "eyes in the sky" constantly observing the earth as they go round in predictable orbits. There are different types of remote sensing satellite data, *viz*. Optical, Microwave, Infrared Radar, etc. This elucidate the relation between the satellite based plant productivity NPP with the field derive biomass. Zhang *et al*. (2009) observed the Global pattern of NPP to GPP ratio derived from MODIS data, they observed that geographically, the NPP/GPP ratio increased with altitude but in the Southern Hemisphere, the NPP/GPP ratio decreased along latitude. MOD17 product, are limited by the spatial resolution. Sims *et al*. (2006) shown that a model based solely on EVI provided as good or better estimates of productivity for most of the sites than did the much more complex MOD17 model . MODIS data inputs are best suited to assessments of large forested tracts of land where stand ages are relatively uniform (Potter *et al*. 2007).

6.2.1. Landsat-8 NDVI and EVI: Similarly, the range of NDVI values observed -0.053 to 0.488 this shows that the NDVI values was saturation up to 0.488 only on the other hand, the EVI2 derived value range shows 0.07 to 0.90 in different month data (Fig. 6.4).

Further there is a limitation of optical satellite data (Landsat imagery) is that fewer cloud-free dates are typically available that can be collected over the course of a growing season in most temperate and humid climate zones as compared to MODIS composite images. In contrast, MODIS composite images provided regular bimonthly time series

6.2.2. Relation between biomass and satellite EVI: Satellite remote sensing provides consistent and systematic observations of vegetation and ecosystems, and has played an increasing role in characterization of vegetation structure and estimation of productivity (Prince & Goward, 1995; Rai, 2006).

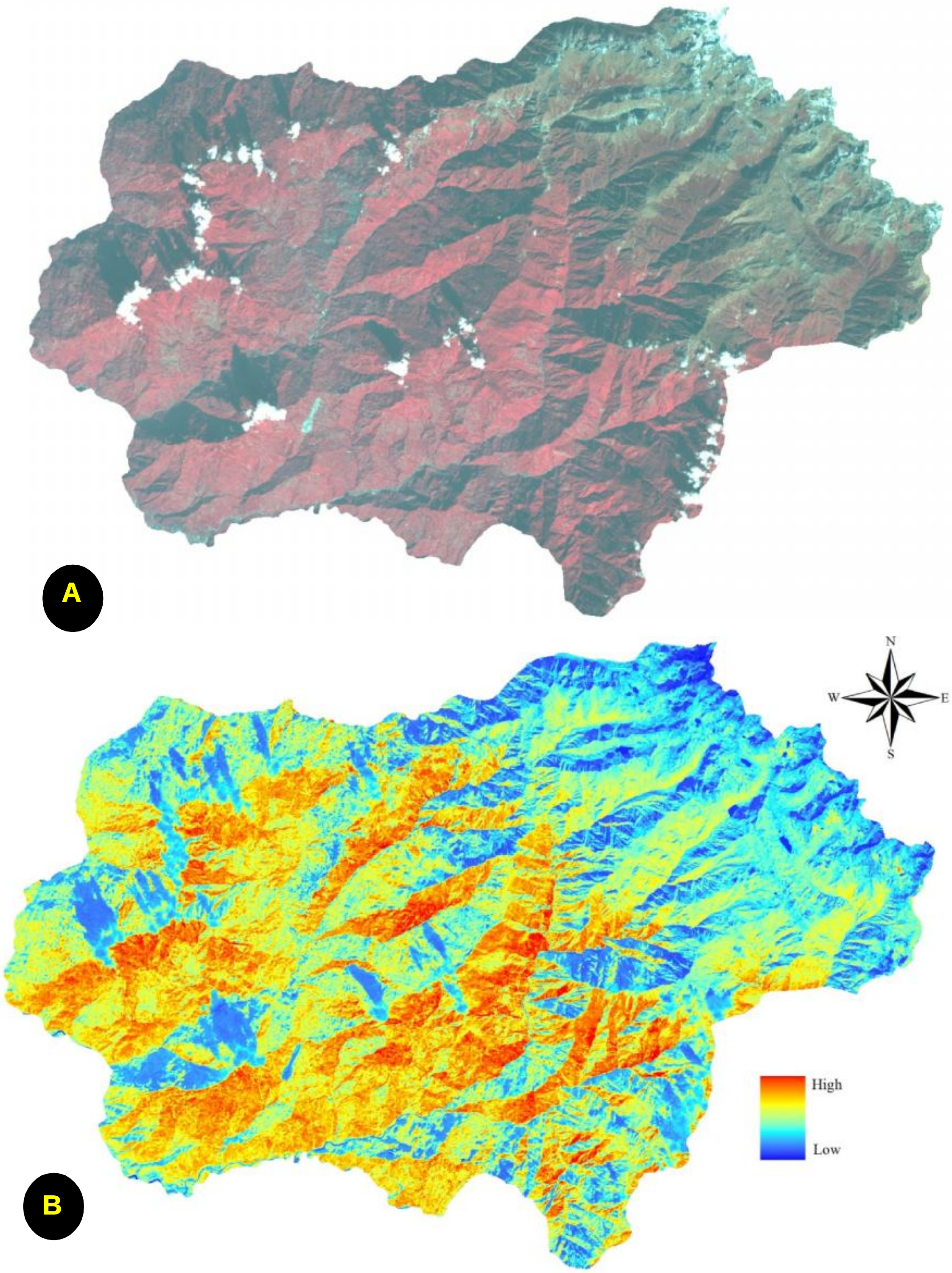

Fig. 6.4. Landsat satellite imagery of 6th December 2013 (A) and NDVI of same period (B)

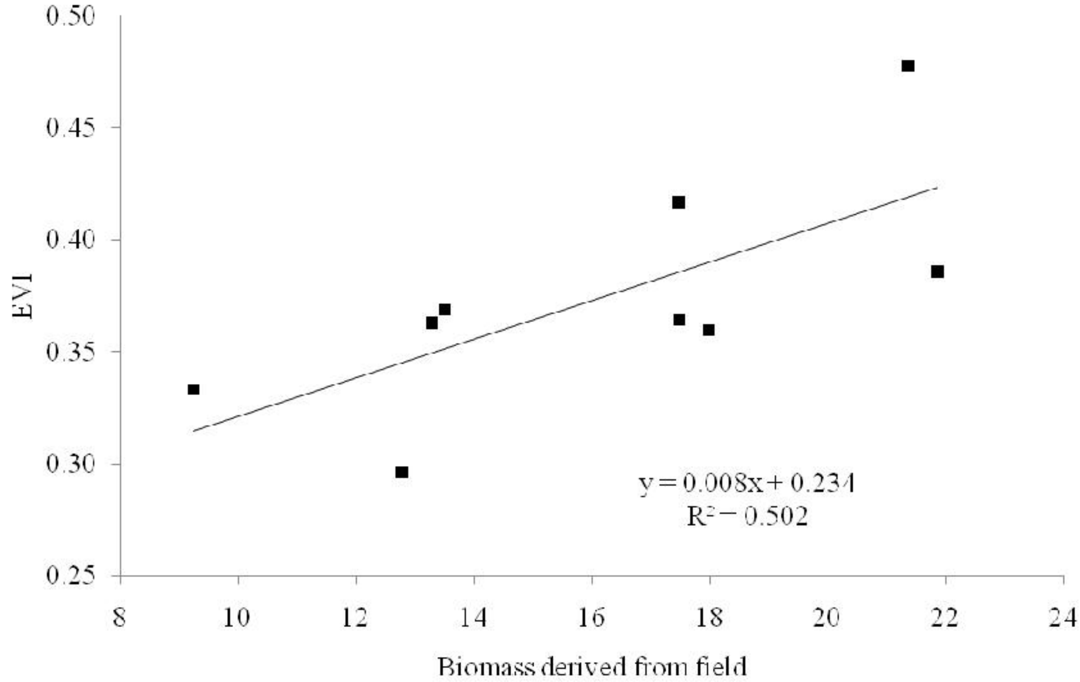

Fig. 6.5. Relation between Biomass vs Landsat EVI in 300m steps

The productivity predicted from Landsat satellite data of 30-meter resolution and has been correlated with the field biomass which shows the significant correlation of R^2 at 0.50, in 300 m elevation steps when the result tested in linier equation (Fig. 6.5).

Further the field biomass and EVI tested using the polynomial regressions between EVI and field biomass were computed along the 100 m elevation steps of Sikkim Himalayas from 500 to 3200 m elevation range. The result is shown in figure 6.6. It was observed R^2 at 0.322.a in second order polynomial.

The second order regression polynomials between EVI and field based biomass along the100 elevation steps of subtropical to sub alpine forest (1200 – 3000 m) of the study area was also performed. Correlation was seen R^2 at 0.31 for EVI values and field values along the elevation (Fig. 6.7a). Further segregate of procured data for temperate and sub-alpine area (2300 – 3000 m) and tested in second order of regression polynomials. A better correlation between field biomass and satellite based EVI along the elevation was observed in (Fig. 6.7b). It is due to may be the moisture contain in the temperate and sub-alpine forest area of Sikkim Himalayas.

Though the derived result also shows the relation with biomass is not quite satisfactory it may due to the following factors:

i. *Data acquisition date*: The data collection date from the field and date of acquisition of satellite imagery may not be the same.

ii. *Sample and Pixel sizes*: The sample size for trees is 20 x 20 m and the pixel size of satellite imagery is 30 x 30 m which may mismatch with other pixels.

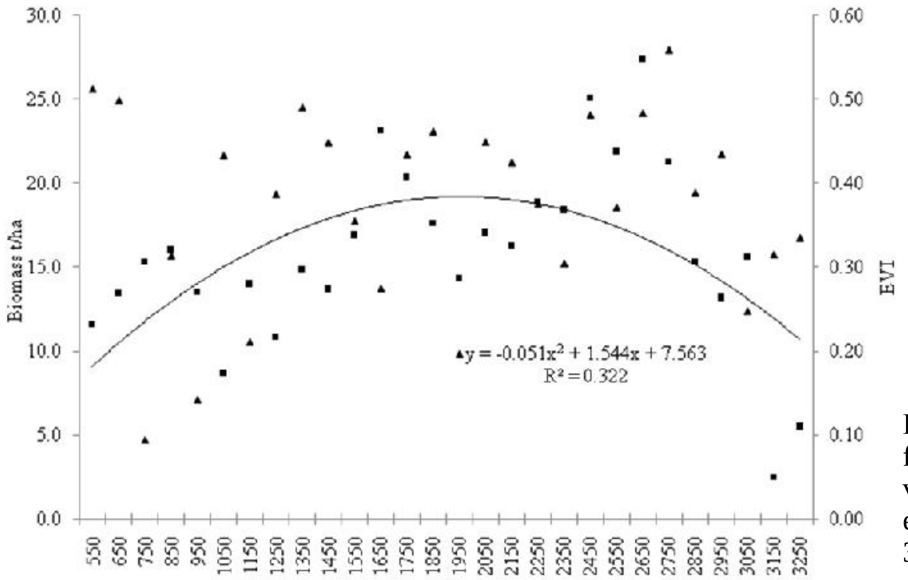

Fig. 6.6. Relation between field biomass vs EVI2 values along the100 m elevation steps from 500 to 3300 m of Sikkim Himalaya

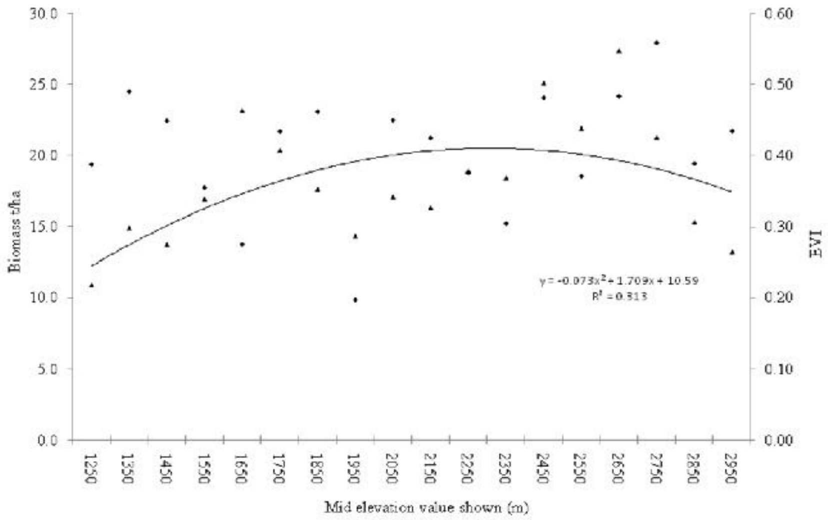

Fig. 6.7a. Relation between field biomass vs EVI2 values along the elevation steps from (A) 1200 – 3000 m and (B) 2300 – 3000 of Sikkim Himalaya

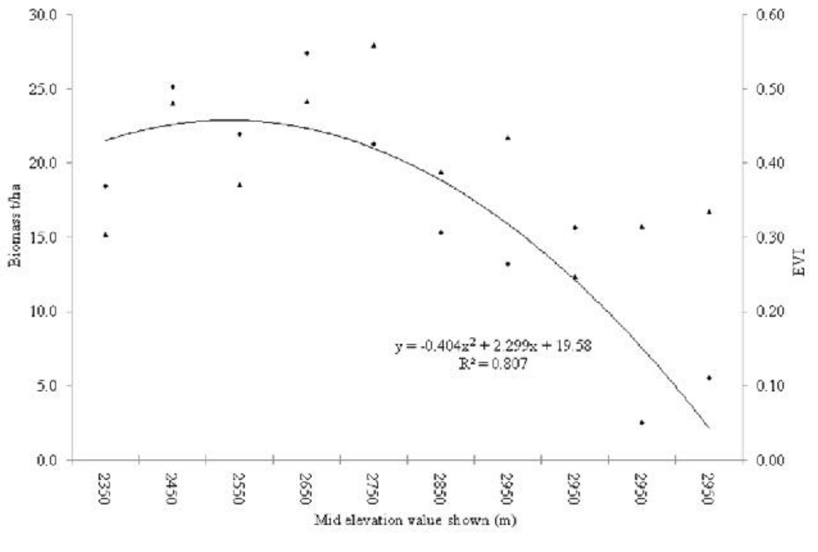

Fig. 6.7b. Relation between field biomass vs EVI2 values along the elevation steps from (A) 1200

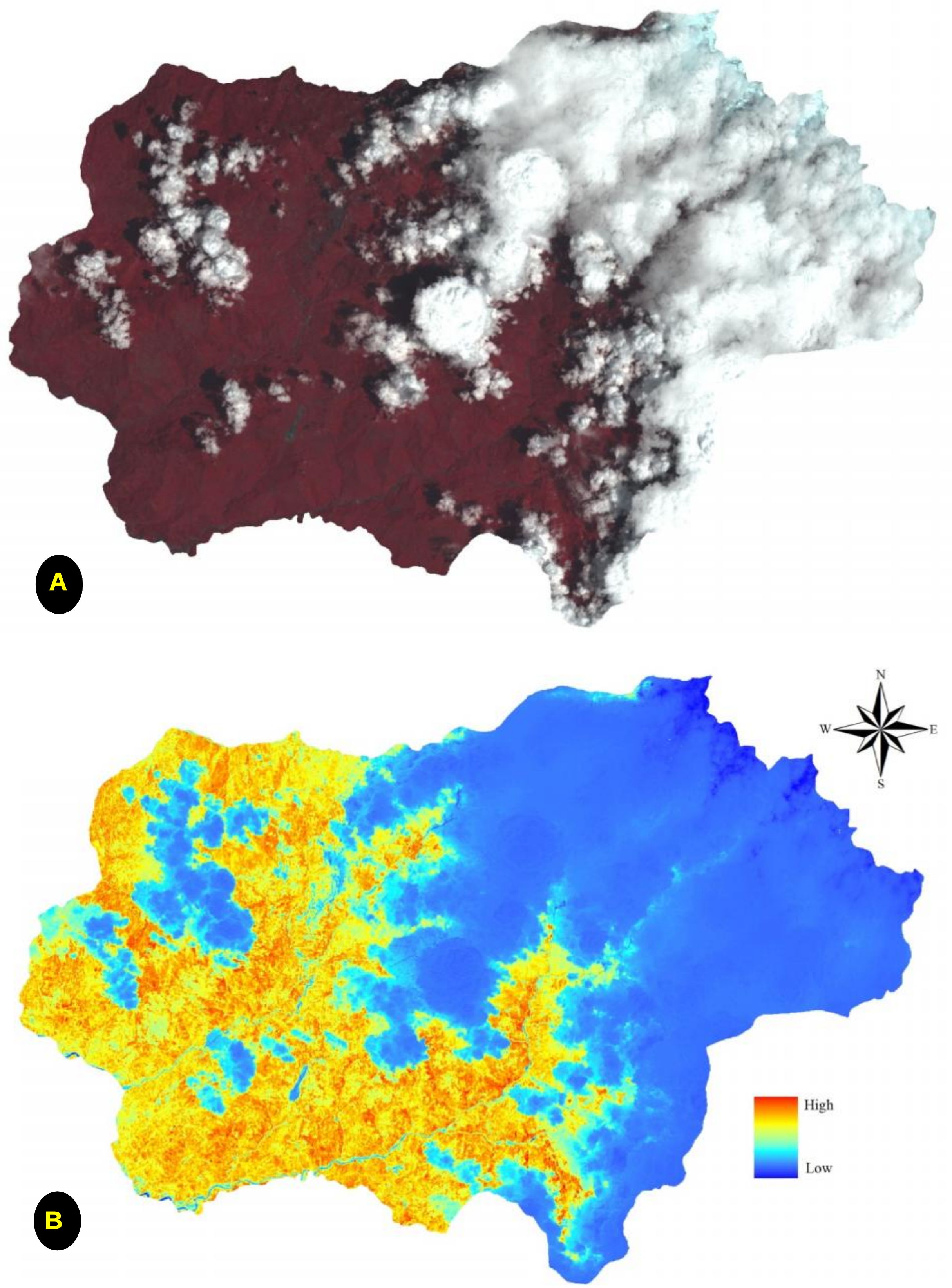

Fig. 6.8. Landsat satellite imagery of 26th April 2013 (A) and (B) EVI of same period indicate the presence of more than 40 % cloud cover.

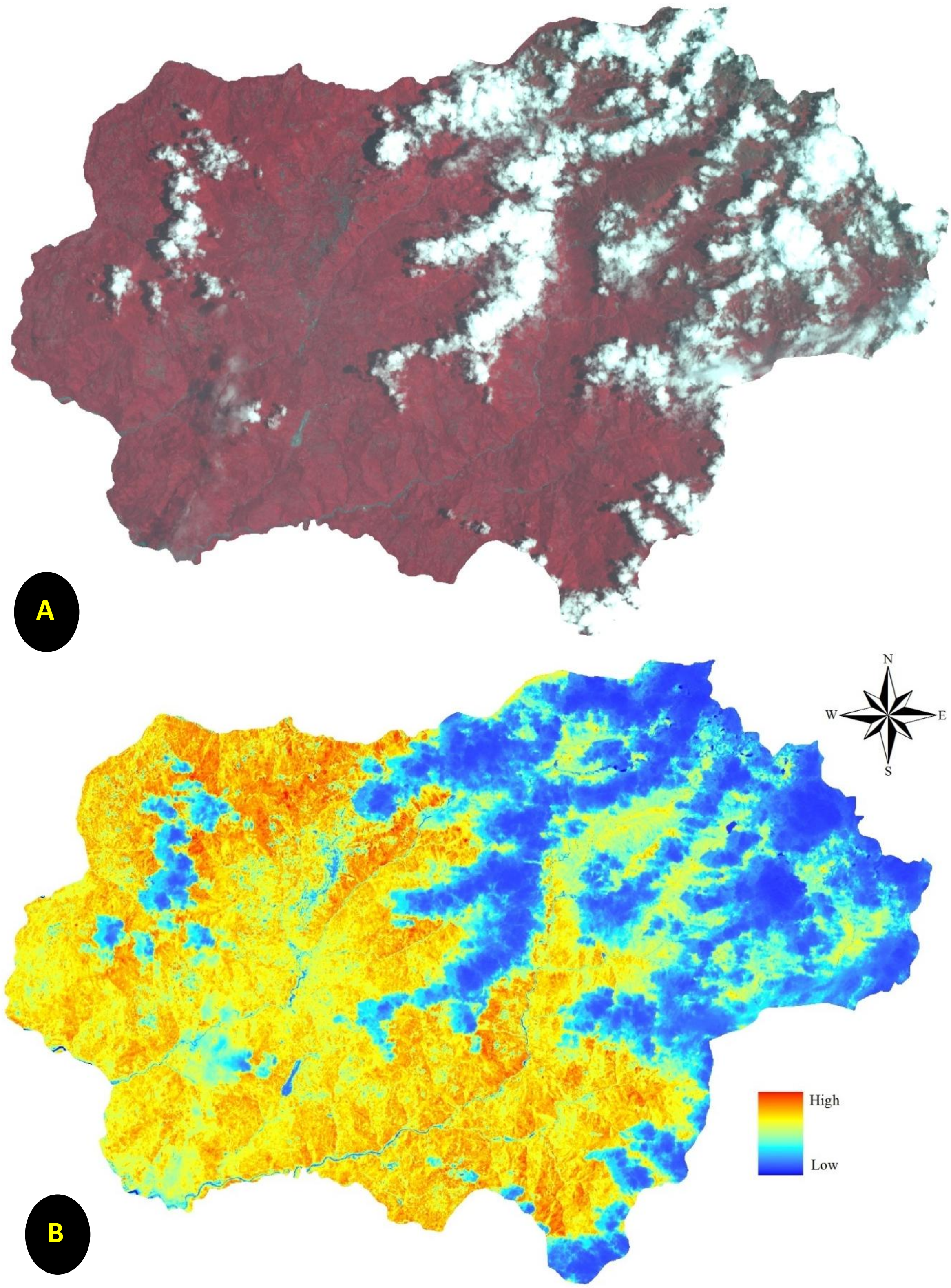

Fig. 6.9. Landsat satellite imagery of 13th June 2013 (A) and (B) EVI of same period

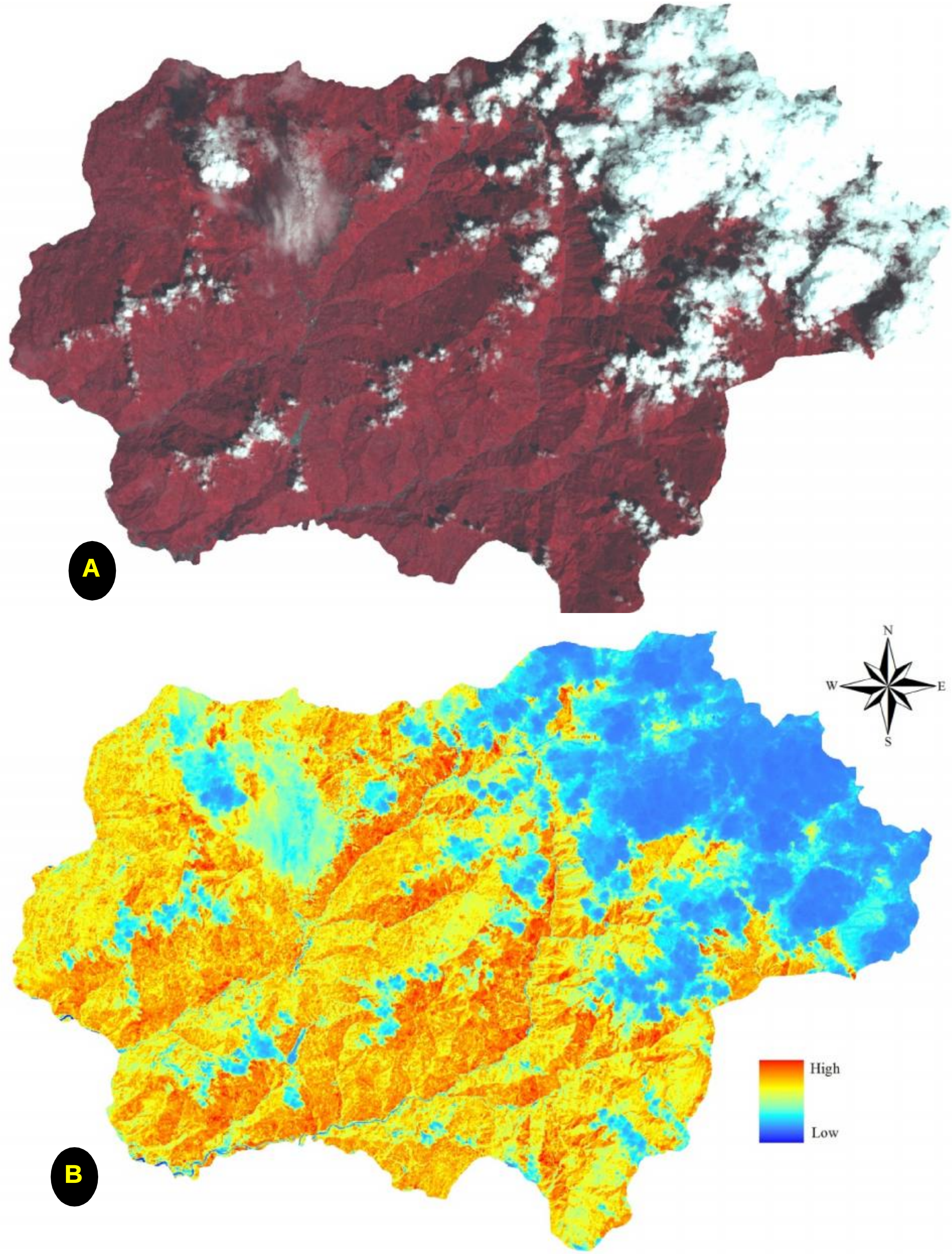

Fig. 6.10. Landsat satellite imagery of 17th September 2013 (A) and (B) EVI of same period

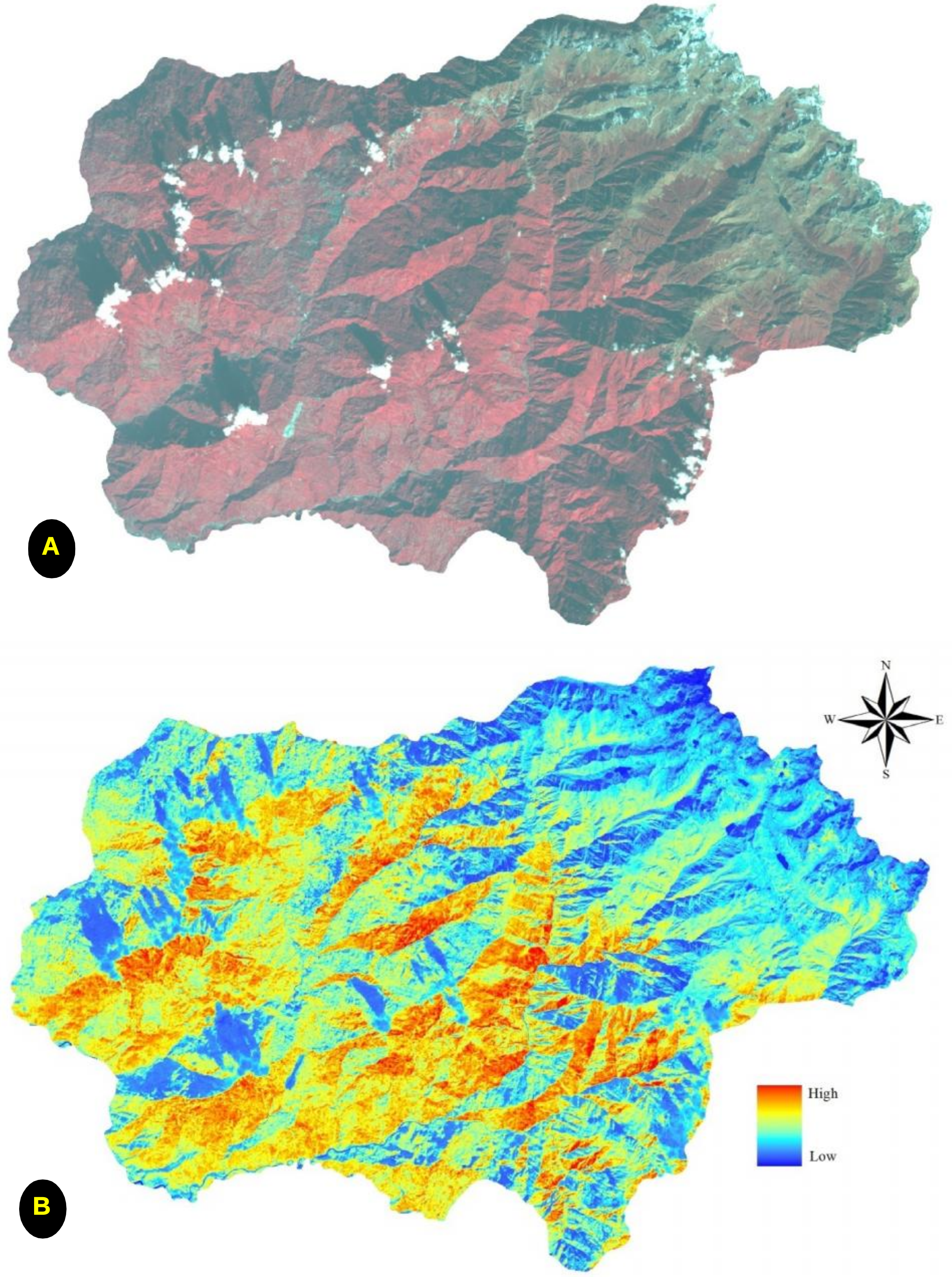

Fig. 6.11. Landsat satellite imagery of 6th December 2013 (A) and (B) EVI of same period

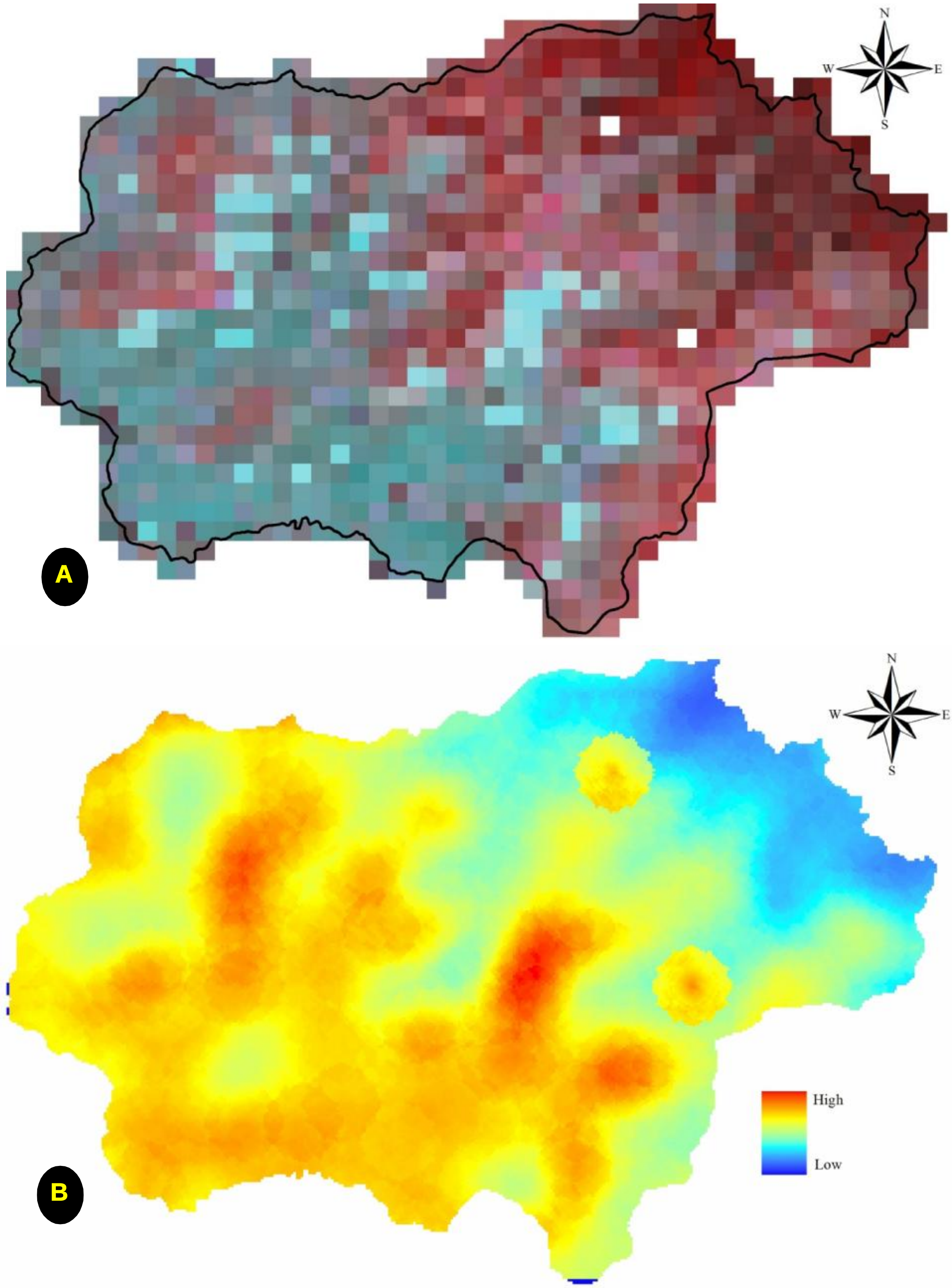

Fig. 6.13. MODIS Productivity imagery (A) and (B) MODIS NPP derive after interpolation

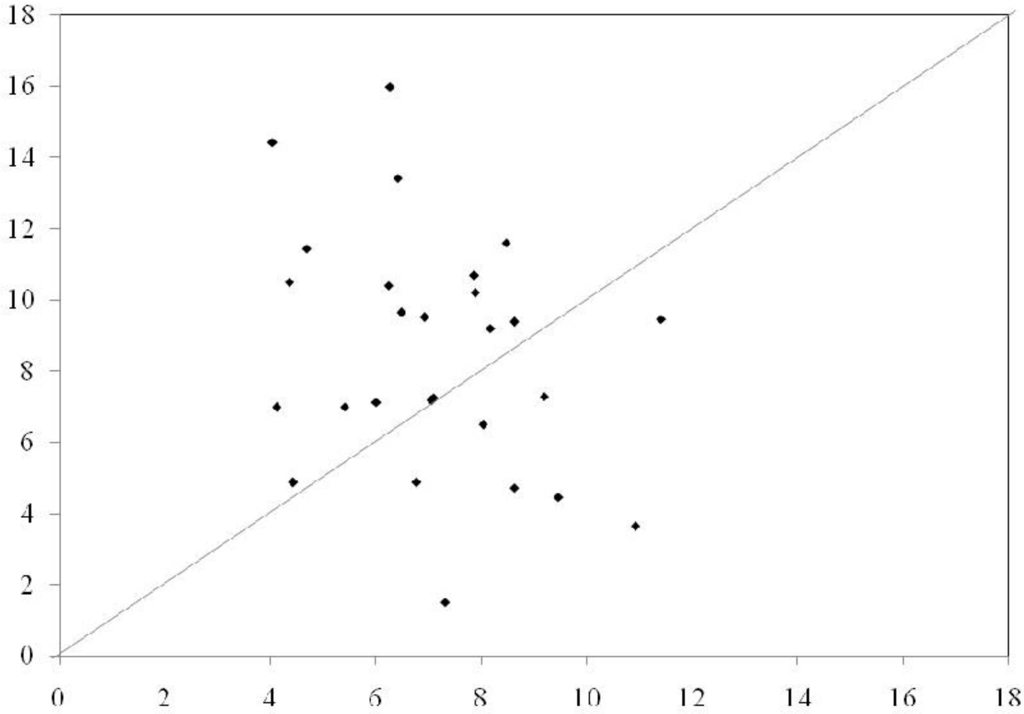

Fig. 6.12. Relation between MODIS NPP and Field derived biomass

iii. *Anthropogenic disturbances*: There are very less correlation in the tropical and temperate forest, it may be due to more anthropogenic disturbances.

The EVI's utility in satellite-driven primary production modelling has previously been demonstrated for several different biome types (Xiao *et al*. 2004) and the highly linear relationship observed in GPP can be estimated through a linear regression model for similar environments with relatively high accuracy, using only EVI as independent variables.

6.2.3. MODIS Productivity: At first the MODIS NPP were downloaded and compared with the field derived biomass. Then, tried to fit the MODIS NPP product in local scale of Sikkim Himalaya (Fig.6.12 & 6.13). This product is also prone to be complicated by the mismatch in scale between ground-based NPP derived from the field and the coarse resolution (1 km) of the MODIS NPP product.

6.2.4. Relation MODIS Productivity with Biomass: The values of MODIS Productivity was not satisfactory as compared to other satellite products. The MODIS (1 km x 1 km) data is not suitable for the estimation of productivity in local scale of study.

Chapter 7

RESULT:

RELATIONSHIP BETWEEN SPECIES RICHNESS AND BIOMASS ALONG THE ALTITUDE

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RELATIONSHIP BETWEEN SPECIES RICHNESS AND BIOMASS ALONG THE ALTITUDE

7.1. Relation between species diversity and productivity

The mountain has different biotic and abiotic gradients. The changes in these factors in mountain are mainly due to the altitudinal gradients. The major trend in relation between elevation and species richness are: (i) decreasing richness with increasing elevation, (ii) plateaus in richness across low elevation then decreasing with or without a mid-elevation peak, and (iii) uni-modal pattern with mid elevational peak (McCain & Grytes, 2010). The first details on changes in natural world with the changes in elevation was observed by Charles Darwin, Alfred Russel Wallace and Von Humboldt (Lomolino, 2001). Differences in the species richness with change in temperature are depending upon the latitude, size, shape and prevailing weather conditions in the mountain region. Air pressure and solar radiation are other factors those foreseeably vary with change in elevation. Precipitation trend in the form of rain, snow or condensation from clouds corresponds to the prevailing weather patterns, the slope and the proximity to the ocean or large water body (Barry, 2008). Other important determinant of species richness along the altitudinal gradients in the mountain may be area, cloud cover and soil quality. The interaction among these abiotic factors determine overall productivity of the species. Fridley *et al.* (2001) reported no consistent change in biomass is evident with the change of number of species.

Relationship between species richness and biomass along the altitudinal gradient is known from various parts of the world (Bhattarai & Vetaas, 2003). Several studies have found negative correlation of species richness and elevation (e.g. Yoda, 1967; Alexander & Hilliard, 1969; Hamilton, 1975; Wolda, 1987; Stevens, 1992; Patterson *et al*., 1998), whereas others have found a hump shaped relationship between species richness and elevation (e.g. Janzen, 1973; Whittaker & Niering, 1975; Rahbek, 1995; Lieberman *et al*., 1996; Gutiérrez, 1997; Fleishman *et al*., 1998; Odland & Birks, 1999; Grytnes & Vetaas, 2002). Whereas, Fargione *et al*. (2007) reported that the selection to complementarily shifts in species richness affects biodiversity-productivity relationships in a long-term biodiversity experiment.

There are several other effects for negative and positive correlation between biomass and species richness along the altitude. Some authors classified it as sampling effect and others classify it as facilitation. Facilitation occurs when an individual attains greater biomass in the presence of inter-specific neighbours because of their beneficial effects on an intermediary resource (Fridley, 2001). Cardinale *et al*. (2007)

seen the impact of plant diversity on biomass, because of species complementary effects. The external factors such as moisture or other environmental conditions are thought to be of much more importance than the internal interactions (Bhattarai *et al.*, 2004). The relation between biodiversity and biomass production has discuss for the grassland at local and regional scale in '*Grassland a global resource*' and they suggested the requirement for up-scaling research in this aspect. Ruijven and Berendse (2005) discussed the effect on nutrient in diversity and productivity relationship.

Another major component is soil. There must be the link between species richness, biodiversity and ecosystem with soil (Coleman & Whitman, 2005). The elevation gradient in the species richness pattern is commonly explained by similar factors to the latitudinal gradient, such as climatic factors, productivity, and other energy-related factors (Richerson & Lum, 1980; Turner *et al*., 1987; Currie, 1991; Rohde, 1992; Wright *et al*., 1993; Grytnes *et al*., 1999; Lomolino, 2001) vary along the elevation gradients and ultimately create the variation in species richness.

The elevation gradient of species richness is intricately related to species-latitude and species-area relationships (Korner, 1999; Lomolino, 2001) and argues that elevation gradients can contribute important insights into developing a general theory of species diversity. The relationship between biomass and plant species richness has been extensively investigated (Thomas & Bowman, 1998; Grytnes & Vetaas 2000; Bhattarai *et al*., 2004; Han *et al*., 2007; Namgail *et al*., 2012).

Factors causing variation in species richness may differ between different organisms and between life-forms of plants. Huston (1994) found that trees and herbaceous species have different responses in Eastern compared to Central and North America. A comparison of various life-forms may allow a finer resolution of precise causal factors than studies on total plant richness.

7.1.1. Conditions in East district of Sikkim: Present study on species richness and biomass production in the East district of Sikkim was envisaged to analyse the plant species richness of along the elevation ranging from 500 – 3300 m amsl. In this study, it is also aimed to study the relationship between elevation change and species richness. The variation in species richness and biomass along the altitudinal gradient is due to the following factors (i) the number of individuals, (ii) the number of species in the species pool, and (iii) habitat heterogeneity (Simova *et al.*, 2013).

To understand the relationship between species richness and biomass the two hypothesis was intended, (i) species richness and biomass vary along the elevation gradient, and (ii) species richness pattern is a function of abiotic factors prevailing along the altitudinal gradient.

The Himalayan elevation gradient is one of the longest bio-climatic elevation gradients in the world. In Sikkim within only 75 km one moves from a tropical to alpine zone (Fig. 2.2). Hills in Sikkim experience humid tropical to sub-tropical climate up to elevation of 1000 m. The range is characterised by agricultural land in tropical moist deciduous forests up to 900 m. The dominant species of this region are *Shorea robusta*, *Syzygium formosum*, *Terminalia myriocarpa* etc and in the sub-tropical forests from 900 – 1800 m the dominant species include *Albizia chinensis*, *Alnus nepalensis. Castanopsis hystrix*, *Engelhardtia spicata* var. *integra*, *Macaranga indica* and *Schima wallichii*. The elevation sector of 1800 – 2800 m is with temperate forests, 2800 – 3500 m with temperate conifers, 3500 – 4000 m as subalpine and above 4000 m as alpine forests/ vegetation (ISRO 1994).

In several studies, researcher had used plant community biomass to predict species richness with different degree of success. In the present study, 28 elevational band ranging from 500 – 3300 m, at every 100 m altitudinal gradient, were examined to analyse relationship between species richness and biomass (Fig. 7.1).

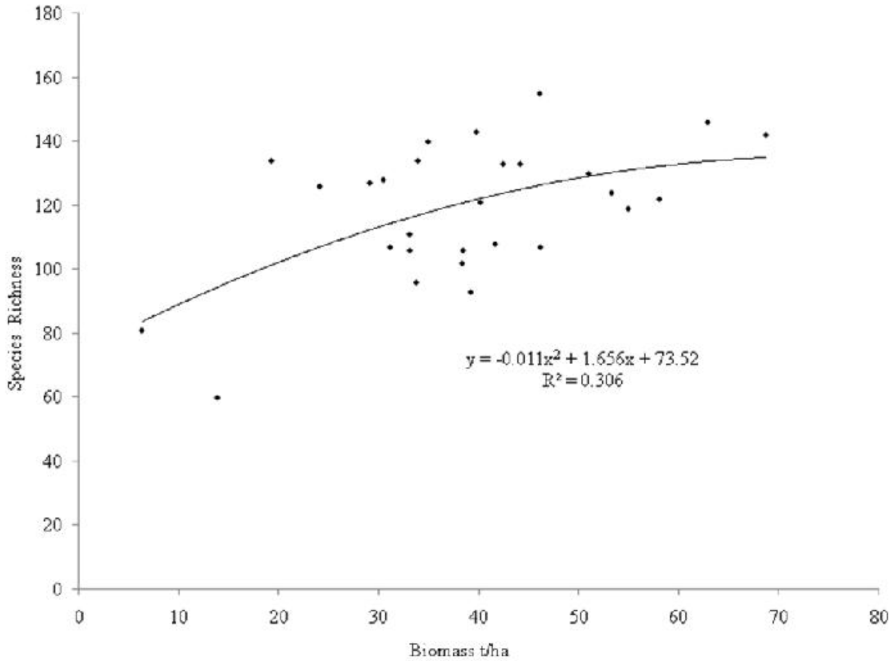


Fig. 7.1. Relation between species richness and biomass along 100 m elevation steps.

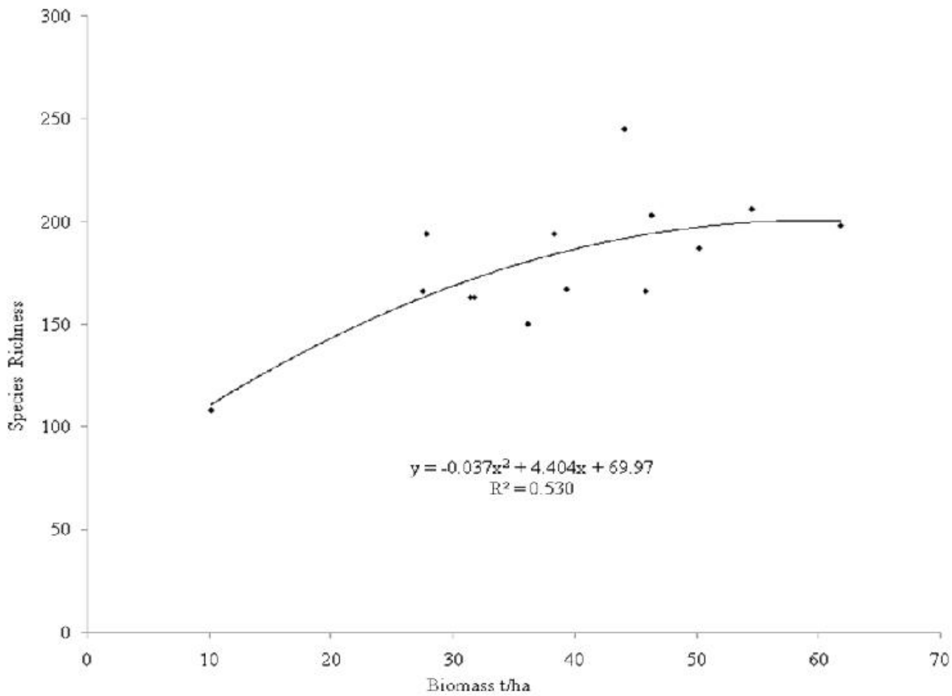


Fig. 7.2. Relation between species richness and biomass along 200 m elevation steps.

The relation between species richness and biomass study at 100 m elevation range, 28 elevational steps with 8 plots of 20 x 20 m, in 200 m elevation range 14 elevational steps with 16 plots of 20 x 20 m and in 300 m elevation range 10 elevation steps with 24 plots of 20 x 20 m were studied. The second

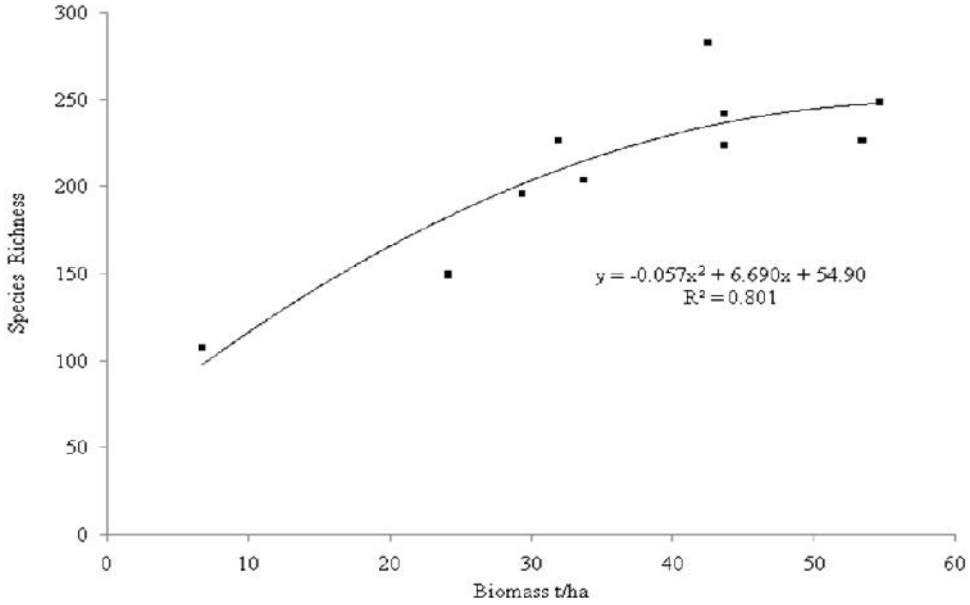


Fig. 7.3. Relation between species richness and biomass along 300 m elevation steps.

7.2. Relation between species diversity and productivity along the altitude

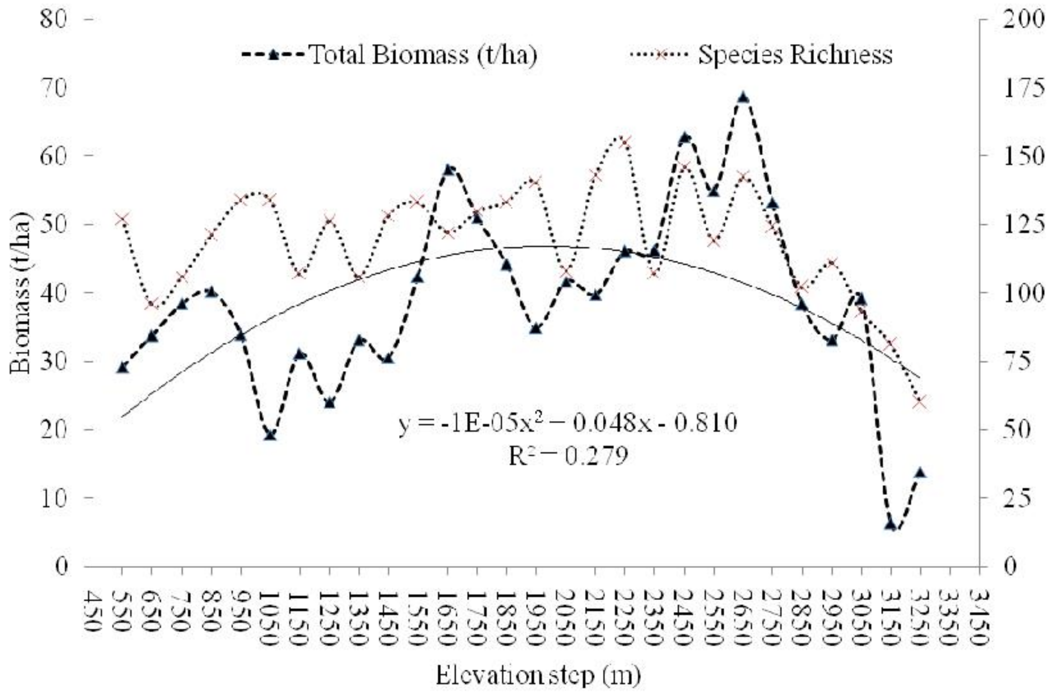


Fig. 7.4. Relationship between biomass and species richness along the 100 m elevation steps.

order polynomial regression was tested for each scale (R^2=0.30) indicates that only 30.0 % of variation in biomass is attributed to change in biomass along the altitude. It may be affirm that there exists no variation in biomass within 100 m elevation steps (Fig. 7.1). Similarly, the study of relationship between species richness in biomass at 200 m and 300 m elevation steps revealed that there exist significantly higher attributes of biomass towards, species richness. Regression coefficient, R^2=0.41.0 in 200 elevation steps and R^2=0.58.0 in 300 elevation steps indicates 41% and 58% variation in species richness is attributed to the biomass (Fig.7.2 & Fig. 7.3).

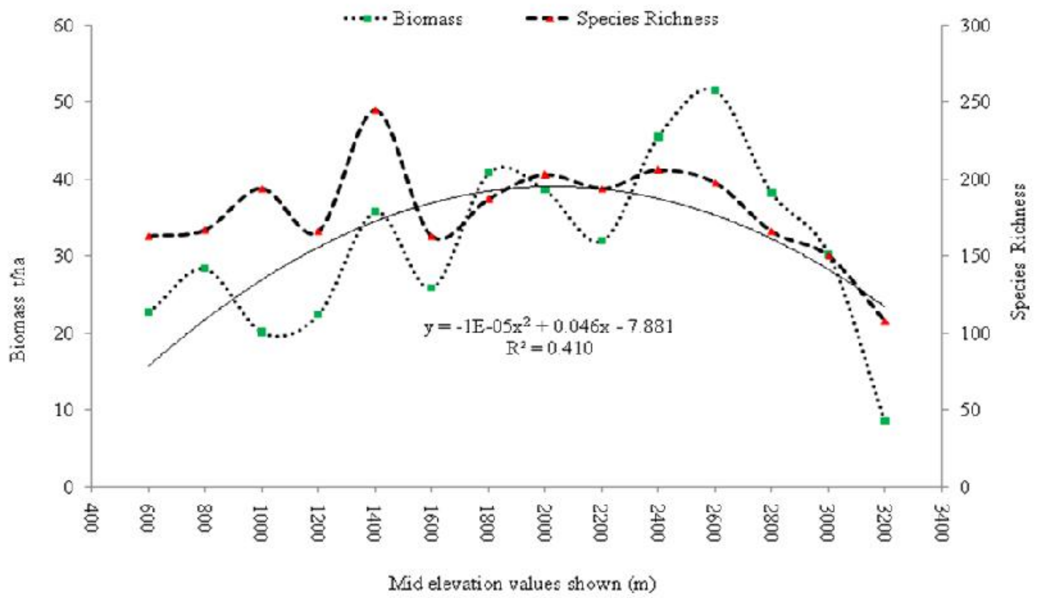


Fig. 7.5. Relationship between biomass and species richness along the 200 m elevation steps.

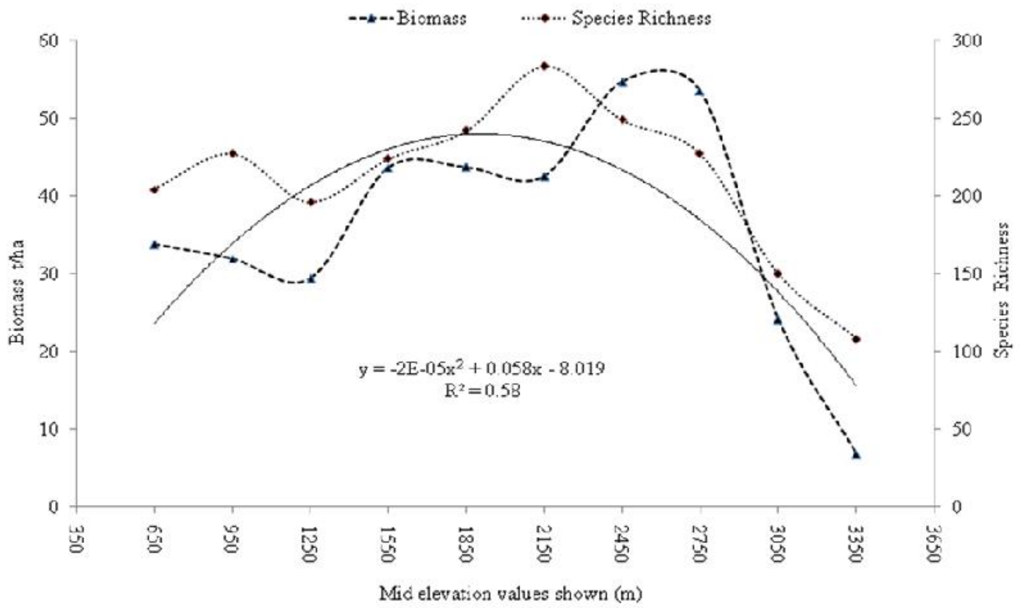


Fig. 7.6. Relationship between biomass and species richness along the 300 m elevation steps.

No significant relationship of biomass and species richness along the 100 m elevational gradient R^2=0.2795, (Fig 7.4) in 200 m elevation gradient R^2=0.4109 (Fig. 7.5) was established. As moved to further higher scale in 300 m the relation was improved up to R^2=58.0 (Fig.7.6.).

7.3. Relation between species richness and other environmental variables-multivariate analysis

The above studies, helped to understand the importance of sample elevation steps to establish the relationship between species richness in biomass.

7.3.1. Correlation of species richness with other factors: The correlation between richness and variables viz; temperature, rainfall, slope, soil, elevation, aspect and biomass was studied.

Table 7.1. Correlation Matrix of species richness with other factors in the East District of Sikkim

	Species Richness	Temperature	Rainfall	Slope	Soil	Elevation	Aspect	Biomass
Species Richness	1							
Temperature	0.527	1						
Rainfall	-0.007	-0.379	1					
Slope	-0.083	-0.094	-0.352	1				
Soil	0.308	0.32	-0.1	0.01	1			
Elevation	-0.542	-0.853	0.466	-0.099	-0.532	1		
Aspect	-0.053	-0.239	-0.012	-0.033	0.295	-0.005	1	
Biomass	0.119	0.025	0.098	-0.02	-0.017	0.042	-0.035	1

The correlation matrix (Table 7.1) compared the multiple data using the GLM model with response variable (Species richness) with other explanatory variables, were found to have strong relationship of species richness with temperature and elevation and the strong relationship between temperature and elevation followed by rainfall. There is also good relation of elevation with soil.

The relationship of biomass with other variable is poor as compare with the species richness.

Table 7.2. Coefficients GLM of Species Richness with other variable

	Estimate	Std. Error t	t value	Pr(>|t|)	
(Intercept)	-9.447	14.061	-0.672	0.502	
Temperature	0.595	0.422	1.411	0.160	
Rainfall	0.020	0.004	4.441	0.000	***
Slope	-0.012	0.058	-0.206	0.837	
Soil	0.001	0.033	0.030	0.976	
Elevation	-0.006	0.002	-3.804	0.000	***
Aspect	-0.001	0.006	-0.092	0.926	
Biomass	0.078	0.039	2.000	0.047	*

Significant Codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

7.3.2. Relationships between species richness and other variables: The relationships between species richness and other variables are shown in Table7.2 and figure 7.7. Total species richness has unimodal relationship with other variables, indicated by a statistically significant second order term in the GLM analysis. It was understood that the relationship of species richness with rainfall, soil and biomass tests are significant as compare to other variables.

The unimodal or hump-shaped relationship between species richness and biomass is tested with data from 200 m and 300 m elevation steps in East district of Sikkim. The result agrees with earlier studies (Grime, 1973, 1997; Al-Mufti *et al*., 1977; Gross *et al*., 2000; Bhattarai *et al*., 2004). However, there was no strong relationship between species richness and biomass at 100 m elevation gradient figure 7.4 which may be the expression of local effects.

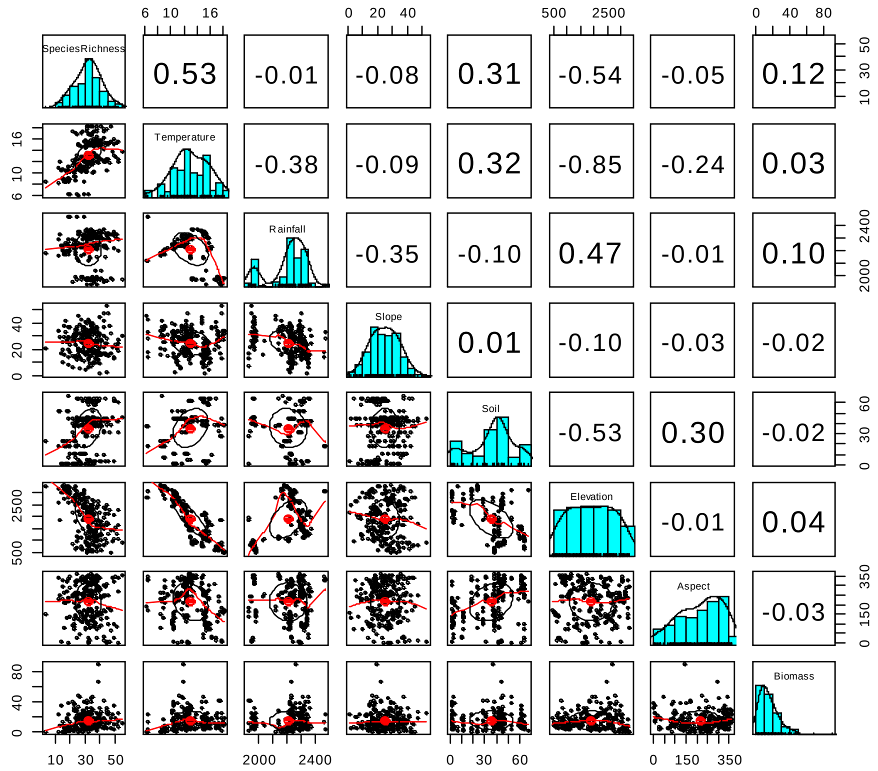


Fig. 7.7. Relationship between species richness and other variables (Temperature rainfall slope, rainfall, soil, elevation aspect and biomass)

Generalized Linear Model (GLM; Mc Cullagh & Nelder, 1989; Dobson, 2002) was used to relate species richness to the explanatory variables. The response variable, species richness, takes the form of discrete data (counts) and may have a poisson distribution of error (McCullagh & Nelder, 1989).

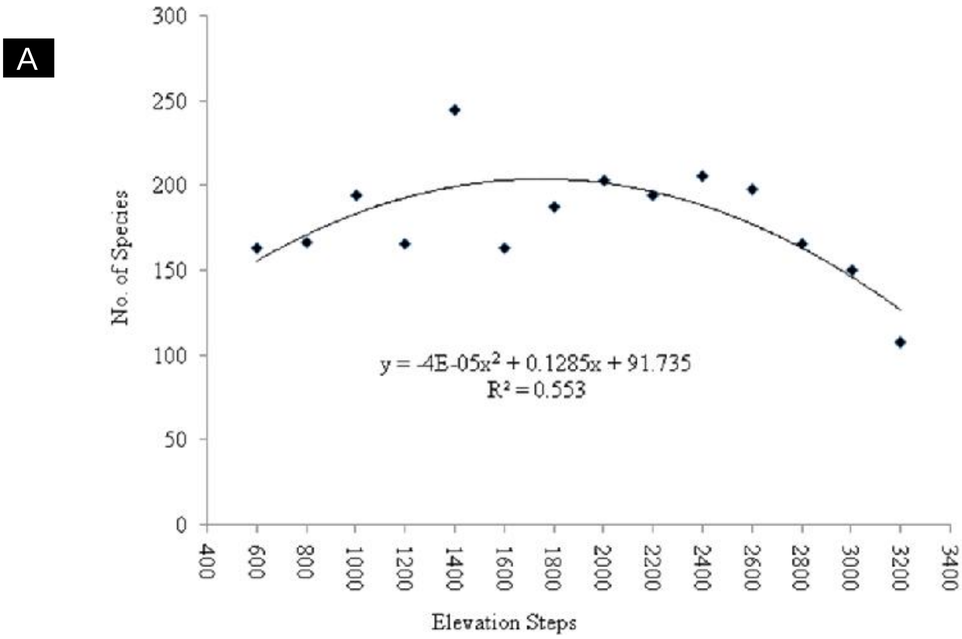
The relation between species richness and other variables like temperature rainfall, soil, elevation aspect etc. tested in GLM (Fig. 7.7 & Table 7.3). The temperatures play a major role among the other variables. The interpretation of the elevation gradient with climate data showed strong correlation between elevation and mean annual temperature (Bhattarai & Vetaas, 2003). This indicates that the temperature and elevation can play a major role in the relation between species richness and biomass along the altitude.

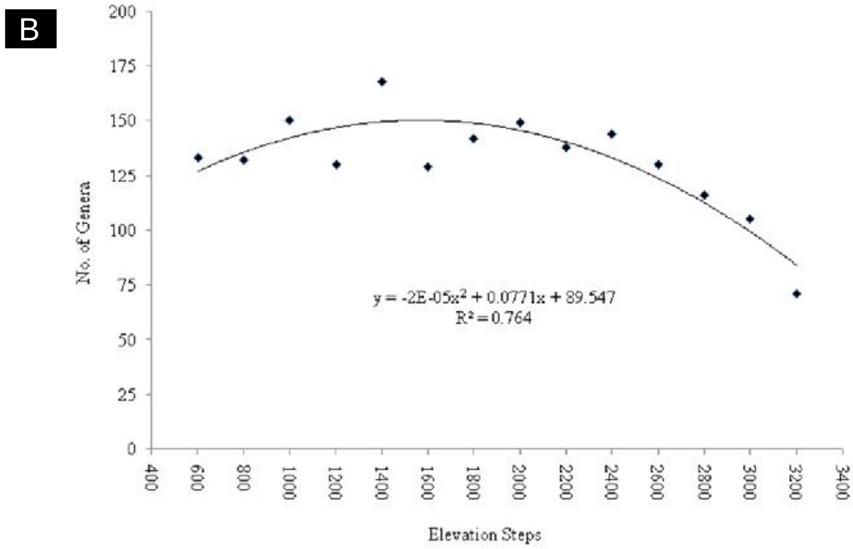
Table 7.3. Analysis of deviance among the response variables

Model: Gaussian, link: identity				
Response: Species Richness				
	Df	Deviance	Resid. Df	Resid. Dev
NULL			223	17587
Temperature	1	4886.8	222	12700
Rainfall	1	762.0	221	11938
Slope	1	63.3	220	11874
Soil	1	338.5	219	11536
Elevation	1	693.3	218	10842
Aspect	1	0.0	217	10842
Biomass	1	197.2	216	10645

Null deviance: 17587 on 223 degrees of freedom; *Residual deviance*: 10645 on 216 degrees of freedom AIC: 1518.6

7.3.3. Relation between diversity with temperature, precipitation and area: Model predictions showed that individual predictors (area, precipitation and temperature) were critical to species diversity. Area was predicted to be the most important factor followed by precipitation; and both the variables were statistically significant ($p<0.00$). The temperature was also found to contribute, but less significantly ($p<0.01$). However, considering two variables simultaneously, both precipitation and temperature were highly influencing the species richness pattern (<$p<0.00$). In other two modelling approaches, the predicted area was highly contributory and significant ($p<0.00$). In contrast, both climatic variables i.e. temperature





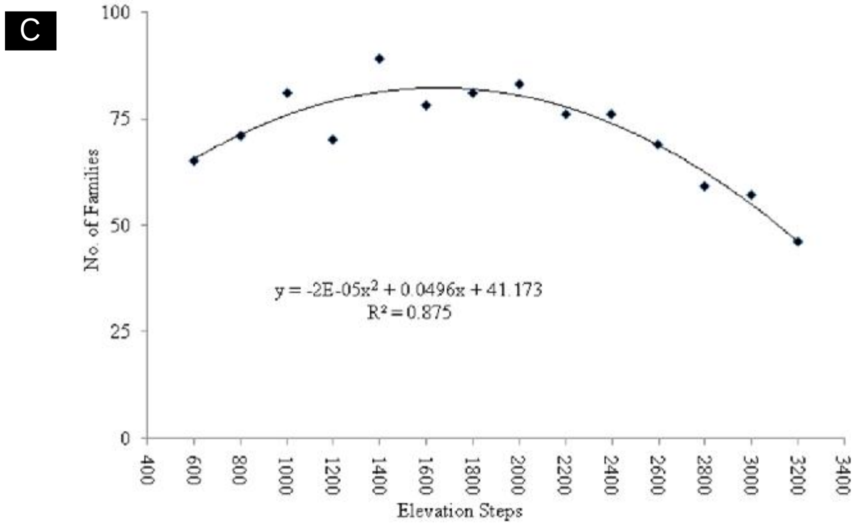
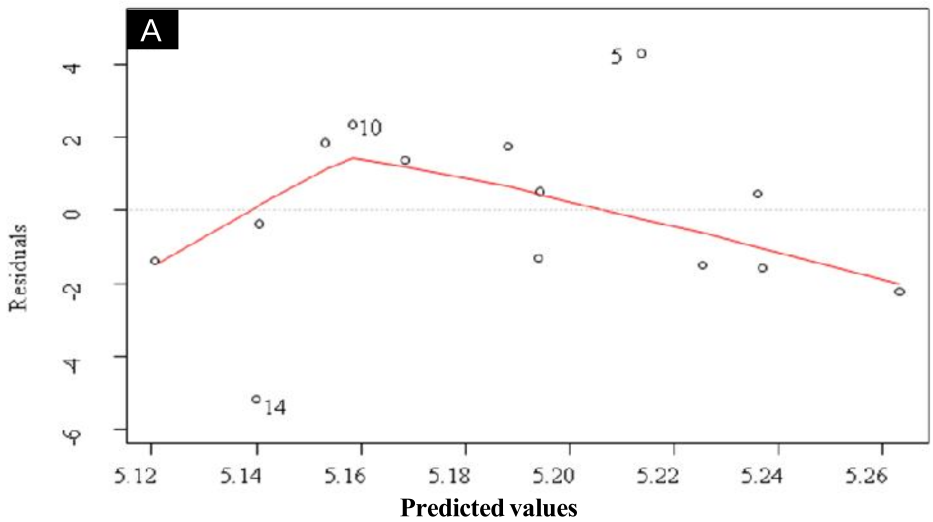


Fig.7.8. Richness pattern along 200m elevation steps for (A) Species, (B) Genera and (C) Families based on best fitted second order polynomial regression model. All models were statistically significant ($p<0.01$) and peaked at1800 m altitude.



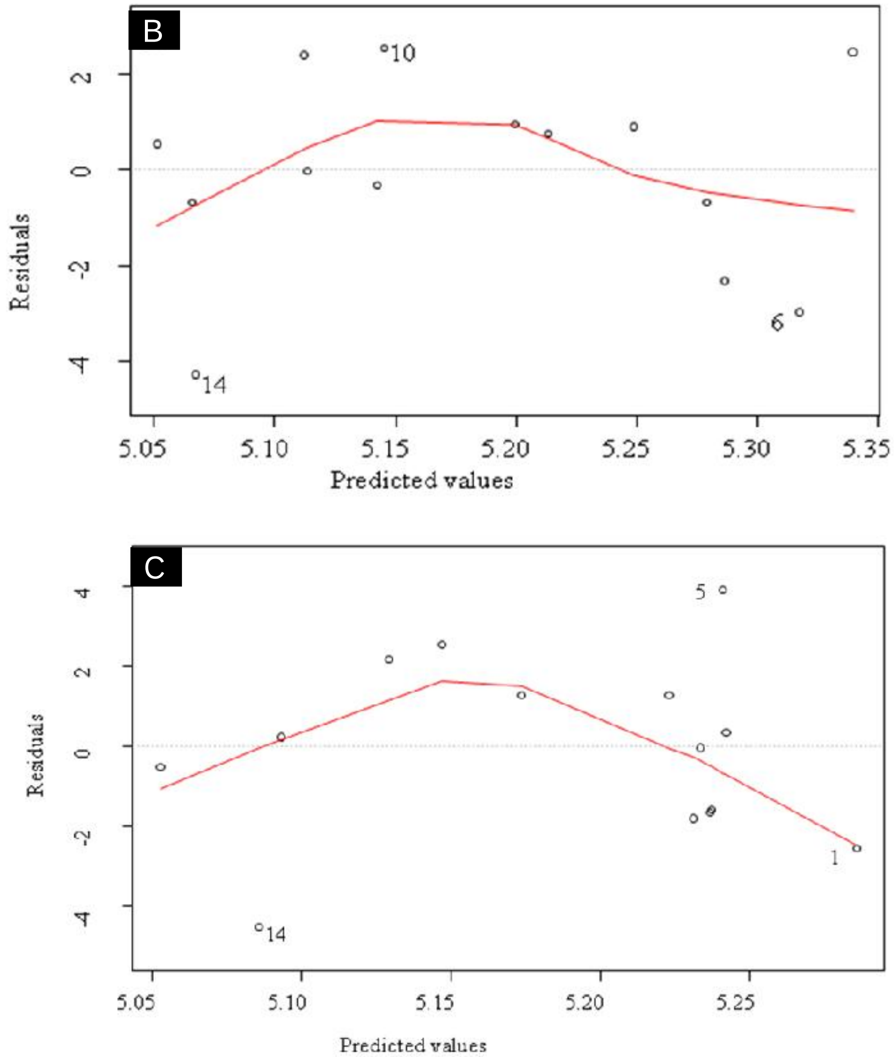


Fig. 7.9. Residual vs. predicted values plot showing species richness at 200 m elevation steps in relation to: (A) Temperature, (B) Precipitation and (C) Area using generalized linear model fitted with Poisson error distribution. The non-linear pattern is clearly indicated with no heteroscedasticity in modelling. Points having values are outliers.

and precipitation were not statistically significant when area was a constituent variable along with these factors. Similarly, the combined effect of three predictors was not statistically significant to explain the species richness pattern along the elevation gradient.

The residual vs. fitted values plots showed curve pattern and the values were well distributed along both sides of the curve.

Chapter 8

DISCUSSION

DISCUSSION

The floristic diversity, richness and originality of the second smallest state of India, Sikkim, is well known (Lama, 2004; Lepcha, 2011; Lepcha & Das, 2012; Das, 2011, 2013; Das & Ghosh, 2007, 2011; Das et al., 2010).The state is experiencing almost all types of climatic conditions, except hot desert, starting from tropical to permanent snow covered areas with polar environmental conditions. The sharp change in altitude (284 to 8598) m within short distance is also important that is directly affecting the structure, function and composition of vegetation in different and innumerable ecological niches in the state. The multi-pronged progress of civilization at the, so far, fastest speed is seriously affecting the Sikkim's original green wealth. With this back ground, it is now prime time to understand (i) the pattern of distribution of biological elements, (ii) species richness areas, (iii) how different species respond to changes in temperature, precipitation and altitude, etc.

8.1. Topology: In East district of Sikkim the elevation is ranging from 340 m to 4649 m. For the present study an elevation sector of 500 – 3300m was taken, as 70% of the areas are covered under this range. The elevation wise geographical areas of East district of Sikkim has also been calculated using the GIS software in each 500m elevation band (Figure 8.1). Slope, Aspect and climatic parameters were also taken in the present study to understand the effect of other variables with species richness and biomass production along the change of altitude. The forest type map prepared as per Champion & Seth (1968) for forest classification was used as a base map to layout the quadrats in the field) Fig. 5.11.The landuse and Landcover maps prepared by Sharma and Das (2015) were used for final analysis (Fig. 8.2). The collected data was analyzed in Microsoft excel.

8.2. Plant diversity: The field data was collected mostly from non-disturbed forest areas using 224 nested quadrat samples in 28 elevation steps from where 664 vascular plant species covering 367 genera and 131 Families. A maximum number of 155 species recorded from the elevation of 2200 – 2300 m and minimum number of 60 species recorded from 3200 – 3300 m elevation steps. *Schima wallichii* contributed the maximum number stands amongst the recorded tree species. The elevation wise number species, Genus and Family has been given in Table 8.1.

8.3. Dominance analysis: The dominant trees recorded from this region include *Castanopsis hystrix, Engelhardtia spicata, Ostodes paniculata* and *Schima wallichii. Alnus nepalensis* and *Ostodes paniculata* are the dominant tree species of tropical and temperate forests and the similar observation has been reported by ISRO in 1994.

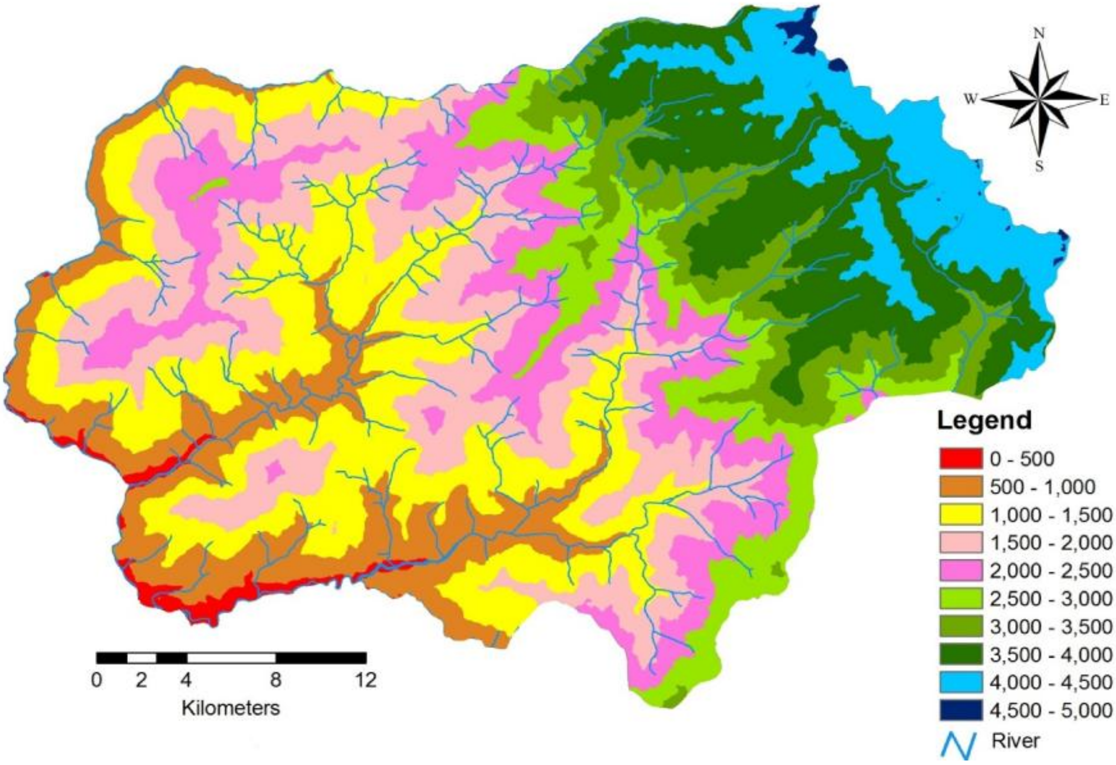


Fig. 8.1. Elevation wise geographical area distribution map of east district of Sikkim

Table 8.1. Detail of vascular plant species Genus and Family in each elevation steps

Elevation Steps	Number Species	Number Genus	Number Family
550	129	108	59
650	96	85	47
750	106	89	53
850	121	103	64
950	134	110	68
1050	134	110	63
1150	109	95	59
1250	126	104	56
1350	106	92	57
1450	128	105	70
1550	133	111	64
1650	122	95	64
1750	130	101	60
1850	134	106	69
1950	140	103	66
2050	109	90	56
2150	143	106	65
2250	155	121	69

Elevation Steps	Number Species	Number Genus	Number Family
2350	109	86	57
2450	146	106	63
2550	119	87	53
2650	142	99	56
2750	124	93	51
2850	102	84	48
2950	112	85	48
3050	86	60	36
3150	80	54	36
3250	60	46	33

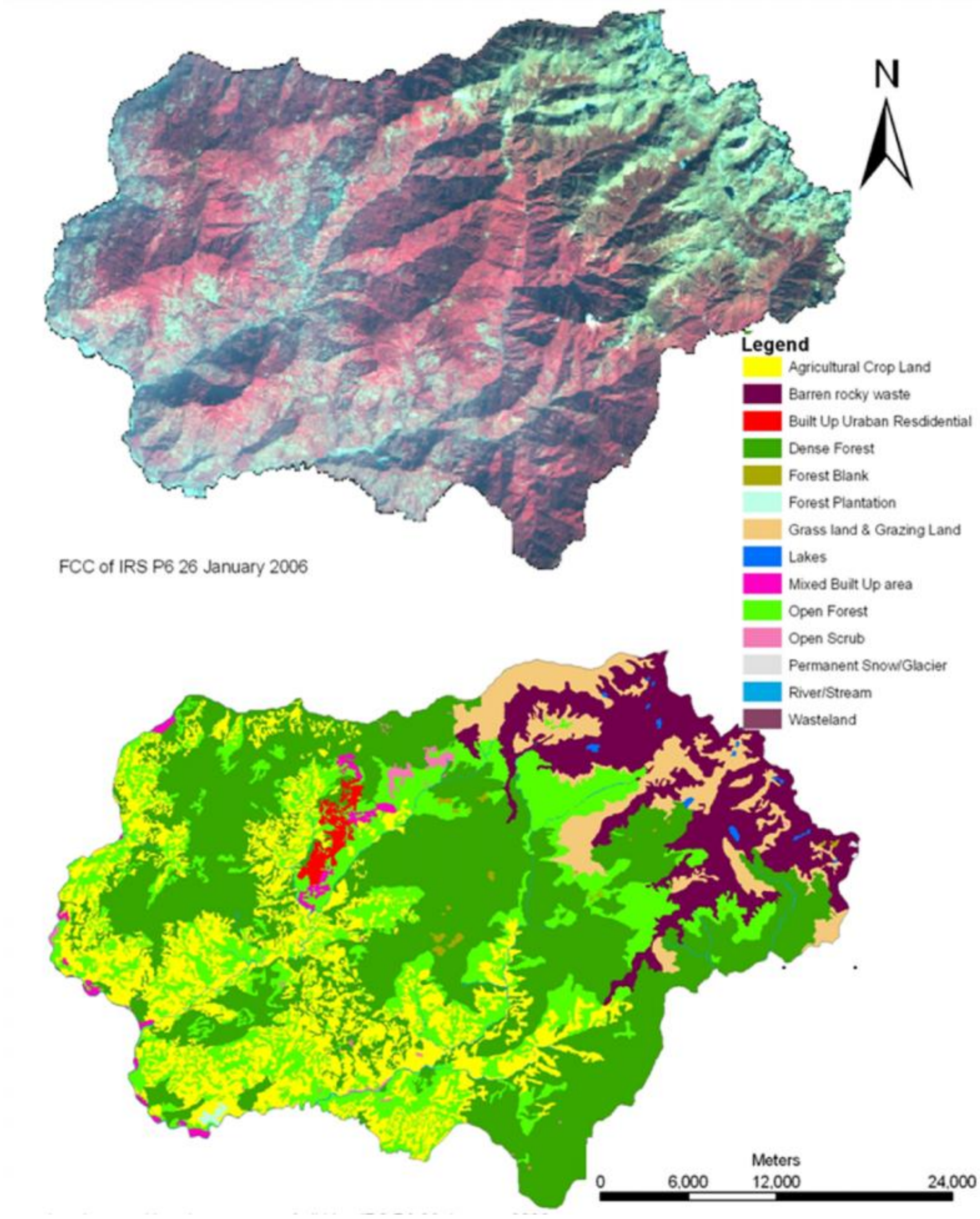


Fig. 8.2. Landuse and landcover map of East district of Sikkim

The Frequency, Relative Frequency, Density, Relative Density, Abundance, Relative Abundance and Importance value Index were also determined for the East district of Sikkim, where *Pteridium aquilinum* is recorded with 100 % frequency but *Schima wallichii* contributed maximum density with highest IVI score of 12.19 followed by *Ostodes paniculata* with IVI score of 4.64.The highest IVI scores of 10 top vascular plant with the IVI is given in Table 8.2.

Table 8.2. List of the highest IVI scores of 10 vascular plants

Sl No.	Botanical Name	F	D	A	RF	RD	RDM	IVI
1	*Schima wallichii*	50.000	44.500	89.000	0.420	7.830	3.941	12.190
2	*Ostodes paniculata*	42.857	15.357	35.833	0.360	2.702	1.587	4.649
3	*Alnus nepalensis*	57.143	12.607	22.063	0.480	2.218	0.977	3.675
4	*Castanopsis hystrix*	71.429	11.607	16.250	0.600	2.042	0.719	3.362
5	*Engelhardtia spicata*	53.571	11.214	20.933	0.450	1.973	0.927	3.350
6	*Nephrolepis cordifolia*	82.143	10.786	13.130	0.690	1.898	0.581	3.169
7	*Symplocos lucida*	39.286	8.071	20.545	0.330	1.420	0.910	2.660
8	*Eupatorium adenophorum*	75.000	8.607	11.476	0.630	1.514	0.508	2.652
9	*Dryopteris sikkimensis*	64.286	8.286	12.889	0.540	1.458	0.571	2.568
10	*Selaginella ciliaris*	64.286	7.893	12.278	0.540	1.389	0.544	2.472

8.4. Diversity Indices: Different vascular plant species recorded in different elevation gradient of East district of Sikkim are not with uniform pattern of distribution. This is influencing the changes in diversity indices in different locations and in different vegetations. To know the plant diversity *viz*. richness, dominance, evenness, etc., the diversity indices like Margalef Index (MI), Simpson's Index (D), Shannon-Wiener Index (H) and Pielou's Index (J) also analysed. The Margalef diversity index showed very high values at all elevation bands with the highest reaching at 2200 – 2300 m; whereas Shannon Weiner Diversity Index values varied between 3.4 and 4.4 [except at the highest elevation band, where the values was the lowest (1.9)] with the highest value of 4.4 at 2200 – 2300 m. Through this the highest species richness was observed at 950 m elevation. The values of different diversity indices in different altitudinal bands has been presented in (Fig. 5.14 to 5.17) which shows the diversity is higher in the elevation at 1050 m, 1850 m and 2250 m, then decrease slowly. This indicate that the diversity is more in the ecotonal regions. The value each indices is given in the Table 5.4.

8.5. Species Richness and Elevation

Maximum area spread is found to be in 1100 – 1500 m elevation range, especially at 1300 – 1400 m band; whereas the north-eastern aspect occupies minimum area with north western aspect occupying maximum area in East district of Sikkim. *Schima wallichii* is found to be occurring abundantly in sub-tropical belt of the district with 1246 counts. A minimum of 60 and maximum of 155 species were noted in 3200 – 3300 m and 2200 – 2300 m elevation bands. At 1800 – 1900 m elevation band a minimum of 29 and maximum of 63 species were noted pointing to an intermediate minima. At 600 – 700 m elevation band, the standard deviation of species range is found to be below 5 indicating greater abundance of species. In general, the number of shrub, herb and lianas decreased from lower to higher elevations with lianas almost absent beyond 3200m elevation. The number of tree species was found to follow a mixed trend, coinciding to the level of disturbance and other abiotic factors. *Pteridium quilinum* is found in all elevation bands indicating maximum tolerance and adaptability, whereas 190 species found with single appearance in one elevation band have narrow tolerance and adaptability range.

A study conducted by Behera and Kushwaha (2007) in Arunachal Pradesh of Eastern Himalaya using data on the tree species (cbh e" 15 cm) gathered at every 200 m steps between 200 m and 2200 m gradients. Tree diversity demonstrated a greater variation along the gradients with a total of 336 species belonging to 185 genera and 78 families. While studying in Helan Mountain, China, Jiang *et al*. (2007) found that the number of species initially increased and then declined, and the curve was markedly 'humped'. They observed richness was the highest between 1800 and 2000 m amsl.

8.5.1. Species richness: In any biodiversitically rich vegetation and flora occurrence and distribution of different species can't be uniform. It certainly respond to different prevailing factors in the habitat. From a study in the 500 – 3300 m elevational range of habitat in the East district of Sikkim led to the record of 664 species of vascular plants. This include almost all habit groups, harbs, shrubs, climbers, lianas, trees, and epiphytes. Major part of the natural vegetation, especially in the tropical to warm temperate belt is dominated by trees. It was noted that at least 158 species of trees, 197 species of Shrubs 91 species of lianas and 304 species of herbs are growing in the study area. To understand the scaling effect the field data is divided into three different scale viz. 100 m elevation steps 200 m elevation steps and 300 m elevation steps. The species richness along the 100 m elevation gradient shown in figure. 8.3.

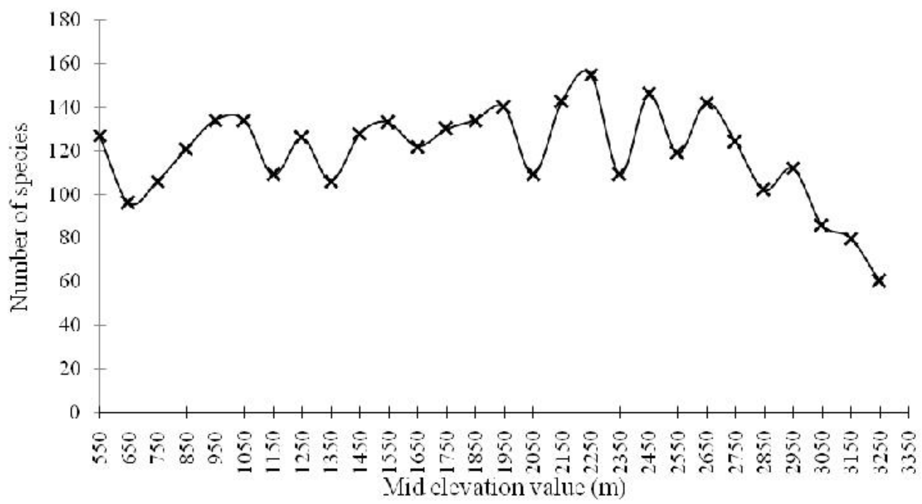


Fig. 8.3. Species richness along the 100m elevation steps

8.6. Distribution of Trees Shrubs and Herbs along the altitude: A total of 664 species of vascular plants were recorded from the East district of Sikkim, out of which only *Pteridium aquilinum* has been found in all the elevation steps, 8 species are found in more than 20 elevations steps and 25 species are found in more than 15 elevations steps and 195 species are found in only single elevation step **(Annexure-V).** In general, 24 tree species are found only in single elevation band, whereas *Acer campbellii* and *Schima wallichii* are found in more than 14 elevation steps and *Albizia chinensis*, *Macaranga indica* are found in more than 10 elevation steps of the study area. It was also observed that 14 species of shrubs were found in more than 10 elevation steps, whereas 59 species of shrubs occurs only in single elevation step. Similarly, 21 species of herbs are recorded in more than 15 elevation steps and 79 species of herbs are found only in single elevation steps. Table 8.3 showing the list of all vascular plant recorded from each elevation band of East district of Sikkim.

Table 8.3. List of tree, shrubs, herbs and epiphyte of the study area

Elevation Steps	Number of Tree	Number of Shrubs	Number of Herbs	Number of Epiphyte
550	20	34	57	25
650	18	16	52	14
750	18	21	59	12
850	28	34	56	8
950	36	40	61	8
1050	30	35	65	12
1150	24	28	54	6
1250	27	31	61	13
1350	18	23	58	9
1450	21	33	69	8
1550	22	43	59	13
1650	25	26	63	10
1750	19	38	68	12
1850	31	28	69	11
1950	19	41	69	13
2050	21	38	42	13
2150	42	30	63	11
2250	33	30	82	15
2350	16	27	65	10
2450	30	28	86	10
2550	24	17	69	9
2650	33	23	84	8
2750	28	19	75	9
2850	12	18	68	10
2950	34	17	59	8
3050	28	19	38	8
3150	21	17	47	0
3250	15	15	35	0

8.7. Species richness along elevation gradient

In general, the species richness showed a gentle mid-elevation peak with a fast declining trend beyond mid-elevation. The pattern became prominent when adjudged from 100 m to 200 m and 300 m elevation bands with R^2 values of 0.502, 0.553 and 0.743 respectively; indicating realisation of scale effect. Similarly, the genera and family richness pattern followed the mirror image of species with mid-elevation peak. The R^2 values increased when plotted from100 m to 200 m and 300 m elevation bands for genera (0.657, 0.764 and 0.862) and families (0.765, 0.875 and 0.907). Though, the species richness pattern along elevation gradient non-linear polynomial relationship, it clearly confirmed the pattern of mid-elevation peak across the taxonomic spectrum (i.e., species, genera and families), and grain size (100 m, 200 m and 300 m elevation bands).

This pattern is in contrast to a hump-shaped pattern found by Vetaas and Grytnes (2002), while studying the distribution of vascular plant species richness along the elevation gradient of Nepal Himalaya, between 1000 to 5000 m and found a hump-shaped pattern. Another study by Bhattarai and Vetaas (2006) showed drastic decrease in tree species richness up to 4000 m elevation in central Himalaya. Behera and Kushwaha (2007) in Arunachal Pradesh of Eastern Himalaya found that the alpha diversity demonstrated a decreasing pattern with two maxima (i.e., elevational peaks) along the gradients; one in 601–1000 m and the other in 1601–1800 m, corresponding to transition zones between tropical-subtropical and subtropical-temperate forests. Acharya *et al*., (2011) observed increase in tree species richness pattern till 1500 m and drastic decrease beyond till 3800 m in Sikkim state. However, the pattern differs once the other life-forms such as shrubs, herbs and lianas are considered. Namgail *et al*. (2012) while analysing the dry alpine communities between 4500 m and 5500 m in Ladakh of Western Himalaya found unimodal relationship between plant species-richness and Elevation between 5,000 and 5,200 m, while it peaked between 3,500 and 4,000 m at entire Ladakh level. In south west Saudi Arabia, the species richness increased from lower elevation to higher elevation up to 2000 m highest in 2000-2500 m, then the species diversity decreased while increasing elevation there is a remarkable change in vegetation species diversity and floristic relation (Hegazy *et al*., 1998). In Costa Rica, Kluge *et al*. (2006) observed that the species richness of the 484 recorded species showed a hump-shaped pattern with elevation (with a richness peak at mid-elevations at 1700 m) related strongly with climatic variables, especially humidity and temperature; while area and species pool were associated less strongly.

In present studies showed that quadrats falling in the transition zones between two forest types possess significantly larger number of species than other steps (Fig. 5.18) with elevations of 900 m, 1800 m and 2200 m. This corresponds to the transition zones between tropical-subtropical and temperate and sub-temperate zone. The 100 m elevation steps there is no direct correlation of elevation with the richness of different ranks of taxa, namely species, genus and family. This may be due to the impact of scale factor. In general, there is no clear idea regarding the species richness along the 100 m elevation gradient (Fig. 5.18).The R^2 value was 0.50 in second order polynomial, but the relation seen increasing in the initial stage but it decreases with the increase of elevation from temperate forest transition zone, which is located at around 2200 m altitude in the East district Sikkim.

Through this study, species richness found increasing along the altitudinal gradient of lower elevation from tropical forest and up to the sub-tropical forest, i.e. up to 1900 – 2000 m elevation. In the temperate zone the number of species decreases with an increase in elevation. List of vascular in each elevation band is presented in Table 8.4.

Table 8.4. List of the number vascular plant species in each 100 m 200 m, and 300 m elevation steps.

Elevation step (m)	No. of Species (100 m)	No. of Species (200 m)	No. of Species (300 m)
550	127	163	204
650	96		
750	106	167	
850	121		227
950	134	194	
1050	134		
1150	109	166	196
1250	126		
1350	106	245	
1450	128		224
1550	133	163	
1650	122		
1750	130	187	242
1850	134		
1950	140	203	
2050	109		249
2150	143	194	
2250	155		
2350	109	206	227
2450	146		
2550	119	198	
2650	142		150
2750	124	166	
2850	102		
2950	112	150	108
3050	86		
3150	80	108	
3250	60		

8.7.1. Along 100 m elevation step: Statistical test has been carried out targeting the elevation bands of 100 m, 200 m and 300 m to find out the species richness in three different classes at species, genus and family levels. In every 100 m elevation steps there are eight sample plots which seems less to see the pattern of species richness curve. The species richness pattern in 100 m elevation band is statically not significant (R^2 Value is 0.502) owing to the effects of local factors in the Eastern Himalayan region as well as topographic factors (steep slope/shortest elevation zone) along this elevation band.

8.7.2. Along 200 m and 300 m elevation steps: Additionally, statistical tests have been carried out targeting the elevation bands of 200 m and 300 m with 16 sample plots and with 24 sample plots of 20 x 20 m, respectively. In the second polynomial regression equation, the relation between species richness in 200 m is $R^2 = 0.553$ and $p<0.01$ and for 300 m it is $R^2=0.73$ and $P<0.01$, which are statically significant and express that the relation between species richness and elevation is improving in the combined data set or in courser resolution or number of sample size may be increased to produce the better result. Behera and Kushwaha (2007) discussed that the fine resolution data may improve the result in the eastern Himalaya. It can been seen that along 100 m elevation step, data set of eight plots of 20 x 20 m are not sufficient to understand the actual relationship between species richness along the elevation step of 100 m in the Eastern Himalaya Sikkim. The list of number vascular plant species in each 100 m, 200 m, 300 m elevation steps are given in Table 8.4.

Though the species richness followed the hump-shaped relationship with elevation showing a peak in between 1500 – 1800 m for species genera and families (Fig. 5.19 & Fig. 5.20).

Obviously, a few studies have assumed that a species with particular altitudinal range will be present within each 100 m band of that range and thus interpolation violates control over sampling area and intensity. Such type of studies have clearly ignored the local ecological factors those might have significant impact on the alpha as well as beta diversity of a place. Furthermore, the magnitudes of change of microclimatic conditions in the 100 m bands are not remarkable compared to that of an individual plot. According to (Ricklefs, 2004; Whittaker*et al*., 2001) the characteristics of biodiversity generally result from two factors, evolutionary history and contemporary ecological conditions. If it assume that evolutionary history is identical, it can understand that the species groups that have the same or similar ecological requirement and ways of adapting or responding to the environment may also exhibit the same or similar distribution of diversity in space. Conversely, Whittaker *et al.* (2010) and Meentemeyer (1989) opined that ecological phenomena are hierarchically structured, which are related closely to the scale of observation. The challenge to contemporary ecology and biogeography is to document scale dependence or independence in different systems. The species pool is regarded as an important factor in determining community richness (Eriksson, 1993). This was seen in the elevation of 950 m where number of individual is less but numbers of species are more as compared to other bands.

The low elevation sites were relatively densely populated probably because of human interferences in these areas facilitates the introduction and establishment of non-native species (Rawal & Pangtey, 1994). These spaces may intensify the establishment of shade intolerant species and enhance the regeneration of mixed pine-broadleaved forests (Wangda & Ohsawa, 2006). As a result of which the maximum species were encountered at lower elevation compared to higher elevation sites. The human impact at lower altitudes was evident in the form of open spaces left after felling of selective species.

8.8. Effect of the forest ecotone

Lomolino, (2001) has studies an ecotone effect (high diversity in the ecotone due to significant overlap between communities) in the context of elevational gradients and source-sink dynamics. The proportion of species shared and the amount of overlap between communities can play a significant role in determining the unimodal pattern of species richness by shifting of species to ecotone zones, which can also be explored further by looking at the contribution of marginal/sink species to the richness dynamics in the zones of overlap. Along a local gradient, richness in the ecotone was likely to be composed of ecotone specialists and a number of low abundance sink species contributed by spill over from adjoining biomes as shown by rescue effect as reported by Brown & Brown (1977) .

Similarly, the floristic and ecological importance of the forest in phytogeographical zonation has remained unquestioned (Odland & Birks, 1999). The plant species richness with the distance is often associated with abrupt change in climatic and other environmental conditions (Kirkpatrick & Brown, 1987).

The Himalayan region is a unique physiogeographical region with an average elevation above 4000 m. Zheng *et al*. (1981) reported that the monsoon and westerly are strongly influenced by climatic zones. The topographic configuration and atmospheric circulation determine the horizontal separation of natural vegetation segments. The vegetation changes successively from southeast to northwest with decreasing moisture from montane forest, are gradually changing through high-altitude scrubs, alpine meadows, and alpine steppes to alpine deserts.

8.9. Species Richness and Environmental Parameters

A main aim of this study was to investigate the evident incompatibility between the need for implements that correctly predict ecological consequences of forest management and the current ecological knowledge and available environmental data. The approach taken in this study is experiential and uses observed environmental and altitudinal distribution patterns as a starting point for generating maps for such studies. This method requires accurate maps of species richness parameters in high resolution. Altitude itself is not an environmental gradient and therefore, is itself virtually nothing to life (Kroner, 2000; Brown, 2001). However, several environmental gradients, either singly or in inter-correlations, act significantly along the changing elevation and therefore, it represents a composite gradient of those environmental variables. It is very difficult to explore the drivers of the complex biological patterns seen along the elevation gradients from the independent effects of single overriding forces (Lomolino, 2001). However, many studies have explored plausible driving factors for the prevailing patterns (Grime, 1997).

This study was undertaken along the high elevation range of East district of Sikkim focusing upon prevailing species richness and production of biomass. Anthropogenic and natural factors (e.g., wild fire, landslide, trekking, tourism, cattle grazing, strong wind, snow avalanche, etc.) responsible for disturbance of forest ecosystem have been identified through field survey. Bedsides, other factors may also have a bearing on sampling effect, facilitation and complementarily.

Total species richness, i.e. of all life-forms or habit-groups, has a significant hump-shaped pattern along the altitudinal gradient (elevation). Maximum species richness occurs at optimal elevation of 2100 – 2200 m, which is the trans-ecotone zone of two type of forests or vegetation. It has been observed that species richness varies in elevation between 1100 – 1200 m and 1300 – 1400m owing to human interference as well as changing climatic conditions. It has been reported that in Sikkim Himalaya, the species decreases along the altitude starting from the elevation range of 2400 – 2600m (Acharaya *et al.*, 2011). As per field observation, the north facing slopes have more species compared to the south facing slopes. Shrubby species decreases after 1800 – 1900 m as the area above 2000 m are mostly covered with different species of bamboos like *Arundinaria acerba*, *Chimonocalamus griffithianus* and *Arundinaria racemosa*. Owing to the dense population of these species in this region there is a less regeneration of other tree and shrub species. In majority of the cases, not a single shrub has been found in 20 x 20 m plots were these species were dominated. The variation of herbs in the region is attributed to the increasing anthropogenic activities or with the aggressive bamboo cover and it may also be due to changing climatic conditions.

Further, studies were also conducted the on geographical area and the species richness along the elevation was observed that the geographical area can play the major role for species richness along the elevation gradient in the Sikkim Himalaya, but further research needed to conclude the relation between geographical area and species richness in such mountainous regions.

8.10. Biomass along altitudinal (Elevation) gradient

Biomass is described as the plant material produced as a result of photosynthesis and its accumulation in different forms in the plant body. Its measurement is based on commonly accepted principles of forest inventory and ecological survey. Good estimation of stem volume forest biomass on account of its ever changing nature remains an interesting and challenging task for the researchers. The field data like forest type, density, stem diameter at breast height and the tree height are normally collected to calculate the biomass. The field inventory is not only a tedious and time consuming task, it becomes too complicated to carry out field survey manually in heterogeneous forests as the number of species within the stand increases.

Biomass has been calculated using the volume of different tree species in the study area using the FSI-2006 volume equation. After calculating the volume of each species, the specific gravity of the tree has been used to calculation the biomass. The general volume equation was used for the trees whose volume formula was not available. The biomass also shows the unimodal relationship along the altitudinal gradient in the study sites.

The biomass of herbs, shrubs and epiphytes were also calculated using the percentile factor among different forest types (Chaturvedi & Singh, 1987; Rawat & Singh, 1988; Singh & Singh, 1991). Data has tested at different elevation bands with 100 m, 200 m and 300 m elevation steps to see the effect of scale. The relationship between biomass along the altitude in different elevation bands were shown in Figs. 5.27, 5.28 & 5.29.

The biomass ranging from 6.3 t/ha at 3150m and 68.6t/ha at 2650m in different elevation range of Sikkim Himalaya. Sundriyal and Sharma (1996) recorded 8.32 t/ha woody biomass from Mamlay watershed in South Sikkim. In the present investigation, the average biomass of East Sikkim was determined to 38.8t/ha, whereas Chhabra *et al*. (2002) reported that Sikkim contributes 48.1Mt/ha.

The above ground (AG) biomass distribution pattern showed alternate increasing and decreasing pattern along the elevation gradient. In general, the AG biomass showed a smooth increase up to mid-elevation and decrease further. The R^2 values increased (i.e., 0.28, 0.41 and 0.58) when plotted from 100 m to 200 m and 300 m elevation bands. The AG biomass pattern along elevation gradient showed non-linear polynomial relationship, where in it confirmed the pattern of mid-elevation peak in the East district. Here, the primary productivity measured by the AG biomass is found to be positively correlated with plant species diversity as the productive forest ecosystems have more species, there by more productivity (Huston, 1994).

Bhattarai *et al*., (2004) observed a significant unimodal relationship between species richness and biomass in an arid sub-alpine grassland of the Central Himalayas, Nepal. They observed lower turnover in the old field than in the common pasture. Namgail *et al*., (2012) while analyzing the dry alpine communities between 4500 m and 5500 m in Ladakh of Western Himalaya reported a hump shaped relationship between aboveground phytomass and Elevation between 5,000 and 5,200 m, while it peaked between 3,500 and 4,000 m at entire Ladakh level. Benito et al., (2014) used 54,000 plots of the Spanish Forest

Inventory and maximum likelihood techniques to quantify how climate, stand structure and diversity shape carbon storage and tree productivity. They found a consistent positive effect of functional diversity on carbon storage and tree productivity was observed in all seven forest types studied. This relationship was not linear, and the largest changes in carbon storage and tree productivity were observed at low levels of functional diversity. They also found a generally positive effect of diversity on carbon storage and tree productivity, supported by both complementarity and selection mechanisms (Benito *et al*., 2014).

Relationship between biomass along the 100 m elevation step has been presented in Fig. 5.27.As it was seen, the pattern of biomass along the altitude in the lower elevation of 500 – 600m starts from 29.1 t/ha. It increases slowly and has reached around 40.0 t/ha in the elevation of step of 800 – 900m which represent the ecotone region of tropical and sub-tropical forest and again it decreases with increasing the elevation zone at 1400m. Between 1000m to 1500m there are major human habitations in East district. And, the decrease of biomass has been attributed to the anthropogenic activities in this eco-region. Besides, there are limited numbers of big trees in this eco-region as most of the trees were harvested for human consumption. The biomass, t/ha, again increases and reached to around 60.0t/ha at the elevation step of 1600 – 1700m which is the second ecotone for sub-tropical and temperate forests. Again, the biomass decreases down to 35.0t/ha at the elevation step of 1900 – 2000 m and then starts increasing with the increase of elevation and it reached around 69.0t/ha at the elevation step of 2600 – 2700 m which is the highest pick of biomass production. After the elevation step of 2700 m the biomass production decreases and it becomes less than 10.0t/ha in the elevation step of 3100 – 3200 m. The overall pattern indicated that the biomass decreases with increase in the elevation excluding the ecotone areas. Similar observation was also reported by Wang *et al.* (2014) who have conducted study above 3100 m ranging up to 4300 m in the elevation gradient on the Tibetan Plateau.

8.11. Satellite based correlation

Geometric and radiometric corrected optical data was procured for the present experiment. The processed data were further used for the assessment of EVI2 (a proxy for biomass).The data was tested in simple linear equation, the pattern of field derived biomass and EVI2 derived from Landsat, shows the positive relationship with $R^2 = 0.5$ as shown in figure 4.31. Similar result was found by Tan *et al*. (2007) during their study on satellite based estimation of biomass for north-east china. They tested their finding using the regression model for NDVI and field based biomass. But, Devagiri *et al.* (2013) and Zheng *et al.* (2004) found the NDVI and area weighted above ground biomass (AGB) $R^2=0.8$. The presently collected data was segregated in three different categories or classes: (a) EVI and field derived biomass in 100 m elevation steps, where the R^2 value was 0.32; (b) present data for above subtropical forest to subalpine forest were tested to see relationship and that was found to be $R^2= 0.31$; (c) such data was again tested for the relation between temperate forest to subalpine forest that showed $R^2=0.80$. This result shows even the fragmented data from different forest zones, the relation of biomass and EVI showed no any recognizable difference. But, if moved further towards the higher elevation the relation shows significant result. This may be due to the high moisture contents in the un- or low disturbed forests of high altitude areas. In such areas disturbances are caused mostly by the large number of visiting tourists and the activities of plant hunters. The field derived biomass production and MODIS productivity (1km x1km) was not found good relationship, it may due to the scale effect (i.e. the total geographical area of the study are is very small 954 sq km)

To understand the better relationship the further extensive research is needed to evaluate the climate change related studies in different sectors of the Sikkim Himalayan regions.

8.12. Relationship between Species Richness and Biomass Production along the altitude

The relationship between species richness and biomass is tested in three different scales, as it was discussed above. It has been observed that there was a better relation in regional scale as compared to the local scale. In first 8 nested quadrats in each of the 28 different elevation steps the R^2 is less than 40%. But, if another eight quadrat in the same points are added the relation becomes more than 50 %. Similarly, if further 8 quadrats are added then the relation between biomass and species richness increases to over 80 %. This shows that there is major role of scale between biomass and species richness in determining the relationship, which can be referred as multi-scale dependant mechanism (Simova *et al*. 2013). They found that, at the smaller spatial scale of individual plots, there was significant curve that shows linear negative relationship between species richness and productivity. Whereas, at the larger site scale it is turning into a non-significant relationship.

The relation between species richness and biomass along the elevation gradient has also been tested using the second order polynomial regression equation, and the determined relation is 27 %, 30 % and 58 % respectively for 100 m, 200 m and 300 m elevation steps.

The result has also been tested with different environmental variables. It was observed that there is a positive relationship of species richness and biomass along the altitude, as it was tested along the 100 m, 200 m and 300 m elevation gradients.

The data has been tested in the GLM model with seven variables. It was found that temperature plays the most important role for the relationship between species richness and biomass accumulation along the elevation gradient. Similar observation has been reported by Bhattarai in 2004. There are several ecological factors those might different types of impacts on different relationships. The relationship between diversity and productivity is based on the ecological effects of complementarity and 'sampling'.complementarity suggests that species richness enhances productivity because of niche differentiation (for example, complementarity) or positive interactions (for example, facilitation) between species and therefore more of the available resources can be exploited. 'Sampling' means that more-diverse communities are, by chance, more likely to contain species with higher average productivity than are with low diverse communities (Venail1 *et al*., 2008).

Both species richness and AG biomass co-vary along elevation gradient showing strongly positive relationships. The relationship became prominent with increasing elevation and grain size of elevation bands i.e., from 100 m to 200 m and 300 m (with R^2 value increase i.e., 0.31, 0.53 and 0.80). Hence, productivity, one of the important factors is found to be correlated with elevation gradient potentially influencing species diversity.

8.13. Relation of diversity with Temperature, Precipitation and Area

The effect of area was highly conspicuous which supports the geographic area hypothesis that in higher areas availability facilitates more species to co-exist. Simultaneously, the crucial impact of precipitation and temperature, both at individual and combined conditions, explain the local effect of climate on species diversity. The non-linear spatial distribution of precipitation greatly affects moisture gradient characterise species diversity along the elevation in tropical areas (Brown, 1988). The precipitation that affects the moisture gradient, influencing high species diversity for epiphytes in tropical Andes (Gentry & Dodson, 1987), in moist temperate forests of Pakistan (Shaheen *et al.*, 2012) and in the grasslands (Cornwell & Grubb, 2003) have been reported. Since, the study was within elevational range of 500 to 3300m, the influence of temperature was comparatively less significant. At higher elevation, the effect of temperature is significant as adiabatic lapse rate becomes lethal to plant physiology. It was assumed that the effect of candidate variables along elevation behave in non-linear fashion was substantiated by the curve pattern. Additionally, heteroscedasticity could be accounted by choosing appropriate poisson error distribution.

Despite combined effects of direct or indirect environmental variables no single parameter could explain the species richness pattern along the elevation (Whittaker, 1972). The more detailed study involving a wide range of ecologically significant variables can provide better explanations to the observed conditions of species richness along the gradients of elevation.

8.14. Status of Conservation in the Study area

Protected Areas (PA) are, and have been, the cornerstones of biodiversity conservation in the present era. Following IUCN guideline (Dudley, 2008) the Govt. of India has recently taken up some serious measures for the conservation of biodiversity by declaring many biodiversity rich areas as Protected or Reserve Areas for *in situ* conservation. As such, the proper management of these PAs, after notification, needed to be maintained with effective monitoring and strong enforcement of laws. Considering this fact, Govt. of Sikkim has declared (i) 01 Biosphere Reserve,(ii) 01 National Park, (iii) 06 Wildlife Sanctuaries and (iv) 01 Bird Sanctuary (Table 8.5).

Table 8.5. Protected area networks in Sikkim

Name of the protected area	Location and district	Area (km^2)	Biogeographic Province	Altitude (m)	Year of Notification
Kanchendzonga National Park	North and West	1784	1B	-	1977
Fambong Lho Wildlife Sanctuary	East Sikkim	51.76	2C	1524-2749	1984
Shingba Rhododendron Sanctuary	North Sikkim	43	1B	3048-4575	1992
Kyongnosla Alpine Sanctuary	East Sikkim	31	2C	3292-4116	1993
Maenam Wildlife Sanctuary	South Sikkim	35.34	2C	2300-3263	1987
Barsey Rhododendron Sanctuary	West Sikkim	104	2C	2200-4100	1996
Pangolakha Wildlife Sanctuary	East Sikkim	128	2C		2000
Kitam Bird Sanctuary	South Sikkim	6	-	320-875	2005
Kanchendzonga Biosphere Reserve	North and West	2620	1B &1C	2725-5537	1997

Source: Lepcha & Das, 2012

Apart from these, many small pockets of forests, mostly located around the monasteries, village herbal gardens are forming part of traditional biodiversity conservation system in Sikkim. There are three sanctuaries [*viz.* Pangolakha Wildlife Sanctuary, Fambong Lho Wildlife Sanctuary and Kyongnosla Alpine Sanctuary] and some botanical and herbal gardens present in the East district of Sikkim for the conservation of biodiversity of the area.

Chapter 9

CONCLUSIONS

CONCLUSION

The survey conducted in Sikkim part of the Eastern Himalaya, covering the altitudinal range of 500 – 3300 m in the East district, which covers wide range of climatic zones from tropical to sub-alpine conditions. The work was aimed to understand the relation between species richness and biomass production with the change of altitude, that is, in turn, linked to different environmental set-up.

After completion of the work and analysis of data, it is now clear that the species composition in the study area changes with the increase or decrease of altitude. During the survey, highest number of species has been recorded from the vegetation located around the 2200 m elevation. However, highest number of tree species has been spotted at the junction of tropical and sub-tropical conditions at around 900 m altitude. At the same time, distribution pattern of different species of trees changes with change of elevation that expresses the degree of adoptability of each and every species to the altitude based changes in the habitat. With the increase or decrease of altitude most of the environmental parameters get affected and those, in turn, again lead to the modification of some other elements of the habitat including soil organic matter, rate of decomposition of rock, water holding capacity of soil, pH of soil and water etc. And, all these are basic factors for the selection of species for any particular habitat. So, a habitat with sharp change in altitude over a very small distance show quick change in nature of vegetation including the participating species of plants.

The species richness was also linked to availability of water, aspect, exposure to strong wind and, of course, with the degree of anthropogenic disturbances including location of human settlements and their type of road link with the urban areas. After altitude, in Sikkim Himalaya, water is a very important factor which is available in sufficient amount for the vegetation in most of the areas. So, apparently, water cannot be the very important factor behind the selection of species especially up to the temperate region. But, aspect of the habitat is extremely important as it is related to the availability of sun-light, facing strong wind or even the severity of snow fall.

Strong wind is very important as it is responsible for soil erosion, land slide, establishment of individual plants, distribution of seeds, availability of pollinators, accumulation and melting of snow, etc. So, in wind-facing and opposite side's vegetation formation will be completely different. Almost no soft soil will be available on the surface and that will work against the establishment of shallow rooted plants, especially those are without rhizome/ runner/ lower prostrate stem producing numerous adventitious root system. That means, strong wind interfere with the anchoring and settlement of plants in the habitat.

The Himalaya Biodiversity Hotspot is also recognised as one 'Hottest of Hotspots' due to excessive loss of natural habitat. It is also true for the Sikkim part of the Himalayas. Anthropogenic activities are the most serious influences and factors for the change of numerous habitat conditions, removal and introduction of species, selection of species, etc. Anthropogenic interference is quite high in many parts of the study area. This directly influence the species richness of an area and is also found true in the East district of Sikkim.

The direct field-based methods for determining the (i) relation between species richness against elevation, and (ii) relation between species richness against biomass accumulation, has resulted almost uniform and acceptable result. Both, species richness and above ground biomass, along the elevation gradient showing strongly positive relationships. So, direct method, in most cases, produce the most reliable and usable result where-ever it is possible to take up.

At the same time, the indirect method of determining such relations using remote sensing techniques using satellite imageries also known to produce similar and reliable results for larges geographical areas. However, for the present investigation, the result was little different mostly due to the utilization of different scales for data collection in field and in remote sensing methods or may be due to the small coverage geographical area of the study.

This proves that through the use of satellite imageries along with suitable ground trothing can also be used effectively to establish such relationships. But, for this proper adjustment between two scales need to develop with some suitable modifications in the methodology. The result produced through this method is more laboratory oriented and can be repeated in quick succession. This method also can indicate the sudden changes in vegetation if any and can raise necessary alarm so that necessary steps can be taken on emergency basis if such a situation arises any time.

However, the essence of the entire work can be summarised as:

1. The flora of the study area has been characterised with quite high species richness
2. The species richness is high in the middle and low altitude areas
3. It decreases with the increase of elevation after 2200 m elevation
4. Species richness and biomass accumulation along the elevation gradient are showing strong positive relationship
5. Tree diversity also reduces fast with the increase of altitude
6. Scaling effect has been seen in the species diversity and biomass along the altitude
7. More intensive research is needed in different scale for better understanding the relationship between species richness and productivity along the altitudinal gradient in the mountainous regions like Sikkim
8. Remote sensing (using Satellite imagery) derived biomass production not showing good relation with field derived result of biomass production, which may be due to differences in scale and also due to the smaller geographical area under study
9. In multivariate analysis of temperature showed strong relationship with species richness along the altitude that, vis-à-vis also shows relation with the biomass production
10. It is essential to conduct such studies in other districts of the state and in regular intervals to monitor the changes if any and for developing proper strategies for effective conservation that is too much important for Sikkim that is well known for its extremely high biodiversity..

Photo Plates

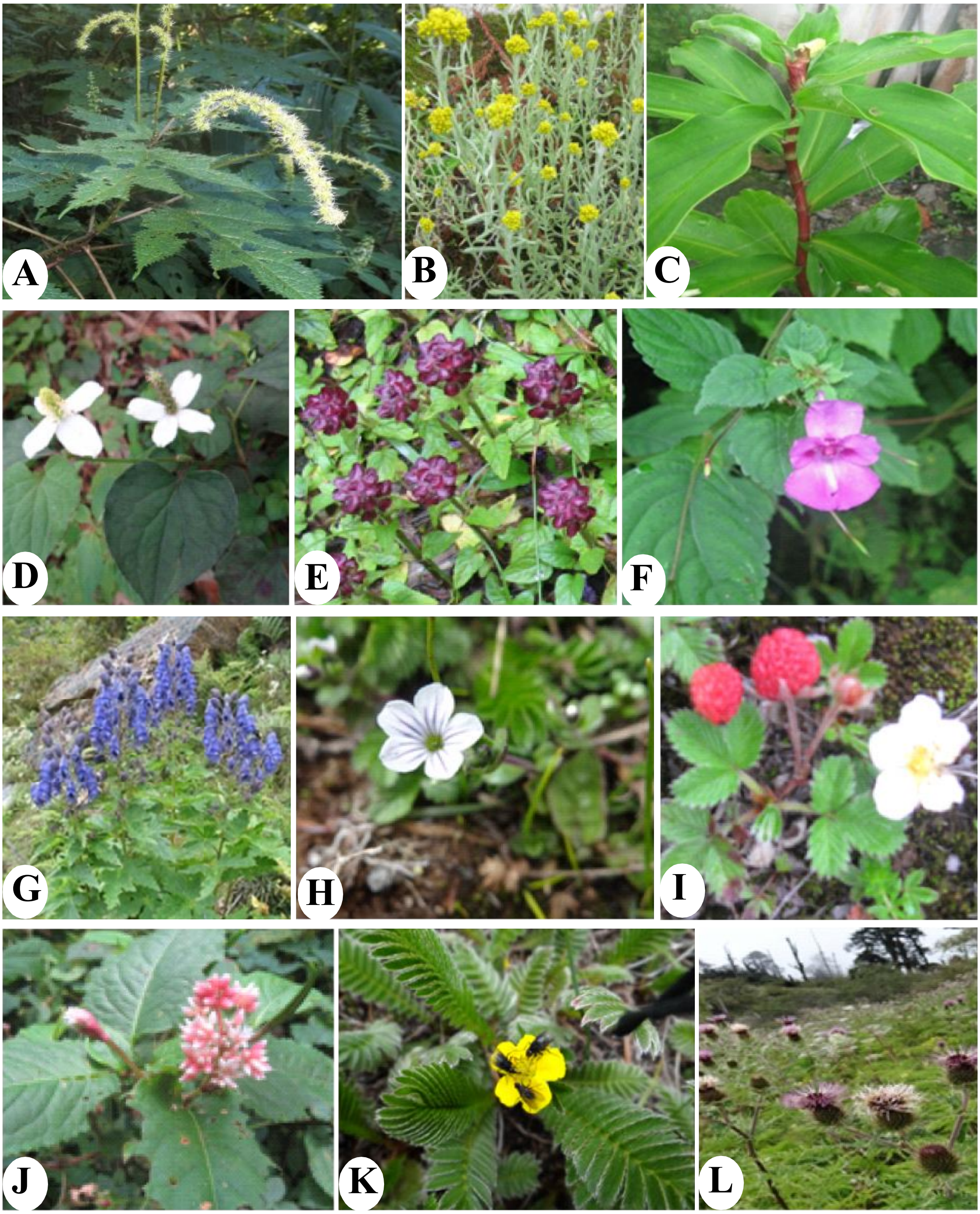


PLATE 1: A. *Girardinia diversifolia;* **B.** *Laphangium affine*; **C.** *Cheilocostus speciosus*; **D.** *Houttuynia cordata*; **E.** *Nepeta connata*; **F.** *Impatiens glandulifera*; **G.** *Aconitum ferox*; **H.** *Oxalis acetosella*; **I.** *Fragaria nubicola*; **J.** *Persicaria chinensis*; **K.** *Potentilla fulgens*; **L.** *Onopordum acanthium.*

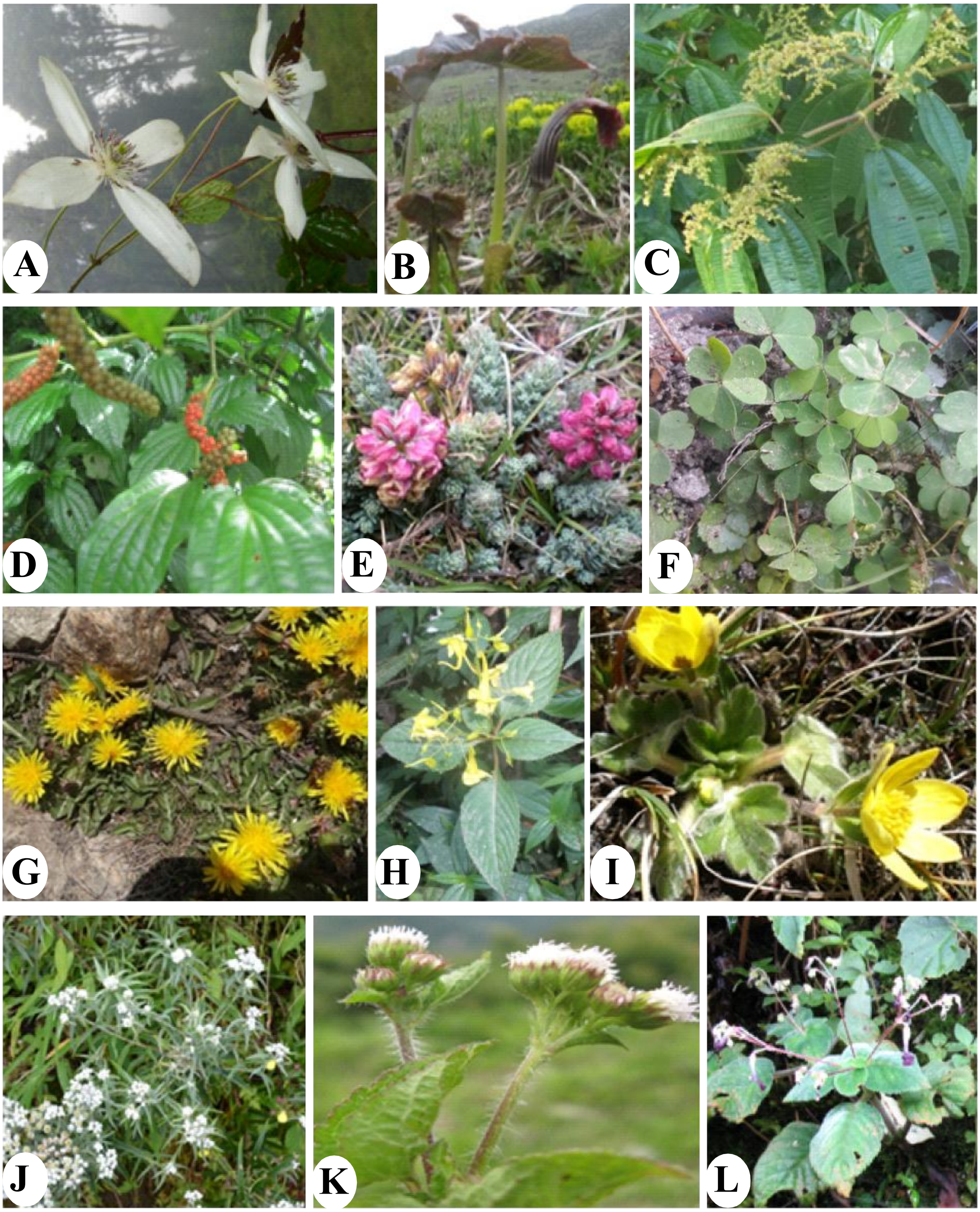


PLATE 2: A. *Clematis montana*; **B.** *Arisaema propinquum*; **C.** *Pilea umbrosa*; **D.** *Piper boehmeriifolium*; **E.** *Myricaria rosea*; **F.** *Oxalis corniculata*; **G.** *Taraxacum campylodes*; **H.** .*Impatiens urticifolia*; **I.** *Ranunculus laetus*; **J.** *Anaphalis busua*; **K.** *Ageratum houstonianum*; **L.** *Didymocarpus albicalyx.*

PLATE 3: A. *Ageratina adenophora*; **B.** *Swertia chirayita*; **C.** *Dobinea vulgaris*; **D.** *Panax pseudoginseng*; **E**. *Rheum aciminatum*; **F**. *Streptopus simplex*; **G**. *Achyranthes bidentata*; **H.** *Selinum wallichianum*; **I.** *Aster himalaicus*; **J.** *Cassiope fastigiata*; **K.** *Erigeron bellidioides*; **L.** *Rhaphidophora decursiva*; **M.** *Euphorbia sikkimensis.*

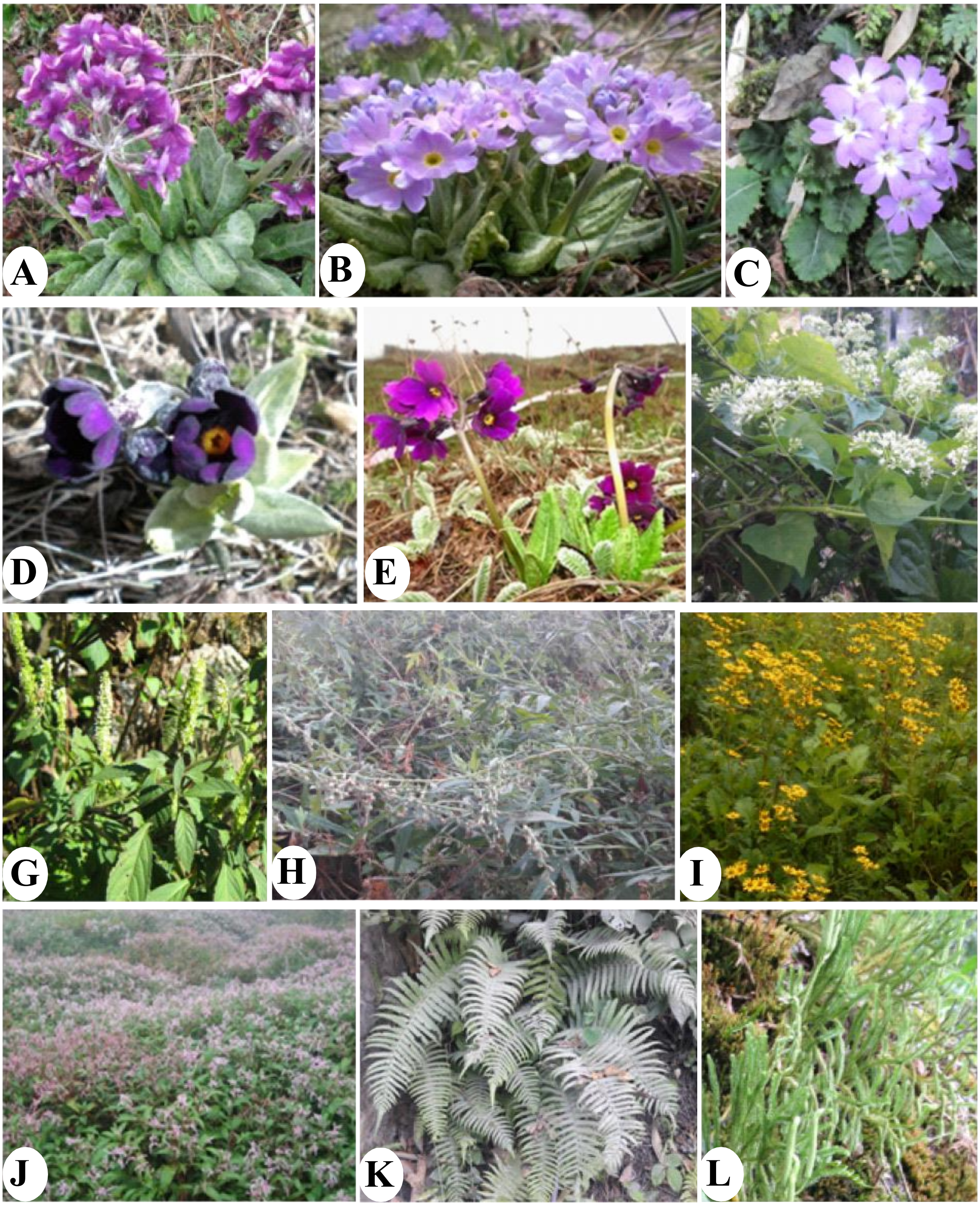


PLATE 4: A. *Primula capitata*; **B.** *Primula drummondiana*; **C.** *Primula edgeworthii*; **D.** *Primula calderiana*; **E.** *Primula macrophylla*; **F.** *Mikania micrantha*; **G.** *Elsholtzia fruticosa*; **H.** *Artemisia nilagirica*; **I.** *Inula orientalis*; **J.** *Polygonum molle*; **K.** *Pseudocyclosorus canus*; **L.** *Lycopodium japonicum.*

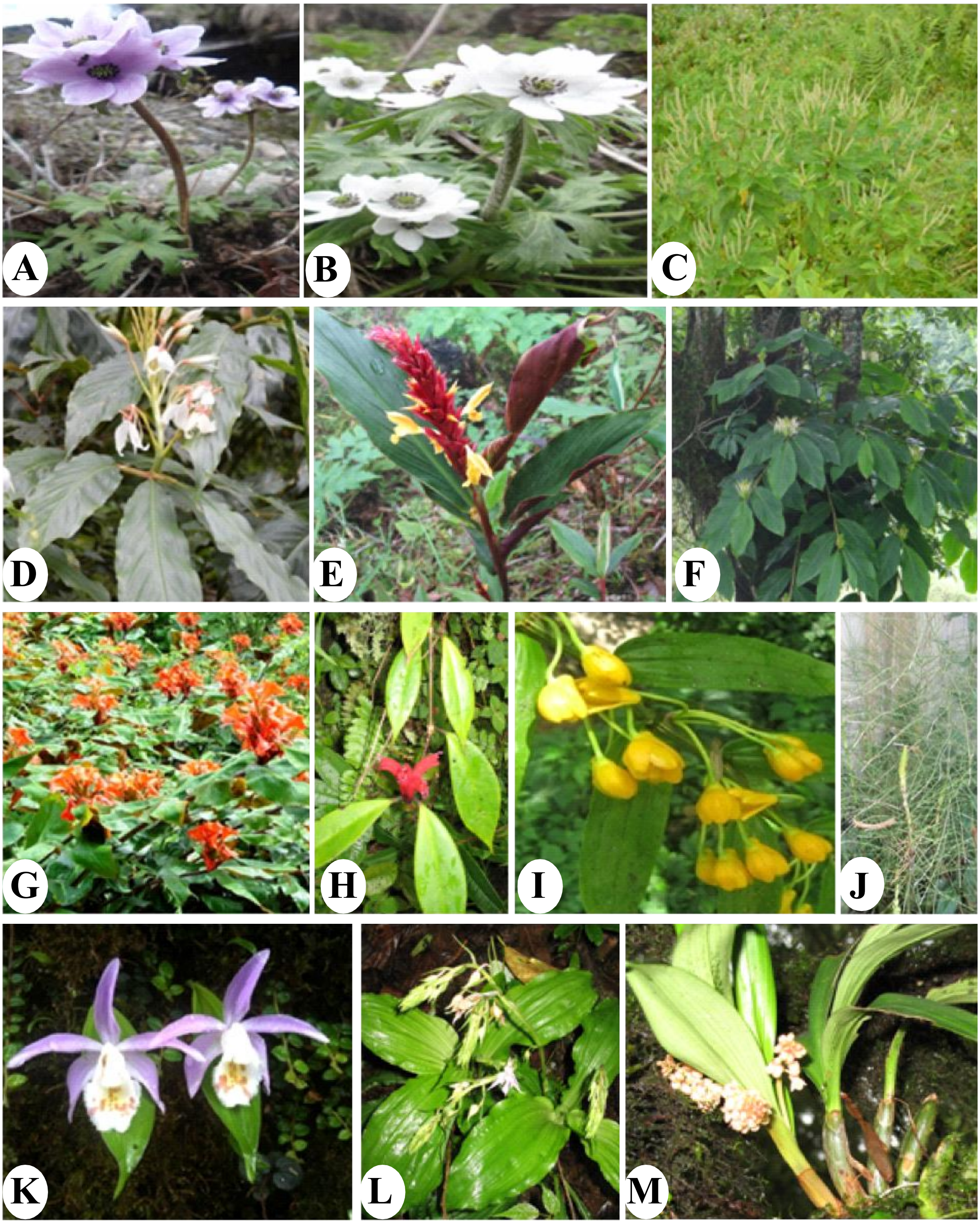


PLATE 5: A. *Anemone obtusiloba*; **B.** *Anemone rivularis*; **C.** *Elsholtzia fruticosa*; **D.** *Hedychium thyrsiforme*; **E.** *Cautleya spicata*; **F.** *Hedychium coccineum*; **G.** *Hedychium greenii*; **H.** *Aeschynanthus hookeri*; **I.** *Dendrobium denneanum*; **J.** *Equisetum arvense*; **K.** *Pleione praecox*; **L.***Clintonia* Spp; **M.** *Liparis* Spp.

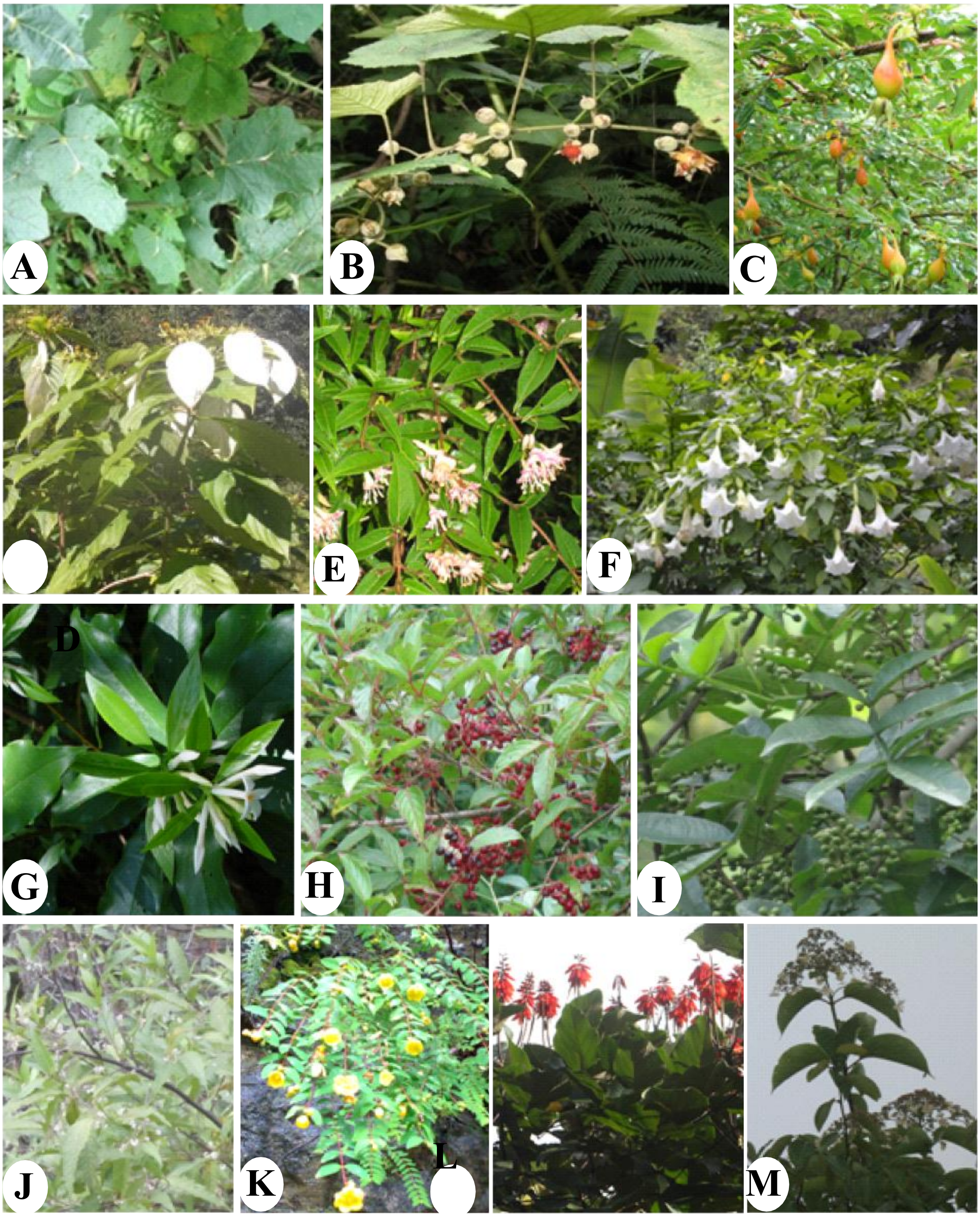


PLATE 6: A. *Solanum viarum*; **B.** *Rubus buergeri*; **C.** *Rosa brunonii*; **D.** *Mussaenda* roxburghii; **E.** *Aster albescens*; **F.** *Brugmansia suaveolens*; **G.** *Daphne bholua*; **H.** *Viburnum erubescens*; **I.** Zanthoxylum nepalense; **J.** *Maesa chisia*; **K.** *Hypericum uralum*; **L.** *Erythrina arborescens*; **M.** *Callicarpa macrophylla*.

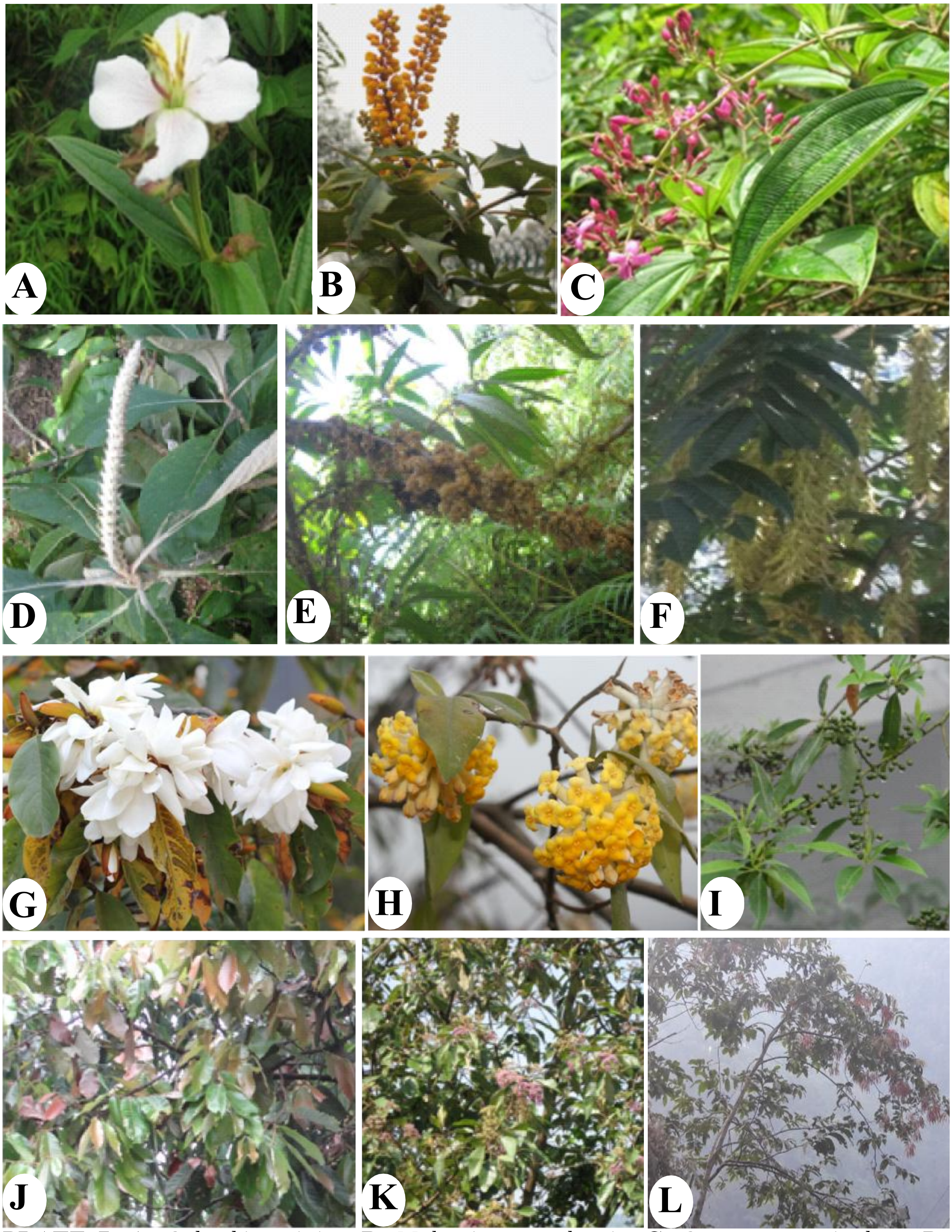


PLATE 7: A. *Osbeckia crinita*; **B.** *Mahonia napaulensis*; **C.** *Oxyspora paniculata*; **D.** *Leucosceptrum canum*; **E.** *Symplocos ramosissima*; **F.** *Engelhardtia spicata*; **G.** *Magnolia doltsopa*; **H.** *Edgeworthia gardneri*; **I.** *Litsea cubeba*; **J.** *Castanopsis indica*; **K.** *Callicarpa arborea*; **L.** *Terminalia myriocarpa.*

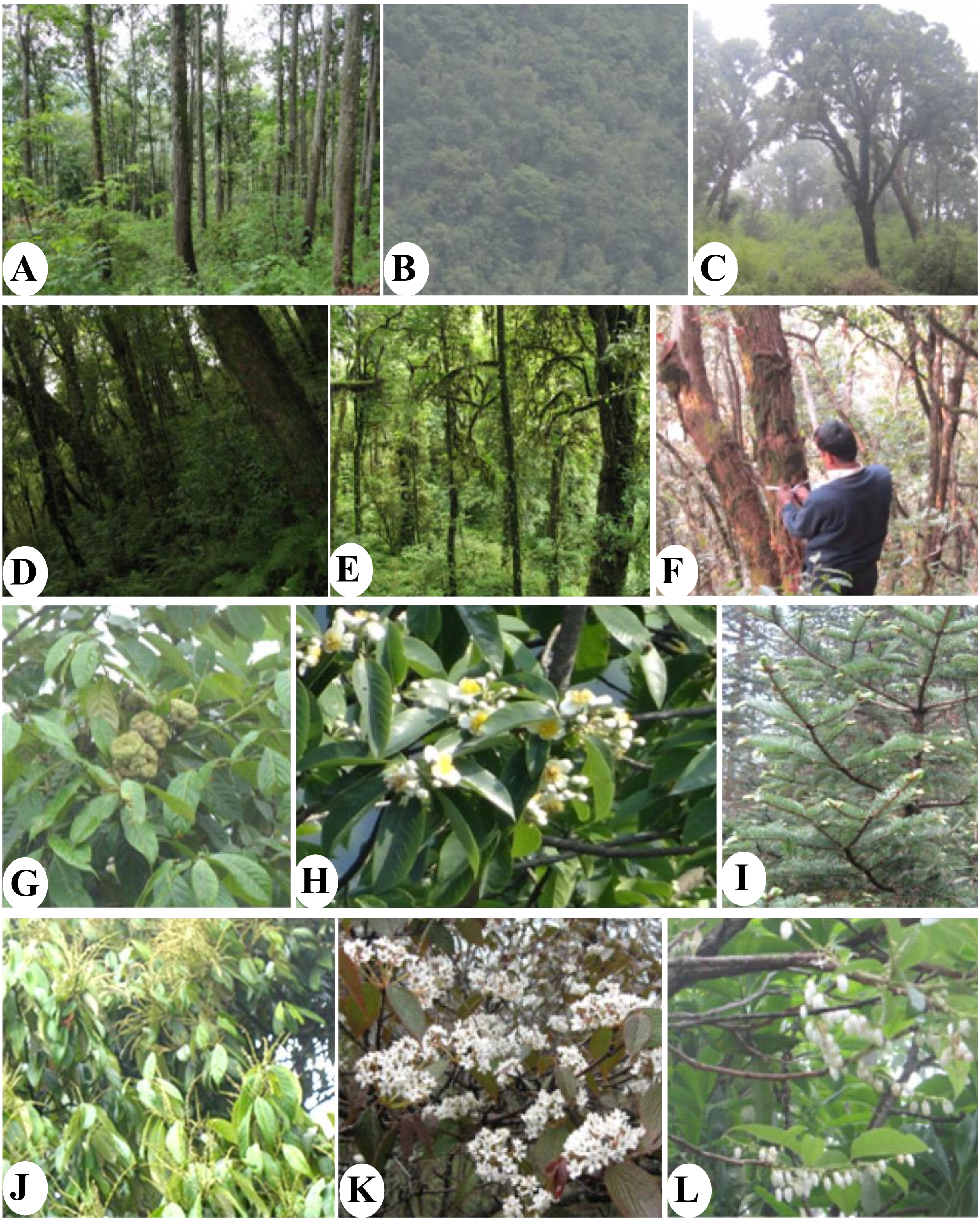


PLATE 7: A. *Osbeckia crinita*; **B.** *Mahonia napaulensis*; **C.** *Oxyspora paniculata*; **D.** *Leucosceptrum canum*; **E.** *Symplocos ramosissima*; **F.** *Engelhardtia spicata*; **G.** *Magnolia doltsopa*; **H.** *Edgeworthia gardneri*; **I.** *Litsea cubeba*; **J.** *Castanopsis indica*; **K.** *Callicarpa arborea*; **L.** *Terminalia myriocarpa*.

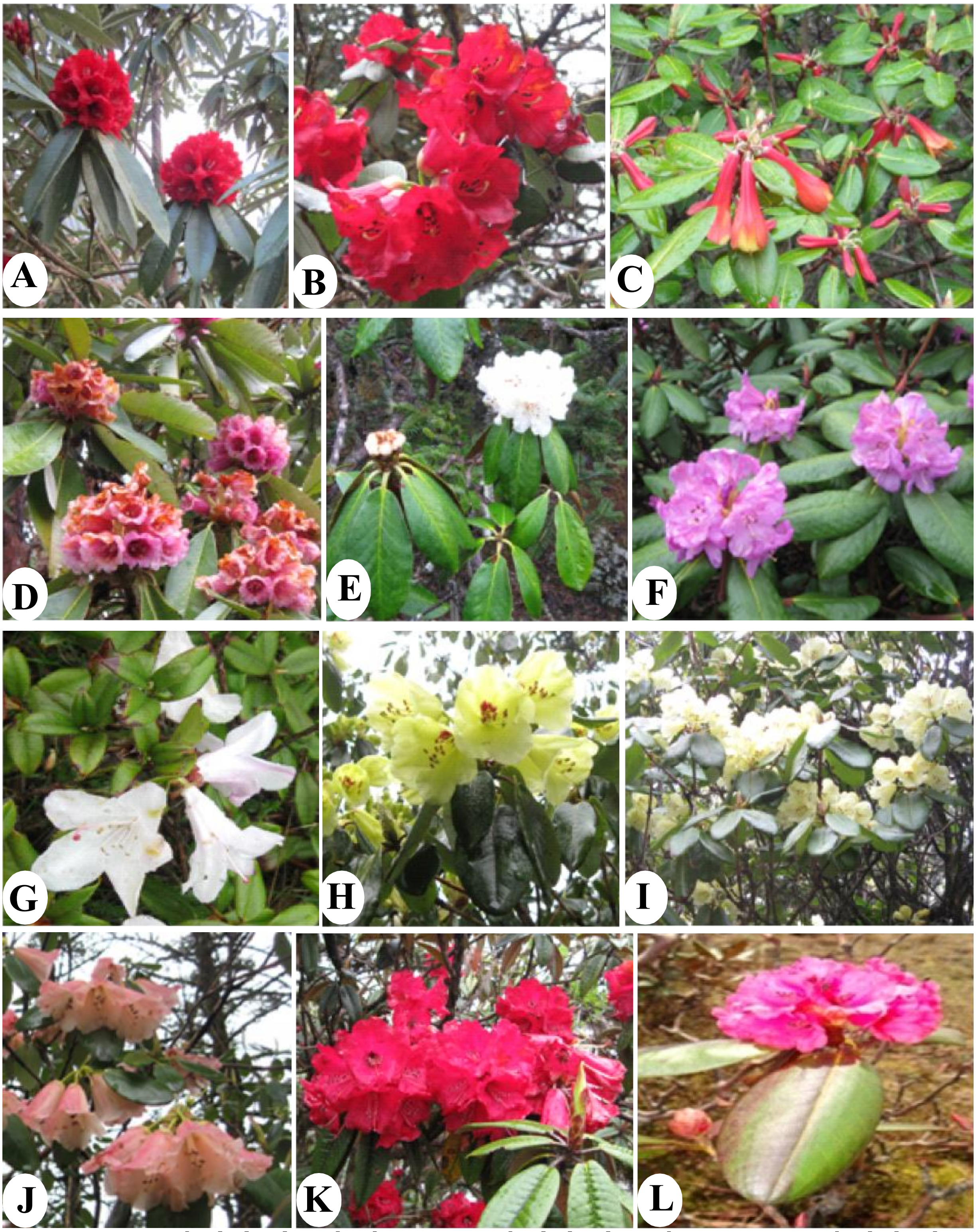


PLATE 9: A. *Rhododendron barbatum*; **B**. *Rhododendron thomsonii*; **C.** *Rhododendron cinnabarinum*; **D.** *Rhododendron decipiens*; **E.** *Rhododendron wightii*; **F.** *Rhododendron wallichii*; **G.** *Rhododendron lanatum*; **H.** *Rhododendron campylocarpum*; **I**. *Rhododendron tubiforme*; **J.** *Rhododendron cyanocarpum*; **K.** *Rhododendron arboreum*; **L.** Form of *Rhododendron thomsonii.*

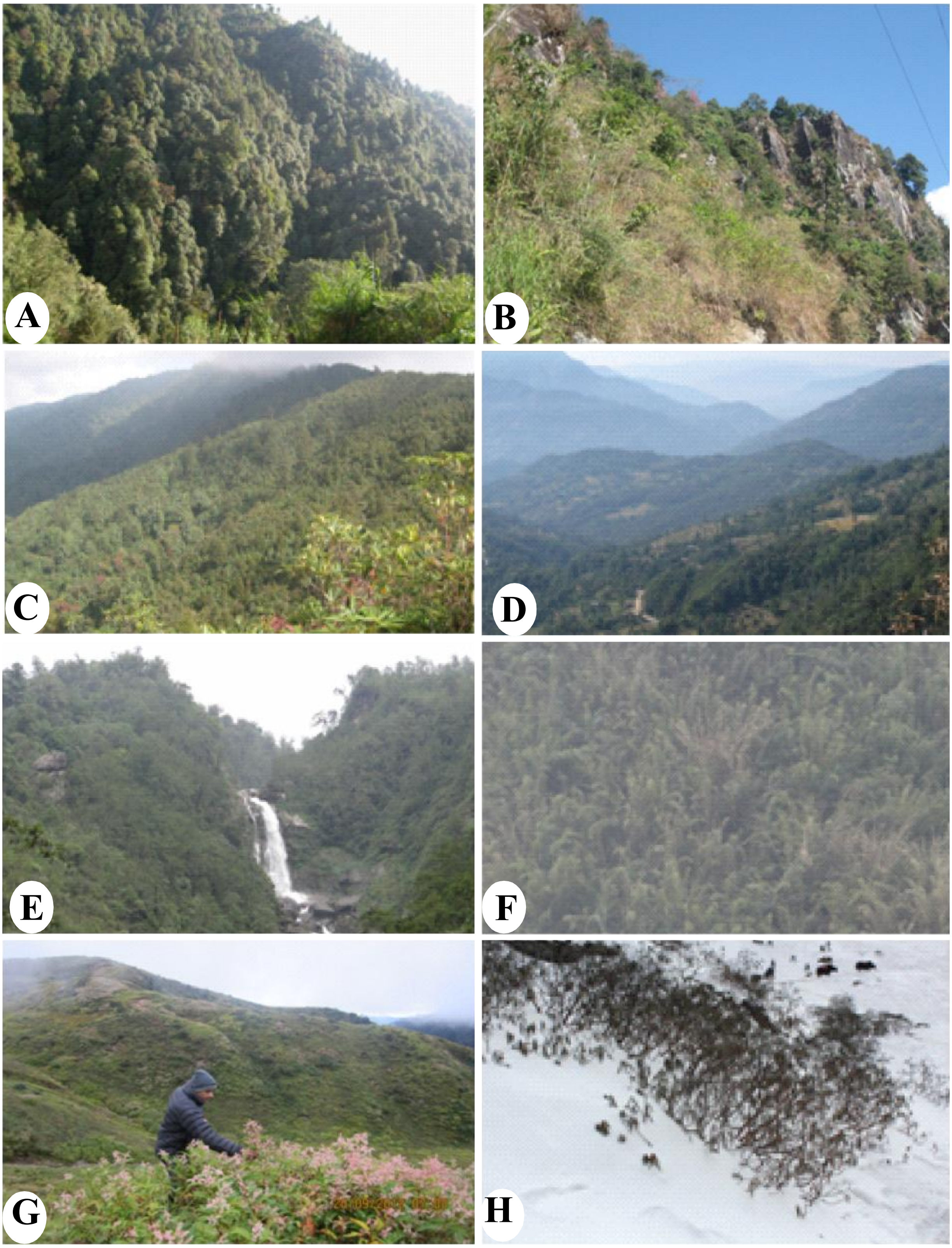


PLATE 10: A. Dense subtropical forest; **B.**Steep slope rockey area of the study area; **C.** Dense Temprate forest of East District Sikkim; **D.** Vegetations near by village; **E.** Vegetation along the river side; **E.** Dense bamboo forest along the hill; **G.**Collection of specimen from alpine area; H. Alpine area covered by snow.

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ANNEXURE I

Annexure I

Importance Value Index of Species of the study area

Sl No	Botanical Name	F	D	A	RF	RD	RA	IVI
1	*Schima wallichii* Choisy	50	44.5	89	0.42	7.92	3.96	12.31
2	*Ostodes paniculata* Blume	42.86	15.36	35.83	0.36	2.73	1.6	4.69
3	*Alnus nepalensis* D.Don	57.14	12.61	22.06	0.48	2.24	0.98	3.71
4	*Castanopsis hystrix* Hook.f. & Thomson *ex* A.DC.	71.43	11.61	16.25	0.6	2.07	0.72	3.39
5	*Engelhardtia spicata* var. *integra* (Kurz) W.E.Manning *ex* Steenis	53.57	11.21	20.93	0.45	2	0.93	3.38
6	*Nephrolepis cordifolia* (L.) C. Presel	82.14	10.79	13.13	0.69	1.92	0.58	3.2
7	*Symplocos lucida* (Thunb.) Siebold & Zucc.	39.29	8.07	20.55	0.33	1.44	0.91	2.68
8	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	75	8.61	11.48	0.63	1.53	0.51	2.68
9	*Dryopteris sikkimensis* (Bedd.) Kuntze	64.29	8.29	12.89	0.54	1.47	0.57	2.59
10	*Selaginella ciliaris* (Retz.) Spring	64.29	7.89	12.28	0.54	1.41	0.55	2.49
11	*Polygonum runcinatum* Buch.-Ham. *ex* D. Don	82.14	7.75	9.43	0.69	1.38	0.42	2.49
12	*Pteridium aquilinum* (L.) Kuhn	100	5.75	5.75	0.84	1.02	0.26	2.12
13	*Elatostema obtusum* Wedd.	64.29	6.18	9.61	0.54	1.1	0.43	2.07
14	*Pouzolzia zeylanica* (L.) Benn.	67.86	6.07	8.95	0.57	1.08	0.4	2.05
15	*Polystichum lentum* (D. Don) T. Moore	82.14	5.79	7.04	0.69	1.03	0.31	2.04
16	*Helicia nilagirica* Bedd.	21.43	4.32	20.17	0.18	0.77	0.9	1.85
17	*Cryptomeria japonica* (Thunb. *ex* L.f.) D.Don	21.43	4.25	19.83	0.18	0.76	0.88	1.82
18	*Syzygium venosum* DC.	25	4.46	17.86	0.21	0.79	0.79	1.8
19	*Macaranga indica* Wight	35.71	4.93	13.8	0.3	0.88	0.61	1.79
20	*Rhododendron barbatum* Wall. *ex* G. Don	32.14	4.71	14.67	0.27	0.84	0.65	1.76
21	*Acer campbellii* Hook.f. & Thomson *ex* Hiern	53.57	4.68	8.73	0.45	0.83	0.39	1.67
22	*Viburnum mullaha* Buch.-Ham.*ex* D. Don	7.14	2	28	0.06	0.36	1.25	1.66
23	*Mallotus roxburghianus* Müll.-Arg.	17.86	3.54	19.8	0.15	0.63	0.88	1.66
24	*Dichroa febrifuga* Lour.	75	4.29	5.71	0.63	0.76	0.25	1.65
25	*Viburnum cylindricum* Buch.-Ham. *ex* D. Don	14.29	3.11	21.75	0.12	0.55	0.97	1.64
26	*Boehmeria platyphylla* D.Don	67.86	4.39	6.47	0.57	0.78	0.29	1.64
27	*Lithocarpus pachyphyllus* (Kurz) Rehder	21.43	3.71	17.33	0.18	0.66	0.77	1.61
28	*Eupatorium cannabinum* L.	64.29	4.11	6.39	0.54	0.73	0.28	1.56
29	*Mussaenda treutleri* Stapf	67.86	3.96	5.84	0.57	0.71	0.26	1.54

Sl No	Botanical Name	F	D	A	RF	RD	RA	IVI
30	*Commelina paludosa* Blume	67.86	3.86	5.68	0.57	0.69	0.25	1.51
31	*Quercus lamellosa* Sm.	46.43	4	8.62	0.39	0.71	0.38	1.49
32	*Pandanus furcatus* Roxb.	21.43	3.21	15	0.18	0.57	0.67	1.42
33	*Setaria palmifolia* (J.Koenig) Stapf	71.43	3.32	4.65	0.6	0.59	0.21	1.4
34	*Rhododendron arboretum* Sm.	21.43	3.14	14.67	0.18	0.56	0.65	1.39
35	*Viburnum cotinifolium* D.Don	42.86	3.61	8.42	0.36	0.64	0.37	1.38
36	*Magnolia hodgsonii* (Hook.f.& Thomson) H.Keng	10.71	2.11	19.67	0.09	0.38	0.88	1.34
37	*Brachiaria distachya* (L.) Stapf	57.14	3.32	5.81	0.48	0.59	0.26	1.33
38	*Viburnum erubescens* Wall.	42.86	3.36	7.83	0.36	0.6	0.35	1.31
39	*Osbeckia crinite* Benth. *ex* C.B. Clarke	64.29	3	4.67	0.54	0.53	0.21	1.28
40	*Cynodon dactylon* (L.) Pers.	60.71	3	4.94	0.51	0.53	0.22	1.27
41	*Lecanthus peduncularis* (Wall. *ex* Royle) Wedd.	67.86	2.86	4.21	0.57	0.51	0.19	1.27
42	*Digitaria ciliaris* (Retz.) Koeler	60.71	2.96	4.88	0.51	0.53	0.22	1.26
43	*Cyperus tenuiculmis* Boeck.	25	2.93	11.71	0.21	0.52	0.52	1.25
44	*Tectaria gemmifera* (Fée) Alston	71.43	2.57	3.6	0.6	0.46	0.16	1.22
45	*Albizia chinensis* (Osbeck) Merr.	35.71	3	8.4	0.3	0.53	0.37	1.21
46	*Castanopsis tribuloides* (Sm.) A.DC.	50	2.96	5.93	0.42	0.53	0.26	1.21
47	*Eurya japonica* Thunb.	64.29	2.64	4.11	0.54	0.47	0.18	1.2
48	*Terminalia myriocarpa* Van Heurck & Müll.-Arg.	35.71	2.82	7.9	0.3	0.5	0.35	1.16
49	*Tetrastigma rumicispermum* (M.A.Lawson) Planch.	67.86	2.39	3.53	0.57	0.43	0.16	1.16
50	*Cupressus torulosa* D.Don	3.57	0.79	22	0.03	0.14	0.98	1.15
51	*Pteris biaurita* L.	46.43	2.71	5.85	0.39	0.48	0.26	1.14
52	*Machilus kurzii* King *ex* Hook.f.	21.43	2.46	11.5	0.18	0.44	0.51	1.13
53	*Maesa chisia* Buch.-Ham. *ex* D. Don	67.86	2.18	3.21	0.57	0.39	0.14	1.1
54	*Ficus hirta* Vahl	60.71	2.29	3.76	0.51	0.41	0.17	1.09
55	*Rubus ellipticus* Sm.	64.29	2.18	3.39	0.54	0.39	0.15	1.08
56	*Digitaria longiflora* (Retz.) Pers.	35.71	2.43	6.8	0.3	0.43	0.3	1.04
57	*Persicaria capitata* (Buch.-Ham. *ex* D.Don) H.Gross	46.43	2.29	4.92	0.39	0.41	0.22	1.02
58	*Edgeworthia gardneri* (Wall.) Meisn.	50	2.25	4.5	0.42	0.4	0.2	1.02
59	*Machilus edulis* King *ex* Hook.f.	32.14	2.32	7.22	0.27	0.41	0.32	1.01
60	*Drymaria cordata* (L.) Willd. *ex* Schult.	53.57	2.07	3.87	0.45	0.37	0.17	0.99
61	*Populus gamblei* Dode	21.43	2.07	9.67	0.18	0.37	0.43	0.98
62	*Achyranthes aspera* L.	50	2.11	4.21	0.42	0.38	0.19	0.98
63	*Piper betleoides* C.DC.	53.57	1.96	3.67	0.45	0.35	0.16	0.97
64	*Rhus succedanea* L.	25	2.11	8.43	0.21	0.38	0.38	0.96
65	*Isachne globosa* (Thunb.) Kuntze	21.43	2	9.33	0.18	0.36	0.42	0.95

Sl No	Botanical Name	F	D	A	RF	RD	RA	IVI
66	*Quercus lineata* Blume	39.29	2.11	5.36	0.33	0.38	0.24	0.95
67	*Isachne himalaica* Hook.f	35.71	2.04	5.7	0.3	0.36	0.25	0.92
68	*Rubia manjith* Roxb. ex Fleming	46.43	1.89	4.08	0.39	0.34	0.18	0.91
69	*Rhododendron thomsonii* Hook.f.	14.29	1.54	10.75	0.12	0.27	0.48	0.87
70	*Alangium chinense* (Lour.) Harms	53.57	1.61	3	0.45	0.29	0.13	0.87
71	*Lyonia ovalifolia* (Wall.) Drude	46.43	1.68	3.62	0.39	0.3	0.16	0.85
72	*Imperata cylindrica* (L.) Raeusch	46.43	1.68	3.62	0.39	0.3	0.16	0.85
73	*Daphne papyracea* Wall. *ex* G.Don	50	1.61	3.21	0.42	0.29	0.14	0.85
74	*Alocasia macrorrhizos* (L.) G.Don	50	1.61	3.21	0.42	0.29	0.14	0.85
75	*Cyperus cyperoides* (Retz.) Kuntze	28.57	1.79	6.25	0.24	0.32	0.28	0.84
76	*Cyperus distans* L.	50	1.57	3.14	0.42	0.28	0.14	0.84
77	*Rhododendron griffithianum* Wight	17.86	1.57	8.8	0.15	0.28	0.39	0.82
78	*Polygonum molle* D.Don	39.29	1.64	4.18	0.33	0.29	0.19	0.81
79	*Triumfetta rhomboidea* Jacq.	42.86	1.61	3.75	0.36	0.29	0.17	0.81
80	*Oplismenus compositus* (L.) P.Beauv.	42.86	1.61	3.75	0.36	0.29	0.17	0.81
81	*Rhododendron hodgsonii* Hook.f.	21.43	1.61	7.5	0.18	0.29	0.33	0.8
82	*Rhododendron triflorum* Hook.f.	25	1.61	6.43	0.21	0.29	0.29	0.78
83	*Abies densa* Griff.	25	1.57	6.29	0.21	0.28	0.28	0.77
84	*Selliguea griffithiana* (Hook.) Fraser-Jenk.	50	1.29	2.57	0.42	0.23	0.11	0.77
85	*Betula utilis* D.Don	17.86	1.43	8	0.15	0.25	0.36	0.76
86	*Dioscorea bulbifera* L.	32.14	1.54	4.78	0.27	0.27	0.21	0.76
87	*Loxogramme involuta* (D.Don)C.Presl	46.43	1.36	2.92	0.39	0.24	0.13	0.76
88	*Heracleum wallichii* DC.	14.29	1.29	9	0.12	0.23	0.4	0.75
89	*Begonia picta* Sm.	25	1.5	6	0.21	0.27	0.27	0.75
90	*Melastoma malabathricum* L.	50	1.21	2.43	0.42	0.22	0.11	0.75
91	*Smilax bracteata* subsp. *veruculosa* (Merr.) T.Koyama	53.57	1.14	2.13	0.45	0.2	0.09	0.75
92	*Diplazium dilatatum* Blume	3.57	0.5	14	0.03	0.09	0.62	0.74
93	*Pilea glaberrima* (Blume) Blume	50	1.18	2.36	0.42	0.21	0.1	0.74
94	*Meliosma dilleniifolia* (Wight & Arn.) Walp.	10.71	1.07	10	0.09	0.19	0.45	0.73
95	*Callicarpa arborea* Roxb.	25	1.46	5.86	0.21	0.26	0.26	0.73
96	*Christella parasitica* H.Lév.	32.14	1.46	4.56	0.27	0.26	0.2	0.73
97	*Hydrocotyle javanica* Thunb.	46.43	1.25	2.69	0.39	0.22	0.12	0.73
98	*Eragrostis unioloides* (Retz.) Nees *ex* Steud.	17.86	1.32	7.4	0.15	0.24	0.33	0.72
99	*Antidesma acidum* Retz.	35.71	1.36	3.8	0.3	0.24	0.17	0.71
100	*Selaginella pallescens* (C.Presl) Spring	35.71	1.32	3.7	0.3	0.24	0.16	0.7
101	*Fragaria vesca* L.	39.29	1.21	3.09	0.33	0.22	0.14	0.69
102	*Plantago asiatica subsp. erosa* (Wall.) Z.Yu Li	32.14	1.29	4	0.27	0.23	0.18	0.68

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103	*Betula alnoides* Buch.-Ham.	35.71	1.25	3.5	0.3	0.22	0.16	0.68
104	*Ehretia acuminate* R.Br.	17.86	1.21	6.8	0.15	0.22	0.3	0.67
105	*Eragrostis atrovirens* (Desf.) Trin.	28.57	1.29	4.5	0.24	0.23	0.2	0.67
106	*Arundinella hookeri* Munro & Keng	28.57	1.29	4.5	0.24	0.23	0.2	0.67
107	*Rubus insignis* Hook.f.	42.86	1.11	2.58	0.36	0.2	0.11	0.67
108	*Artemisia japonica* Thunb.	46.43	1	2.15	0.39	0.18	0.1	0.67
109	*Isachne albens* Trin.	21.43	1.25	5.83	0.18	0.22	0.26	0.66
110	*Acer oblongum* Wall. *ex* DC.	21.43	1.25	5.83	0.18	0.22	0.26	0.66
111	*Symplocos glomerata* King *ex* C.B.Clarke	25	1.25	5	0.21	0.22	0.22	0.66
112	*Bombax ceiba* L.	25	1.25	5	0.21	0.22	0.22	0.66
113	*Anaphalis contorta* (D.Don) Hook.f	25	1.25	5	0.21	0.22	0.22	0.66
114	*Cyperus alopecuroides* Rottb.	28.57	1.25	4.38	0.24	0.22	0.19	0.66
115	*Arisaema galeatum* N.E.Br.	35.71	1.18	3.3	0.3	0.21	0.15	0.66
116	*Urtica dioica* L.	39.29	1.14	2.91	0.33	0.2	0.13	0.66
117	*Cyperus longus* L.	28.57	1.21	4.25	0.24	0.22	0.19	0.65
118	*Pteris longipes* D.Don	35.71	1.14	3.2	0.3	0.2	0.14	0.65
119	*Bidens pilosa* L.	35.71	1.14	3.2	0.3	0.2	0.14	0.65
120	*Drypetes longifolia* (Blume) Pax & K.Hoffm.	21.43	1.18	5.5	0.18	0.21	0.24	0.64
121	*Prunus cerasoides* Buch.-Ham. *ex* D.Don	42.86	1	2.33	0.36	0.18	0.1	0.64
122	*Brassaiopsis mitis* C.B. Clarke	42.86	1	2.33	0.36	0.18	0.1	0.64
123	*Cissus repens* Lam.	46.43	0.89	1.92	0.39	0.16	0.09	0.64
124	*Cyperus difformis* L.	7.14	0.71	10	0.06	0.13	0.45	0.63
125	*Fragaria daltoniana* J. Gay	28.57	1.18	4.13	0.24	0.21	0.18	0.63
126	*Rhododendron falconeri* Hook.f.	17.86	1.11	6.2	0.15	0.2	0.28	0.62
127	*Cyperus rotundus* L.	28.57	1.14	4	0.24	0.2	0.18	0.62
128	*Juniperus procera* Hochst.	14.29	1	7	0.12	0.18	0.31	0.61
129	*Lycopodium clavatum* L.	25	1.11	4.43	0.21	0.2	0.2	0.61
130	*Swertia chirayita* (Roxb.) Buch.-Ham. ex C.B.Clarke	28.57	1.11	3.88	0.24	0.2	0.17	0.61
131	*Mikania micrantha* Kunth	32.14	1.07	3.33	0.27	0.19	0.15	0.61
132	*Cymbopogon microthecus* (Hook.f.) A.Camus	32.14	1.07	3.33	0.27	0.19	0.15	0.61
133	*Cyperus odoratus* L.	7.14	0.68	9.5	0.06	0.12	0.42	0.6
134	*Leucosceptrum canum* Sm.	28.57	1.07	3.75	0.24	0.19	0.17	0.6
135	*Bischofia javanica* Blume	28.57	1.07	3.75	0.24	0.19	0.17	0.6
136	*Selaginella martensii* Spring	32.14	1.04	3.22	0.27	0.18	0.14	0.6
137	*Liparis viridifolia* (Bl.) Lindl.	35.71	1	2.8	0.3	0.18	0.12	0.6
138	*Shorea robusta* Gaertn.	3.57	0.39	11	0.03	0.07	0.49	0.59
139	*Selaginella willdenovii* (Desv. *ex* Poir.) Baker	14.29	0.96	6.75	0.12	0.17	0.3	0.59

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140	*Drynaria coronans* (Wall. *ex* Mett.) T.Moore	28.57	1.04	3.63	0.24	0.18	0.16	0.59
141	*Magnolia cathcartii* (Hook.f. & Thomson) Noot.	7.14	0.64	9	0.06	0.11	0.4	0.58
142	*Mallotus tetracoccus* (Roxb.) Kurz	14.29	0.93	6.5	0.12	0.17	0.29	0.58
143	*Cyperus cuspidatus* Kunth	14.29	0.93	6.5	0.12	0.17	0.29	0.58
144	*Eragrostis nigra* Nees ex Steud.	17.86	1	5.6	0.15	0.18	0.25	0.58
145	*Litsea sericea* (Wall.*ex* Nees) Hook.f.	25	1.04	4.14	0.21	0.18	0.18	0.58
146	*Magnolia campbellii* Hook.f.& Thomson	32.14	0.96	3	0.27	0.17	0.13	0.58
147	*Cymbidium mastersii* Griff. *ex*. Lindl.	32.14	0.96	3	0.27	0.17	0.13	0.58
148	*Oxalis corniculata* L.	42.86	0.79	1.83	0.36	0.14	0.08	0.58
149	*Machilus glaucescens* (T.Nees) H.W. Li	21.43	1	4.67	0.18	0.18	0.21	0.57
150	*Elsholtzia flava* Benth.	39.29	0.82	2.09	0.33	0.15	0.09	0.57
151	*Oplismenus burmanni* (Retz.) P. Beauv.	10.71	0.79	7.33	0.09	0.14	0.33	0.56
152	*Dioscorea pentaphylla* L.	17.86	0.93	5.2	0.15	0.17	0.23	0.55
153	*Arundinella nepalensis* Trin.	28.57	0.93	3.25	0.24	0.17	0.14	0.55
154	*Pilea umbrosa* Blume	35.71	0.82	2.3	0.3	0.15	0.1	0.55
155	*Brachiaria villosa* (Lam.) A. Camus	35.71	0.82	2.3	0.3	0.15	0.1	0.55
156	*Rhododendron campylocarpum* Hook.f.	3.57	0.36	10	0.03	0.06	0.45	0.54
157	*Pteris linearis* Poir.	21.43	0.93	4.33	0.18	0.17	0.19	0.54
158	*Leucas lanata* Benth.	39.29	0.71	1.82	0.33	0.13	0.08	0.54
159	*Persicaria polystachya* Opiz	32.14	0.82	2.56	0.27	0.15	0.11	0.53
160	*Tinospora sinensis* (Lour.) Merr.	35.71	0.75	2.1	0.3	0.13	0.09	0.53
161	*Actinodaphne sikkimensis* Meisn.	7.14	0.57	8	0.06	0.1	0.36	0.52
162	*Swertia angustifolia* Buch.-Ham.*ex* D.Don	32.14	0.79	2.44	0.27	0.14	0.11	0.52
163	*Glochidion acuminatum* Müll.-Arg.	32.14	0.79	2.44	0.27	0.14	0.11	0.52
164	*Apios carnea* (Wall.) Benth.	39.29	0.64	1.64	0.33	0.11	0.07	0.52
165	*Anaphalis margaritacea* (L.) Benth. & Hook.f.	14.29	0.79	5.5	0.12	0.14	0.24	0.51
166	*Premna barbata* Wall. *ex* Schauer	32.14	0.75	2.33	0.27	0.13	0.1	0.51
167	*Cirrhopetalum wallichii* Lindl.	32.14	0.75	2.33	0.27	0.13	0.1	0.51
168	*Albizia lucidior* (Steud.) I.C.Nielsen	39.29	0.61	1.55	0.33	0.11	0.07	0.51
169	*Magnolia lanuginosa* (Wall.) Figlar & Noot.	17.86	0.82	4.6	0.15	0.15	0.2	0.5
170	*Syzygium formosum* (Wall.) Masam.	25	0.82	3.29	0.21	0.15	0.15	0.5
171	*Axonopus compressus* (Swartz) P.Beauv.	25	0.82	3.29	0.21	0.15	0.15	0.5
172	*Symplocos cochinchinensis* (Lour.) S.Moore	28.57	0.79	2.75	0.24	0.14	0.12	0.5
173	*Reevesia pubescens* Mast.	35.71	0.64	1.8	0.3	0.11	0.08	0.5
174	*Garuga floribunda* Decne.	17.86	0.79	4.4	0.15	0.14	0.2	0.49
175	*Remusatia hookeriana* Schott	25	0.79	3.14	0.21	0.14	0.14	0.49
176	*Prunus nepalensis* Ser.	25	0.79	3.14	0.21	0.14	0.14	0.49

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177	*Persicaria lapathifolia* (L.) Delarbre	25	0.79	3.14	0.21	0.14	0.14	0.49
178	*Persicaria amplexicaulis* (D.Don) Ronse Decr.	25	0.79	3.14	0.21	0.14	0.14	0.49
179	*Elatostema platyphyllum* Wedd.	25	0.79	3.14	0.21	0.14	0.14	0.49
180	*Plectranthus barbatus* Andrews	28.57	0.75	2.63	0.24	0.13	0.12	0.49
181	*Ageratum conyzoides* (L.) L.	28.57	0.75	2.63	0.24	0.13	0.12	0.49
182	*Isachne mauritiana* Kunth	21.43	0.79	3.67	0.18	0.14	0.16	0.48
183	*Astilbe rivularis* Buch.-Ham.	21.43	0.79	3.67	0.18	0.14	0.16	0.48
184	*Arundinaria racemosa* Munro	21.43	0.79	3.67	0.18	0.14	0.16	0.48
185	*Thysanolaena latifolia* (Roxb. *ex* Hornem.) Honda	28.57	0.71	2.5	0.24	0.13	0.11	0.48
186	*Strobilanthes atropurpureus* Nees	14.29	0.71	5	0.12	0.13	0.22	0.47
187	*Yushania pantlingii* (Gamble) R.B.Majumdar	21.43	0.75	3.5	0.18	0.13	0.16	0.47
188	*Syzygium cumini* (L.) Skeels	25	0.71	2.86	0.21	0.13	0.13	0.47
189	*Anisomeles indica* (L.) Kuntze	25	0.71	2.86	0.21	0.13	0.13	0.47
190	*Peranema paleolulata* (Pic.Serm.) Fraser-Jenk.	28.57	0.68	2.38	0.24	0.12	0.11	0.47
191	*Colebrookea oppositifolia* Sm.	17.86	0.71	4	0.15	0.13	0.18	0.46
192	*Walsura tubulata* Hiern	21.43	0.71	3.33	0.18	0.13	0.15	0.46
193	*Morus alba* L.	21.43	0.71	3.33	0.18	0.13	0.15	0.46
194	*Yushania maling* (Gamble) R.B.Majumdar & Karthik	14.29	0.68	4.75	0.12	0.12	0.21	0.45
195	*Sorbusthomsonii* (King *ex* Hook.f.) Rehder	14.29	0.68	4.75	0.12	0.12	0.21	0.45
196	*Rubus nepalensis* (Hook.f.) Kuntze	25	0.68	2.71	0.21	0.12	0.12	0.45
197	*Paspalum scrobiculatum* L.	25	0.68	2.71	0.21	0.12	0.12	0.45
198	*Osbeckia stellata* Buch.-Ham. *ex* Ker Gawl.	35.71	0.5	1.4	0.3	0.09	0.06	0.45
199	*Oxyspora paniculata* (D.Don) DC.	17.86	0.68	3.8	0.15	0.12	0.17	0.44
200	*Pavetta indica* L.	21.43	0.68	3.17	0.18	0.12	0.14	0.44
201	*Chimonocalamus griffithianus* (Munro) Hsueh &T.P.Yi	21.43	0.68	3.17	0.18	0.12	0.14	0.44
202	*Tectaria macrodonta* C.Chr.	25	0.64	2.57	0.21	0.11	0.11	0.44
203	*Rhododendron vaccinioides* Hook.	25	0.64	2.57	0.21	0.11	0.11	0.44
204	*Crassocephalum crepidioides* (Benth.) S.Moore	28.57	0.61	2.13	0.24	0.11	0.09	0.44
205	*Eurya cerasifolia* (D.Don) Kobuski	10.71	0.57	5.33	0.09	0.1	0.24	0.43
206	*Dendrobium densiflorum* Lindl.	17.86	0.64	3.6	0.15	0.11	0.16	0.43
207	*Chrysopogon aciculatus* (Retz.) Trin.	17.86	0.64	3.6	0.15	0.11	0.16	0.43
208	*Bridelia retusa* (L.) Juss.	21.43	0.64	3	0.18	0.11	0.13	0.43
209	*Adiantum capillus-veneris* L.	21.43	0.64	3	0.18	0.11	0.13	0.43
210	*Houttuynia cordata* Thunb.	25	0.61	2.43	0.21	0.11	0.11	0.43
211	*Clerodendrum glandulosum* Lindl.	25	0.61	2.43	0.21	0.11	0.11	0.43
212	*Rohdea nepalensis* (Raf.) N.Tanaka	28.57	0.57	2	0.24	0.1	0.09	0.43
213	*Impatiens urticifolia* Wall.	14.29	0.61	4.25	0.12	0.11	0.19	0.42

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214	*Solanum aculeatissimum* Jacq.	21.43	0.61	2.83	0.18	0.11	0.13	0.42
215	*Rubus phengodes* Focke	28.57	0.54	1.88	0.24	0.1	0.08	0.42
216	*Lepisorus loriformis* (Wall. *ex* Mett.)Ching	32.14	0.46	1.44	0.27	0.08	0.06	0.42
217	*Oleandra wallichii* (Hook.) C.Presl	17.86	0.61	3.4	0.15	0.11	0.15	0.41
218	*Pogonatherum crinitum* (Thunb.) Kunth	25	0.57	2.29	0.21	0.1	0.1	0.41
219	*Himalayacalamus hookerianus* (Munro) Stapleton	25	0.57	2.29	0.21	0.1	0.1	0.41
220	*Brassaiopsis hispida* Seem.	25	0.57	2.29	0.21	0.1	0.1	0.41
221	*Arthromeris wallichiana* (Spreng.) Ching	25	0.57	2.29	0.21	0.1	0.1	0.41
222	*Leucostegia truncata* (D.Don) Fraser-Jenk.	7.14	0.43	6	0.06	0.08	0.27	0.4
223	*Brucea javanica* (L.) Merr.	14.29	0.57	4	0.12	0.1	0.18	0.4
224	*Viburnum grandiflorum* Wall. *ex* DC.	21.43	0.57	2.67	0.18	0.1	0.12	0.4
225	*Litsea albescens* (Hook.f.) D.G.Long	21.43	0.57	2.67	0.18	0.1	0.12	0.4
226	*Erythrina stricta* Roxb.	21.43	0.57	2.67	0.18	0.1	0.12	0.4
227	*Quercus glauca* Thunb.	25	0.54	2.14	0.21	0.1	0.1	0.4
228	*Huperzia pulcherrima* (Wall. *ex* Hook. & Grev.) T.Sen & U.Sen	25	0.54	2.14	0.21	0.1	0.1	0.4
229	*Dendrobium fuscescens* Griff.	25	0.54	2.14	0.21	0.1	0.1	0.4
230	*Ageratum houstonianum* Mill.	25	0.54	2.14	0.21	0.1	0.1	0.4
231	*Begonia palmata* D.Don	10.71	0.5	4.67	0.09	0.09	0.21	0.39
232	*Pogonatherum paniceum* (Lam.) Hack.	21.43	0.54	2.5	0.18	0.1	0.11	0.39
233	*Ficus neriifolia* Sm.	21.43	0.54	2.5	0.18	0.1	0.11	0.39
234	*Elatostema acuminatum* (Poir.) Brongn.	21.43	0.54	2.5	0.18	0.1	0.11	0.39
235	*Choerospondias axillaris* (Roxb.) B.L.Burtt & A.W.Hill	21.43	0.54	2.5	0.18	0.1	0.11	0.39
236	*Acer caudatum* Wall.	21.43	0.54	2.5	0.18	0.1	0.11	0.39
237	*Woodsia obtusa* Torr.	25	0.5	2	0.21	0.09	0.09	0.39
238	*Symplocos dryophila* C.B.Clarke	25	0.5	2	0.21	0.09	0.09	0.39
239	*Bambusa nutans* Wall. *ex* Munro	25	0.5	2	0.21	0.09	0.09	0.39
240	*Aleuritopteris subdimorpha* (C.B.Clarke & Baker) Fraser-Jenk.	25	0.5	2	0.21	0.09	0.09	0.39
241	*Azadirachta indica* Juss.	7.14	0.39	5.5	0.06	0.07	0.24	0.38
242	*Rhamnus napalensis* (Wall.) M.A.Lawson	14.29	0.54	3.75	0.12	0.1	0.17	0.38
243	*Pteracanthus urticifolius* (Wall. *ex* Kuntze) Bremek.	17.86	0.54	3	0.15	0.1	0.13	0.38
244	*Persicaria hydropiper* (L.) Delarbre	25	0.46	1.86	0.21	0.08	0.08	0.38
245	*Girardinia diversifolia* (Link) Friis	25	0.46	1.86	0.21	0.08	0.08	0.38
246	*Pouzolzia hirta* Blume *ex* Hassk.	28.57	0.43	1.5	0.24	0.08	0.07	0.38
247	*Nyssa javanica* (Blume) Wangerin	10.71	0.46	4.33	0.09	0.08	0.19	0.37
248	*Globba clarkei* Baker	10.71	0.46	4.33	0.09	0.08	0.19	0.37
249	*Aster albescens* (DC.) Wall.*ex* Hand.-Mazz	10.71	0.46	4.33	0.09	0.08	0.19	0.37
250	*Persicaria glabra* (Willd.) M.Gómez	14.29	0.5	3.5	0.12	0.09	0.16	0.37
251	*Rhaphidophora decursiva* (Roxb.) Schott	21.43	0.5	2.33	0.18	0.09	0.1	0.37

Sl No	Botanical Name	F	D	A	RF	RD	RA	IVI
252	*Dioscorea hamiltonii* Hook.f.	21.43	0.5	2.33	0.18	0.09	0.1	0.37
253	*Vaccinium vacciniaceum* (Roxb.) Sleumer	28.57	0.39	1.38	0.24	0.07	0.06	0.37
254	*Woodwardia unigemmata* (Makino) Nakai	17.86	0.5	2.8	0.15	0.09	0.12	0.36
255	*Toxicodendron hookeri* (K.C.Sahni & Bahadur) C.Y. Wu & T.L.Ming	17.86	0.5	2.8	0.15	0.09	0.12	0.36
256	*Duchesnea indica* (Jacks.) Focke	17.86	0.5	2.8	0.15	0.09	0.12	0.36
257	*Cymbidium longifolium* D.Don	17.86	0.5	2.8	0.15	0.09	0.12	0.36
258	*Pyrrosia porosa* (C.Presl) Hovenkamp	21.43	0.46	2.17	0.18	0.08	0.1	0.36
259	*Porana paniculata* Roxb.	21.43	0.46	2.17	0.18	0.08	0.1	0.36
260	*Vaccinium nummularia* Hook.f. & Thoms. *ex* C.B.Clarke	25	0.43	1.71	0.21	0.08	0.08	0.36
261	*Cyperus squarrosus* L.	25	0.43	1.71	0.21	0.08	0.08	0.36
262	*Adiantum incisum* Forssk.	25	0.43	1.71	0.21	0.08	0.08	0.36
263	*Boehmeria macrophylla* Hornem.	28.57	0.36	1.25	0.24	0.06	0.06	0.36
264	*Tectaria polymorpha* (Wall. *ex* Hook.) Copeland	7.14	0.36	5	0.06	0.06	0.22	0.35
265	*Odontosoria chinensis* (L.) Sm.	7.14	0.36	5	0.06	0.06	0.22	0.35
266	*Albizia procera* (Roxb.) Benth.	7.14	0.36	5	0.06	0.06	0.22	0.35
267	*Viola betonicifolia* Sm.	14.29	0.46	3.25	0.12	0.08	0.14	0.35
268	*Eucalyptus tereticornis* Sm.	14.29	0.46	3.25	0.12	0.08	0.14	0.35
269	*Arundo donax* L.	17.86	0.46	2.6	0.15	0.08	0.12	0.35
270	*Anaphalis busua* (Buch.-Ham.) DC.	17.86	0.46	2.6	0.15	0.08	0.12	0.35
271	*Drynaria guercifolia* (L.) Sm.	21.43	0.43	2	0.18	0.08	0.09	0.35
272	*Asplenium gueinzianum* Mett. *ex* Kuhn	21.43	0.43	2	0.18	0.08	0.09	0.35
273	*Actinidia callosa* Lindl.	21.43	0.43	2	0.18	0.08	0.09	0.35
274	*Mimosa himalayana* Gamble	25	0.39	1.57	0.21	0.07	0.07	0.35
275	*Cautleya gracilis* (Sm.) Dandy	25	0.39	1.57	0.21	0.07	0.07	0.35
276	*Cardiocrinum giganteum* (Wall.) Makino	3.57	0.21	6	0.03	0.04	0.27	0.34
277	*Dendrocalamus hamiltonii* T.Nees & Arn.*ex* Munro	25	0.36	1.43	0.21	0.06	0.06	0.34
278	*Paederia foetida* L.	14.29	0.43	3	0.12	0.08	0.13	0.33
279	*Elatostema sessile* J.R.Forst. & G.Forst.	17.86	0.43	2.4	0.15	0.08	0.11	0.33
280	*Davallodes membrunulosa* (Wall. *ex* Hook.) Copel	17.86	0.43	2.4	0.15	0.08	0.11	0.33
281	*Arisaema tortuosum* (Wall.) Schott	17.86	0.43	2.4	0.15	0.08	0.11	0.33
282	*Viola canescens* Wall.	21.43	0.39	1.83	0.18	0.07	0.08	0.33
283	*Dicranopteris linearis* (Burm.f.) Underw.	21.43	0.39	1.83	0.18	0.07	0.08	0.33
284	*Achyranthes bidentata* Blume	21.43	0.39	1.83	0.18	0.07	0.08	0.33
285	*Hedychium coccineum* Buch.-Ham. *ex* Sm.	25	0.32	1.29	0.21	0.06	0.06	0.33
286	*Rubus acuminatus* Sm.	7.14	0.32	4.5	0.06	0.06	0.2	0.32
287	*Elaphoglossum marginatum* (Wall. *ex* Fee)T.Moore	7.14	0.32	4.5	0.06	0.06	0.2	0.32
288	*Persicaria nepalensis* (Meisn.) Miyabe	10.71	0.39	3.67	0.09	0.07	0.16	0.32

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289	*Allantodia spectabilis* (Wall.*ex* Mett.) Ching	10.71	0.39	3.67	0.09	0.07	0.16	0.32
290	*Lemmaphyllum rostratum* (Bedd.) Tagawa	10.71	0.39	3.67	0.09	0.07	0.16	0.32
291	*Plantago rugelii* Decne.	17.86	0.39	2.2	0.15	0.07	0.1	0.32
292	*Microsorum punctatum* (L.) Copel.	17.86	0.39	2.2	0.15	0.07	0.1	0.32
293	*Toona ciliata* M.Roem.	21.43	0.36	1.67	0.18	0.06	0.07	0.32
294	*Saurauia fasciculate* Wall.	21.43	0.36	1.67	0.18	0.06	0.07	0.32
295	*Rumex nepalensis* Spreng.	21.43	0.36	1.67	0.18	0.06	0.07	0.32
296	*Hemiphragma heterophyllum* Wall.	21.43	0.36	1.67	0.18	0.06	0.07	0.32
297	*Viola pilosa* Blume	14.29	0.39	2.75	0.12	0.07	0.12	0.31
298	*Lithocarpus fenestratus* (Roxb.) Rehder	14.29	0.39	2.75	0.12	0.07	0.12	0.31
299	*Himalaiella deltoidea* (DC.) Raab-Straube	14.29	0.39	2.75	0.12	0.07	0.12	0.31
300	*Elsholtzia fruticosa* (D.Don) Rehder	10.71	0.36	3.33	0.09	0.06	0.15	0.3
301	*Viburnum nervosum* D.Don	14.29	0.36	2.5	0.12	0.06	0.11	0.3
302	*Liparis resupinata* Ridl.	14.29	0.36	2.5	0.12	0.06	0.11	0.3
303	*Impatiens racemosa* DC.	14.29	0.36	2.5	0.12	0.06	0.11	0.3
304	*Berchemia floribunda* (Wall.) Brongn.	14.29	0.36	2.5	0.12	0.06	0.11	0.3
305	*Berberisvirescens* Hook.f.	14.29	0.36	2.5	0.12	0.06	0.11	0.3
306	*Arctium lappa* L.	14.29	0.36	2.5	0.12	0.06	0.11	0.3
307	*Antidesma acuminatum* Wall	14.29	0.36	2.5	0.12	0.06	0.11	0.3
308	*Allantodia stoliczkae* (Bedd.) Ching	14.29	0.36	2.5	0.12	0.06	0.11	0.3
309	*Tsuga dumosa* (D.Don) Eichl.	17.86	0.36	2	0.15	0.06	0.09	0.3
310	*Phegopteris hexagonoptera* (Michx.) Fée	17.86	0.36	2	0.15	0.06	0.09	0.3
311	*Lantana camara* L.	17.86	0.36	2	0.15	0.06	0.09	0.3
312	*Ilex dipyrena* Wall.	17.86	0.36	2	0.15	0.06	0.09	0.3
313	*Cautleya spicata* (Sm.) Baker	17.86	0.36	2	0.15	0.06	0.09	0.3
314	*Athyrium filix-femina* (L.) Roth	17.86	0.36	2	0.15	0.06	0.09	0.3
315	*Cyanotis vaga* (Lour.) Schult..& Schult.f.	21.43	0.32	1.5	0.18	0.06	0.07	0.3
316	*Trichosanthes lepiniana* (Naudin) Cogniaux	25	0.25	1	0.21	0.04	0.04	0.3
317	*Premula pulchra* Watt	7.14	0.29	4	0.06	0.05	0.18	0.29
318	*Polystichum acrostichoides* (Michx.) Schott	7.14	0.29	4	0.06	0.05	0.18	0.29
319	*Lindenbergia grandiflora* (Buch.-Ham.*ex* D. Don) Benth.	7.14	0.29	4	0.06	0.05	0.18	0.29
320	*Cyathula capitata* Moq.	7.14	0.29	4	0.06	0.05	0.18	0.29
321	*Pyrrosia costata* (C.Presl) Tagawa & K.Iwats	17.86	0.32	1.8	0.15	0.06	0.08	0.29
322	*Potentilla fulgens* Trevir.	17.86	0.32	1.8	0.15	0.06	0.08	0.29
323	*Magnolia champaca* (L.) Baill. *ex* Pierre	17.86	0.32	1.8	0.15	0.06	0.08	0.29
324	*Litsea salicifolia* (J.Roxb. *ex* Nees) Hook.f.	17.86	0.32	1.8	0.15	0.06	0.08	0.29
325	*Hemarthria compressa* (L.f.) R.Br.	17.86	0.32	1.8	0.15	0.06	0.08	0.29
326	*Evodia fraxinifolia* (Hook.) Benth.	17.86	0.32	1.8	0.15	0.06	0.08	0.29

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327	*Elaeocarpus rugosus* Roxb. *ex* G.Don	17.86	0.32	1.8	0.15	0.06	0.08	0.29
328	*Cinnamomum impressinervium* Meisn.	17.86	0.32	1.8	0.15	0.06	0.08	0.29
329	*Balantium antarcticum* (Labill.) C.Presl	17.86	0.32	1.8	0.15	0.06	0.08	0.29
330	*Aster sikkimmensis* Hook.f.& Thomson	17.86	0.32	1.8	0.15	0.06	0.08	0.29
331	*Rubus calycinoides* Kuntze	21.43	0.29	1.33	0.18	0.05	0.06	0.29
332	*Himalayacalamus falconeri* (Hook.f. *ex* Munro) Keng.f.	21.43	0.29	1.33	0.18	0.05	0.06	0.29
333	*Buddleja asiatica* Lour.	3.57	0.18	5	0.03	0.03	0.22	0.28
334	Trichomanes accedens C. Presl	3.57	0.18	5	0.03	0.03	0.22	0.28
335	*Pyrrosia lanceolata* (L.) Farw.	10.71	0.32	3	0.09	0.06	0.13	0.28
336	*Persicaria vivipara* (L.) Ronse Decr.	10.71	0.32	3	0.09	0.06	0.13	0.28
337	*Mallotus nepalensis* Müll.-Arg.	10.71	0.32	3	0.09	0.06	0.13	0.28
338	*Bulbophyllum guttulatum* (Hook.f) N.P.Balkr.	10.71	0.32	3	0.09	0.06	0.13	0.28
339	*Athyrium foliolosum* T.Moore *ex* R. Sim	10.71	0.32	3	0.09	0.06	0.13	0.28
340	*Arisaema nepenthoides* (Wall.) Mart.	10.71	0.32	3	0.09	0.06	0.13	0.28
341	*Holmskioldia sanguine* Retz.	14.29	0.32	2.25	0.12	0.06	0.1	0.28
342	*Ficus sarmentosa* Buch.-Ham. *ex* Sm.	14.29	0.32	2.25	0.12	0.06	0.1	0.28
343	*Cyperus compressus* L.	14.29	0.32	2.25	0.12	0.06	0.1	0.28
344	*Strobilanthes capitata* (Nees) T. Anderson	21.43	0.25	1.17	0.18	0.04	0.05	0.28
345	*Meliosma simplicifolia* (Roxb.) Walp.	17.86	0.29	1.6	0.15	0.05	0.07	0.27
346	*Quercus laurifolia* Michx.	7.14	0.25	3.5	0.06	0.04	0.16	0.26
347	*Persicaria alpina* (All.) H.Gross	7.14	0.25	3.5	0.06	0.04	0.16	0.26
348	*Drynaria propinqua* (Wall. *ex* Mett.) J.Sm	7.14	0.25	3.5	0.06	0.04	0.16	0.26
349	*Curcuma angustifolia* Roxb.	7.14	0.25	3.5	0.06	0.04	0.16	0.26
350	*Caelogyne stricta* D.Don	7.14	0.25	3.5	0.06	0.04	0.16	0.26
351	*Sorbus cuspidata* (Spach.) Hedl.	10.71	0.29	2.67	0.09	0.05	0.12	0.26
352	*Primula denticulate* Sm.	10.71	0.29	2.67	0.09	0.05	0.12	0.26
353	*Premula capitata* Hook.f	10.71	0.29	2.67	0.09	0.05	0.12	0.26
354	*Machilus gamblei* King *ex* Hook.f.	10.71	0.29	2.67	0.09	0.05	0.12	0.26
355	*Asplenium tenuifolium* D.Don	10.71	0.29	2.67	0.09	0.05	0.12	0.26
356	*Artocarpus lacucha* Buch.-Ham.	10.71	0.29	2.67	0.09	0.05	0.12	0.26
357	*Exbucklandia populnea* (R.Br. *ex* Griff.) R.W.Br.	14.29	0.29	2	0.12	0.05	0.09	0.26
358	*Equisetum arvense* L.	14.29	0.29	2	0.12	0.05	0.09	0.26
359	*Pyrrosia mannii* (Giesenh.) Ching	17.86	0.25	1.4	0.15	0.04	0.06	0.26
360	*Hydrocotyle sibthorpioides* Lam.	17.86	0.25	1.4	0.15	0.04	0.06	0.26
361	*Cissampelos pareira* L.	17.86	0.25	1.4	0.15	0.04	0.06	0.26
362	*Astragalus stipulatus* (L.) A. Gray	17.86	0.25	1.4	0.15	0.04	0.06	0.26
363	*Artemisia vulgaris* L.	17.86	0.25	1.4	0.15	0.04	0.06	0.26

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364	*Pilea scripta* (Buch.-Ham. *ex* D. Don) Wedd.	10.71	0.25	2.33	0.09	0.04	0.1	0.24
365	*Oberonia falcata* King & Pantl.	10.71	0.25	2.33	0.09	0.04	0.1	0.24
366	*Melochia corchorifolia* L.	10.71	0.25	2.33	0.09	0.04	0.1	0.24
367	*Aster trinervis* Roxb.	10.71	0.25	2.33	0.09	0.04	0.1	0.24
368	*Arisaema griffithii* Schott	10.71	0.25	2.33	0.09	0.04	0.1	0.24
369	*Primula petiolaris* Wall.	14.29	0.25	1.75	0.12	0.04	0.08	0.24
370	*Litsea cubeba* (Lour.) Pers.	14.29	0.25	1.75	0.12	0.04	0.08	0.24
371	*Impatiens discolour* DC.	14.29	0.25	1.75	0.12	0.04	0.08	0.24
372	*Dendrobium longicornu* Lindl.	14.29	0.25	1.75	0.12	0.04	0.08	0.24
373	*Clematis buchananiana* DC.	14.29	0.25	1.75	0.12	0.04	0.08	0.24
374	*Begonia malabarica* Lam.	14.29	0.25	1.75	0.12	0.04	0.08	0.24
375	*Sinopodophyllum hexandrum* (Royle) T.S.Ying	17.86	0.21	1.2	0.15	0.04	0.05	0.24
376	*Ficus subincisa* Buch.-Ham. *ex* Sm.	17.86	0.21	1.2	0.15	0.04	0.05	0.24
377	*Coelogyne corymbosa* Lindl.	17.86	0.21	1.2	0.15	0.04	0.05	0.24
378	*Pyrrosia flocculosa* (D.Don) Ching	3.57	0.14	4	0.03	0.03	0.18	0.23
379	*Lepisorus sublinearis* (Baker ex Takeda) Ching	3.57	0.14	4	0.03	0.03	0.18	0.23
380	*Dendrocnide sinuata* (Blume) Chew	3.57	0.14	4	0.03	0.03	0.18	0.23
381	*Bulbophyllum sterile* (Lam.) Suresh	3.57	0.14	4	0.03	0.03	0.18	0.23
382	*Terminalia chebula* Retz.	7.14	0.21	3	0.06	0.04	0.13	0.23
383	*Ulmus lanceifolia* Roxb. ex Wall.	7.14	0.21	3	0.06	0.04	0.13	0.23
384	*Pholidota imbricate* Lindl.	7.14	0.21	3	0.06	0.04	0.13	0.23
385	*Pichisermollodes albopes* (C. Chr. & Ching) Fraser-Jenk	7.14	0.21	3	0.06	0.04	0.13	0.23
386	*Lepisorus clathretus* (C.B.Clarke) Ching	7.14	0.21	3	0.06	0.04	0.13	0.23
387	*Terminalia crenulata* Roth	14.29	0.21	1.5	0.12	0.04	0.07	0.23
388	*Selaginella acanthostachys* Baker	14.29	0.21	1.5	0.12	0.04	0.07	0.23
389	*Piper boehmeriifolium* (Miq.) Wall. *ex* C. DC	14.29	0.21	1.5	0.12	0.04	0.07	0.23
390	*Lepisorus mehrae* Fraser-Jenk.	14.29	0.21	1.5	0.12	0.04	0.07	0.23
391	*Ageratina ligustrina* (DC.) R.M.King & H.Rob.	14.29	0.21	1.5	0.12	0.04	0.07	0.23
392	*Galium elegans* Wall. ex Roxb.	14.29	0.21	1.5	0.12	0.04	0.07	0.23
393	*Fraxinus floribunda* Wall.	14.29	0.21	1.5	0.12	0.04	0.07	0.23
394	*Dryopsis apiciflora* (Wall. *ex* Mett.) Holttum & P.J. Edwards	14.29	0.21	1.5	0.12	0.04	0.07	0.23
395	*Dioscorea deltoidea* Wall. *ex* Griseb.	14.29	0.21	1.5	0.12	0.04	0.07	0.23
396	*Cyrtomium hookerianum* C.Chr.	14.29	0.21	1.5	0.12	0.04	0.07	0.23
397	*Castanopsis indica* A.DC.	14.29	0.21	1.5	0.12	0.04	0.07	0.23
398	*Brugmansia suaveolens* (Humboldt & Bonpland *ex* Willd.) Berchtold & J.Presl	14.29	0.21	1.5	0.12	0.04	0.07	0.23
399	*Asplenium yoshinagae* Makino	14.29	0.21	1.5	0.12	0.04	0.07	0.23

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400	*Urtica hyperborea* Jacq. *ex* Wedd.	10.71	0.21	2	0.09	0.04	0.09	0.22
401	*Stephania elegans* Hook.f.& Thomson	10.71	0.21	2	0.09	0.04	0.09	0.22
402	*Pilea ternifolia* Wedd.	10.71	0.21	2	0.09	0.04	0.09	0.22
403	*Pholidota articulate* Lindl.	10.71	0.21	2	0.09	0.04	0.09	0.22
404	*Erigeron karvinskianus* DC.	10.71	0.21	2	0.09	0.04	0.09	0.22
405	*Coniogramme procera* Fee	10.71	0.21	2	0.09	0.04	0.09	0.22
406	*Aralia leschenaultii* (DC.) J.Wen	10.71	0.21	2	0.09	0.04	0.09	0.22
407	*Rubus kumaonensis* N.P. Balkr.	14.29	0.18	1.25	0.12	0.03	0.06	0.21
408	*Magnolia doltsopa* (Buch.-Ham. *ex*DC.) Figlar	14.29	0.18	1.25	0.12	0.03	0.06	0.21
409	*Glochidion thomsonii* (Müll.-Arg.) Hook.f.	14.29	0.18	1.25	0.12	0.03	0.06	0.21
410	*Daphne glacialis* (W.W.Sm. & Cave) A.P. Das	14.29	0.18	1.25	0.12	0.03	0.06	0.21
411	*Dittoceras andersonii* Hook.f.	14.29	0.18	1.25	0.12	0.03	0.06	0.21
412	*Zanthoxylum acanthopodium* DC.	7.14	0.18	2.5	0.06	0.03	0.11	0.2
413	*Vittaria sikkimensis* Kuhn	7.14	0.18	2.5	0.06	0.03	0.11	0.2
414	*Uncifera obtusifolia* Lindl.	7.14	0.18	2.5	0.06	0.03	0.11	0.2
415	*Pilea approximata* CB. Clarke	7.14	0.18	2.5	0.06	0.03	0.11	0.2
416	*Myrsine semiserrata* Wall.	7.14	0.18	2.5	0.06	0.03	0.11	0.2
417	*Lygodium flexuosum* (L.) Sw.	7.14	0.18	2.5	0.06	0.03	0.11	0.2
418	*Hydrangea robusta* Hook.f. & Thomson	7.14	0.18	2.5	0.06	0.03	0.11	0.2
419	*Huperzia hamiltonii* (Spring) Trev.	7.14	0.18	2.5	0.06	0.03	0.11	0.2
420	*Gynocardia odorata* R.Br.	7.14	0.18	2.5	0.06	0.03	0.11	0.2
421	*Elaeocarpus lanceifolius* Roxb.	7.14	0.18	2.5	0.06	0.03	0.11	0.2
422	*Cyperus niveus* Retz.	7.14	0.18	2.5	0.06	0.03	0.11	0.2
423	*Cyperus haspan* L.	7.14	0.18	2.5	0.06	0.03	0.11	0.2
424	*Veronica serpyllifolia* L.	10.71	0.18	1.67	0.09	0.03	0.07	0.2
425	*Setaria pumila* (Poir.) Roemer & Schult.	10.71	0.18	1.67	0.09	0.03	0.07	0.2
426	*Poa annua* L.	10.71	0.18	1.67	0.09	0.03	0.07	0.2
427	*Microlepia strigosa* (Thunb.) C.Presl	10.71	0.18	1.67	0.09	0.03	0.07	0.2
428	*Juniperus recurva* Buch.-Ham. *ex* D.Don	10.71	0.18	1.67	0.09	0.03	0.07	0.2
429	*Juglans regia* L.	10.71	0.18	1.67	0.09	0.03	0.07	0.2
430	*Ficus roxburghii* Lour.	10.71	0.18	1.67	0.09	0.03	0.07	0.2
431	*Erigeron Canadensis* L.	10.71	0.18	1.67	0.09	0.03	0.07	0.2
432	*Cyathea chinensis* Copel.	10.71	0.18	1.67	0.09	0.03	0.07	0.2
433	*Bulbophyllum yoksunense* J.J. Sm.	10.71	0.18	1.67	0.09	0.03	0.07	0.2
434	*Arisaema intermedium* Blume	10.71	0.18	1.67	0.09	0.03	0.07	0.2
435	*Abies spectabilis* (D.Don) Mirb.	10.71	0.18	1.67	0.09	0.03	0.07	0.2
436	*Mallotus philippensis* (Lam.) Müll.-Arg.	14.29	0.14	1	0.12	0.03	0.04	0.19
437	*Emilia sonchifolia* (L.) DC.	14.29	0.14	1	0.12	0.03	0.04	0.19

Sl No	Botanical Name	F	D	A	RF	RD	RA	IVI
438	*Zanthoxylum rhetsa* DC.	3.57	0.11	3	0.03	0.02	0.13	0.18
439	*Vittaria doniana* Hieron.	3.57	0.11	3	0.03	0.02	0.13	0.18
440	*Sterculia lanceifolia* G. Don	3.57	0.11	3	0.03	0.02	0.13	0.18
441	*Pyrularia edulis* (Wall.) A.DC.	3.57	0.11	3	0.03	0.02	0.13	0.18
442	*Oenanthe thomsonii* C.B.Clarke	3.57	0.11	3	0.03	0.02	0.13	0.18
443	*Mahonia napaulensis* DC.	3.57	0.11	3	0.03	0.02	0.13	0.18
444	*Laphangium affine* (D.Don) Tzvelev	3.57	0.11	3	0.03	0.02	0.13	0.18
445	*Knema cinerea* var. *glauca* (Blume) Y.H.Li	3.57	0.11	3	0.03	0.02	0.13	0.18
446	*Ixeris polycephala* Cassini	3.57	0.11	3	0.03	0.02	0.13	0.18
447	*Impatiens puberula* DC.	3.57	0.11	3	0.03	0.02	0.13	0.18
448	*Fragaria nubicola* (Lindl. *ex* Hook.f.) Lacaita	3.57	0.11	3	0.03	0.02	0.13	0.18
449	*Duabanga grandiflora* (DC.) Walp.	3.57	0.11	3	0.03	0.02	0.13	0.18
450	*Acer laevigatum* Wall.	3.57	0.11	3	0.03	0.02	0.13	0.18
451	*Acampe rigida* (Buch.-Ham. *ex*. Sm.) P.F.Hunt	3.57	0.11	3	0.03	0.02	0.13	0.18
452	*Acampe ochracea* Lindl.	3.57	0.11	3	0.03	0.02	0.13	0.18
453	*Pteris wallichiana* J. Agardh	10.71	0.14	1.33	0.09	0.03	0.06	0.18
454	*Piper suipigua* D.Don	10.71	0.14	1.33	0.09	0.03	0.06	0.18
455	*Persicaria tinctoria* (Aiton) H.Gross	10.71	0.14	1.33	0.09	0.03	0.06	0.18
456	*Mucuna macrocarpa* Wall.	10.71	0.14	1.33	0.09	0.03	0.06	0.18
457	*Berberis asiatica* DC.	10.71	0.14	1.33	0.09	0.03	0.06	0.18
458	*Lindsaea odorata* Roxb.	10.71	0.14	1.33	0.09	0.03	0.06	0.18
459	*Dendrobium hookerianum* Lindl.	10.71	0.14	1.33	0.09	0.03	0.06	0.18
460	*Daphne bholua* Buch.-Ham. ex D.Don	10.71	0.14	1.33	0.09	0.03	0.06	0.18
461	*Bauhinia scandens* L.	10.71	0.14	1.33	0.09	0.03	0.06	0.18
462	*Arisaema flavum* (Forssk.) Schott	10.71	0.14	1.33	0.09	0.03	0.06	0.18
463	*Stachys melissifolia* Benth.	7.14	0.14	2	0.06	0.03	0.09	0.17
464	*Polypodium polypodioides* (L.) Watt	7.14	0.14	2	0.06	0.03	0.09	0.17
465	*Polypodiodes amoena* (Wall. *ex* Mett.) Ching	7.14	0.14	2	0.06	0.03	0.09	0.17
466	*Persea odoratissima* (Nees) Kosterm.	7.14	0.14	2	0.06	0.03	0.09	0.17
467	*Panisea demissa* (D.Don) Pfitzer	7.14	0.14	2	0.06	0.03	0.09	0.17
468	*Meliosma pinnata* (Roxb.) Maxim.	7.14	0.14	2	0.06	0.03	0.09	0.17
469	*Lasiococca symphyllifolia* (Kurz) Hook.f.	7.14	0.14	2	0.06	0.03	0.09	0.17
470	*Impatiens sulcata* Wall.	7.14	0.14	2	0.06	0.03	0.09	0.17
471	*Eriobotrya petiolata* Hook.f.	7.14	0.14	2	0.06	0.03	0.09	0.17
472	*Dryopteris filix-mas* (L.) Schott	7.14	0.14	2	0.06	0.03	0.09	0.17
473	*Casearia glomerata* Roxb.	7.14	0.14	2	0.06	0.03	0.09	0.17
474	*Berberis angulosa* Wall. *ex* Hook.& Thomson	7.14	0.14	2	0.06	0.03	0.09	0.17
475	*Aucuba himalaica* Hook.f. & Thomson	7.14	0.14	2	0.06	0.03	0.09	0.17

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476	*Arthromeris himalayensis* (Hook.) Ching	7.14	0.14	2	0.06	0.03	0.09	0.17
477	*Rubus splendidissimus* H.Hara	7.14	0.11	1.5	0.06	0.02	0.07	0.15
478	*Toxicodendron griffithii* (Hook. f.) Kuntze	7.14	0.11	1.5	0.06	0.02	0.07	0.15
479	*Rhododendron fulgens* Hook.f.	7.14	0.11	1.5	0.06	0.02	0.07	0.15
480	*Remusatia pumila* (D.Don) H.Li & A.Hay	7.14	0.11	1.5	0.06	0.02	0.07	0.15
481	*Quercus robur* L.	7.14	0.11	1.5	0.06	0.02	0.07	0.15
482	*Pteris spinescens* C.Presl	7.14	0.11	1.5	0.06	0.02	0.07	0.15
483	*Pseudognaphalium hypoleucum* (DC.) Hilliard& B.L.Burtt	7.14	0.11	1.5	0.06	0.02	0.07	0.15
484	*Pogostemon fraternus* Miq.	7.14	0.11	1.5	0.06	0.02	0.07	0.15
485	*Physalis divaricata* D.Don	7.14	0.11	1.5	0.06	0.02	0.07	0.15
486	*Phlebodium aureum* (L.) Sm.	7.14	0.11	1.5	0.06	0.02	0.07	0.15
487	*Lyonia villosa* (Wall. *ex* C.B.Clarke) Hand.-Mazz.	7.14	0.11	1.5	0.06	0.02	0.07	0.15
488	*Impatiens scabrida* DC	7.14	0.11	1.5	0.06	0.02	0.07	0.15
489	*Hippochaete debilis* (Roxb. *ex* Vaucher) Ching	7.14	0.11	1.5	0.06	0.02	0.07	0.15
490	*Hedychium spicatum* Sm.	7.14	0.11	1.5	0.06	0.02	0.07	0.15
491	*Diploknema butyracea* (Roxb.) H.J.Lam	7.14	0.11	1.5	0.06	0.02	0.07	0.15
492	*Coelogyne prolifera* Lindl.	7.14	0.11	1.5	0.06	0.02	0.07	0.15
493	*Citrus maxima* (Burm.f.) Merr.	7.14	0.11	1.5	0.06	0.02	0.07	0.15
494	*Carex caryophyllea* Latourr.	7.14	0.11	1.5	0.06	0.02	0.07	0.15
495	*Brassaiopsis glomerulata* (Blume) Regel	7.14	0.11	1.5	0.06	0.02	0.07	0.15
496	*Brachiaria subquadripara* (Trin.) Hitchc.	7.14	0.11	1.5	0.06	0.02	0.07	0.15
497	*Berberis hookeri* Lem.	7.14	0.11	1.5	0.06	0.02	0.07	0.15
498	*Begonia josephi* DC.	7.14	0.11	1.5	0.06	0.02	0.07	0.15
499	*Bauhinia purpurea* L.	7.14	0.11	1.5	0.06	0.02	0.07	0.15
500	*Asplenium phyllitidis* D.Don	7.14	0.11	1.5	0.06	0.02	0.07	0.15
501	*Adiantum lunulatum* Burm.f.	7.14	0.11	1.5	0.06	0.02	0.07	0.15
502	*Rubus lineatus* Reinw.*ex* Blume	10.71	0.11	1	0.09	0.02	0.04	0.15
503	*Pleione humilis* (Sm.) D.Don	10.71	0.11	1	0.09	0.02	0.04	0.15
504	*Maianthemum oleraceum* (Baker) LaFrankie	10.71	0.11	1	0.09	0.02	0.04	0.15
505	*Leea macrophylla* Roxb.*ex*Hornem.	10.71	0.11	1	0.09	0.02	0.04	0.15
506	*Laportea bulbifera* (Siebold &Zucc.) Wedd.	10.71	0.11	1	0.09	0.02	0.04	0.15
507	*Erythrina arborescens* Roxb.	10.71	0.11	1	0.09	0.02	0.04	0.15
508	*Dennstaedtia appendiculata* (Wall.*ex*Hook.) J.Sm	10.71	0.11	1	0.09	0.02	0.04	0.15
509	*Digitaria sanguinalis* (L.) Scop.	10.71	0.11	1	0.09	0.02	0.04	0.15
510	*Arisaema speciosum* (Wall.) Mart.	10.71	0.11	1	0.09	0.02	0.04	0.15
511	*Vittaria taeniophylla* Copel.	3.57	0.07	2	0.03	0.01	0.09	0.13

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512	*Synotis cappa* (Buch.-Ham.*ex* D.Don) C. Jeffrey & Y.L.Chen	3.57	0.07	2	0.03	0.01	0.09	0.13
513	*Symplosos theifolia* D.Don	3.57	0.07	2	0.03	0.01	0.09	0.13
514	*Swertia paniculata* Wall.	3.57	0.07	2	0.03	0.01	0.09	0.13
515	*Senna tora* (L.) Roxb.	3.57	0.07	2	0.03	0.01	0.09	0.13
516	*Rhododendron dalhousieae* Hook.f.	3.57	0.07	2	0.03	0.01	0.09	0.13
517	*Rhododendron anthopogon* D.Don	3.57	0.07	2	0.03	0.01	0.09	0.13
518	*Phyllanthus emblica* L.	3.57	0.07	2	0.03	0.01	0.09	0.13
519	*Persicaria bistorta* (L.) Samp.	3.57	0.07	2	0.03	0.01	0.09	0.13
520	*Machilus gammieana* King	3.57	0.07	2	0.03	0.01	0.09	0.13
521	Litsea monopetala (Roxb.) Pers.	3.57	0.07	2	0.03	0.01	0.09	0.13
522	*Lithocarpus elegans* (Blume) Hatus. *ex* Soepadmo	3.57	0.07	2	0.03	0.01	0.09	0.13
523	*Ione bicolour* Lindl.	3.57	0.07	2	0.03	0.01	0.09	0.13
524	*Huperzia serrata* (Thunb.) Trevis.	3.57	0.07	2	0.03	0.01	0.09	0.13
525	*Grewia serrulata* DC.	3.57	0.07	2	0.03	0.01	0.09	0.13
526	*Flemingia strobilifera* (L.) W.T.Aiton	3.57	0.07	2	0.03	0.01	0.09	0.13
527	*Esmeralda cathcartii* (Lindl.) Rchb.f.	3.57	0.07	2	0.03	0.01	0.09	0.13
528	*Drymaria villosa* Schltdl. & Cham.	3.57	0.07	2	0.03	0.01	0.09	0.13
529	*Diplazium muricatum* Alderw.	3.57	0.07	2	0.03	0.01	0.09	0.13
530	*Dendrobium eriiflorum* Griff.	3.57	0.07	2	0.03	0.01	0.09	0.13
531	*Cheilocostus speciosus* (J.Koenig) C.D.Specht	3.57	0.07	2	0.03	0.01	0.09	0.13
532	*Bulbophyllum thomsonii* Hook.f.	3.57	0.07	2	0.03	0.01	0.09	0.13
533	*Berberis wallichiana* DC.	3.57	0.07	2	0.03	0.01	0.09	0.13
534	*Beilschmiedia sikkimensis* King *ex* Hook.f.	3.57	0.07	2	0.03	0.01	0.09	0.13
535	*Aster tricephalus* C.B.Clarke	3.57	0.07	2	0.03	0.01	0.09	0.13
536	*Arundina graminifolia* (D.Don) Hochr.	3.57	0.07	2	0.03	0.01	0.09	0.13
537	*Arisaema echinatum* (Wall.) Schott	3.57	0.07	2	0.03	0.01	0.09	0.13
538	*Arachniodes davalliaeformis* (Christ) Nakaike	3.57	0.07	2	0.03	0.01	0.09	0.13
539	*Aleuritopteris dubia* (C.Hope) Ching	3.57	0.07	2	0.03	0.01	0.09	0.13
540	*Zanthoxylum oxyphyllum* Edgw.	7.14	0.07	1	0.06	0.01	0.04	0.12
541	*Vittaria flexuosa* Fée	7.14	0.07	1	0.06	0.01	0.04	0.12
542	*Tetrastigma serrulatum* (Roxb.) Planch.	7.14	0.07	1	0.06	0.01	0.04	0.12
543	*Tetrastigma obtectum* (Wall. *ex* M.A. Lawson) Planch. *ex* Franch.	7.14	0.07	1	0.06	0.01	0.04	0.12
544	*Steriochilus hirtus* Lindl.	7.14	0.07	1	0.06	0.01	0.04	0.12
545	*Senna occidentalis* (L.) Link	7.14	0.07	1	0.06	0.01	0.04	0.12
546	*Selliguea oxyloba* (Wall.*ex* Kunze.) Fraser-Jenk	7.14	0.07	1	0.06	0.01	0.04	0.12
547	*Satyrium nepalense* D.Don	7.14	0.07	1	0.06	0.01	0.04	0.12

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548	*Pteris scabririgens* Fraser-Jenk., S.C.Verma & T.G. Walker	7.14	0.07	1	0.06	0.01	0.04	0.12
549	*Prunus persica* (L.) Batsch	7.14	0.07	1	0.06	0.01	0.04	0.12
550	*Plagiogyria pycnophylla* (Kuntze) Mett.	7.14	0.07	1	0.06	0.01	0.04	0.12
551	*Neyraudia arundinacea* (L.) Henrard	7.14	0.07	1	0.06	0.01	0.04	0.12
552	*Nepeta lamiopsis* Benth. *ex* Hook.f.	7.14	0.07	1	0.06	0.01	0.04	0.12
553	*Lonicera standishii* Jacques	7.14	0.07	1	0.06	0.01	0.04	0.12
554	*Leptodermis kumaonensis* R.Parker	7.14	0.07	1	0.06	0.01	0.04	0.12
555	*Isachne sikkimensis* Bor	7.14	0.07	1	0.06	0.01	0.04	0.12
556	*Huperzia squarrosa* (Forst.) Trev.	7.14	0.07	1	0.06	0.01	0.04	0.12
557	*Hedychium gracile* Roxb.	7.14	0.07	1	0.06	0.01	0.04	0.12
558	*Habenaria pectinata* D.Don	7.14	0.07	1	0.06	0.01	0.04	0.12
559	*Eurya acuminate* DC.	7.14	0.07	1	0.06	0.01	0.04	0.12
560	*Coelogyne flaccid* Lindl.	7.14	0.07	1	0.06	0.01	0.04	0.12
561	*Clerodendrum infortunatum* L.	7.14	0.07	1	0.06	0.01	0.04	0.12
562	Ardisia macrocarpa Wall.	7.14	0.07	1	0.06	0.01	0.04	0.12
563	*Angelica archangelica* L.	7.14	0.07	1	0.06	0.01	0.04	0.12
564	*Ampelocalamus patellaris* (Gamble) Stapleton	7.14	0.07	1	0.06	0.01	0.04	0.12
565	*Agave Americana* L.	7.14	0.07	1	0.06	0.01	0.04	0.12
566	*Zanthoxylum bungeanum* Maxim.	3.57	0.04	1	0.03	0.01	0.04	0.08
567	*Zanthoxylum armatum* DC.	3.57	0.04	1	0.03	0.01	0.04	0.08
568	*Xanthium strumarium* L.	3.57	0.04	1	0.03	0.01	0.04	0.08
569	*Vanda pumila* Hook.f.	3.57	0.04	1	0.03	0.01	0.04	0.08
570	*Urtica parviflora* Roxb.	3.57	0.04	1	0.03	0.01	0.04	0.08
571	*Trichotosia pulvinata* (Lindl.) Kraenzl.	3.57	0.04	1	0.03	0.01	0.04	0.08
572	*Cymbopogon pendulus* (Nees ex Steud.) J.F. Watson	3.57	0.04	1	0.03	0.01	0.04	0.08
573	*Thunia bracteata* (Roxb.) Schltr.	3.57	0.04	1	0.03	0.01	0.04	0.08
574	*Tetrastigma bracteolatum* (Wall.) Planch.	3.57	0.04	1	0.03	0.01	0.04	0.08
575	*Magnolia globosa* Hook.f. & Thomson	3.57	0.04	1	0.03	0.01	0.04	0.08
576	*Syzygium kurzii* (Duthie) N.P.Balakr.	3.57	0.04	1	0.03	0.01	0.04	0.08
577	*Styrax hookeri* C.B.Clarke	3.57	0.04	1	0.03	0.01	0.04	0.08
578	*Strobilanthes urticifolia* Wall. *ex* Kuntze	3.57	0.04	1	0.03	0.01	0.04	0.08
579	*Spiranthes sinensis* (Pers.) Ames	3.57	0.04	1	0.03	0.01	0.04	0.08
580	*Sphenomeris chinensis* (L.) Maxon	3.57	0.04	1	0.03	0.01	0.04	0.08
581	*Solanum torvum* Sw.	3.57	0.04	1	0.03	0.01	0.04	0.08
582	*Sigesbeckia orientalis* L.	3.57	0.04	1	0.03	0.01	0.04	0.08
583	*Sida acuta* Burm.f.	3.57	0.04	1	0.03	0.01	0.04	0.08
584	*Senecio buimalia* Buch.-Ham. *ex* D.Don	3.57	0.04	1	0.03	0.01	0.04	0.08

Sl No	Botanical Name	F	D	A	RF	RD	RA	IVI
585	*Schisandra grandiflora* (Wall.) Hook.f.& Thomson	3.57	0.04	1	0.03	0.01	0.04	0.08
586	*Sauropus androgynus* (L.) Merr.	3.57	0.04	1	0.03	0.01	0.04	0.08
587	*Sapindus rarak* DC.	3.57	0.04	1	0.03	0.01	0.04	0.08
588	*Sambucus javanica* Blume	3.57	0.04	1	0.03	0.01	0.04	0.08
589	*Rubus rugosus* Sm.	3.57	0.04	1	0.03	0.01	0.04	0.08
590	*Rubus niveus* Thunb.	3.57	0.04	1	0.03	0.01	0.04	0.08
591	*Rubus fragarioides* Bertol.	3.57	0.04	1	0.03	0.01	0.04	0.08
592	*Ranunculus laetus* Wall. ex Hook.f. & J.W.Thomson	3.57	0.04	1	0.03	0.01	0.04	0.08
593	*Pteridium revolutum* (Blume) Nakai	3.57	0.04	1	0.03	0.01	0.04	0.08
594	*Prunus wallichii* Steud.	3.57	0.04	1	0.03	0.01	0.04	0.08
595	*Prinsepia utilis* Royle	3.57	0.04	1	0.03	0.01	0.04	0.08
596	*Selinum wallichianum* (DC.) Raizada & H.O. Saxena	3.57	0.04	1	0.03	0.01	0.04	0.08
597	*Potentilla multifida* L.	3.57	0.04	1	0.03	0.01	0.04	0.08
598	*Porpax elwesii* (Rchb.f) Rolfe	3.57	0.04	1	0.03	0.01	0.04	0.08
599	*Persicaria campanulata* (Hook.f.) Ronse Decr.	3.57	0.04	1	0.03	0.01	0.04	0.08
600	*Pogostemon benghalensis* (Burm.f.) Kuntze	3.57	0.04	1	0.03	0.01	0.04	0.08
601	*Podochilus cultratus* Lindl.	3.57	0.04	1	0.03	0.01	0.04	0.08
602	*Podocarpus neriifolius* D.Don	3.57	0.04	1	0.03	0.01	0.04	0.08
603	*Pleione praecox* (Sm.) D.Don	3.57	0.04	1	0.03	0.01	0.04	0.08
604	*Platanthera arcuata* Lindl.	3.57	0.04	1	0.03	0.01	0.04	0.08
605	*Pilea bracteosa* Wedd.	3.57	0.04	1	0.03	0.01	0.04	0.08
606	*Phalaenopsis mannii* Rchb.f.	3.57	0.04	1	0.03	0.01	0.04	0.08
607	*Persicaria chinensis* (L.) H.Gross	3.57	0.04	1	0.03	0.01	0.04	0.08
608	*Peristrophe fera* C.B.Clarke	3.57	0.04	1	0.03	0.01	0.04	0.08
609	*Parthenium hysterophorus* L.	3.57	0.04	1	0.03	0.01	0.04	0.08
610	*Panisea uniflora* Lindl.	3.57	0.04	1	0.03	0.01	0.04	0.08
611	*Panax pseudo-ginseng* Wall.	3.57	0.04	1	0.03	0.01	0.04	0.08
612	*Oroxylum indicum* (L.) Kurz	3.57	0.04	1	0.03	0.01	0.04	0.08
613	*Oberonia rufilabris* Lindl.	3.57	0.04	1	0.03	0.01	0.04	0.08
614	*Oberonia obcordata* Lindl.	3.57	0.04	1	0.03	0.01	0.04	0.08
615	*Nerium oleander* L.	3.57	0.04	1	0.03	0.01	0.04	0.08
616	*Nasturtium officinale* R.Br.	3.57	0.04	1	0.03	0.01	0.04	0.08
617	*Musa paradisiacal* L.	3.57	0.04	1	0.03	0.01	0.04	0.08
618	*Morus indica* L.	3.57	0.04	1	0.03	0.01	0.04	0.08
619	*Micropera mannii* (Hook.f.)Tang & F.T.Wang	3.57	0.04	1	0.03	0.01	0.04	0.08
620	*Meizotropis buteiformis* Voigt	3.57	0.04	1	0.03	0.01	0.04	0.08
621	*Meconopsis simplicifolia* (D. Don) Walp.	3.57	0.04	1	0.03	0.01	0.04	0.08

Sl No	Botanical Name	F	D	A	RF	RD	RA	IVI
622	*Marsilea minuta* L.	3.57	0.04	1	0.03	0.01	0.04	0.08
623	*Malaxis muscifera* (Lindl.) Kuntze	3.57	0.04	1	0.03	0.01	0.04	0.08
624	*Lepidagathis incurve* Buch.-Ham. *ex* D. Don	3.57	0.04	1	0.03	0.01	0.04	0.08
625	*Juncus prismatocarpus* R.Br.	3.57	0.04	1	0.03	0.01	0.04	0.08
626	*Holboellia latifolia* Wall.	3.57	0.04	1	0.03	0.01	0.04	0.08
627	*Henckelia urticifolia* (Buch.-Ham. *ex* D.Don) Dietrich	3.57	0.04	1	0.03	0.01	0.04	0.08
628	*Hedychium ellipticum* Buch.-Ham. *ex* Sm.	3.57	0.04	1	0.03	0.01	0.04	0.08
629	*Hedera nepalensis* K.Koch	3.57	0.04	1	0.03	0.01	0.04	0.08
630	*Gastrochilus calceolaris* (Sm.) D.Don	3.57	0.04	1	0.03	0.01	0.04	0.08
631	*Ficus religiosa* L.	3.57	0.04	1	0.03	0.01	0.04	0.08
632	*Ficus nemoralis* Wall.	3.57	0.04	1	0.03	0.01	0.04	0.08
633	*Euphorbia hirta* L.	3.57	0.04	1	0.03	0.01	0.04	0.08
634	*Eria stricta* Lindl.	3.57	0.04	1	0.03	0.01	0.04	0.08
635	*Eria lasiopetala* (Willd.) Ormerod	3.57	0.04	1	0.03	0.01	0.04	0.08
636	*Epipactis royleana* Lindl.	3.57	0.04	1	0.03	0.01	0.04	0.08
637	*Elsholtzia eriostachya* Benth	3.57	0.04	1	0.03	0.01	0.04	0.08
638	*Drepanostachyum intermedium* (Munro) Keng f.	3.57	0.04	1	0.03	0.01	0.04	0.08
639	*Diplazium esculentum* (Retz.) Sw.	3.57	0.04	1	0.03	0.01	0.04	0.08
640	*Dioscorea oppositifolia* L.	3.57	0.04	1	0.03	0.01	0.04	0.08
641	*Desmodium multiflorum* DC.	3.57	0.04	1	0.03	0.01	0.04	0.08
642	*Dennstaedtia scabra* (Wall. *ex* Hook.) T moore	3.57	0.04	1	0.03	0.01	0.04	0.08
643	*Datura metel* L.	3.57	0.04	1	0.03	0.01	0.04	0.08
644	*Cyrtomium caryotideum* (Wall. *ex* Hook.f. & Grev.) C. Presl	3.57	0.04	1	0.03	0.01	0.04	0.08
645	*Cymbidium iridioides* D.Don	3.57	0.04	1	0.03	0.01	0.04	0.08
646	*Cymbidium eburneum* Lindl.	3.57	0.04	1	0.03	0.01	0.04	0.08
647	*Cymbidium aloifolium* (L.) Sw.	3.57	0.04	1	0.03	0.01	0.04	0.08
648	*Cyathea spinulosa* Wall. *ex* Hook..	3.57	0.04	1	0.03	0.01	0.04	0.08
649	*Clerodendrum japonicum* (Thunb.) Sweet	3.57	0.04	1	0.03	0.01	0.04	0.08
650	*Cinnamonum caudatum* Nees	3.57	0.04	1	0.03	0.01	0.04	0.08
651	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	3.57	0.04	1	0.03	0.01	0.04	0.08
652	*Cheilanthes farinosa* (Forssk.) Kaulf.	3.57	0.04	1	0.03	0.01	0.04	0.08
653	*Cephalostachyum capitatum* Munro	3.57	0.04	1	0.03	0.01	0.04	0.08
654	*Celtis tetrandra* Roxb.	3.57	0.04	1	0.03	0.01	0.04	0.08
655	*Boehmeria rugulosa* Wedd.	3.57	0.04	1	0.03	0.01	0.04	0.08
656	*Beaumontia grandiflora* Wall.	3.57	0.04	1	0.03	0.01	0.04	0.08
657	*Aster flaccidus* Bunge	3.57	0.04	1	0.03	0.01	0.04	0.08

Sl No	Botanical Name	F	D	A	RF	RD	RA	IVI
658	*Arisaema concinnum* Schott	3.57	0.04	1	0.03	0.01	0.04	0.08
659	*Enkianthus deflexus* (Griff.) C.K. Schneid.	3.57	0.04	1	0.03	0.01	0.04	0.08
660	*Amomum subulatum* Roxb.	3.57	0.04	1	0.03	0.01	0.04	0.08
661	*Aleuritopteris albomarginata* (C.B.Clarke) Ching	3.57	0.04	1	0.03	0.01	0.04	0.08
662	*Alangium alpinum* (C.B. Clarke) W.W. Sm. & Cave	3.57	0.04	1	0.03	0.01	0.04	0.08
663	*Aesculus indica* (Wall.*ex* Cambess.)Hook.	3.57	0.04	1	0.03	0.01	0.04	0.08
664	*Acorus calamus* L.	3.57	0.04	1	0.03	0.01	0.04	0.08

ANNEXURE II

Annexure II

Importance Value Index at Genus level in the Study area

Sl No.	Genus	Frequency	Density	Abundance	RF	RD	RDM	IVI
1	*Schima*	50.00	44.50	89.00	0.54	7.92	6.00	14.46
2	*Rhododendron*	39.29	16.54	42.09	0.42	2.94	2.84	6.20
3	*Ostodes*	42.86	15.36	35.83	0.46	2.73	2.42	5.61
4	*Engelhardtia*	53.57	15.68	29.27	0.57	2.79	1.97	5.34
5	*Castanopsis*	85.71	14.79	17.25	0.92	2.63	1.16	4.71
6	*Viburnum*	60.71	13.00	21.41	0.65	2.31	1.44	4.41
7	*Alnus*	57.14	12.61	22.06	0.61	2.24	1.49	4.34
8	*Cyperus*	96.43	13.32	13.81	1.03	2.37	0.93	4.34
9	*Eupatorium*	85.71	12.71	14.83	0.92	2.26	1.00	4.18
10	*Selaginella*	85.71	11.43	13.33	0.92	2.03	0.90	3.85
11	*Symplocos*	57.14	10.68	18.69	0.61	1.90	1.26	3.77
12	*Nephrolepis*	82.14	10.79	13.13	0.88	1.92	0.89	3.69
13	*Polygonum*	96.43	9.43	9.78	1.03	1.68	0.66	3.37
14	*Dryopteris*	67.86	8.43	12.42	0.73	1.50	0.84	3.06
15	*Elatostema*	75.00	7.93	10.57	0.80	1.41	0.71	2.93
16	*Isachne*	75.00	7.14	9.52	0.80	1.27	0.64	2.72
17	*Quercus*	71.43	7.00	9.80	0.76	1.25	0.66	2.67
18	*Persicaria*	82.14	6.86	8.35	0.88	1.22	0.56	2.66
19	*Acer*	60.71	6.57	10.82	0.65	1.17	0.73	2.55
20	*Pouzolzia*	75.00	6.50	8.67	0.80	1.16	0.58	2.54
21	*Machilus*	42.86	6.14	14.33	0.46	1.09	0.97	2.52
22	*Pteridium*	100.00	5.79	5.79	1.07	1.03	0.39	2.49
23	*Polystichum*	82.14	6.07	7.39	0.88	1.08	0.50	2.46
24	*Rubus*	92.86	5.61	6.04	0.99	1.00	0.41	2.40
25	*Helicia*	21.43	4.32	20.17	0.23	0.77	1.36	2.36
26	*Cryptomeria*	21.43	4.25	19.83	0.23	0.76	1.34	2.32
27	*Pteris*	85.71	5.11	5.96	0.92	0.91	0.40	2.23
28	*Digitaria*	67.86	5.39	7.95	0.73	0.96	0.54	2.22
29	*Macaranga*	35.71	4.93	13.80	0.38	0.88	0.93	2.19
30	*Magnolia*	57.14	5.04	8.81	0.61	0.90	0.59	2.10
31	*Lithocarpus*	21.43	3.79	17.67	0.23	0.67	1.19	2.09
32	*Mallotus*	46.43	4.93	10.62	0.50	0.88	0.72	2.09
33	*Boehmeria*	67.86	4.79	7.05	0.73	0.85	0.48	2.05
34	*Dichroa*	75.00	4.29	5.71	0.80	0.76	0.39	1.95
35	*Arisaema*	85.71	3.96	4.63	0.92	0.71	0.31	1.94

Sl No.	Genus	Frequency	Density	Abundance	RF	RD	RDM	IVI
36	*Brachiaria*	71.43	4.25	5.95	0.76	0.76	0.40	1.92
37	*Mussaenda*	67.86	3.96	5.84	0.73	0.71	0.39	1.83
38	*Pandanus*	21.43	3.21	15.00	0.23	0.57	1.01	1.81
39	*Commelina*	67.86	3.86	5.68	0.73	0.69	0.38	1.80
40	*Albizia*	57.14	3.96	6.94	0.61	0.71	0.47	1.79
41	*Tectaria*	78.57	3.57	4.55	0.84	0.64	0.31	1.78
42	*Ficus*	67.86	3.61	5.32	0.73	0.64	0.36	1.73
43	*Osbeckia*	71.43	3.50	4.90	0.76	0.62	0.33	1.72
44	*Setaria*	71.43	3.50	4.90	0.76	0.62	0.33	1.72
45	*Eurya*	67.86	3.29	4.84	0.73	0.58	0.33	1.64
46	*Pilea*	78.57	2.68	3.41	0.84	0.48	0.23	1.55
47	*Terminalia*	46.43	3.25	7.00	0.50	0.58	0.47	1.55
48	*Dioscorea*	50.00	3.21	6.43	0.54	0.57	0.43	1.54
49	*Ageratum*	67.86	2.93	4.32	0.73	0.52	0.29	1.54
50	*Lecanthus*	67.86	2.86	4.21	0.73	0.51	0.28	1.52
51	*Cynodon*	60.71	3.00	4.94	0.65	0.53	0.33	1.52
52	*Fragaria*	53.57	3.00	5.60	0.57	0.53	0.38	1.49
53	*Tetrastigma*	71.43	2.57	3.60	0.76	0.46	0.24	1.47
54	*Melastoma*	64.29	2.71	4.22	0.69	0.48	0.28	1.46
55	*Betula*	53.57	2.68	5.00	0.57	0.48	0.34	1.39
56	*Piper*	67.86	2.32	3.42	0.73	0.41	0.23	1.37
57	*Achyranthes*	53.57	2.50	4.67	0.57	0.45	0.31	1.33
58	*Eragrostis*	42.86	2.61	6.08	0.46	0.46	0.41	1.33
59	*Maesa*	67.86	2.18	3.21	0.73	0.39	0.22	1.33
60	*Edgeworthia*	57.14	2.43	4.25	0.61	0.43	0.29	1.33
61	*Litsea*	60.71	2.25	3.71	0.65	0.40	0.25	1.30
62	*Anaphalis*	35.71	2.50	7.00	0.38	0.45	0.47	1.30
63	*Prunus*	71.43	1.89	2.65	0.76	0.34	0.18	1.28
64	*Oplismenus*	42.86	2.39	5.58	0.46	0.43	0.38	1.26
65	*Rhus*	25.00	2.21	8.86	0.27	0.39	0.60	1.26
66	*Populus*	21.43	2.07	9.67	0.23	0.37	0.65	1.25
67	*Begonia*	35.71	2.36	6.60	0.38	0.42	0.45	1.25
68	*Cupressus*	7.14	1.04	14.50	0.08	0.18	0.98	1.24
69	*Drymaria*	53.57	2.14	4.00	0.57	0.38	0.27	1.22
70	*Arundinaria*	32.14	2.07	6.44	0.34	0.37	0.43	1.15
71	*Swertia*	46.43	1.96	4.23	0.50	0.35	0.29	1.13
72	*Rubia*	46.43	1.89	4.08	0.50	0.34	0.27	1.11
73	*Brassaiopsis*	57.14	1.68	2.94	0.61	0.30	0.20	1.11
74	*Daphne*	53.57	1.75	3.27	0.57	0.31	0.22	1.11
75	*Lyonia*	50.00	1.79	3.57	0.54	0.32	0.24	1.09

Sl No.	Genus	Frequency	Density	Abundance	RF	RD	RDM	IVI
76	*Plantago*	50.00	1.68	3.36	0.54	0.30	0.23	1.06
77	*Hydrocotyle*	57.14	1.50	2.63	0.61	0.27	0.18	1.06
78	*Imperata*	46.43	1.68	3.62	0.50	0.30	0.24	1.04
79	*Alocasia*	50.00	1.61	3.21	0.54	0.29	0.22	1.04
80	*Antidesma*	42.86	1.71	4.00	0.46	0.31	0.27	1.03
81	*Abies*	35.71	1.75	4.90	0.38	0.31	0.33	1.02
82	*Drynaria*	39.29	1.71	4.36	0.42	0.31	0.29	1.02
83	*Cymbidium*	46.43	1.57	3.38	0.50	0.28	0.23	1.01
84	*Triumfetta*	42.86	1.61	3.75	0.46	0.29	0.25	1.00
85	*Heracleum*	14.29	1.29	9.00	0.15	0.23	0.61	0.99
86	*Impatiens*	42.86	1.57	3.67	0.46	0.28	0.25	0.99
87	*Pyrrosia*	46.43	1.50	3.23	0.50	0.27	0.22	0.98
88	*Selliguea*	50.00	1.36	2.71	0.54	0.24	0.18	0.96
89	*Syzygium*	35.71	1.57	4.40	0.38	0.28	0.30	0.96
90	*Urtica*	42.86	1.39	3.25	0.46	0.25	0.22	0.93
91	*Callicarpa*	25.00	1.46	5.86	0.27	0.26	0.40	0.92
92	*Smilax*	53.57	1.14	2.13	0.57	0.20	0.14	0.92
93	*Christella*	32.14	1.46	4.56	0.34	0.26	0.31	0.91
94	*Yushania*	25.00	1.43	5.71	0.27	0.25	0.39	0.91
95	*Elsholtzia*	46.43	1.21	2.62	0.50	0.22	0.18	0.89
96	*Liparis*	35.71	1.36	3.80	0.38	0.24	0.26	0.88
97	*Pogonatherum*	42.86	1.25	2.92	0.46	0.22	0.20	0.88
98	*Ehretia*	17.86	1.21	6.80	0.19	0.22	0.46	0.87
99	*Adiantum*	42.86	1.18	2.75	0.46	0.21	0.19	0.85
100	*Shorea*	3.57	0.39	11.00	0.04	0.07	0.74	0.85
101	*Walsura*	39.29	1.21	3.09	0.42	0.22	0.21	0.85
102	*Lepisorus*	46.43	1.04	2.23	0.50	0.18	0.15	0.83
103	*Dendrobium*	42.86	1.11	2.58	0.46	0.20	0.17	0.83
104	*Bombax*	25.00	1.25	5.00	0.27	0.22	0.34	0.83
105	*Viola*	28.57	1.25	4.38	0.31	0.22	0.30	0.82
106	*Drypetes*	21.43	1.18	5.50	0.23	0.21	0.37	0.81
107	*Juniperus*	21.43	1.18	5.50	0.23	0.21	0.37	0.81
108	*Glochidion*	46.43	0.96	2.08	0.50	0.17	0.14	0.81
109	*Asplenium*	42.86	1.04	2.42	0.46	0.18	0.16	0.81
110	*Aster*	35.71	1.14	3.20	0.38	0.20	0.22	0.80
111	*Bidens*	35.71	1.14	3.20	0.38	0.20	0.22	0.80
112	*Cissus*	46.43	0.89	1.92	0.50	0.16	0.13	0.79
113	*Himalayacalamus*	46.43	0.86	1.85	0.50	0.15	0.12	0.77
114	*Primula*	28.57	1.11	3.88	0.31	0.20	0.26	0.76
115	*Lycopodium*	25.00	1.11	4.43	0.27	0.20	0.30	0.76

Sl No.	Genus	Frequency	Density	Abundance	RF	RD	RDM	IVI
116	*Vaccinium*	46.43	0.82	1.77	0.50	0.15	0.12	0.76
117	*Cymbopogon*	32.14	1.07	3.33	0.34	0.19	0.22	0.76
118	*Mikania*	32.14	1.07	3.33	0.34	0.19	0.22	0.76
119	*Diplazium*	7.14	0.61	8.50	0.08	0.11	0.57	0.76
120	*Bischofia*	28.57	1.07	3.75	0.31	0.19	0.25	0.75
121	*Leucosceptrum*	28.57	1.07	3.75	0.31	0.19	0.25	0.75
122	*Oxalis*	42.86	0.79	1.83	0.46	0.14	0.12	0.72
123	*Strobilanthes*	28.57	1.00	3.50	0.31	0.18	0.24	0.72
124	*Actinodaphne*	7.14	0.57	8.00	0.08	0.10	0.54	0.72
125	*Loxogramme*	25.00	0.96	3.86	0.27	0.17	0.26	0.70
126	*Huperzia*	35.71	0.86	2.40	0.38	0.15	0.16	0.70
127	*Arundinella*	28.57	0.93	3.25	0.31	0.17	0.22	0.69
128	*Axonopus*	28.57	0.93	3.25	0.31	0.17	0.22	0.69
129	*Cautleya*	39.29	0.75	1.91	0.42	0.13	0.13	0.68
130	*Remusatia*	28.57	0.89	3.13	0.31	0.16	0.21	0.68
131	*Leucas*	39.29	0.71	1.82	0.42	0.13	0.12	0.67
132	*Girardinia*	39.29	0.68	1.73	0.42	0.12	0.12	0.66
133	*Tinospora*	35.71	0.75	2.10	0.38	0.13	0.14	0.66
134	*Apios*	39.29	0.64	1.64	0.42	0.11	0.11	0.65
135	*Clerodendrum*	35.71	0.71	2.00	0.38	0.13	0.13	0.64
136	*Cirrhopetalum*	32.14	0.75	2.33	0.34	0.13	0.16	0.64
137	*Premna*	32.14	0.75	2.33	0.34	0.13	0.16	0.64
138	*Garuga*	17.86	0.79	4.40	0.19	0.14	0.30	0.63
139	*Arthromeris*	32.14	0.71	2.22	0.34	0.13	0.15	0.62
140	*Reevesia*	35.71	0.64	1.80	0.38	0.11	0.12	0.62
141	*Astilbe*	21.43	0.79	3.67	0.23	0.14	0.25	0.62
142	*Plectranthus*	28.57	0.75	2.63	0.31	0.13	0.18	0.62
143	*Thysanolaena*	28.57	0.75	2.63	0.31	0.13	0.18	0.62
144	*Morus*	25.00	0.75	3.00	0.27	0.13	0.20	0.60
145	*Eeagrostis*	14.29	0.68	4.75	0.15	0.12	0.32	0.59
146	*Colebrookea*	17.86	0.71	4.00	0.19	0.13	0.27	0.59
147	*Anisomeles*	25.00	0.71	2.86	0.27	0.13	0.19	0.59
148	*Berberis*	28.57	0.68	2.38	0.31	0.12	0.16	0.59
149	*Erythrina*	28.57	0.68	2.38	0.31	0.12	0.16	0.59
150	*Peranema*	28.57	0.68	2.38	0.31	0.12	0.16	0.59
151	*Bulbophyllum*	21.43	0.71	3.33	0.23	0.13	0.22	0.58
152	*Hedychium*	35.71	0.54	1.50	0.38	0.10	0.10	0.58
153	*Paspalum*	25.00	0.68	2.71	0.27	0.12	0.18	0.57
154	*Oxyspora*	17.86	0.68	3.80	0.19	0.12	0.26	0.57
155	*Athyrium*	21.43	0.68	3.17	0.23	0.12	0.21	0.56

Sl No.	Genus	Frequency	Density	Abundance	RF	RD	RDM	IVI
156	*Chimonocalamus*	21.43	0.68	3.17	0.23	0.12	0.21	0.56
157	*Pavetta*	21.43	0.68	3.17	0.23	0.12	0.21	0.56
158	*Leucostegia*	7.14	0.43	6.00	0.08	0.08	0.40	0.56
159	*Aleuritopteris*	28.57	0.61	2.13	0.31	0.11	0.14	0.56
160	*Crassocephalum*	28.57	0.61	2.13	0.31	0.11	0.14	0.56
161	*Solanum*	25.00	0.64	2.57	0.27	0.11	0.17	0.56
162	*Chrysopogon*	17.86	0.64	3.60	0.19	0.11	0.24	0.55
163	*Bridelia*	21.43	0.64	3.00	0.23	0.11	0.20	0.55
164	*Rohdea*	28.57	0.57	2.00	0.31	0.10	0.13	0.54
165	*Houttuynia*	25.00	0.61	2.43	0.27	0.11	0.16	0.54
166	Enkianthus	21.43	0.61	2.83	0.23	0.11	0.19	0.53
167	*Oleandra*	17.86	0.61	3.40	0.19	0.11	0.23	0.53
168	*Brucea*	14.29	0.57	4.00	0.15	0.10	0.27	0.52
169	*Azadirachta*	7.14	0.39	5.50	0.08	0.07	0.37	0.52
170	*Epegenium*	25.00	0.54	2.14	0.27	0.10	0.14	0.51
171	*Rhamnus*	14.29	0.54	3.75	0.15	0.10	0.25	0.50
172	*Choerospondias*	21.43	0.54	2.50	0.23	0.10	0.17	0.49
173	*Bambusa*	25.00	0.50	2.00	0.27	0.09	0.13	0.49
174	*Elaeocarpus*	25.00	0.50	2.00	0.27	0.09	0.13	0.49
175	*Globba*	10.71	0.46	4.33	0.11	0.08	0.29	0.49
176	*Nyssa*	10.71	0.46	4.33	0.11	0.08	0.29	0.49
177	*Allantodia*	17.86	0.54	3.00	0.19	0.10	0.20	0.49
178	*Pteracanthus*	17.86	0.54	3.00	0.19	0.10	0.20	0.49
179	*Acampe*	3.57	0.21	6.00	0.04	0.04	0.40	0.48
180	*Alangium*	3.57	0.21	6.00	0.04	0.04	0.40	0.48
181	*Odontosoria*	7.14	0.36	5.00	0.08	0.06	0.34	0.48
182	*Toxicodendron*	17.86	0.50	2.80	0.19	0.09	0.19	0.47
183	*Woodwardia*	17.86	0.50	2.80	0.19	0.09	0.19	0.47
184	*Coelogyne*	28.57	0.39	1.38	0.31	0.07	0.09	0.47
185	*Zanthoxylum*	10.71	0.43	4.00	0.11	0.08	0.27	0.46
186	*Porana*	21.43	0.46	2.17	0.23	0.08	0.15	0.46
187	*Artemisia*	21.43	0.46	2.17	0.23	0.08	0.15	0.46
188	*Eucalyptus*	14.29	0.46	3.25	0.15	0.08	0.22	0.45
189	*Arundo*	17.86	0.46	2.60	0.19	0.08	0.18	0.45
190	*Cinnamomum*	25.00	0.39	1.57	0.27	0.07	0.11	0.44
191	*Mimosa*	25.00	0.39	1.57	0.27	0.07	0.11	0.44
192	*Actinidia*	21.43	0.43	2.00	0.23	0.08	0.13	0.44
193	*Elaphoglossum*	7.14	0.32	4.50	0.08	0.06	0.30	0.44
194	*Lemmaphyllum*	10.71	0.39	3.67	0.11	0.07	0.25	0.43
195	*Woodsia*	10.71	0.39	3.67	0.11	0.07	0.25	0.43

Sl No.	Genus	Frequency	Density	Abundance	RF	RD	RDM	IVI
196	*Paederia*	14.29	0.43	3.00	0.15	0.08	0.20	0.43
197	*Davallodes*	17.86	0.43	2.40	0.19	0.08	0.16	0.43
198	*Pholidota*	17.86	0.43	2.40	0.19	0.08	0.16	0.43
199	*Vittaria*	17.86	0.43	2.40	0.19	0.08	0.16	0.43
200	*Dendrocalamus*	25.00	0.36	1.43	0.27	0.06	0.10	0.43
201	*Dicranopteris*	21.43	0.39	1.83	0.23	0.07	0.12	0.42
202	*Erigeron*	21.43	0.39	1.83	0.23	0.07	0.12	0.42
203	*Microsorum*	17.86	0.39	2.20	0.19	0.07	0.15	0.41
204	*Himalaiella*	14.29	0.39	2.75	0.15	0.07	0.19	0.41
205	*Pyrularia*	14.29	0.39	2.75	0.15	0.07	0.19	0.41
206	*Buddleja*	3.57	0.18	5.00	0.04	0.03	0.34	0.41
207	*Hemiphragma*	21.43	0.36	1.67	0.23	0.06	0.11	0.41
208	*Rumex*	21.43	0.36	1.67	0.23	0.06	0.11	0.41
209	*Saurauia*	21.43	0.36	1.67	0.23	0.06	0.11	0.41
210	*Toona*	21.43	0.36	1.67	0.23	0.06	0.11	0.41
211	*Curcuma*	7.14	0.29	4.00	0.08	0.05	0.27	0.40
212	*Lindenbergia*	7.14	0.29	4.00	0.08	0.05	0.27	0.40
213	*Ilex*	17.86	0.36	2.00	0.19	0.06	0.13	0.39
214	*Lantana*	17.86	0.36	2.00	0.19	0.06	0.13	0.39
215	*Phegopteris*	17.86	0.36	2.00	0.19	0.06	0.13	0.39
216	*Potentilla*	17.86	0.36	2.00	0.19	0.06	0.13	0.39
217	*Tsuga*	17.86	0.36	2.00	0.19	0.06	0.13	0.39
218	*Cyanotis*	21.43	0.32	1.50	0.23	0.06	0.10	0.39
219	*Arctium*	14.29	0.36	2.50	0.15	0.06	0.17	0.39
220	*Berchemia*	14.29	0.36	2.50	0.15	0.06	0.17	0.39
221	*Trichosanthes*	25.00	0.25	1.00	0.27	0.04	0.07	0.38
222	*Balantium*	17.86	0.32	1.80	0.19	0.06	0.12	0.37
223	*Evodia*	17.86	0.32	1.80	0.19	0.06	0.12	0.37
224	*Hemarthria*	17.86	0.32	1.80	0.19	0.06	0.12	0.37
225	*Oberonia*	17.86	0.32	1.80	0.19	0.06	0.12	0.37
226	*Holmskioldia*	14.29	0.32	2.25	0.15	0.06	0.15	0.36
227	*Cardiocrinum*	7.14	0.25	3.50	0.08	0.04	0.24	0.36
228	*Artocarpus*	10.71	0.29	2.67	0.11	0.05	0.18	0.35
229	*Sorbus*	10.71	0.29	2.67	0.11	0.05	0.18	0.35
230	*Equisetum*	14.29	0.29	2.00	0.15	0.05	0.13	0.34
231	*Exbucklandia*	14.29	0.29	2.00	0.15	0.05	0.13	0.34
232	*Dendrocnide*	3.57	0.14	4.00	0.04	0.03	0.27	0.33
233	*Astragalus*	17.86	0.25	1.40	0.19	0.04	0.09	0.33
234	*Bauhinia*	17.86	0.25	1.40	0.19	0.04	0.09	0.33
235	*Cissampelos*	17.86	0.25	1.40	0.19	0.04	0.09	0.33

Sl No.	Genus	Frequency	Density	Abundance	RF	RD	RDM	IVI
236	*Cyrtomium*	17.86	0.25	1.40	0.19	0.04	0.09	0.33
237	*Pogostemon*	7.14	0.21	3.00	0.08	0.04	0.20	0.32
238	*Melochia*	10.71	0.25	2.33	0.11	0.04	0.16	0.32
239	*Clematis*	14.29	0.25	1.75	0.15	0.04	0.12	0.32
240	*Mahonia*	14.29	0.25	1.75	0.15	0.04	0.12	0.32
241	*Sinopodophyllum*	17.86	0.21	1.20	0.19	0.04	0.08	0.31
242	*Brugmansia*	14.29	0.21	1.50	0.15	0.04	0.10	0.29
243	*Dryopsis*	14.29	0.21	1.50	0.15	0.04	0.10	0.29
244	*Fraxinus*	14.29	0.21	1.50	0.15	0.04	0.10	0.29
245	*Gallium*	14.29	0.21	1.50	0.15	0.04	0.10	0.29
246	*Aralia*	10.71	0.21	2.00	0.11	0.04	0.13	0.29
247	*Coniogramme*	10.71	0.21	2.00	0.11	0.04	0.13	0.29
248	*Cyathea*	10.71	0.21	2.00	0.11	0.04	0.13	0.29
249	*Stephania*	10.71	0.21	2.00	0.11	0.04	0.13	0.29
250	*Gynocardia*	7.14	0.18	2.50	0.08	0.03	0.17	0.28
251	*Hydrangea*	7.14	0.18	2.50	0.08	0.03	0.17	0.28
252	*Lygodium*	7.14	0.18	2.50	0.08	0.03	0.17	0.28
253	*Myrsine*	7.14	0.18	2.50	0.08	0.03	0.17	0.28
254	*Uncifera*	7.14	0.18	2.50	0.08	0.03	0.17	0.28
255	*Dittoceras*	14.29	0.18	1.25	0.15	0.03	0.08	0.27
256	*Citrus*	3.57	0.11	3.00	0.04	0.02	0.20	0.26
257	*Duabanga*	3.57	0.11	3.00	0.04	0.02	0.20	0.26
258	*Ixeris*	3.57	0.11	3.00	0.04	0.02	0.20	0.26
259	*Knema*	3.57	0.11	3.00	0.04	0.02	0.20	0.26
260	*Laphangium*	3.57	0.11	3.00	0.04	0.02	0.20	0.26
261	*Oenanthe*	3.57	0.11	3.00	0.04	0.02	0.20	0.26
262	*Selinum*	3.57	0.11	3.00	0.04	0.02	0.20	0.26
263	*Sterculia*	3.57	0.11	3.00	0.04	0.02	0.20	0.26
264	*Juglans*	10.71	0.18	1.67	0.11	0.03	0.11	0.26
265	*Microlepia*	10.71	0.18	1.67	0.11	0.03	0.11	0.26
266	*Panisea*	10.71	0.18	1.67	0.11	0.03	0.11	0.26
267	*Poa*	10.71	0.18	1.67	0.11	0.03	0.11	0.26
268	*Veronica*	10.71	0.18	1.67	0.11	0.03	0.11	0.26
269	*Emilia*	14.29	0.14	1.00	0.15	0.03	0.07	0.25
270	*Aucuba*	7.14	0.14	2.00	0.08	0.03	0.13	0.24
271	*Casearia*	7.14	0.14	2.00	0.08	0.03	0.13	0.24
272	*Eriobotrya*	7.14	0.14	2.00	0.08	0.03	0.13	0.24
273	*Lasiococca*	7.14	0.14	2.00	0.08	0.03	0.13	0.24
274	*Persea*	7.14	0.14	2.00	0.08	0.03	0.13	0.24
275	*Polypodiodes*	7.14	0.14	2.00	0.08	0.03	0.13	0.24

Sl No.	Genus	Frequency	Density	Abundance	RF	RD	RDM	IVI
276	*Polypodium*	7.14	0.14	2.00	0.08	0.03	0.13	0.24
277	*Stachys*	7.14	0.14	2.00	0.08	0.03	0.13	0.24
278	*Dennstaedtia*	10.71	0.14	1.33	0.11	0.03	0.09	0.23
279	*Lindsaea*	10.71	0.14	1.33	0.11	0.03	0.09	0.23
280	*Mucuna*	10.71	0.14	1.33	0.11	0.03	0.09	0.23
281	*Pleione*	10.71	0.14	1.33	0.11	0.03	0.09	0.23
282	*Senna*	10.71	0.14	1.33	0.11	0.03	0.09	0.23
283	*Laportea*	10.71	0.11	1.00	0.11	0.02	0.07	0.20
284	*Leea*	10.71	0.11	1.00	0.11	0.02	0.07	0.20
285	*Maianthemum*	10.71	0.11	1.00	0.11	0.02	0.07	0.20
286	*Carex*	7.14	0.11	1.50	0.08	0.02	0.10	0.20
287	*Diploknema*	7.14	0.11	1.50	0.08	0.02	0.10	0.20
288	*Hippochaete*	7.14	0.11	1.50	0.08	0.02	0.10	0.20
289	*Phlebodium*	7.14	0.11	1.50	0.08	0.02	0.10	0.20
290	*Physalis*	7.14	0.11	1.50	0.08	0.02	0.10	0.20
291	*Pseudognaphalium*	7.14	0.11	1.50	0.08	0.02	0.10	0.20
292	*Arachniodes*	3.57	0.07	2.00	0.04	0.01	0.13	0.19
293	*Arundina*	3.57	0.07	2.00	0.04	0.01	0.13	0.19
294	*Beilschmiedia*	3.57	0.07	2.00	0.04	0.01	0.13	0.19
295	*Cheilocostus*	3.57	0.07	2.00	0.04	0.01	0.13	0.19
296	*Eria*	3.57	0.07	2.00	0.04	0.01	0.13	0.19
297	*Esmeralda*	3.57	0.07	2.00	0.04	0.01	0.13	0.19
298	*Flemingia*	3.57	0.07	2.00	0.04	0.01	0.13	0.19
299	*Grewia*	3.57	0.07	2.00	0.04	0.01	0.13	0.19
300	*Ione*	3.57	0.07	2.00	0.04	0.01	0.13	0.19
301	*Phyllanthus*	3.57	0.07	2.00	0.04	0.01	0.13	0.19
302	*Synotis*	3.57	0.07	2.00	0.04	0.01	0.13	0.19
303	*Agave*	7.14	0.07	1.00	0.08	0.01	0.07	0.16
304	*Ampelocalamus*	7.14	0.07	1.00	0.08	0.01	0.07	0.16
305	*Angelica*	7.14	0.07	1.00	0.08	0.01	0.07	0.16
306	*Ardisia*	7.14	0.07	1.00	0.08	0.01	0.07	0.16
307	*Habenaria*	7.14	0.07	1.00	0.08	0.01	0.07	0.16
308	*Leptodermis*	7.14	0.07	1.00	0.08	0.01	0.07	0.16
309	*Lonicera*	7.14	0.07	1.00	0.08	0.01	0.07	0.16
310	*Meconopsis*	7.14	0.07	1.00	0.08	0.01	0.07	0.16
311	*Nepeta*	7.14	0.07	1.00	0.08	0.01	0.07	0.16
312	*Neyraudia*	7.14	0.07	1.00	0.08	0.01	0.07	0.16
313	*Plagiogyria*	7.14	0.07	1.00	0.08	0.01	0.07	0.16
314	*Satyrium*	7.14	0.07	1.00	0.08	0.01	0.07	0.16
315	*Sphenomeris*	7.14	0.07	1.00	0.08	0.01	0.07	0.16

Sl No.	Genus	Frequency	Density	Abundance	RF	RD	RDM	IVI
316	*Steriochilus*	7.14	0.07	1.00	0.08	0.01	0.07	0.16
317	*Acorus*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
318	*Aesculus*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
319	*Amomum*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
320	*Ageratina*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
321	*Beaumontia*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
322	*Celtis*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
323	*Cephalostachyum*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
324	*Cheilanthes*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
325	*Datura*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
326	*Desmodium*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
327	*Drepanostachyum*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
328	*Epipactis*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
329	*Euphorbia*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
330	*Gastrochilus*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
331	*Hedera*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
332	*Henckelia*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
333	*Holboellia*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
334	*Juncus*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
335	*Lepidagathis*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
336	*Malaxis*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
337	*Marsilea*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
338	*Micropera*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
339	*Musa*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
340	*Nasturtium*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
341	*Nerium*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
342	*Oroxylum*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
343	*Panax*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
344	*Parthenium*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
345	*Peristrophe*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
346	*Phalaenopsis*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
347	*Platanthera*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
348	*Podocarpus*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
349	*Podochilus*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
350	*Porpax*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
351	*Ulmus*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
352	*Prinsepia*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
353	*Ranunculus*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
354	*Rhaphidophora*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
355	*Sambucus*	3.57	0.04	1.00	0.04	0.01	0.07	0.11

Sl No.	Genus	Frequency	Density	Abundance	RF	RD	RDM	IVI
356	*Sapindus*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
357	*Sauropus*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
358	*Schisandra*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
359	*Senecio*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
360	*Sida*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
361	*Sigesbeckia*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
362	*Styrax*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
363	Meliosma	3.57	0.04	1.00	0.04	0.01	0.07	0.11
364	*Thunia*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
365	*Trichotosia*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
366	*Vanda*	3.57	0.04	1.00	0.04	0.01	0.07	0.11
367	*Xanthium*	3.57	0.04	1.00	0.04	0.01	0.07	0.11

ANNEXURE III

Annexure III

IVI of recorded plant Families of the study area

Sl. No.	Families	Frequency	Density	Abundance	RF	RD	RDM	IVI
1	Theaceae	50.00	44.71	89.43	0.93	7.96	9.68	18.57
2	Poaceae	100.00	43.89	43.89	1.86	7.81	4.75	14.42
3	Euphorbiaceae	75.00	25.79	34.38	1.39	4.59	3.72	9.70
4	Urticaceae	100.00	27.07	27.07	1.86	4.82	2.93	9.61
5	Fagaceae	89.29	25.57	28.64	1.66	4.55	3.10	9.31
6	Asteraceae	96.43	23.54	24.41	1.79	4.19	2.64	8.62
7	Ericaceae	75.00	19.18	25.57	1.39	3.41	2.77	7.57
8	Juglandaceae	57.14	15.86	27.75	1.06	2.82	3.00	6.89
9	Polygonaceae	100.00	16.82	16.82	1.86	2.99	1.82	6.67
10	Dryopteridaceae	100.00	16.36	16.36	1.86	2.91	1.77	6.54
11	Betulaceae	78.57	15.29	19.45	1.46	2.72	2.11	6.29
12	Adoxaceae	64.29	13.04	20.28	1.19	2.32	2.20	5.71
13	Cyperaceae	96.43	13.43	13.93	1.79	2.39	1.51	5.69
14	Rosaceae	96.43	12.00	12.44	1.79	2.14	1.35	5.27
15	Selaginellaceae	85.71	11.43	13.33	1.59	2.03	1.44	5.07
16	Symplocaceae	57.14	10.68	18.69	1.06	1.90	2.02	4.98
17	Nephrolepidaceae	82.14	10.79	13.13	1.53	1.92	1.42	4.87
18	Lauraceae	75.00	9.57	12.76	1.39	1.70	1.38	4.48
19	Polypodiaceae	100.00	9.11	9.11	1.86	1.62	0.99	4.46
20	Orchidaceae	89.29	9.07	10.16	1.66	1.61	1.10	4.37
21	Lamiaceae	92.86	8.71	9.38	1.72	1.55	1.02	4.29
22	Pteridaceae	96.43	7.82	8.11	1.79	1.39	0.88	4.06
23	Rubiaceae	92.86	7.25	7.81	1.72	1.29	0.85	3.86
24	Cupressaceae	35.71	6.21	17.40	0.66	1.11	1.88	3.65
25	Leguminosae	100.00	6.07	6.07	1.86	1.08	0.66	3.59
26	Fabaceae	82.14	6.64	8.09	1.53	1.18	0.88	3.58
27	Sapindaceae	64.29	6.64	10.33	1.19	1.18	1.12	3.49
28	Proteaceae	21.43	4.32	20.17	0.40	0.77	2.18	3.35
29	Araceae	71.43	5.71	8.00	1.33	1.02	0.87	3.21
30	Melastomataceae	78.57	5.39	6.86	1.46	0.96	0.74	3.16
31	Magnoliaceae	57.14	5.07	8.88	1.06	0.90	0.96	2.92
32	Hydrangeaceae	78.57	4.46	5.68	1.46	0.79	0.62	2.87
33	Moraceae	67.86	4.64	6.84	1.26	0.83	0.74	2.83
34	Commelinaceae	78.57	4.18	5.32	1.46	0.74	0.58	2.78

Sl. No.	Families	Frequency	Density	Abundance	RF	RD	RDM	IVI
35	Primulaceae	92.86	3.54	3.81	1.72	0.63	0.41	2.77
36	Phyllanthaceae	75.00	4.11	5.48	1.39	0.73	0.59	2.72
37	Araliaceae	89.29	3.46	3.88	1.66	0.62	0.42	2.69
38	Thymelaeaceae	64.29	4.18	6.50	1.19	0.74	0.70	2.64
39	Malvaceae	75.00	3.86	5.14	1.39	0.69	0.56	2.64
40	Vitaceae	82.14	3.57	4.35	1.53	0.64	0.47	2.63
41	Pandanaceae	21.43	3.21	15.00	0.40	0.57	1.62	2.59
42	Pentaphylacaceae	67.86	3.07	4.53	1.26	0.55	0.49	2.30
43	Tectariaceae	71.43	2.93	4.10	1.33	0.52	0.44	2.29
44	Anacardiaceae	57.14	3.25	5.69	1.06	0.58	0.62	2.26
45	Combretaceae	46.43	3.25	7.00	0.86	0.58	0.76	2.20
46	Dioscoreaceae	50.00	3.21	6.43	0.93	0.57	0.70	2.20
47	Amaranthaceae	60.71	2.79	4.59	1.13	0.50	0.50	2.12
48	Plantaginaceae	67.86	2.50	3.68	1.26	0.44	0.40	2.10
49	Piperaceae	67.86	2.32	3.42	1.26	0.41	0.37	2.04
50	Cornaceae	60.71	2.07	3.41	1.13	0.37	0.37	1.87
51	Zingiberaceae	60.71	2.04	3.35	1.13	0.36	0.36	1.85
52	Athyriaceae	25.00	2.21	8.86	0.46	0.39	0.96	1.82
53	Caryophyllaceae	53.57	2.14	4.00	0.99	0.38	0.43	1.81
54	Begoniaceae	35.71	2.36	6.60	0.66	0.42	0.71	1.80
55	Salicaceae	28.57	2.21	7.75	0.53	0.39	0.84	1.76
56	Pinaceae	50.00	2.11	4.21	0.93	0.37	0.46	1.76
57	Lycopodiaceae	53.57	1.96	3.67	0.99	0.35	0.40	1.74
58	Myrtaceae	42.86	2.04	4.75	0.80	0.36	0.51	1.67
59	Gentianaceae	46.43	1.96	4.23	0.86	0.35	0.46	1.67
60	Thelypteridaceae	50.00	1.82	3.64	0.93	0.32	0.39	1.65
61	Balsaminaceae	42.86	1.57	3.67	0.80	0.28	0.40	1.47
62	Acanthaceae	39.29	1.61	4.09	0.73	0.29	0.44	1.46
63	Sabiaceae	32.14	1.50	4.67	0.60	0.27	0.51	1.37
64	Meliaceae	35.71	1.46	4.10	0.66	0.26	0.44	1.37
65	Apiaceae	28.57	1.50	5.25	0.53	0.27	0.57	1.37
66	Dipterocarpaceae	3.57	0.39	11.00	0.07	0.07	1.19	1.33
67	Berberidaceae	42.86	1.18	2.75	0.80	0.21	0.30	1.30
68	Aspleniaceae	46.43	1.07	2.31	0.86	0.19	0.25	1.30
69	Boraginaceae	17.86	1.21	6.80	0.33	0.22	0.74	1.28
70	Violaceae	28.57	1.25	4.38	0.53	0.22	0.47	1.23
71	Solanaceae	42.86	1.00	2.33	0.80	0.18	0.25	1.23
72	Smilacaceae	42.86	0.96	2.25	0.80	0.17	0.24	1.21
73	Putranjivaceae	21.43	1.18	5.50	0.40	0.21	0.60	1.20
74	Oxalidaceae	42.86	0.79	1.83	0.80	0.14	0.20	1.13

Sl. No.	Families	Frequency	Density	Abundance	RF	RD	RDM	IVI
75	Asparagaceae	39.29	0.75	1.91	0.73	0.13	0.21	1.07
76	Actinidiaceae	35.71	0.79	2.20	0.66	0.14	0.24	1.04
77	Rhamnaceae	28.57	0.89	3.13	0.53	0.16	0.34	1.03
78	Rutaceae	28.57	0.86	3.00	0.53	0.15	0.32	1.01
79	Burseraceae	17.86	0.79	4.40	0.33	0.14	0.48	0.95
80	Saxifragaceae	21.43	0.79	3.67	0.40	0.14	0.40	0.93
81	Saururaceae	25.00	0.61	2.43	0.46	0.11	0.26	0.84
82	Davalliaceae	17.86	0.61	3.40	0.33	0.11	0.37	0.81
83	Simaroubaceae	14.29	0.57	4.00	0.27	0.10	0.43	0.80
84	Elaeocarpaceae	25.00	0.50	2.00	0.46	0.09	0.22	0.77
85	Woodsiaceae	25.00	0.50	2.00	0.46	0.09	0.22	0.77
86	Lindsaeaceae	21.43	0.54	2.50	0.40	0.10	0.27	0.76
87	Oleandraceae	17.86	0.54	3.00	0.33	0.10	0.32	0.75
88	Blechnaceae	17.86	0.50	2.80	0.33	0.09	0.30	0.72
89	Santalaceae	17.86	0.50	2.80	0.33	0.09	0.30	0.72
90	Convolvulaceae	21.43	0.46	2.17	0.40	0.08	0.23	0.72
91	Menispermaceae	21.43	0.46	2.17	0.40	0.08	0.23	0.72
92	Lomariopsidaceae	7.14	0.32	4.50	0.13	0.06	0.49	0.68
93	Equisetaceae	21.43	0.39	1.83	0.40	0.07	0.20	0.67
94	Gleicheniaceae	21.43	0.39	1.83	0.40	0.07	0.20	0.67
95	Liliaceae	17.86	0.39	2.20	0.33	0.07	0.24	0.64
96	Scrophulariaceae	3.57	0.18	5.00	0.07	0.03	0.54	0.64
97	Cucurbitaceae	25.00	0.25	1.00	0.46	0.04	0.11	0.62
98	Aquifoliaceae	17.86	0.36	2.00	0.33	0.06	0.22	0.61
99	Verbenaceae	17.86	0.36	2.00	0.33	0.06	0.22	0.61
100	Dicksoniaceae	17.86	0.32	1.80	0.33	0.06	0.19	0.58
101	Hamamelidaceae	14.29	0.29	2.00	0.27	0.05	0.22	0.53
102	Ranunculaceae	14.29	0.29	2.00	0.27	0.05	0.22	0.53
103	Apocynaceae	17.86	0.25	1.40	0.33	0.04	0.15	0.53
104	Platanaceae	7.14	0.21	3.00	0.13	0.04	0.32	0.50
105	Oleaceae	14.29	0.21	1.50	0.27	0.04	0.16	0.47
106	Cyatheaceae	10.71	0.21	2.00	0.20	0.04	0.22	0.45
107	Achariaceae	7.14	0.18	2.50	0.13	0.03	0.27	0.44
108	Lygodiaceae	7.14	0.18	2.50	0.13	0.03	0.27	0.44
109	Lythraceae	3.57	0.11	3.00	0.07	0.02	0.32	0.41
110	Myristicaceae	3.57	0.11	3.00	0.07	0.02	0.32	0.41
111	Sterculiaceae	3.57	0.11	3.00	0.07	0.02	0.32	0.41
112	Garryaceae	7.14	0.14	2.00	0.13	0.03	0.22	0.37
113	Sapotaceae	7.14	0.11	1.50	0.13	0.02	0.16	0.31
114	Costaceae	3.57	0.07	2.00	0.07	0.01	0.22	0.30

Sl. No.	Families	Frequency	Density	Abundance	RF	RD	RDM	IVI
115	Caprifoliaceae	7.14	0.07	1.00	0.13	0.01	0.11	0.25
116	Plagiogyriaceae	7.14	0.07	1.00	0.13	0.01	0.11	0.25
117	Acoraceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18
118	Alangiaceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18
119	Bignoniaceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18
120	Brassicaceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18
121	Cannabaceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18
122	Dennstaedtiaceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18
123	Gesneriaceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18
124	Juncaceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18
125	Marsileaceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18
126	Musaceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18
127	Nyctaginaceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18
128	Papaveraceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18
129	Podocarpaceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18
130	Schisandraceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18
131	Styracaceae	3.57	0.04	1.00	0.07	0.01	0.11	0.18

ANNEXURE IV

Annexure IV

Volume Equation used for trees of the study area

Sl No	Name of Tree Species	Volume equation used
1	*Abies densa* Griff.	$V= 0.12167-0.0114D+0.000812D^2$ (cm)
2	*Acer caesium* Wall. ex Brandis	$\sqrt{V} = -0.162945+3.109717D$
3	*Acer campbellii* Hook.f. & Thomson ex Hiern *Cinnamomum impressinervium* Meisn. *Evodia fraxinifolia* (Hook.) Benth. *Exbucklandia populnea* (R.Br. ex Griff.) R.W.Br. *Juglans regia* L. *Macaranga indica* Wight *Syzygium cumini* (L.) Skeels	$V/D^2= 0.06674/D^2-0.02039/D+0.001559$ (cm)
4	*Acer caudatum* Wall.	$\sqrt{V} = -0.162945+3.109717D$
5	*Albizia chinensis* (Osbeck) Merr.	$V = 0.29208+0.00092412 D^2$
6	*Albizia procera* (Roxb.) Benth.	$\sqrt{V} = -0.469497+3.698566D$
7	*Alnus nepalensis* D.Don	$V =0.7287-0.042628 D+0.00137D^2$ (cm)
8	*Artocarpus lacucha*Buch.-Ham.	$\sqrt{V} = 0.06692+2.61991D$
9	*Beilschmiedia sikkimensis* King ex Hooker *Elaeocarpus lanceifolius* Roxb. *Engelhardtia spicata var. integra* (Kurz) W.E.Manning ex Steenis *Rhododendron hodgsonii* Hook.f.	$V/D^2= 0.25564/D^2-0.030418/D+0.0012897$ (cm)
10	*Betula alnoides*Buch.-Ham.	$V= (-0.1211+1.58826)D+1.96643 D^2$
11	*Betula utilis* D.Don *Litsea cubeba* (Lour.) Pers. *Litsea sericea* (Wall.ex Nees) Hook.f. *Machilus edulis* King ex Hook.f. *Machilus gammieana* King *Nyssa javanica* (Blume) Wangerin *Persea odoratissima* (T.Nees) Kosterm. *Prunus nepalensis* Ser.	$V= 0.12652-0.018037D+0.000956D^2$ (cm)
12	*Bischofia javanica* Blume	$\sqrt{V} = (-0.00273) +2.56199D$
13	*Castanopsis hystrix* Hook.f. & Thomson *ex* A. DC.	$\sqrt{V} = 0.3464+3.99269D-1.64666D$
14	*Castanopsis tribuloides* (Sm.) A.DC. *Lithocarpus pachyphyllus* (Kurz) Rehder *Quercus lamellosa* Sm. *Quercus lineata* Blume	$V/D^2 =0.001184+0.1812/ D^2-0.02348/D$(cm)
15	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	$V= 0.1097-0.88666D+6.097D^2-1.62672D^3$

16	*Cryptomeria japonica* (Thunb.) D.Don	$V= -0.01097+5.30991D^2$
17	*Ficus hirta* Vahl *Ficus neriifolia*Sm. *Ficus religiosa*L. *Ficus roxburghii*Lour. *Ficus subincisa* Buch.-Ham. ex Sm.	$\sqrt{V} = 0.3629+3.95389D-0.84421 D^2$
18	*Lyonia ovalifolia* (Wall.) Drude	$V=0.1456-2.10543D+11.81097D^2-6.56089D^3$
19	*Machilus gamblei*King ex Hook.f. *Machilus glaucescens* (T.Nees) H.W. Li *Machilus kurzii* King ex Hook.f.	$V/D^2 = 4.84009-0.02402D^2$
20	*Magnolia doltsopa* (Buch.-Ham. ex DC.) Figlar	$V/D^2 =0.0002138+0.002517/D+0.00001064D-0.00000004D^2$
21	*Rhododendron arboreum*Sm. *Rhododendron barbatum* Wall. ex G.Don *Rhododendron campylocarpum* Hook.f. *Rhododendron dalhousieae* Hook.f. *Rhododendron falconeri* Hook.f. *Rhododendron griffithianum* Wight *Rhododendron thomsonii* Hook.f. *Rhododendron triflorum* Hook.f. *Rhododendron vaccinioides* Hook.	$\sqrt{V} = 0.306492+4.31536D-1.749908 \log D$
22	*Schima wallichii* Choisy	$\sqrt{V} =0.28069+4.6198D-1.65381 \log D$
23	*Shorea robusta* Gaert.	$V/D^2 =-0.32546/D^2+9.78645$
24	*Symplocos lucida* (Thunb.) Siebold & Zucc.	$V=0.03754+0.000587D^2$
25	*Terminalia crenulata* Roth	$\sqrt{V} = 0.14325+3.07937D$
26	*Toona ciliata* M.Roem.	$\sqrt{V} = -0.27525+3.0319D$
27	General volume formula	$V=0.3555-0.037D+0.001259D^2$ (cm)

ANNEXURE V

Annexure V

List of plants species along the altitude showing the species distribution range (lower elevation 500 and upper elevation range 3300 (5 to 32)

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
1	*Abies densa* Griff.	Pinaceae														√			√			√			√		√	√		√	1800-3300
2	*Abies spectabilis* (D.Don) Mirb.	Pinaceae											√					√													1500-2100
3	*Acampe ochracea* Lindl.	Orchidaceae	√																												500
4	*Acampe rigida* (Buch.-Ham.*ex.* Sm.) P.F. Hunt	Orchidaceae	√																												500
5	*Acer campbellii* Hook.f. & Thomson *ex* Hiern	Sapindaceae											√	√		√	√		√	√		√	√	√	√	√	√	√	√	√	1500-3300
6	*Acer caudatum* Wall.	Sapindaceae															√				√			√				√	√	√	1900-3300
7	*Acer laevigatum* Wall.	Sapindaceae																				√									2400
8	*Acer oblongum* Wall. *ex* DC.	Sapindaceae										√							√	√		√				√	√				1400-2900
9	*Achyranthes aspera* L.	Amaranthaceae	√	√	√	√	√	√	√	√	√	√	√	√			√		√												500-2200
10	*Achyranthes bidentata* Blume	Amaranthaceae			√	√	√								√		√		√												700-2200
11	*Acorus calamus* L.	Acoraceae																					√								2500
12	*Actinidia callosa* Lindl.	Actinidiaceae				√	√	√	√		√		√																		800-1600
13	*Actinodaphne sikkimensis* Meisn.	Lauraceae				√				√																					800-1300
14	*Adiantum capillus-veneris* L.	Pteridaceae				√															√	√	√			√	√				800-3000
15	*Adiantum incisum* Forssk.	Pteridaceae			√	√					√		√	√		√				√											700-2300
16	*Adiantum lunulatum* Burm.f.	Pteridaceae																		√			√								2200-2600
17	*Aesculus indica* (Wall. *ex* Cambess.) Hook.	Sapindaceae											√																		1500
18	*Agave Americana* L.	Asparagaceae													√		√														1700-2000

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
19	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	Asteraceae	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√				√	√		500-3200
20	*Ageratina ligustrina* (DC.) R.M.King & H.Rob.	Urticaceae				√		√						√								√									800-2500
21	*Ageratum conyzoides* (L.) L.	Asteraceae			√	√	√	√	√	√		√	√																		700-1600
22	*Ageratum houstonianum* Mill.	Asteraceae					√	√	√	√		√	√						√												900-2200
23	*Alangium alpinum* (C.B. Clarke) W.W. Sm. & Cave	Alangiaceae									√																				1300
24	*Alangium chinense* (Lour.) Harms	Alangiaceae	√	√	√	√	√	√		√		√			√			√		√	√	√	√	√							500-2700
25	*Albizia chinensis* (Osbeck) Merr.	Leguminosae	√	√	√		√	√			√	√	√		√			√													500-2100
26	*Albizia lucidior* (Steud.) I.C.Nielsen	Leguminosae	√	√		√	√		√	√	√				√	√	√			√											500-2300
27	*Albizia procera* (Roxb.) Benth.	Leguminosae		√					√																						600-1200
28	*Aleuritopteris albomarginata* (C.B.Clarke) Ching	Pteridaceae																								√					2800
29	*Aleuritopteris dubia* (C. Hope) Ching	Pteridaceae								√																					1200
30	*Aleuritopteris subdimorpha* (C.B.Clarke & Baker) Fraser-Jenk.	Pteridaceae	√				√	√	√	√	√	√																			500-1500
31	*Allantodia spectabilis* (Wall. *ex* Mett.) Ching	Athyriaceae																							√	√	√				2700-3000
32	*Allantodia stoliczkae* (Bedd.) Ching	Athyriaceae																						√	√	√	√				2600-3000
33	*Allantodia succulenta* (Clarke) Ching	Athyriaceae																			√										2300
34	*Alnus nepalensis* D.Don	Betulaceae					√	√	√	√		√	√	√	√	√	√	√	√	√		√		√			√				900-3000
35	*Alocasia macrorrhizos* (L.) G. Don	Araceae	√	√	√			√			√		√	√	√	√	√		√			√				√			√		500-3100
36	*Amomum subulatum* Roxb.	Zingiberaceae											√																		1500
37	*Ampelocalamus patellaris*	Poaceae						√					√																		1000-1600

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
38	*Anaphalis busua* (Buch.-Ham.) DC.	Asteraceae																		√			√		√	√	√				2200-3000
39	*Anaphalis contorta* (D.Don) Hook.f	Asteraceae												√		√						√				√	√		√	√	1600-3300
40	*Anaphalis margaritacea* (L.) Benth. & Hook. f.	Asteraceae																		√			√		√				√		2200-3200
41	*Angelica archangelica* L.	Apiaceae																		√										√	2200-3300
42	*Anisomeles indica* (L.) Kuntze	Lamiaceae		√		√								√	√	√					√			√							600-2700
43	*Antidesma acidum* Retz.	Phyllanthaceae	√	√	√	√	√		√	√			√		√	√															500-1900
44	*Antidesma acuminatum* Wall.	Euphorbiaceae							√	√							√														1100-2000
45	*Apios carnea* (Wall.) Benth.	Leguminosae	√			√	√	√		√	√	√	√	√	√		√														500-2000
46	*Arachniodes davalliaeformis* (Christ) Nakaike	Dryopteridaceae																			√										2300
47	*Aralia leschenaultii* (DC.) J.Wen	Araliaceae														√			√					√							1800-2700
48	*Arctium lappa* L.	Asteraceae																√										√	√	√	2000-3300
49	*Ardisia macrocarpa* Wall.	Myristicaceae									√	√																			1300-1500
50	*Arisaema concinnum* Schott	Araceae										√																			1400
51	*Arisaema echinatum* (Wall.) Schott	Araceae																						√							2600
52	*Arisaema flavum* (Forssk.) Schott	Araceae											√									√		√							1500-2700
53	*Arisaema galeatum* N.E. Br.	Araceae											√	√	√	√	√	√	√		√	√		√							1500-2700
54	*Arisaema griffithii* Schott	Araceae											√				√		√												1500-2200
55	*Arisaema intermedium* Blume	Araceae																		√		√				√					2200-2900
56	*Arisaema nepenthoides* (Wall.) Martius	Araceae										√	√	√																	1400-1700
57	*Arisaema speciosum* (Wall.) Martius	Araceae														√	√					√									1800-2500
58	*Arisaema tortuosum* (Wall.) Schott	Araceae										√		√	√	√			√												1400-2200

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
59	*Artemisia japonica* Thunb.	Asteraceae			√	√	√	√	√	√	√	√	√		√	√											√			√	700-3300
60	*Artemisia vulgaris* L.	Asteraceae																		√		√	√						√	√	2200-3300
61	*Arthromeris himalayensis* (Hook.) Ching	Polypodiaceae																									√	√			2900-3100
62	*Arthromeris wallichiana* (Spreng.) Ching	Polypodiaceae										√	√		√										√	√			√	√	1400-3300
63	*Artocarpus lacucha* Buch.-Ham.	Moraceae	√	√				√																							500-1100
64	*Arundina graminifolia* (D.Don) Hochr.	Orchidaceae	√																												500
65	*Arundinaria racemosa* Munro	Poaceae																	√		√					√	√	√	√		2100-3200
66	*Arundinella hookeri* Munro & Keng	Poaceae																			√		√	√	√	√	√	√	√		2300-3200
67	*Arundinella nepalensis* Trin.	Poaceae			√	√	√		√						√	√	√	√													2100-2300
68	*Arundo donax* L.	Poaceae				√	√										√		√						√						800-2800
69	*Asplenium gueinzianum* Kunze *ex* Mett.	Aspleniaceae											√		√	√	√	√				√									1500-2500
70	*Asplenium phyllitidis* D.Don	Aspleniaceae	√	√																											500-700
71	*Asplenium tenuifolium* D. Don	Aspleniaceae									√					√				√											1300-2300
72	*Asplenium yoshinagae* Makino	Aspleniaceae		√	√									√	√																600-1800
73	*Aster albescens* (DC.) Wall.*ex* Hand.-Mazz.	Asteraceae					√						√					√													900-2100
74	*Aster flaccidus* Bunge	Asteraceae																								√					2800
75	*Aster sikkimmensis* Hook.f. & Thomson	Asteraceae																					√		√	√	√		√		2500-3200
76	*Aster tricephalus* C.B.Clarke	Asteraceae																			√										2300
77	*Aster trinervis* Roxb.	Asteraceae																						√	√				√		2600-3200
78	*Astilbe rivularis* Buch.-Ham.	Saxifragaceae												√		√				√				√					√	√	1600-3300
79	*Astragalus stipulatus* (L.) A.Gray	Leguminosae		√	√	√	√					√																			600-1500

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
80	*Athyrium filix-femina* (L.) Roth	Athyriaceae																					√	√	√	√	√				2500-3000
81	*Athyrium foliolosum* T. Moore *ex* R.Sim	Athyriaceae																			√			√	√						2300-2800
82	*Aucuba himalaica* Hook.f. &Thomson	Garryaceae																				√	√								2400-2600
83	*Axonopus compressus* (Sw.) P. Beauv.	Poaceae	√		√		√			√	√	√											√								500-2600
84	*Azadirachta indica* Juss.	Meliaceae	√			√																									800
85	*Balantium antarcticum* (Labill.) C. Presl	Dicksoniaceae		√				√			√	√												√							600-2700
86	*Bambusa nutans* Wall.*ex* Munro	Poaceae	√		√			√			√	√	√		√																500-1800
87	*Bauhinia purpurea* L.	Leguminosae	√				√																								500-1000
88	*Bauhinia scandens* L.	Leguminosae																		√		√	√								2200-2500
89	*Beaumontia grandiflora* Wall.	Apocynaceae			√																										700
90	*Begonia josephii* DC.	Begoniaceae																					√		√						2500-2800
91	*Begonia malabarica* Lam.	Begoniaceae										√		√							√	√									1400-2500
92	*Begonia palmata* D.Don	Begoniaceae										√					√				√										1400-2400
93	*Begonia picta* Sm.	Begoniaceae								√										√	√	√	√	√	√						1200-2800
94	*Beilschmiedia sikkimensis* King *ex* Hook.f.	Lauraceae																			√										2300
95	*Berberis angulosa* Wall.*ex*Hook.f. & Thomson	Berberidaceae											√																√		1500-3200
96	*Berberis asiatica* DC.	Berberidaceae	√						√																						500-1100
97	*Berberis hookeri* Lem.	Berberidaceae																										√		√	3100-3300
98	*Berberisvirescens* Hook.f.	Berberidaceae								√		√								√		√									1200-2500
99	*Berberis wallichiana* DC.	Berberidaceae																		√											2300
100	*Berchemia floribunda* (Wall.) Brongn.	Rhamnaceae					√					√	√				√														900-2000

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
101	*Betula alnoides* Buch.-Ham.	Betulaceae					√	√					√	√	√		√		√				√	√	√						900-2800
102	*Betula utilis* D.Don	Betulaceae																								√	√	√	√	√	2800-3300
103	*Bidens pilosa* L.	Asteraceae			√	√	√	√	√	√	√	√				√				√											700-2300
104	*Bischofia javanica* Blume	Phyllanthaceae	√	√		√		√	√	√	√		√																		500-1600
105	*Boehmeria macrophylla* Hornem.	Urticaceae						√	√	√		√	√	√	√		√														1000-2000
106	*Boehmeria platyphylla* D.Don	Urticaceae	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√									500-2500
107	*Boehmeria rugulosa* Wedd.	Urticaceae																		√											2200
108	*Bombax ceiba* L.	Malvaceae	√	√	√		√								√				√												500-2200
109	*Brachiaria ramosa* (L.) Stapf	Poaceae		√				√	√	√	√	√	√			√	√	√		√	√		√	√	√	√					600-2900
110	*Brachiaria subquadripara* (Trin.) Hitchc.	Poaceae						√			√																				1000-1400
111	*Brachiaria villosa* (Lam.) A. Camus	Poaceae	√	√				√							√	√		√			√				√				√	√	500-3300
112	*Brassaiopsis glomerulata* (Blume) Regel	Araliaceae	√										√																		500-1600
113	*Brassaiopsis hispida* Seem.	Araliaceae																	√	√		√	√	√	√	√					2100-2900
114	*Brassaiopsis mitis* C.B.Clarke	Araliaceae	√			√		√	√				√	√			√			√	√	√	√				√				500-3000
115	*Bridelia retusa* (L.) Juss.	Phyllanthaceae	√			√	√	√	√					√																	500-1700
116	*Brucea javanica* (L.) Merr.	Simaroubaceae			√	√	√		√																						700-1200
117	*Brugmansia suaveolens* (Humb. & Bonpl. ex Willd.) Bercht. & J.Presl	Solanaceae			√				√				√	√																	700-1700
118	*Buddleja asiatica* Lour.	Scrophulariaceae																											√		3100
119	*Bulbophyllum guttulatum* (Hook.f.)N.P.Balakr.	Orchidaceae	√	√	√																										500-800
120	*Bulbophyllum sterile* (Lam.) Suresh	Orchidaceae	√																												500
121	*Bulbophyllum thomsonii* Hook.f.	Orchidaceae	√																												500

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
122	*Bulbophyllum yoksunense* J.J.Sm.	Orchidaceae																				√	√		√						2400-2800
123	*Callicarpa arborea* Roxb.	Lamiaceae	√	√				√		√			√		√			√													500-2100
124	*Cardiocrinum giganteum* (Wall.) Makino	Liliaceae																			√										2300
125	*Carex caryophyllea* Latourr.	Cyperaceae					√													√											900-2300
126	*Casearia glomerata* Roxb.	Salicaceae														√			√												1800-2400
127	*Castanopsis hystrix* Hook.f. & Thomson *ex* A.DC.	Fagaceae	√	√	√	√	√	√	√	√	√	√		√	√	√	√		√	√			√	√		√	√				500-3000
128	*Castanopsis indica* A.DC.	Fagaceae								√	√	√					√														1200-2000
129	*Castanopsis tribuloides* (Sm.) A.DC.	Fagaceae			√	√		√			√	√		√	√	√	√	√	√			√			√			√			700-3100
130	*Cautleya spicata* (Sm.) Baker	Zingiberaceae								√										√	√	√		√							1200-2700
131	*Cautleya gracilis* (Sm.) Dandy	Zingiberaceae			√				√	√	√	√	√																	√	700-3300
132	*Celtis tetrandra* Roxb.	Cannabaceae						√																							1000
133	*Cephalostachyumcapitatum* Munro	Poaceae																								√					2800
134	*Cheilanthes farinosa* (Forssk.) Kaulf.	Pteridaceae								√																					1200
135	*Cheilocostus speciosus* (J.Koenig) C.D.Specht	Costaceae	√																												500
136	*Chimonocalamusgriffithianus* (Munro) Hsueh & T.P.Yi	Poaceae																√	√	√	√	√						√			2000-3100
137	*Choerospondias axillaris* (Roxb.) B.L.Burtt & A.W.Hill	Anacardiaceae	√			√	√	√		√	√																				500-1400
138	*Christella parasitica* H.Lev.	Thelypteridaceae				√	√					√	√	√			√		√										√	√	800-3300
139	*Chrysopogon aciculatus* (Retz.) Trin.	Poaceae	√				√						√				√		√												500-2200
140	*Cinnamomum impressinervium* Meissn.	Lauraceae																√		√			√	√	√						2000-2800
141	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	Lauraceae																				√									2400

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
142	*Cinnamonum caudatum* Nees	Lauraceae										√																			1400
143	*Cirrhopetalum wallichii* Lindl.	Orchidaceae																		√	√	√	√	√	√	√	√	√			2200-3100
144	*Cissampelos pareira* L.	Menispermaceae	√	√	√	√													√												500-2200
145	*Cissus repens* Lam.	Vitaceae	√	√	√			√		√					√	√	√		√	√	√	√			√						500-2800
146	*Citrus maxima* (Burm.f.) Merr.	Rutaceae							√																						1100
147	*Clematis buchananiana* DC	Ranunculaceae																		√	√	√					√				2200-3000
148	*Clerodendrum glandulosum* Lindl.	Lamiaceae						√	√	√	√	√	√	√																	1000-1700
149	*Clerodendrum infortunatum* L.	Lamiaceae	√			√																									500-900
150	*Clerodendrum japonicum* (Thunb.) Sweet	Lamiaceae		√					√																						600-1200
151	*Coelogyne corymbosa* Lindl.	Orchidaceae																				√	√	√	√	√					2400-2900
152	*Coelogyne flaccid* Lindl.	Orchidaceae						√									√														1000-3000
153	*Coelogyne prolifera* Lindl.	Orchidaceae					√	√																							1000-1200
154	*Coelogynestricta*(D.Don) Schltr.	Orchidaceae						√		√																					1000-1300
155	*Colebrookea oppositifolia* Sm.	Lamiaceae	√	√						√								√	√												500-2200
156	*Commelina paludosa* Blume	Commelinaceae	√	√	√	√	√	√	√	√	√	√	√		√			√	√		√		√		√	√	√				500-3000
157	*Coniogramme procera* Fee	Pteridaceae																		√		√		√							2200-2700
158	*Crassocephalum crepidioides* (Benth.) S.Moore	Asteraceae		√	√	√		√	√	√								√		√											600-2300
159	*Cryptomeria japonica* (Thunb. ex L.f.) D.Don	Cupressaceae												√		√	√	√	√	√											1600-2300
160	*Cupressus torulosa* D.Don	Cupressaceae															√														1900
161	*Curcuma angustifolia* Roxb.	Zingiberaceae															√					√									1900-2500
162	*Cyanotis vaga* (Lour.) Schult. & Schult.f.	Commelinaceae							√			√	√			√				√		√									1100-2500
163	*Cyathea chinensis* Copel.	Cyatheaceae															√				√	√									1900-2500

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
164	*Cyathea spinulosa* Wall. *ex* Hook.	Cyatheaceae																			√										2200
165	*Cyathula capitata* Moq.	Amaranthaceae																				√		√							2400-2700
166	*Cymbidium aloifolium* (L.) Sw.	Orchidaceae	√																												500
167	*Cymbidium eburneum* Lindl.	Orchidaceae	√																												500
168	*Cymbidium iridioides* D.Don	Orchidaceae								√																					1200
169	*Cymbidium longifolium* D.Don	Orchidaceae													√	√	√	√	√												1700-2200
170	*Cymbidium mastersii* Griff. *ex.* Lindl.	Orchidaceae						√	√	√	√	√	√	√	√	√															1000-1900
171	*Cymbopogon flexuosus* (Nees ex Steud.) J.F. Watson	Poaceae	√		√	√	√	√	√	√	√	√																			500-1500
172	*Cymbopogon pendulus* (Nees ex Steud.) J.F. Watson	Poaceae							√																						1100
173	*Cynodon dactylon* (L.) Pers.	Poaceae					√		√	√	√	√				√			√	√		√	√	√	√	√	√	√	√	√	900-3300
174	*Cyperus alopecuroides* Rottb.	Cyperaceae	√	√	√	√	√	√		√	√																				500-1400
175	*Cyperus compressus* L.	Cyperaceae	√																	√								√	√		500-3200
176	*Cyperus cuspidatus* Kunth	Cyperaceae																				√	√		√	√					2400-2900
177	*Cyperus cyperoides* (Retz.) Kuntze	Cyperaceae			√		√	√	√			√	√	√				√													700-2100
178	*Cyperus difformis* L.	Cyperaceae																					√	√							2500-2700
179	*Cyperus distans* L.	Cyperaceae		√	√		√									√	√			√		√	√	√	√	√	√	√	√		600-3200
180	*Cyperus haspan* L.	Cyperaceae														√									√						1800-2800
181	*Cyperus longus* L.	Cyperaceae	√		√			√		√				√	√				√									√			500-3100
182	*Cyperus niveus* Retz.	Cyperaceae																		√				√							2200-2700
183	*Cyperus odoratus* L.	Cyperaceae																											√	√	3100-3300
184	*Cyperus rotundus* L.	Cyperaceae					√		√						√	√			√	√		√		√							900-2700
185	*Cyperus squarrosus* L.	Cyperaceae									√				√		√		√			√					√		√		1300-3200

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
186	*Cyperus tenuiculmis* Boeck.	Cyperaceae																						√	√	√	√	√	√	√	2600-3300
187	*Cyrtomium caryotideum* (Wall. *ex* Hook. & Grev.) C. Presl	Dryopteridaceae														√															1800
188	*Cyrtomium hookerianum* C.Chr.	Dryopteridaceae																					√	√	√		√				2500-3000
189	*Daphne bholua* Buch.-Ham. ex D.Don	Thymelaeaceae															√		√										√		1900-3200
190	*Daphne glacialis* (W.W.Sm. & Cave) A.P. Das	Thymelaeaceae																								√	√	√	√		2800-3200
191	*Daphne papyracea* Wall.*ex* G. Don	Thymelaeaceae											√			√	√	√	√	√	√	√	√	√	√		√	√		√	1500-3300
192	*Datura metel* L.	Solanaceae				√																									800
193	*Davallodes membrunulosa* (Wall. *ex* Hook.) Copel	Davalliaceae	√	√	√		√				√																				500-1400
194	*Dendrobium densiflorum* Lindl.	Orchidaceae	√	√	√	√	√																								500-1000
195	*Dendrobium eriiflorum* Griff.	Orchidaceae															√														1900
196	*Dendrobium hookerianum* Lindl.	Orchidaceae																					√	√	√						2500-2800
197	*Dendrobium longicornu* Lindl.	Orchidaceae															√	√	√								√				1900-3000
198	*Dendrocalamus hamiltonii* T.Nees & Arn. *ex* Munro	Poaceae		√		√		√			√	√	√		√																600-1800
199	*Dendrocnide sinuata* (Blume) Chew	Urticaceae	√																												500
200	*Dennstaedtia appendiculata* (Wall. *ex* Hook.) J. Sm	Dennstaedtiaceae										√		√							√										1400-2400
201	*Dennstaedtia scabra* (Wall. ex Hook.) T. Moore	Dennsaedtiaceae																			√										2300
202	*Desmodium multiflorum* DC.	Leguminosae																			√										2300
203	*Dichroa febrifuga* Lour.	Hydrangeaceae			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√					√	700-3300
204	*Dicranopteris linearis* (Burm.f.) Underw.	Gleicheniaceae										√	√		√	√	√			√											1400-2300
205	*Digitaria ciliaris* (Retz.)	Poaceae		√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√						√					600-2900

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
206	*Digitaria longiflora* (Retz.) Pers.	Poaceae	√	√	√		√	√	√		√	√					√		√												500-2200
207	*Digitaria sanguinalis* (L.) Scop.	Poaceae			√					√								√													700-2100
208	*Dioscorea bulbifera* L.	Dioscoreaceae	√	√		√	√		√			√	√		√		√														500-2000
209	*Dioscorea deltoidea* Wall. *ex* Griseb.	Dioscoreaceae				√	√		√														√								800-2600
210	*Dioscorea hamiltonii* Hook.f.	Dioscoreaceae				√	√						√		√		√		√												800-2200
211	*Dioscorea oppositifolia* L.	Dioscoreaceae	√																												500
212	*Dioscorea pentaphylla* L.	Dioscoreaceae	√	√							√			√		√															500-1900
213	*Diplazium dilatatum* Burm.f.	Athyriaceae																			√										2300
214	*Diplazium esculentum* (Retz.) Sw.	Athyriaceae																			√										2300
215	*Diplazium muricatum* Alderw.	Athyriaceae														√															1800
216	*Diploknema butyracea* (Roxb.) H.J.Lam	Sapotaceae					√			√																					900-1300
217	*Dittoceras andersonii* Hook.f.	Apocynaceae			√																√				√	√					700-2900
218	*Drepanostachyum intermedium* (Munro) Keng f.	Poaceae																						√							2600
219	*Drymaria cordata* (L.) Willd. *ex* Schult.	Caryophyllaceae	√	√	√	√	√	√	√	√	√	√	√	√	√				√	√											500-2300
220	*Drymaria villosa* Schltdl. & Cham.	Caryophyllaceae											√																		1500
221	*Drynaria coronans* (Wall. *ex* Mett.) T. Moore	Polypodiaceae	√			√	√	√	√	√		√	√																		500-1600
222	*Drynaria propinqua* (Wall *.ex* Mett.) J.Sm	Polypodiaceae																√	√												2000-2200
223	*Drynaria quercifolia* (L) J.Sm	Polypodiaceae	√	√		√	√	√		√																					500-1300
224	*Dryopsis apiciflora* (Wall. *ex* Mett.) Holttum & P.J. Edwards	Dryopteridaceae																			√		√						√	√	2300-3300
225	*Dryopteris filix-mas* (L.) Schott	Dryopteridaceae			√																						√				700-3000

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
226	*Dryopteris sikkimensis* (Bedd.) Kuntze	Dryopteridaceae	√	√	√	√	√	√	√	√	√	√	√	√	√		√		√	√	√	√									500-2500
227	*Drypetes longifolia* (Burm.f.) Pax & K.Hoffm.	Putranjivaceae					√	√	√		√	√		√																	900-1700
228	*Duabanga grandiflora* (DC.) Walp.	Lythraceae							√																						1100
229	*Duchesnea indica* (Jacks.) Focke	Rosaceae														√											√	√	√	√	1800-3300
230	*Edgeworthia gardneri* (Wall.) Meisn.	Thymelaeaceae									√	√	√	√		√	√	√	√	√	√	√		√				√	√		1300-3200
231	*Eeagrostis multicaulis* Steud.	Poaceae				√				√	√														√			√	√		800-3200
232	*Ehretia acuminate* R.Br.	Boraginaceae	√		√				√				√	√																	500-1700
233	*Elaeocarpus lanceifolius* Roxb.	Elaeocarpaceae							√							√															1100-1900
234	*Elaeocarpus rugosus* Roxb.*ex* G.Don	Elaeocarpaceae			√	√	√						√					√													700-2100
235	*Elaphoglossum marginatum* T.Moore	Lomariopsidaceae									√	√																			1300-1500
236	*Elatostema acuminatum* (Poir.) Brongn.	Urticaceae					√								√	√		√	√						√						900-2800
237	*Elatostema obtusum* Wedd.	Urticaceae		√				√	√					√	√	√	√	√		√	√	√	√	√	√	√	√	√	√		600-3200
238	*Elatostema platyphyllum* Wedd.	Urticaceae												√	√		√		√												1600-2200
239	*Elatostema sessile* J.R.Forst. & G.Forst	Urticaceae						√				√		√							√			√							1000-2700
240	*Elsholtzia eriostachya* Benth.	Nyctaginaceae																											√		3100
241	*Elsholtzia flava* Benth.	Lamiaceae									√		√				√		√	√	√	√	√	√	√		√				1300-3000
242	*Elsholtzia fruticosa* (D.Don) Rehder	Lamiaceae															√	√				√									1900-2500
243	*Emilia sonchifolia* (L.) DC.	Asteraceae		√					√		√			√																	600-1700
244	*Engelhardia spicata* var. *integra* (Kurz) W.E.Manning ex Steenis	Juglandaceae	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√													500-2100

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
245	*Enkianthus deflexus* (Griff.) C.K. Schneid.	Ericaceae																	√												2100
246	*Epegenium fuscescens* Griff.	Orchidaceae																		√	√	√	√	√	√	√					2200-2900
247	*Epipactis royleana* Lindl.	Orchidaceae																			√										2800
248	*Equisetum arvense* L.	Equisetaceae							√			√		√		√															1100-1900
249	*Eragrostis atrovirens* (Desf.) Trin.	Poaceae	√							√				√				√		√		√	√			√					500-2900
250	*Eragrostis nigra* Nees ex Steud.	Poaceae												√	√			√	√		√										1600-2400
251	*Eragrostis unioloides* (Retz.) Nees *ex* Steud.	Poaceae		√			√		√					√					√												600-2200
252	*Eria lasiopetala* (Willd.) Ormerod	Orchidaceae	√																												500
253	*Eria stricta* Lindl.	Orchidaceae	√																												500
254	*Erigeron Canadensis* L.	Asteraceae							√	√	√																				1100-1400
255	*Erigeron karvinskianus* DC.	Asteraceae	√											√							√										500-2400
256	*Eriobotrya petiolata* Hook.f.	Rosaceae																√		√											2000-2300
257	*Erythrina arborescens* W.Roxb.	Leguminosae	√												√		√														500-2000
258	*Erythrina stricta* W.Roxb.	Leguminosae			√						√			√	√	√				√											700-2300
259	*Esmeralda cathcartii* (Lindl.) Rchb.f.	Orchidaceae	√																												500
260	*Eucalyptus tereticornis* Sm.	Myristicaceae	√	√						√						√															500-1900
261	*Eupatorium cannabinum* L.	Asteraceae	√	√	√	√	√	√	√	√	√	√		√	√	√	√		√	√	√	√									500-2500
262	*Euphorbia hirta* L.	Euphorbiaceae														√															1800
263	*Eurya acuminate* DC.	Pentaphylacaceae					√													√											900-2300
264	*Eurya cerasifolia* (D.Don) Kobuski	Pentaphylacaceae																√	√						√						2000-2800
265	*Eurya japonica* Thunb.	Pentaphylacaceae			√		√	√		√		√	√	√	√	√	√	√	√	√	√	√	√	√			√				700-3000

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
266	*Evodia fraxinifolia* (Hook.) Benth.	Rutaceae					√									√		√	√			√									900-2500
267	*Exbucklandia populnea* (R.Br. *ex* Griff.) R.W.Br.	Hamamelidaceae				√													√						√		√				800-3000
268	*Ficus hirta* Vahl	Moraceae	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√			√									500-2500
269	*Ficus nemoralis* Wall.	Moraceae																	√												2100
270	*Ficus neriifolia* Sm.	Moraceae												√		√		√		√	√	√									1600-2500
271	*Ficus religiosa* L.	Moraceae								√																					1200
272	*Ficus roxburghii* Lour.	Moraceae	√					√		√																					500-1300
273	*Ficus sarmentosa* Buch.-Ham. *ex* Sm.	Moraceae												√			√	√			√										1600-2400
274	*Ficus subincisa* Buch.-Ham. *ex* Sm.	Moraceae										√		√		√	√		√												1400-2200
275	*Flemingia strobilifera* (L.) W.T.Aiton	Leguminosae		√																											600
276	*Fragaria daltoniana* J.Gay	Rosaceae																				√	√	√	√	√	√	√	√		2400-3200
277	*Fragaria nubicola* (Lindl. *ex* Hook.) Lacaita	Rosaceae																					√								2500
278	*Fragaria vesca* L.	Rosaceae													√		√		√	√	√	√	√	√		√	√			√	1700-3300
279	*Fraxinus floribunda* Wall.	Oleaceae											√		√		√														1500-2000
280	*Galium elegans* Wall. *ex* Roxb.	Rubiaceae																					√		√	√	√				2500-3000
281	*Garuga floribunda* Decne.	Burseraceae														√		√	√	√	√										1800-2400
282	*Gastrochilus calceolaris* (Sm.) D.Don	Orchidaceae																√													2000
283	*Girardinia diversifolia* (Link) Friis	Urticaceae			√						√				√		√		√				√			√					700-2900
284	*Globba clarkei* Baker	Zingiberaceae											√	√	√																1500-1800
285	*Glochidion acuminatum* Müll.-Arg.	Phyllanthaceae														√		√	√	√				√	√		√	√	√		1800-3200
286	*Glochidion thomsonii* (Müll.-Arg.) Hook.f.	Phyllanthaceae				√	√				√		√																		800-1600

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287	*Grewia serrulata* DC.	Malvaceae	√																												500
288	*Gynocardia odorata* R.Br.	Achariaceae					√	√																							900-1100
289	*Habenaria pectinata* D.Don	Orchidaceae						√			√																				1000-1400
290	*Hedera nepalensis* K.Koch	Araliaceae																√													2000
291	*Hedychium coccineum* Buch.-Ham. *ex* Sm.	Zingiberaceae	√			√	√				√		√		√		√														500-2000
292	*Hedychium ellipticum* Buch.-Ham. *ex* Sm.	Zingiberaceae	√																												500
293	*Hedychium gracile* Roxb.	Zingiberaceae				√				√																					800-1300
294	*Hedychium spicatum* Sm.	Zingiberaceae																		√	√										2200-2400
295	*Helicia nilagirica* Bedd.	Proteaceae						√		√	√	√						√	√												1000-2200
296	*Hemarthria compressa* (L.f.) R.Br.	Poaceae								√	√	√		√	√																1200-1800
297	*Hemiphragma heterophyllum* Wall.	Plantaginaceae																				√	√		√	√			√	√	2400-3300
298	*Henckelia urticifolia* (Buch.-Ham. *ex* D.Don) Dietrich	Gesneriaceae	√																												500
299	*Heracleum wallichii* DC.	Apiaceae														√					√			√			√				1800-3000
300	*Himalaiella deltoidea* (DC.) Raab-Straube	Asteraceae														√								√	√					√	1800-3300
301	*Himalayacalamus falconeri* (Hook. *ex* Munro) Keng f.	Poaceae																						√	√	√	√	√		√	2600-3300
302	*Himalayacalamus hookerianus* (Munro) Stapleton	Poaceae												√	√		√	√	√	√	√										1600-2400
303	*Hippochaete debilis* (Roxb.*ex* Vaucher) Ching	Equisetaceae																		√								√			2200-3100
304	*Holboellia latifolia* Wall.	Berberidaceae																√													2000
305	*Holmskioldia sanguine* Retz.	Lamiaceae				√							√					√				√									800-2500
306	*Houttuynia cordata*Thunb.	Saururaceae											√	√	√	√	√		√							√					1500-2900
307	*Huperzia hamiltonii* (Spring) Trev.	Lycopodiaceae																		√	√										2200-2400

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308	*Huperzia pulcherrima* (Wall. *ex* Hook. et Grev.) T.Sen & U.Sen	Lycopodiaceae												√	√	√	√	√		√	√										1600-2400
309	*Huperzia serrata* (Thunb.) Trevis.	Lycopodiaceae	√																												500
310	*Huperzia squarrosa* (Forst.) Trev.	Lycopodiaceae			√	√																									600-800
311	*Hydrangea robusta* Hook.f.& Thomson	Hydrangeaceae																		√								√			2200-3100
312	*Hydrocotyle javanica* Thunb.	Araliaceae			√		√	√	√	√		√	√		√					√	√	√		√	√						700-2800
313	*Hydrocotyle sibthorpioides* Lam.	Araliaceae																			√			√			√	√		√	2200-3300
314	*Ilex dipyrena* Wall.	Aquifoliaceae														√				√	√				√				√		1800-3200
315	*Impatiens discolour* DC.	Balsaminaceae		√												√	√						√								600-2600
316	*Impatiens puberula* DC.	Balsaminaceae																						√							2600
317	*Impatiens racemosa* DC.	Balsaminaceae						√	√		√	√																			1000-1500
318	*Impatiens scabrida* DC.	Balsaminaceae								√	√																				1200-1400
319	*Impatiens sulcata* Wall.	Balsaminaceae																				√	√								2400-2600
320	*Impatiens urticifolia* Wall.	Balsaminaceae														√				√		√	√								1800-2600
321	*Imperata cylindrica* (L.) Raeusch.	Poaceae	√		√		√	√	√	√	√	√		√		√		√								√				√	500-3300
322	*Ione bicolour* Lindl.	Orchidaceae																		√											2200
323	*Isachne albens*Trin.	Poaceae										√	√	√	√			√	√												1400-2200
324	*Isachne globosa* (Thunb.) Kuntze	Poaceae		√	√			√		√	√	√																			600-1500
325	*Isachne himalaica* Hook.f.	Poaceae	√	√	√		√	√	√			√	√																√	√	500-3300
326	*Isachne sikkimensis* Bor	Poaceae																			√			√							2300-2700
327	*Ixeris polycephala* Cass.	Asteraceae																					√								2500
328	*Juglans regia* L.	Juglandaceae											√	√													√				1500-3000

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
329	*Juncus prismatocarpus* R.Br.	Juncaceae																					√								2500
330	*Juniperus procera* Hochst.	Cupressaceae															√		√								√		√		1900-3200
331	*Juniperus recurva* Buch.-Ham. *ex* D.Don	Cupressaceae																								√			√	√	2800-3300
332	*Knema cinerea* var. *glauca* (Blume) Y.H. Li	Myristicaceae				√																									800
333	*Lantana camara* L.	Verbenaceae		√			√			√	√	√																			600-1500
334	*Laphangium affine* (D.Don) Tzvelev	Asteraceae																												√	3200-3300
335	*Laportea bulbifera* (Siebold & Zucc.) Wedd.	Urticaceae	√			√									√																500-1800
336	*Lasiococca symphyllifolia* (Kurz) Hook. f.	Euphorbiaceae	√			√																									500-800
337	*Lecanthus peduncularis* (Wall.*ex* Royle) Wedd.	Urticaceae	√	√		√		√	√	√		√	√	√	√		√	√	√	√	√	√	√			√	√				500-3000
338	*Leea macrophylla* Roxb. *ex* Hornem.	Vitaceae			√	√	√																								700-1000
339	*Lemmaphyllum rostratum* (Bedd.) Tagawa	Polypodiaceae								√	√	√																			1200-1500
340	*Lepidagathis incurve* Buch.-Ham. *ex* D. Don	Acanthaceae															√														1900
341	*Lepisorus clathretus* (C.B.Clarke) Ching	Polypodiaceae																									√	√			2900-3100
342	*Lepisorus loriformis* (Wall. *ex* Mett.) Ching	Polypodiaceae																		√	√	√		√	√	√	√	√	√		2200-3200
343	*Lepisorus mehrae* Fraser-Jenk.	Polypodiaceae														√	√	√	√												1800-2200
344	*Lepisorus sublinearis* (Baker) Ching	Polypodiaceae																	√												2100
345	*Leptodermis kumaonensis* R.Parker	Rubiaceae														√				√											1800-2300
346	*Leucas lanata* Benth.	Lamiaceae		√			√			√					√	√	√				√	√		√	√		√				600-3000
347	*Leucosceptrum canum* Sm.	Lamiaceae														√			√	√		√		√	√	√	√				1800-3000

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
348	*Leucostegia truncata* (D.Don) Fraser-Jenk.	Davalliaceae	√	√																											500-700
349	*Lindenbergia grandiflora* (Buch.-Ham.*ex* D. Don) Benth.	Plantaginaceae					√		√																						900-1200
350	*Lindsaea odorata* Roxb.	Lindsaeaceae														√			√						√						1800-2800
351	*Liparis resupinata* Ridl.	Orchidaceae											√	√			√	√													1500-2100
352	*Liparis viridifolia* (Blume) Lindl.	Orchidaceae								√	√	√	√	√	√	√	√	√	√												1200-2200
353	*Lithocarpus elegans* (Blume) Hatus. *ex* Soepadmo	Fagaceae																						√							2600
354	*Lithocarpus fenestratus* (Roxb.) Rehder	Fagaceae					√					√	√	√																	900-1700
355	*Lithocarpus pachyphyllus* (Kurz) Rehder	Fagaceae																				√	√	√	√	√	√				2400-3000
356	*Litsea albescens* (Hook.f.) D.G. Long	Lauraceae															√		√	√	√	√	√								1900-2600
357	*Litsea cubeba* (Lour.) Pers.	Lauraceae					√								√					√				√							900-2600
358	*Litsea monopetala* (Roxb.) Pers.	Lauraceae				√																									800
359	*Litsea salicifolia* (J.Roxb. *ex* Nees) Hook.f.	Lauraceae					√	√	√									√											√		900-3200
360	*Litsea sericea* (Wall. *ex* Nees) Hook.f.	Lauraceae																	√	√		√		√	√		√	√			2100-3100
361	*Lonicera acuminate* Wall.	Caprifoliaceae																					√	√							2500-2700
362	*Loxogramme cuspidata* (Zenker) M.G. Price	Polypodiaceae													√	√															1700-1900
363	*Loxogramme involuta* (D.Don) C.Presl	Polypodiaceae		√	√	√	√	√	√	√	√		√	√	√	√	√														600-2000
364	*Lycopodium clavatum* L.	Lycopodiaceae															√			√		√	√			√	√			√	1900-3300
365	*Lygodium flexuosum* (L.) Sw.	Lygodiaceae			√	√																									700-900
366	*Lyonia ovalifolia* (Wall.) Drude	Ericaceae				√				√	√	√	√	√										√	√	√	√	√	√	√	800-3300

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
367	*Lyonia villosa* (Wall.*ex* C.B.Clarke) Hand.-Mazz.	Ericaceae																	√						√						2100-2800
368	*Macaranga indica* Wight	Euphorbiaceae		√		√	√	√	√	√		√	√	√																	600-1700
369	*Machilus edulis* King *ex* Hook.f.	Lauraceae														√	√	√	√	√		√		√	√		√				1800-3000
370	*Machilus gamblei* King *ex* Hook.f.	Lauraceae																	√			√		√							2100-2700
371	*Machilus gammieana* King	Lauraceae																							√						2700
372	*Machilus glaucescens* (Nees) H.W. Li	Lauraceae														√	√		√				√	√			√				1800-3000
373	*Machilus kurzii* King *ex* Hook.f.	Lauraceae																		√	√	√	√	√				√			2200-3100
374	*Maesa chisia* Buch.-Ham. *ex* D. Don	Primulaceae	√		√	√	√	√	√	√	√	√	√	√	√	√		√	√	√		√		√		√					500-2900
375	*Magnolia campbellii* Hook.f. & Thomson	Magnoliaceae																	√			√	√	√	√	√	√	√	√		2100-3200
376	*Magnolia cathcartii* (Hook.f. & Thomson) Noot.	Magnoliaceae														√	√														1800-2000
377	*Magnolia champaca* (L.) Baill. *ex* Pierre	Magnoliaceae									√		√		√																1300-1800
378	*Magnolia doltsopa* (Buch.-Ham. *ex* DC.) Figlar	Magnoliaceae														√			√			√			√						1800-2800
379	*Magnolia globosa* Hook.f. & Thomson	Magnoliaceae																	√												2100
380	*Magnolia hodgsonii* (Hook.f. & Thomson) H.Keng	Magnoliaceae				√	√			√																					700-1300
381	*Magnolia lanuginosa* (Wall.) Figlar & Noot.	Magnoliaceae												√		√			√	√		√									1600-2500
382	*Mahonia napaulensis* DC.	Berberidaceae											√							√							√				1500-3000
383	*Maianthemum oleraceum* (Baker) LaFrankie	Asparagaceae																						√	√	√					2600-2900
384	*Malaxis muscifera* (Lindl.) Kuntze	Orchidaceae																									√				2900

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
385	*Mallotus nepalensis* Müll.-Arg.	Euphorbiaceae										√												√			√				1400-3000
386	*Mallotus philippensis* (Lam.) Müll.-Arg.	Euphorbiaceae	√				√	√										√													500-2100
387	*Mallotus roxburghianus* Müll.-Arg.	Euphorbiaceae			√	√								√	√																700-1800
388	*Mallotus tetracoccus* (Roxb.) Kurz	Euphorbiaceae					√	√	√						√																900-1800
389	*Marsilea minuta* L.	Marsileaceae																				√									2400
390	*Meconopsis simplicifolia* (D.Don) Walp.	Papaveraceae																						√							2600
391	*Meizotropis buteiformis* Voigt	Leguminosae								√																					1200
392	*Melastoma malabathricum* L.	Melastomataceae			√	√	√	√		√	√	√			√	√	√		√	√	√		√								700-2600
393	*Meliosma dilleniifolia* (Wight & Arn.) Walp.	Sabiaceae															√	√	√												1900-2200
394	*Meliosma pinnata* (Roxb.) Maxim.	Sabiaceae																				√								√	2400-3300
395	*Meliosma simplicifolia* (Roxb.) Walp.	Sabiaceae					√						√		√	√	√														900-2000
396	*Melochia corchorifolia* L.	Malvaceae					√					√								√											900-2300
397	*Microlepia strigosa* (Thunb.) C. Presl	Dennstaedtiaceae														√				√		√									1800-2500
398	*Micropera manni* (Hook.f.)Tang & F.T. Wang	Orchidaceae		√																											600
399	*Microsorum punctatum* (L.) Copel	Polypodiaceae			√		√	√	√	√																					700-1300
400	*Mikania micrantha* Kunth	Asteraceae	√	√	√	√		√											√					√	√	√					500-2900
401	*Mimosa himalayana* Gamble	Leguminosae					√		√	√					√	√	√				√										900-2400
402	*Morus alba* L.	Moraceae	√	√	√	√		√		√																					500-1300
403	*Morus indica* L.	Moraceae														√															1800
404	*Mucuna macrocarpa* Wall.	Leguminosae																						√	√	√					2600-2900
405	*Musa xparadisiaca* L.	Musaceae												√																	1600

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
406	*Mussaenda treutleri* Stapf	Rubiaceae	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√		√	√								500-2600
407	*Myrsine semiserrata* Wall.	Primulaceae																		√	√										2200-2400
408	*Nasturtium officinale* R.Br.	Brassicaceae																						√							2600
409	*Nepeta lamiopsis* Benth. *ex* Hook.f.	Lamiaceae																			√						√				2300-3000
410	*Nephrolepis cordifolia* (L.) C. Presel	Nephrolepidaceae	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√				√	√	√	√	√	√		√		500-3200
411	*Nerium oleander* L.	Apocynaceae				√																									800
412	*Neyraudia arundinacea* (L.) Henrard	Poaceae													√					√											1700-2300
413	*Nyssa javanica* (Blume) Wangerin	Cornaceae														√	√					√									1800-2500
414	*Oberonia falcata* King & Pantl.	Orchidaceae									√	√	√																		1300-1600
415	*Oberonia obcordata* Lindl.	Orchidaceae		√																											600
416	*Oberonia rufilabris* Lindl.	Orchidaceae								√																					1200
417	*Odontosoria chinensis* (L.) Sm.	Lindsaeaceae												√						√											1600-2300
418	*Oenanthe thomsonii* C.B. Clarke	Apiaceae																				√									2400
419	*Oleandra wallichii* (Hook.) C.Presl	Oleandraceae																				√	√	√	√	√					2400-2900
420	*Oplismenus burmannii* (Retz.) P. Beauvois	Poaceae				√	√			√																					800-1300
421	*Oplismenus compositus* (L.) P.Beauvois	Poaceae		√	√	√	√	√		√		√			√										√	√	√	√			600-3100
422	*Oroxylum indicum* (L.) Kurz	Bignoniaceae					√																								900
423	*Osbeckia crinite* Benth. *ex* C.B. Clarke	Melastomataceae	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√								700-2600
424	*Osbeckia stellata* Buch.-Ham. *ex* Ker Gawl.	Melastomataceae			√	√	√						√		√		√	√				√									700-2500
425	*Ostodes paniculata* Blume	Euphorbiaceae	√	√	√	√	√	√	√	√	√	√	√		√																500-1800
426	*Oxalis corniculata* L.	Oxalidaceae	√	√	√	√		√	√			√	√	√	√	√			√												500-2200

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
427	*Oxyspora paniculata* (D. Don) DC.	Melastomataceae											√	√	√		√	√													1500-2100
428	*Paederia foetida* L.	Rubiaceae					√											√	√			√									2000-2500
429	*Panax pseudo-ginseng* Wall.	Araliaceae																										√			3000
430	*Pandanus furcatus* Roxb.	Pandanaceae	√	√	√		√	√		√																					500-1300
431	*Panisea demissa* (D.Don) Pfitzer	Orchidaceae																√	√												2000-2200
432	*Panisea uniflora* (Lindl.) Lindl.	Orchidaceae						√																							1000
433	*Parthenium hysterophorus* L.	Asteraceae						√																							1000
434	*Paspalum scrobiculatum* L.	Poaceae										√		√	√	√	√			√		√									1400-2500
435	*Pavetta indica* L.	Rubiaceae	√			√	√	√		√								√													500-2100
436	*Peranema paleolulata* (Pichi-Serm.) Fraser-Jenk.	Dryopteridaceae											√							√		√	√	√	√		√			√	1500-3300
437	*Peristrophe fera* C.B. Clarke	Acanthaceae																√													2000
438	*Persea odoratissima* (Nees) Kosterm.	Lauraceae											√										√								1500-2600
439	*Persicaria alpine* (All.) H. Gross	Polygonaceae																		√		√									2200-2500
440	*Persicaria amplexicaulis* (D.Don) Ronse Decr.	Polygonaceae																		√		√	√		√	√	√		√		2200-3200
441	*Persicaria bistorta* (L.) Samp.	Polygonaceae																						√							2600
442	*Persicaria campanulata* (Hook.f.) Ronse Decr.	Polygonaceae																		√											2200
443	*Persicaria capitata* (Buch.-Ham.*ex* D.Don) H.Gross	Polygonaceae		√				√	√	√	√	√	√	√				√	√			√	√	√							600-2700
444	*Persicaria chinensis* (L.) H. Gross	Polygonaceae													√																1700
445	*Persicaria glabra* (Willd.) M.Gómez	Polygonaceae																		√		√		√	√						2200-2800
446	*Persicaria hydropiper* (L.) Delarbre	Polygonaceae			√									√				√	√			√	√		√						700-2800

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
447	*Persicaria lapathifolia* (L.) Delarbre	Polygonaceae			√								√	√					√						√			√	√		700-3200
448	*Persicaria nepalensis* (Meisn.) Miyabe	Polygonaceae																	√			√			√						2100-2800
449	*Persicaria polystachya* Opiz	Polygonaceae													√	√	√		√	√		√		√	√	√					1700-2900
450	*Persicaria tinctoria* (Aiton) H.Gross	Polygonaceae							√			√		√																	1100-1700
451	*Persicaria vivipara* (L.) Ronse Decr.	Polygonaceae																					√		√		√				2500-3000
452	*Phalaenopsis mannii* Rchb.f.	Orchidaceae	√																												500
453	*Phegopteris hexagonoptera* (Michx.) Fée	Thelypteridaceae														√				√		√				√		√			1800-3100
454	*Phlebodium aureum* (L.) Sm.	Polypodiaceae	√			√																									500-900
455	*Pholidota articulate* Lindl.	Orchidaceae				√	√		√																						800-1200
456	*Pholidota imbricate* Lindl.	Orchidaceae						√											√												1000-2200
457	*Phyllanthus emblica* L.	Phyllanthaceae																											√		3100
458	*Physalis divaricata* D. Don	Solanaceae																			√						√				2300-3000
459	*Pilea approximata* CB.Clarke	Urticaceae																						√						√	2600-3300
460	*Pilea bracteosa* Wedd.	Urticaceae																		√											2200
461	*Pilea glaberrima* (Blume) Blume	Urticaceae		√		√	√			√		√	√	√	√		√		√	√	√		√					√			600-3100
462	*Pilea scripta* (Buch.-Ham. *ex* D. Don) Wedd.	Urticaceae																		√	√	√									2200-2500
463	*Pilea ternifolia* Wedd.	Urticaceae																						√					√	√	2600-3300
464	*Pilea umbrosa* Blume	Urticaceae												√		√	√			√	√	√	√	√			√	√			1600-3100
465	*Piper betleoides* C.DC.	Piperaceae	√	√	√	√	√	√		√	√		√	√	√		√	√	√						√						500-2800
466	*Piper suipigua* D.Don	Piperaceae																	√	√						√					2100-2800
467	*Piper boehmeriifolium* (Miq.) Wall. *ex* C. DC	Piperaceae														√		√				√				√					1800-2900

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
468	*Plagiogyria pycnophylla* (Kunze) Mett.	Plagiogyriaceae													√				√												1700-2200
469	*Plantago asiatica subsp. erosa* (Wall.) Z.Yu Li	Plantaginaceae	√		√	√		√					√		√		√	√	√												500-2200
470	*Plantago depressa* Willd.	Plantaginaceae																		√			√		√	√		√			2200-3100
471	*Platanthera arcuata* Lindl.	Orchidaceae																					√								2500
472	*Plectranthus barbatus* Andrews	Lamiaceae														√				√		√	√			√	√	√	√		1800-3200
473	*Pleione humilis* (Sm.) D.Don	Orchidaceae																		√							√	√			2200-3100
474	*Pleione praecox* (Sm.) D.Don	Orchidaceae																									√				2900
475	*Poa annua* L.	Poaceae														√				√								√			1800-3100
476	*Podocarpus neriifolius* D.Don	Podocarpaceae	√																												500
477	*Podochilus cultratus* Lindl.	Orchidaceae			√																										700
478	*Pogonatherum crinitum* (Thunb.) Kunth	Poaceae				√	√			√					√		√		√									√			800-3100
479	*Pogonatherum paniceum* (Lam.) Hack	Poaceae	√			√	√		√	√		√																			500-1500
480	*Pogostemon benghalensis* (Burm.f.) Kuntze	Lamiaceae							√																						1100
481	*Pogostemon fraternus* Miq.	Lamiaceae																		√		√									2200-2500
482	*Polygonum molle* D. Don	Polygonaceae													√	√				√		√		√	√	√	√	√	√	√	1700-3300
483	*Polygonum runcinatum* Buch.-Ham.*ex* D Don	Polygonaceae	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√		√			√	√	√		500-3200
484	*Polypodiodes amoena* (Wall.*ex* Mett.) Ching	Polypodiaceae											√						√												1500-2200
485	*Polypodium polypodioides* (L.) Watt	Polypodiaceae														√						√									1800-2400
486	*Polystichum acrostichoides* (Michx.) Schott	Dryopteridaceae																				√	√								2400-2600
487	*Polystichum lentum* (D. Don) T. Moore	Dryopteridaceae	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√			√		√	√		500-3200

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
488	*Populus gamblei* Dode	Salicaceae	√					√	√	√	√	√																			500-1500
489	*Porana paniculata* Roxb.	Convolvulaceae				√	√		√	√	√	√																			800-1500
490	*Porpax elwesii* (Rchb.f) Rolfe	Orchidaceae			√																										700
491	*Potentilla fulgens* Trevir.	Rosaceae													√						√			√	√			√			1700-3100
492	*Potentilla multifida* L.	Rosaceae																										√			3000
493	*Pouzolzia hirta* Blume *ex* Hassk.	Urticaceae					√							√	√			√		√				√	√	√					900-2900
494	*Pouzolzia zeylanica* (L.) Benn.	Urticaceae	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√	√	√			√							500-2700
495	*Premna barbata* Wall.*ex* Schauer	Lamiaceae	√				√	√	√		√	√		√						√				√							500-2700
496	*Primula capitata* Hook.	Primulaceae																								√		√		√	2800-3300
497	*Primula denticulate* Sm.	Primulaceae																					√			√				√	2500-3300
498	*Primula petiolaris* Wall.	Primulaceae																					√	√	√		√				2500-2900
499	*Primula pulchra* Watt	Primulaceae																										√	√		3000-3200
500	*Prinsepia utilis* Royle	Rosaceae																							√						2700
501	*Prunus cerasoides* Buch.-Ham. *ex* D.Don	Rosaceae				√	√	√	√	√			√	√		√	√	√	√											√	800-3300
502	*Prunus nepalensis* Ser.	Rosaceae														√							√	√	√		√	√	√		1800-3200
503	*Prunus persica* (L.) Batsch	Rosaceae			√								√																		700-1600
504	*Prunus wallichii* Steud.	Rosaceae																		√											2200
505	*Pseudognaphalium hypoleucum* (DC.) Hilliard & B.L.Burtt	Asteraceae																		√		√									2200-2500
506	*Pteracanthus urticifolius* (Wall.*ex* Kuntze) Bremek	Acanthaceae										√				√	√			√					√						1400-2800
507	*Pteridium aquilinum* (L.) Kuhn	Dennstaedtiaceae	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	500-3300
508	*Pteridium revolutum* (Blume) Nakai	Dennstaedtiaceae																									√				2900
509	*Pteris biaurita* L.	Pteridaceae	√	√	√	√		√	√	√	√	√	√	√			√	√													500-2100

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
510	*Pteris linearis* Poir.	Pteridaceae								√	√	√		√	√				√												1200-2200
511	*Pteris longipes* D. Don	Pteridaceae										√	√	√	√	√		√	√					√	√		√				1400-3000
512	*Pteris scabririgens* Fraser-Jenk., S.C. Verma & T.G. Walker	Pteridaceae																				√	√								2400-2600
513	*Pteris spinescens* C. Presl	Pteridaceae																											√	√	3100-3300
514	*Pteris wallichiana* J. Agardh	Pteridaceae						√				√														√					1000-2900
515	*Pyrrosia costata* (C.Presl) Tagawa & K.Iwats.	Polypodiaceae	√	√				√		√	√																				500-1400
516	*Pyrrosia flocculosa* (D.Don) Ching	Polypodiaceae				√																									800
517	*Pyrrosia lanceolata* (L.) Farw.	Polypodiaceae	√	√	√																										500-800
518	*Pyrrosia mannii* (Giesenh.) Ching	Polypodiaceae	√		√	√					√		√																		500-1600
519	*Pyrrosia porosa* (C.Presl) Hovankamp	Polypodiaceae				√								√	√	√	√	√													800-2100
520	*Pyrularia edulis* (Wall.) A.DC.	Santalaceae																					√								2500
521	*Quercus glauca* Thunb.	Fagaceae				√	√	√		√		√			√		√														800-2000
522	*Quercus lamellose* Sm.	Fagaceae														√	√	√	√	√	√	√	√	√	√	√	√	√			1800-3100
523	*Quercus lanata* Sm.	Fagaceae						√										√													1000-2100
524	*Quercus laurifolia* Michx.	Fagaceae																	√					√							2100-2700
525	*Quercus lineata* Blume	Fagaceae				√	√		√	√					√				√	√	√		√	√	√						800-2800
526	*Ranunculus laetus* Wall. *ex* Hook.f. & J.W. Thomson	Ranunculaceae																			√										2300
527	*Reevesia pubescens* Mast.	Malvaceae	√					√		√			√			√	√	√	√	√			√								500-2600
528	*Remusatia hookeriana* Schott	Araceae										√	√	√	√		√	√	√												1400-2200
529	*Remusatia pumila* (D.Don) H.Li & A.Hay	Araceae														√	√														1800-2000
530	*Rhamnus napalensis* (Wall.) M.A. Lawson	Rhamnaceae	√	√		√												√													500-2100

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
531	*Rhaphidophora decursiva* (Roxb.) Schott	Araceae								√	√	√	√	√	√																1200-1800
532	*Rhododendron anthopogon* D. Don	Ericaceae																									√				2900
533	*Rhododendron arboretum* Sm.	Ericaceae																	√							√	√	√	√	√	2100-3300
534	*Rhododendron barbatum* Wall. *ex* G. Don	Ericaceae																	√			√		√	√	√	√	√	√	√	2100-3300
535	*Rhododendron campylocarpum* Hook.f.	Ericaceae																										√			3000
536	*Rhododendron dalhousieae* Hook.f.	Ericaceae																												√	3300
537	*Rhododendron falconeri* Hook.f.	Ericaceae																							√		√	√	√	√	2700-3300
538	*Rhododendron fulgens* Hook.f.	Ericaceae																											√	√	3100-3300
539	*Rhododendron griffithianum* Wight	Ericaceae																					√				√	√	√	√	2500-3300
540	*Rhododendron hodgsonii* Hook.f.	Ericaceae																					√	√	√		√	√	√		2500-3200
541	*Rhododendron thomsonii* Hook.f.	Ericaceae																									√	√	√	√	2900-3300
542	*Rhododendron triflorum* Hook.f.	Ericaceae																		√		√	√	√	√			√	√		2200-3200
543	*Rhododendron vaccinioides* Hook.	Ericaceae																					√	√		√	√	√	√	√	2500-3300
544	*Rhus succedanea* L.	Anacardiaceae										√	√	√	√		√	√	√												1400-2200
545	*Rohdea nepalensis* (Raf.) N.Tanaka	Asparagaceae							√			√	√							√				√	√		√	√			1100-3100
546	*Rubia manjith* Roxb. ex Fleming	Rubiaceae									√		√	√				√		√	√	√	√	√	√	√	√			√	1300-3300
547	*Rubus acuminatus* Sm.	Rosaceae														√				√											1800-2300
548	*Rubus calycinoides* Kuntze	Rosaceae				√		√									√					√		√					√		800-3200
549	*Rubus ellipticus* Sm.	Rosaceae				√			√	√		√	√	√	√	√	√	√	√	√		√	√	√			√	√		√	800-3300

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
550	*Rubus fragarioides* Bertol.	Rosaceae																			√										2300
551	*Rubus insignis* Hook.f.	Rosaceae					√	√	√				√	√		√		√	√		√	√	√							√	900-3300
552	*Rubus kumaonensis* N.P. Balkr.	Rosaceae												√	√		√		√												1600-2200
553	*Rubus lineatus* Reinw.*ex* Blume	Rosaceae					√								√									√							900-2700
554	*Rubus nepalensis* (Hook.f.) Kuntze	Rosaceae		√																		√	√	√	√	√	√				600-3000
555	*Rubus niveus*Thunb.	Rosaceae																						√							2600
556	*Rubus phengodes* Focke	Rosaceae							√		√	√							√	√						√		√	√		1100-3200
557	*Rubus rugosus* Sm.	Rosaceae					√																								900
558	*Rubus splendidissimus* H.Hara	Rosaceae																										√	√		3000-3200
559	*Rumex nepalensis* Spreng.	Polygonaceae															√			√		√		√	√	√					1900-2900
560	*Sambucus javanica* Blume	Adoxaceae									√																				1300
561	*Sapindus rarak* DC.	Sapindaceae						√																							1000
562	*Satyrium nepalense* D.Don	Orchidaceae									√				√																1300-1800
563	*Saurauia fasciculate* Wall.	Actinidiaceae					√			√	√									√			√				√				900-3000
564	*Sauropus androgynus* (L.) Merr.	Euphorbiaceae		√																											600
565	*Schima wallichii* Choisy	Theaceae	√	√	√	√	√	√	√	√	√	√	√	√	√				√												500-2200
566	*Schisandra grandiflora* (Wall.) Hook.f. & Thomson	Schisandraceae																						√							2600
567	*Selaginella acanthostachys* Baker	Selaginellaceae																					√	√	√					√	2500-3300
568	*Selaginella ciliaris* (Retz.) Spring	Selaginellaceae			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√				√				700-3000
569	*Selaginella martensii* Spring	Selaginellaceae			√		√			√	√	√	√		√						√				√						700-2800
570	*Selaginella pallescens* (C. Presl) Spring	Selaginellaceae			√											√	√		√		√	√	√		√			√	√		700-3200

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571	*Selaginella willdenovii* (Desv. *ex* Poir.) Baker	Selaginellaceae						√		√	√	√																			1000-1500
572	*Selinum wallichianum* (DC.) Raizada & H.O. Saxena	Apiaceae																										√			3000
573	*Selliguea griffithiana* (Hook) Fraser-Jenk.	Polypodiaceae											√	√	√		√			√	√	√	√	√	√	√	√	√	√		1500-3200
574	*Selliguea oxyloba* (Wall. *ex* Kunze.) Fraser-Jenk.	Polypodiaceae																		√	√										2200-2400
575	*Senecio buimalia* Buch.-Ham. *ex* D.Don	Asteraceae																						√							2600
576	*Senna occidentalis* (L.) Link	Leguminosae			√																√										700-2400
577	*Senna tora* L.Roxb.	Leguminosae					√																								900
578	*Setaria palmifolia* (J.Koenig) Stapf	Poaceae	√	√	√	√	√	√	√	√		√	√		√	√	√	√	√	√		√	√	√			√				500-3000
579	*Setaria pumila* (Poir.) Roem. & Schult.	Poaceae						√				√	√																		1000-1600
580	*Shorea robusta* Gaertn.	Dipterocarpaceae				√																									800
581	*Sida acuta* Burm.f.	Malvaceae						√																							1000
582	*Sigesbeckia orientalis* L.	Asteraceae					√																								900
583	*Sinopodophyllum hexandrum* (Royle) T.S.Ying	Berberidaceae						√	√	√		√																√			1000-3100
584	*Smilax bracteata* C.Presl	Smilacaceae			√		√	√	√	√	√	√		√	√		√		√	√	√						√		√		700-3200
585	*Solanum aculeatissimum* Jacq.	Solanaceae													√					√		√	√	√			√				1700-3000
586	*Solanum torvum* Sw.	Solanaceae							√																						1100
587	*Sorbus cuspidata* (Spach) Hedl.	Rosaceae																						√		√	√				2600-3000
588	*Sorbusthomsonii* (King ex Hook.f.) Rehder	Rosaceae																									√	√	√	√	2900-3300
589	*Sphenomeris chinensis* (L.) Maxon	Lindsaeaceae						√																							1000
590	*Spiranthes sinensis* (Pers.) Ames	Orchidaceae									√																				1300

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591	*Stachys melissifolia* Benth.	Lamiaceae									√		√																		1300-1600
592	*Stephania elegans* Hook.f. & Thomson	Menispermaceae	√		√			√																							500-1100
593	*Sterculia lanceifolia* G. Don	Sterculiaceae																						√							2600
594	*Steriochilus hirtus* Lindl.	Orchidaceae	√	√																											500-700
595	*Strobilanthes atropurpureus* Nees	Acanthaceae						√								√				√	√										1000-2400
596	*Strobilanthes capitata* (Nees) T. Anderson	Acanthaceae														√				√		√		√	√	√					1800-2900
597	*Strobilanthes urticifolia* Wall. *ex* Kuntze	Acanthaceae																						√							2600
598	*Styrax hookeri* C.B.Clarke	Styracaceae													√																1700
599	*Swertia angustifolia* Buch.-Ham. *ex* D. Don	Gentianaceae												√			√				√	√	√	√							1600-2700
660	*Swertia chirayita* (Roxb.) Buch.-Ham. ex C.B.Clarke	Gentianaceae														√		√		√	√	√	√	√							1800-2700
601	*Swertia paniculata* Wall.	Gentianaceae																									√				2900
602	*Symplocos cochinchinensis* (Lour.) S. Moore	Symplocaceae										√	√				√			√											1400-2300
603	*Symplocos dryophila* C.B. Clarke	Symplocaceae														√				√			√			√	√	√	√		1800-3200
604	*Symplocos glomerata* King *ex* C.B. Clarke	Symplocaceae														√	√	√	√	√	√	√									1800-2500
605	*Symplocos lucida* (Thunb.) Siebold & Zucc.	Symplocaceae														√	√	√	√	√	√	√	√	√		√		√			1800-3100
606	*Symplosos theifolia* D.Don	Symplocaceae																			√										2300
607	*Synotis cappa* (Buch.-Ham. *ex* D.Don) C.Jeffrey & Y.L.Chen	Asteraceae																			√										2300
608	*Syzygium cumini* (L.) Skeels	Myristicaceae	√		√		√	√	√	√	√																				500-1400
609	*Syzygium formosum* (Wall.) Masam.	Myristicaceae	√			√			√	√	√	√		√																	500-1700

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610	*Syzygium kurzii* (Duthie) N.P.Balakr.	Myristicaceae				√																									800
611	*Syzygium venosum* DC.	Myrtaceae			√			√				√	√	√	√			√													700-2100
612	*Tectaria gemmifera* (Fée) Alston	Tectariaceae	√	√		√	√	√	√		√	√			√	√	√		√	√	√	√	√	√	√	√	√				500-3000
613	*Tectaria macrodonta* C.Chr.	Dryopteridaceae		√						√			√								√	√	√	√							600-2700
614	*Tectaria polymorpha* (Wall. *ex* Hook.) Copel.	Tectariaceae	√	√																											500-700
615	*Terminalia chebula* Retz.	Combretaceae				√								√																	800-1700
616	*Terminalia crenulata* Roth	Combretaceae					√												√		√					√					900-2900
617	*Terminalia myriocarpa*Van Heurck & Müll.-Arg.	Combretaceae		√	√	√	√	√	√	√				√	√	√															600-1900
618	*Tetrastigma bracteolatum* (Wall.) Planch.	Vitaceae						√																							1000
619	*Tetrastigma obtectum* (Wall. *ex* M.A. Lawson) Planch. *ex* Franch.	Vitaceae															√							√							1900-2700
620	*Tetrastigma rumicispermum* (M.A.Lawson) Planch.	Vitaceae	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√		√	√		√							500-2700
621	*Tetrastigma serrulatum* (Roxb.) Planch.	Vitaceae	√																							√					500-2900
622	*Thunia bracteata* (Roxb.) Schltr.	Orchidaceae						√																							1000
623	*Thysanolaena latifolia* (Roxb. *ex* Hornem.) Honda	Poaceae		√	√		√	√	√	√			√	√																	600-1700
624	*Tinospora sinensis* (Lour.) Merr.	Menispermaceae	√	√	√																										500-800
625	*Toona ciliate* M.Roem.	Meliaceae					√	√					√				√	√					√								900-2600
626	*Toxicodendron griffithii* (Hook. f.) Kuntze	Anacardiaceae													√		√														1700-2000
627	*Toxicodendron hookeri* (K.C. Sahni & Bahadur) C.Y. Wu & T.L. Ming	Anacardiaceae	√																√	√	√			√							500-2700

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628	*Trichosanthes lepiniana* (Naudin) Cogn.	Cucurbitaceae	√	√				√							√	√	√			√											500-2300
629	*Trichotosia pulvinata* (Lind.) Kraenzl.	Orchidaceae			√																										700
630	*Triumfetta rhomboidea* Jacq.	Malvaceae	√		√	√	√		√	√	√	√	√			√						√				√					500-2900
631	*Tsuga dumosa* (D.Don) Eichler	Pinaceae																		√			√	√	√	√					2200-2900
632	*Ulmus lanceifolia* Roxb. *ex* Wall.	Ulmaceae	√			√																									500-900
633	*Uncifera obtusifolia* Lindl.	Orchidaceae							√	√																					1100-1300
634	*Urtica dioica* L.	Urticaceae			√										√	√	√		√	√		√		√	√	√			√		700-3200
635	*Urtica hyperborean* Jacq. *ex* Wedd.	Urticaceae																		√		√							√		2200-3200
636	*Urtica parviflora* Roxb.	Urticaceae														√															1800
637	*Vaccinium nummularia* Hook.f. &Thoms. *ex* C.B.Clarke	Ericaceae																		√		√	√		√	√	√	√			2200-3100
638	*Vaccinium vacciniaceum* (Roxb.) Sleumer	Ericaceae														√	√	√	√	√	√		√	√							1700-2700
639	*Vanda pumila* Hook.f.	Orchidaceae		√																											600
640	*Veronica serpyllifolia* L.	Plantaginaceae																		√		√			√						2200-2800
641	*Viburnum cotinifolium* D. Don	Adoxaceae												√			√		√		√	√		√	√	√	√	√	√	√	1600-3300
642	*Viburnum cylindricum* Buch.-Ham. *ex* D. Don	Adoxaceae											√				√	√	√												1500-2200
643	*Viburnum erubescens* Wall.	Adoxaceae														√	√			√	√	√	√	√	√	√	√	√	√		1800-3200
644	*Viburnum grandiflorum* Wall. *ex* DC.	Adoxaceae											√				√				√			√		√		√			1500-3100
645	*Viburnum mullaha* Buch.-Ham.*ex* D. Don	Adoxaceae											√	√																	1500-1700
646	*Viburnum nervosum* D. Don	Adoxaceae												√			√	√							√						2600-2800
647	*Viola betonicifolia* Sm.	Violaceae																						√	√	√	√				2600-3000
648	*Viola canescens* Wall.	Violaceae																		√	√	√	√	√	√						2200-2800

Sl. No	Botanical Name	Family	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Range
649	*Viola pilosa* Blume	Violaceae																					√	√	√	√					2500-2900
650	*Vittaria doniana* Hieron.	Vitaceae	√																												500
651	*Vittaria flexuosa* Fée	Vitaceae											√							√											1500-2300
652	*Vittaria sikkimensis* Kuhn	Vitaceae	√	√																											500-700
653	*Vittaria taeniophylla* Copel.	Vitaceae																										√			3000
654	*Walsura tubulata* Hiern	Meliaceae				√	√	√				√	√								√										800-2400
655	*Woodsia obtusa* Torrey	Woodsiaceae	√	√				√	√		√		√		√																500-1800
656	*Woodwardia unigemmata* (Makino) Nakai	Blechnaceae																		√		√				√	√		√		2200-3200
657	*Xanthium strumarium* L.	Asteraceae				√																									800
658	*Yushania maling* (Gamble) R.B.Majumdar & Karthik.	Poaceae																				√	√	√	√						2400-2800
659	*Yushania pantlingii* (Gamble) R.B.Majumdar	Poaceae																					√	√	√	√	√	√			2500-3100
660	*Zanthoxylum acanthopodium* DC.	Rutaceae																√							√						2000-2800
661	*Zanthoxylum armatum* DC.	Rutaceae																√													2000
662	*Zanthoxylum bungeanum* Maxim.	Rutaceae																								√					2800
663	*Zanthoxylum oxyphyllum* Edgw.	Rutaceae																							√	√					2700-2900
664	*Zanthoxylum rhetsa* DC.	Rutaceae																√													2000

ANNEXURE VI

Annexure VI

Detail description of Soil Classes found in Sikkim

Source: NBSS&LUP, 1996

Soil Unit	Description	Soil class
1	Moderately shallow, somewhat excessively drained, coarse-loamy over fragmental soils on steep slope(30-50%) with loamy surface, slight surface stoniness and moderate erosion	Coarse-loamy over fragmental, thermic Typic Haplumbrepts
	Associated with shallow, somewhat excessively drained, coarse-loamy soils with loamy surface, moderate stoniness and moderate erosion.	Coarse-loamy, thermic Lithic Udorthents
3	Deep, well drained, fine-loamy soils on steep slope (30-50%) with foamy surface, slight stoniness and moderate erosion; associated with deep, somewhat excessively drained, coarse-loamy soils with —loamy surface, moderate stoniness and moderate erosion	Fine-loamy, thermic Pachic Haplumbrepts Coarse-loamy, thermic Entic Haplumbrepts
4	Moderately deep., well drained, fine-loamy soils on steep slope (30-50% with loamy surface, slight stoniness and moderate erosion	Fine-loamy, thermic Typic Haplumbrepts
	Associated with moderately shallow, somewhat excessively drained, loamy-skeletal soils with gravelly loamy surface, moderate stoniness and severe erosion.	Loamy-skeletal thermic Umbric Dystrochrepts
6	Deep, well moderately steep slope (15-30%; with loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Typic Hapludolls
	Associated with moderately deep, excessively drained, coarse-loamy soils with sandy surface, severe erosion and slight stoniness.	Coarse-loamy, thermic Typic Udorthents
7	Moderately deep, somewhat excessively drained, fine-loamy soils on moderately steep slope (15-30%) with loamy surface, moderate erosion and slight stoniness Associated with moderately deep, some-what excessively drained, loamy-skeletal soils with loamy surface, moderate erosion and slight stoniness.	Fine-loamy, thermic Cumulic Haplumbrepts
8	Deep, excessively drained, fine-loamy soils *Q* on moderately steep slope <15-30%V with loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Pachic Haplumbrepts
	Associated with moderately deep, excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness	Coarse-loamy, thermic Typic Haplumbrepts

Soil Unit	Description	Soil class
10	Deep, somewhat excessively drained, fine-loamy soils on very steep slope (>50%) with loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Typic Haplumbrepts
	Associated with moderately deep, somewhat excessively drained, coarse-loamy over fragmental soils with loamy surface, moderate erosion and slight stoniness	Coarse-loamy over fragmental thermic Typic Udorthents
11	Deep, somewhat excessively drained, coarse-loamy soils on very steep slope (>50%) with loamy surface, moderate erosion and slight stoniness	Coarse-loamy thermic Typic Hapludolls
	associated with deep, somewhat excessively drained, coarse-loamy over f fragmental soils with loamy surface., moderate erosion and slight stoniness	Coarse-loamy, over fragmented thermic Entic Hapludolls.
13	Deep, somewhat excessively drained, coarse-loamy soils on very steep slope (>50%) with loamy surface, moderate erosion and slight stoniness	Coarse-loamy, thermic Mollic Udarents
	Associated with moderate erosion, excessively drained, coarse-loamy soils with gravelly loamy surface, severe erosion and strong stoniness	Coarse-loamy, thermic Entic Hapludolls
14	Moderately deep, "well drained, fins-loamy soils on very steep slope >50% with loamy surface, severe erosion and slight stoniness	Fine-Loamy, thermic Typic Dystrochrepts
	Associated with deep, somewhat excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness	Coarse-loamy, thermic Typic Haplumbrepts
15	Deep, somewhat excessively drained, coarse-loamy soils on very steep slope (>50%) with loamy surface, severe erosion and moderate stoniness	Coarse-loamy, thermic Typic Hapludolls
	Associated with deep, somewhat excessively drained, coarse loamy soils with gravelly loamy surface, severe erosion and moderate stoniness	Coarse-loamy, thermic Dystric Eurochrepts
16	Moderately deep, somewhat excessively drained, coarse-loamy over fragmental soils very steep slope (>50%) with loamy, moderate erosion and stoniness	Coarse-loamy over Fragmental thermic Typic Udorthents
	Associated with shallow, somewhat excessively drained, coarse-loamy soils with foamy surface, moderate erosion and slight stoniness	Coarse-loamy, thermic Lithic Haplumbrepts
17	Deep, well drained, fine soils on very steep slope (>50%) with loamy surface, moderate erosion and slight stoniness	Fine, thermic Umbric Dystrochrepts
	Associated with deep, somewhat excessively drained, fine-loamy soils with loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Umbric Dystrochrepts
18	Moderately deep, somewhat excessively drained, coarse loamy soils on very steep slope (>50%) with loamy surface, moderate erosion and slight stoniness	Coarse-loamy, thermic Entic Hapludolls
	Associated with deep, somewhat excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness	Coarse-loamy, thermic Dystric Eurochrepts

Soil Unit	Description	Soil class
19	Deep, somewhat excessively drained coarse-loamy soils on very steep slope (>50%) with loamy surface, severe erosion and moderate stoniness	Coarse-loamy, thermic Typic Hapludolls
	Associated with deep, somewhat excessively drained, dark brown to brown, moderately acidic coarse-loamy soils with loamy surface, moderate erosion and slight stoniness	Coarse-loamy, thermic Entic Hapludolls
21	Deep, somewhat excessively drained, coarse loamy soils on very steep slope (>50%), with loamy surface, moderate erosion and slight stoniness	Coarse-loamy, thermic Typic Hapludolls
	Associated with moderately shallow, somewhat excessively drained, loamy-skeletal soils with gravelly loamy surface, severe erosion and slight stoniness	Loamy-skeletal, thermic Entic Hapludolls
23	Moderately shallow, somewhat excessively drained coarse-loamy soils on very steep slope (>50%)with loamy surface, moderate stoniness	Coarse-loamy, thermic Typic Haplumbrepts
	Associated with moderately deep, somewhat excessively drained, coarse- silty soils with loamy surface, moderate erosion and slight stoniness	Coarse-loamy, thermic Lithic Udorthents
24	Moderately shallow, somewhat excessively drained coarse-loamy soils on very steep slope (>50%)with loamy surface, moderate stoniness	Loamy, skeletal mesic Typic Haplumbrepts
	Associated with moderately deep, somewhat excessively drained, coarse- silty soils with loamy surface, moderate erosion and slight stoniness	Coarse-loamy, mesic Typic Udorthents
25	Moderately deep somewhat excessively loamy soils on very steep slope (>50%) with loamy surface, moderate erosion and slight stoniness	Coarse-loamy, thermic Typic Haplumbrepts
	Associated with moderately shallow, somewhat excessively drained, coarse-loamy soils with gravelly loamy surface, severe erosion and moderate stoniness	Coarse-loamy, thermic Typic Udorthents
28	Moderately shallow somewhat excessively drained, coarse-loamy soils on very steep slope (>50%) with gravelly loamy surface, severe erosion and moderate stoniness	Coarse-loamy, thermic Umbric Dystrochrepts
	associated with moderately shadow, excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness	Loamy-skeletal, over fragmental, thermic Entic Hapludolls
29	Moderately deep somewhat excessively drained, coarse-loamy soils on escarpments with loamy surface and moderate erosion	Coarse-loamy, thermic Typic Hapludolls
	associated with deep, somewhat excessively drained fine loamy soils with loamy surface and severe erosion	Fine- loamy, thermic Umbric Dystrochrepts
30	Moderately deep excessively drained, fine-loamy soils on escarpments with gravelly loamy surface and moderate erosion	Fine- loamy, thermic Umbric Dystrochrepts
	Associated with deep, somewhat excessively drained, fine-loamy surface and severe erosion	Loamy- skeletal, thermic Entic Haplumbrepts

Soil Unit	Description	Soil class
31	Deep, somewhat excessively drained, fine -loamy soils on escarpments with loamy surface and moderate erosion	Fine- loamy, thermic Umbric Dystrochrepts
	Associated with moderately deep, excessively drained, sandy soils with loamy surface and severe erosion	Thermic Typic Udipsamments
32	Moderately shallow excessively drained, fine loamy soils on escarpments with loamy surface and severe erosion	Loamy-skeletal, thermic Typic Udorthents
	Associated with deep, somewhat excessively drained, fine-loamy soils with loamy surface and moderate erosion	Fine- loamy, thermic Typic Dystrochrepts
33	Moderately deep, excessively drained, loamy-skeletal soils on escarpments with gravelly loamy surface and severe erosion	Loamy-skeletal, thermic Typic Udorthents
	Associated with moderately deep, excessively drained, loamy-skeletal soils with gravelly loamy surface and severe erosion	Loamy-skeletal, thermic Entic Hapludolls
35	Moderately deep, excessively drained, loamy-skeletal soils on escarpments with gravelly loamy surface, moderate erosion and slight stoniness	Loamy-skeletal, thermic Entic Hapludolls
	Associated with moderately shallow, excessively drained, loamy-skeletal soils with gravelly loamy surface, severe erosion and moderate stoniness	Loamy-skeletal, thermic Typic Udorthents
36	Moderately shallow, excessively drained, line-loamy soils on escarpments with loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Typic Haplumbrepts
	Associated with moderately shallow, excessively drained, fine-loamy soils with loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Umbric Dystrochrepts
37	Deep, well drained, fine-loamy soils steep slopes (30-50 %) with loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Typic Paleudolls
	Associated with deep, well drained, fine-loamy soils with gravelly loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Typic Hapludolls
38	Deep, somewhat excessively drained, fine-loamy soils on steep slope (30-50%! with gravelly loamy surface, severe erosion and slight stoniness	Fine-loamy, thermic Entic Haplumbrepts
	Associated with deep, somewhat excessively drained, loamy-skeletal soils with gravelly loamy surface, severe erosion and moderate stoniness	Loamy-skeletal, thermic Umbric Dystrochrepts
40	Moderately shallow, somewhat excessively drained, coarse-loamy soils on steep slope (30-50%) with loamy surface, moderate erosion and moderate stoniness	Coarse-loamy, thermic Cumulic Haplumbrepts
	Associated with moderately deep, well drained, fine-loamy soils with loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Typic Haplumbrepts

Soil Unit	Description	Soil class
41	Moderately deep, somewhat excessively drained, coarse-loamy soils on steep slope (30-50%> with loamy surface, moderate erosion and slight stoniness	Coarse-foamy, thermic Cumulic Haplumbrepts
	Associated with shallow, somewhat excessively drained, fine-loamy soils with loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Lithic Haplumbrepts
42	Deep, somewhat excessively drained, loamy-skeletal soils on steep slope (30-50%} with gravelly loamy surface, severe erosion and moderate stoniness	Loamy skeletal, thermic Umbric Dystrochrepts
	Associated with moderately shallow, somewhat excessively drained, loamy-skeletal soil, with gravelly loamy surface, severe erosion and moderate stoniness	Loamy-skeletal, thermic Typic Dystrochrepts
43	Deep, well drained, fine-silty soils on steep slopes (30-50%) with loamy surface, moderate erosion and slight stoniness	Fine-silty, thermic Pachic Haplumbrepts
	associated with moderately deep, well drained, fine-loamy soils with loamy surface, moderate erosion and moderate stoniness	Fine-loamy, thermic Typic C
44	Moderately shallow, well drained, fine-silty soils on steep slope (30-50%) with loamy surface, moderate erosion and slight stoniness	Fine-silty, thermic Typic Haplumbrepts
	associated with moderately deep, well drained, fine-loamy soils with loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Umbric Dystrochrepts
45	Deep, somewhat excessively drained, coarse-loamy soils on steep slope (30-50%) with loamy surface, moderate erosion and slight stoniness	Coarse loamy, thermic Typic Haplumbrepts
	Associated with deep, somewhat excessively drained, coarse-loamy soils with loamy surface, severe erosion and moderate stoniness	Coarse loamy, thermic Umbric Dystrochrepts
46	Deep, well drained, fine-loamy soils on steep slope (30-50%) with loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Typic Argjudolls
	Associated with deep, well drained, fine-loamy soils with gravelly loamy surface, moderate erosion and slight stoniness	Fine-foamy, thermic Cumulic Hapludolls
47	Deep, somewhat excessively drained, coarse-loamy soils on steep slope (30-50%) with gravelly loamy surface, moderate erosion and moderate stoniness	Coarse-loamy, thermic Pachic Haplumbrepts
	Associated with deep, well drained, fine-- loamy soils with loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Umbric Dystrochrepts
48	Deep, somewhat excessively drained, loamy-skeletal soils on steep slope (30-50%) with gravelly loamy surface, moderate erosion and slight stoniness	Loamy-skeletal, thermic. Typic Hapludolls
	Associated with shallow, somewhat excessively drained, coarse-loamy soils with gravelly loamy surface, severe erosion and moderate stoniness	Coarse-loamy, thermic Lithic Udorthents

Soil Unit	Description	Soil class
49	Deep, well drained, fine-loamy soils on steep slope (30-50%) with loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Typic Haplumbrepts
	Associated with moderately deep, somewhat excessively drained, sandy-skeletal over fragmental soils with gravelly loamy surface, severe erosion and moderate stoniness	Sandy-skeletal, over fragmental, thermic Typic Udorthents
52	Deep, somewhat excessively drained, fine-loamy soils on steep slope (30-50%) with loamy surface, moderate erosion and slight stoniness Associated with deep, somewhat excessively drained, fine loamy soils with loamy surface, slight erosion and stoniness	Fine-loamy, thermic Typic Hapludolls Fine-loamy, thermic Typic Argiudolls
53	Moderately deep, somewhat drained, coarse-loamy soils on steep slope (30-50%) with loamy surface, slight erosion and slight stoniness	Coarse-loamy, mesic Cumulic Haplumbrepts
	Associated with moderately shallow, somewhat excessively drained, loamy-skeletal soils with gravelly loamy surface, severe erosion and slight stoniness	Loamy-skeletal mesic Typic Udorthents
55	Moderately shallow, somewhat excessively drained, coarse-loamy soils on steep slope (30-50%) with gravelly loamy surface, moderate erosion and moderate stoniness	Coarse-loamy, mesic Typic Haplumbrepts
	Associated with shallow, somewhat excessively drained, loamy-skeletal soils with gravelly loamy surface, severe erosion and moderate stoniness	Loamy-skeletal, mesic Lithic Udorthents
57	Shallow, excessively drained, loamy-skeletal soils on steep slope (30-50%) with gravelly loamy surface, severe erosion and strong stoniness; associated with boulders and morrains	Loamy-skeletal, mesic Lithic Udorthents
58	Deep, well drained, fine-loamy over fragmental soils on moderately steep slope (15-30%) with loamy surface, moderate erosion and slight stoniness	Fine-loamy, over fragmental, thermic Typic Haplumbrepts
	Associated with deep, well drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness	Coarse-loamy, thermic Moilic Udarents
59	Moderately deep, somewhat excessively drained, coarse-loamy soils on moderately steep slope 0 5-30%) with loamy surface, moderate erosion and slight stoniness	Coarse-loamy, thermic Cumulic Hapludolls
	Associated with deep, well drained, tine-loamy soils with gravelly loamy surface, moderate erosion and moderate stoniness	Fine-loamy, thermic Typic Argiudolls
60	Moderately deep, somewhat excessively drained, coarse-loamy soils on moderately steep slope (15-30%) with loamy surface, moderate erosion and slight stoniness	Coarse loamy thermic Cumulic Haplumbrepts
	Associated with deep, well drained, fine-silty soils with loamy surface, moderate erosion and slight stoniness.	Fine-silty, thermic Cumulic Haplumbrepts

Soil Unit	Description	Soil class
61	Deep, well drained, fine-loamy moderately steep slope (15-30%) with loamy surface, moderate erosion and slight stoniness	Fine-loamy, thermic Fluventic Eurochrepts
	Associated with shallow, somewhat excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness	Coarse-loamy, thermic Lithic Hapludolls
64	Moderately shallow, somewhat excessively drained, loamy-skeletal soils on moderately steep slope j 15-30%) with loamy surface, moderate erosion and slight stoniness	Loamy-skeletal, thermic Cumulic Hapludolls
	Associated with moderately deep, somewhat excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness	Coarse-loamy, thermic Typic Udorthents
66	Shallow, excessively drained, loamy-skeletal soils with gravelly loamy surface, very severe erosion and moderate stoniness; associated with rocks	Loamy-skeletal, thermic Lithic Udorthents
67	Shallow, excessively drained, loamy-skeletal soils on cliff with gravelly loamy surface, severe erosion and slight stoniness	Loamy Skeletal Thermic Lithic Haplumbrepts
	Associated with very shallow, excessively drained, coarse-loamy soil with loamy surface and severe erosion	Coarse-loamy, thermic Lithic Udorthents
68	Very shallow, excessively drained, loamy-skeletal soils on cliff with gravelly loamy surface, severe erosion and slight stoniness; associated with rocks Glaciers/ice sheet/perpetual snow cover	

ANNEXURE VII

PUBLICATIONS

LIST OF PUBLICATIONS

Publications based on thesis:

Sharma, N.; Das, A.P. and Shrestha, D.G., 2015. Landuse and Landcover mapping of East District of Sikkim using IRS P6 satellite imagery. *Pleione* 9(1): 193 – 200

Publications outside the thesis work:

Tambe, S.; Arrawatia, M.L. and **Sharma, N**. 2011. Assessing the priorities for sustainable forest management in the Sikkim Himalaya, India: a remote sensing based approach. *Journal of the Indian Society of Remote Sensing*, 39(4): 555 – 564.

Basistha, B.C.; **Sharma, N.P**.; Lepcha, L.; Arrawatia, M.L. and Sen, A. 2010. Ecology of Hippophaesalicifolia D. Don of temperate and sub-alpine forests of North Sikkim Himalayas—a case study. *Symbiosis*, 50(1-2): 87 – 95.

Radha Krishna Sharma, Dharmendra Lamsal, **Narpati Sharma**, D.G.Shrestha, M.L. Arrawatia, 2010. Frequency studies of different shade trees in large cardamom plantations of three districts of Sikkim together with shrubs, herbs and climbers. *Pleione* 4(2): 221 - 229.

Lepcha, L.; Mandal, P.; Misra, T.K. and **Sharma, N.P.** 2010. Comparative study of Plant Biodiversity and Physico-chemical Parameters of Soils of Landslide Prone areas. *International Journal of Ecology & Development*™, 17(F10), pp.66-76.

Narpati Sharma, N.; Sharma, R.K.; Luitel, K.K.; Arrawatia, M. L.; Shrestha, D.G.; Pradhan S. 2010. Study of Forest Fires of Sikkim Himalayas using Remote Sensing and GIS Techniques. *Proceeding of International workshop on Biodiversity and Climate change*, IIT Kharagpur.

Sharma, N.; Pradhan, S.; Arrawatia, M.L. and Shrestha, D.G., 2010. Study on types and distribution of wetlands in Sikkim Himalayas using satellite imagery with remote sensing and GIS technique. *Proceedings of the Lake 2010: Wetlands, Biodiversity and Climate Change*, IISc Banglore.

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Landuse and Landcover mapping of East District of Sikkim using IRS P6 satellite imagery

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Abstract

Satellite based remote sensing technology is the best methods to estimate the forest cover/ Landuse and land cover mapping in the hilly areas. East Sikkim, having the total geographical area of 954 sq km, ranging over the altitude 300 m (Rangpo) to 4500 m (Nathula), is having tropical to alpine forests. Based on altitude, these forests can be divided into three types *viz*. Lower Hill forest, Middle Hill forest and Upper Hill forest. Present work used clouds free IRS P6 Jan 26, 2006 satellite imagery was used. The imagery was geo- referenced to Survey of India (SOI) topomaps with less RMS error and knowledge based classified using the slandered vegetation classification legend. A ground based vegetation classes were used during the image classification. The vegetation types when compared with the altitudinal zones of the area shows good relationship. The LISS III image was classified using the ERDAS Imagine (9.1) software by applying two different method of classification in a GIS environment viz. visual interpretation technique and supervised classification. These classification showed 83.72 % overall accuracy.

Key words: Landuse and Landcover, East Sikkim, Satellite Imagery

INTRODUCTION

Land use is influenced by economic, cultural, political, environmental, historical and many other factors at multiple scales. On the other hand, land cover is one of the many biophysical attributes of the land that affect how ecosystems functions (Turner *et al*. 1995).

The accurate, meaningful, current data on land use are essential for planning and management of critical concern area such as flood plains and wetlands, energy resource development and production areas, wildlife habitat, recreational lands, and areas such as major residential and industrial development sites etc. (Anderson 1976)

The forest vegetation is largely disturbed because of the increasing rate of deforestation due to unsustainable extraction of timber, fuel wood and fodder as well as encroachment for settlements (SER 2013; ISE 2001).

Land use deals to man's activities and the various use which are carried on land, and on the other hand, land cover deals to natural vegetation, water bodies, rocks, soils etc. The land use information is an important element in forming policies regarding economic, demographic and environmental issues; but a very good skill is required to classify the different land use and land cover using the satellite imagery. An individual land use and land cover categories are formed from collection of diverse objects, features, and structures that are often not individually resolved and the image. The Remote Sensing technology along with GIS is a perfect device to identify, locate and map various types of lands associated with different landform units (Sharma *et al*. 2009).

The visual interpretation using the satellite imagery provides the idea of the basic distribution of vegetation dynamics (Ravan *et al*. 1995). Identification of changed area in landuse and landcover is possible with less time, at low cost and with better accuracy using Satellite based Remote Sensing Technology (Roy& Giriraj 2008).

Study Area:

East district of Sikkim, India, lies between the coordinates 27º 08' 08.39" N to 27º 25' 26.86" N and 88º 26' 26.02" E to 88º 55' 22.81" E and covers an area of 954 sq km. The elevation of study area is ranging from 300 m in the foot hills (at Rangpo) to 4500 m (at Nathula - the trade route with China). The study area bounded in the west River Teesta, River Dikchu/ Rateychu in the north, in south River Rangpo and in east Bhutan and Tibet/china.

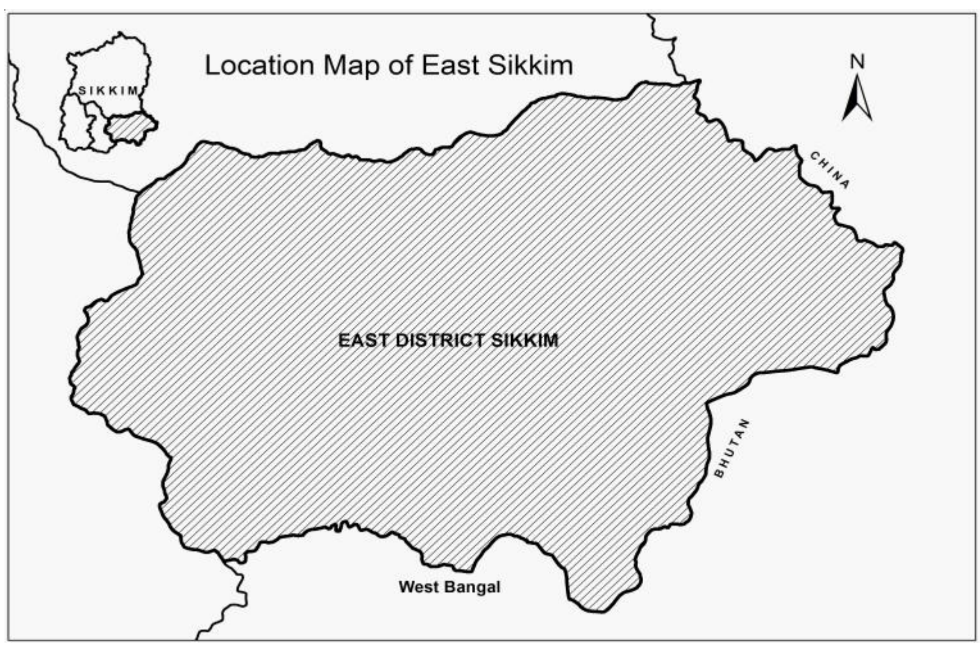

Fig. 1. Location of East Sikkim district of Sikkim, India

METHODOLOGY

The IRS P6 January 26, 2006 imagery was used in the classification of LULCs through ERDAS Imagine software (9.1). The images were geometrically corrected and geo-coded to the Universal Transverse Mercator (UTM) Co-ordinate system, using 1:50000 scale, approximately 20 evenly distributed ground control points were selected from the image. These were used to spatially resample the images using a nearest neighbor algorithm, which takes the value of pixels in the input image that is closest to the computed co-ordinate. This method is fast and does not alter the original pixel values. The transformation had a root mean square (RMS) error of between 0.4 and 0.7 pixel, indicating that the image rectification was accurate to within one pixel. After registration, the TIFF imagery was converted into Image format imagery which describes all the information of the image like scale, resolution, projection etc. checking the image with the help of projected topomap.

The boundary of East district of Sikkim was generated with the help of Toposheet and Satellite imagery. The western boundary of the study area was bounded by River Teesta which is clearly seen in the satellite imagery, the northern boundary is bounded by River Dikchu/ Rateychu, the half of the southern boundary is bounded with River Rangpo Chu and the other half boundary is shared with Bhutan and the eastern boundary is shared with Tibet Autonomous Region (TAR) boarder.

The imagery was subset by using the AOI (Area of Interest) of the study area boundary. The acquired images were classified based on onscreen/ head's up interpretation using image interpretation keys. Semi-automated approach was also considered while analyzing few categories at local level.

In onscreen visual interpretation, the imagery is displayed onto computer screen (normally as FCC) and intended classes are delineated based on image interpretation elements, ancillary and legacy data. (Anderson 1976) Resultant output from this will be vector format, which supports complex GIS analysis and has smaller file size. Advantages of visual/ manual interpretation approaches are as follows (NRSA 2012)

1. Context/ texture/ pattern based classes can be delineated
2. Various enhancement options are possible to exploit the capability of multiband/ multi-season data
3. Minimizes issue of sensor radiometry and date of pass
4. Polygons of change only to be updated on T1 output using T2 data
5. Temporal assessment is time effective
6. Adoptability and operational feasibility is high.

Visual interpretation

Much interpretation and identification of targets in remote sensing is performed manually or visually, i.e. by a human interpreter. In many cases, this is done using imagery displayed in a pictorial or photograph-type format, independent of what type of sensor was used to collect the data and how the data were collected. In this case we refer to the data as being in analog format. Visual interpretation may also be performed by examining digital imagery displayed on a computer screen. Both analogue and digital imagery can be displayed as black and white (i.e. monochromes) images, or as colour images by combining different channels or bands representing the different wavelengths. Visual interpretation requires little, if any specialized equipment, whereas digital analysis requires specialized and often expensive equipment (Anderson 1976).

Manual interpretation is often limited to analyzing only a single channel of data or a single image at a time due to difficulty in performing visual interpretation with multiple images. This Visual interpretation is a subjective process, meaning that the results will vary with different interpreters (NRSA 2012). The supervised classification technique is also use to cross-check the visual interpretation layer, for shadow and snow cover areas.

RESULT AND DISCUSSION

Through onscreen interpretation (visual interpretation), the different class polygons were digitized based on terrain knowledge acquired during fieldwork and distributed throughout the study area. The interpretation elements like tone (light, medium, dark, very light, very dark), texture (course, medium, fine, even, uneven, mottled, uniform), colour (brighter, gray, light blue, grayish white, dull white, light pink, yellowish white), patterns (discrete-contiguous

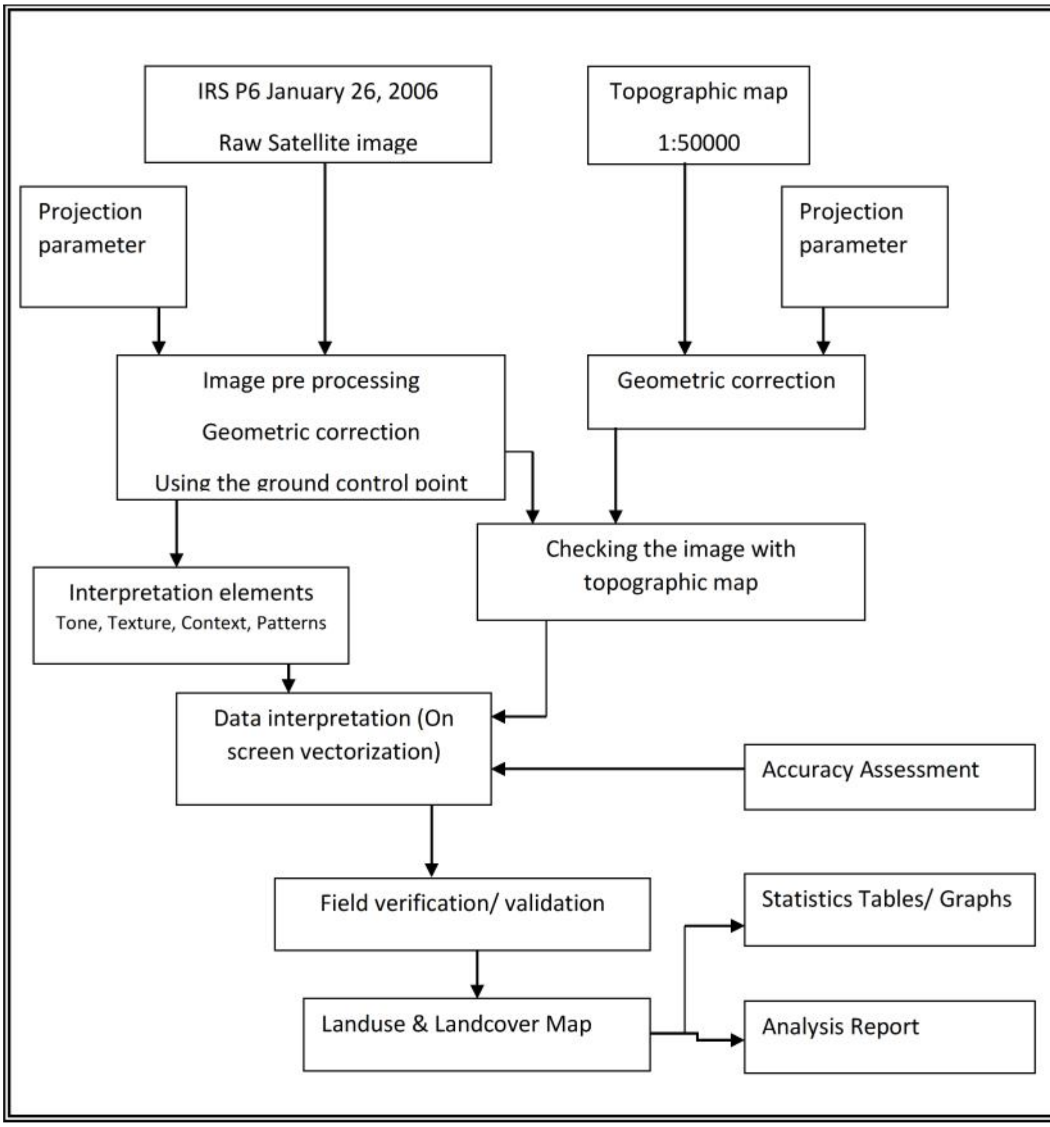

Fig. 2: Flow-chart of detail methodology

patches), size (small, medium, large, uniform or varied), shape (compact, regular, elongate, square, irregular, rectangular), association etc, were kept in mind during visual interpretation of the image.

On the basis of IRS P6 images, LULCs of the study region was classified into six categories in level I viz.: built-up, agricultural land, forest, barren rocky, water-bodies, snow-glacial area and in level II the six classes of level I were further classified into 13 different categories these are shown in Table 1. During the classification of the satellite imagery, some elements of the image interpretation were keeping in mind like (small, medium, large, uniform or varied), shape (compact, regular, elongate, square, irregular, rectangular), tone (light, medium, dark, very light, very dark) texture (course, medium, fine, even, uneven, mottled, uniform), association, shadow, site, pattern etc.

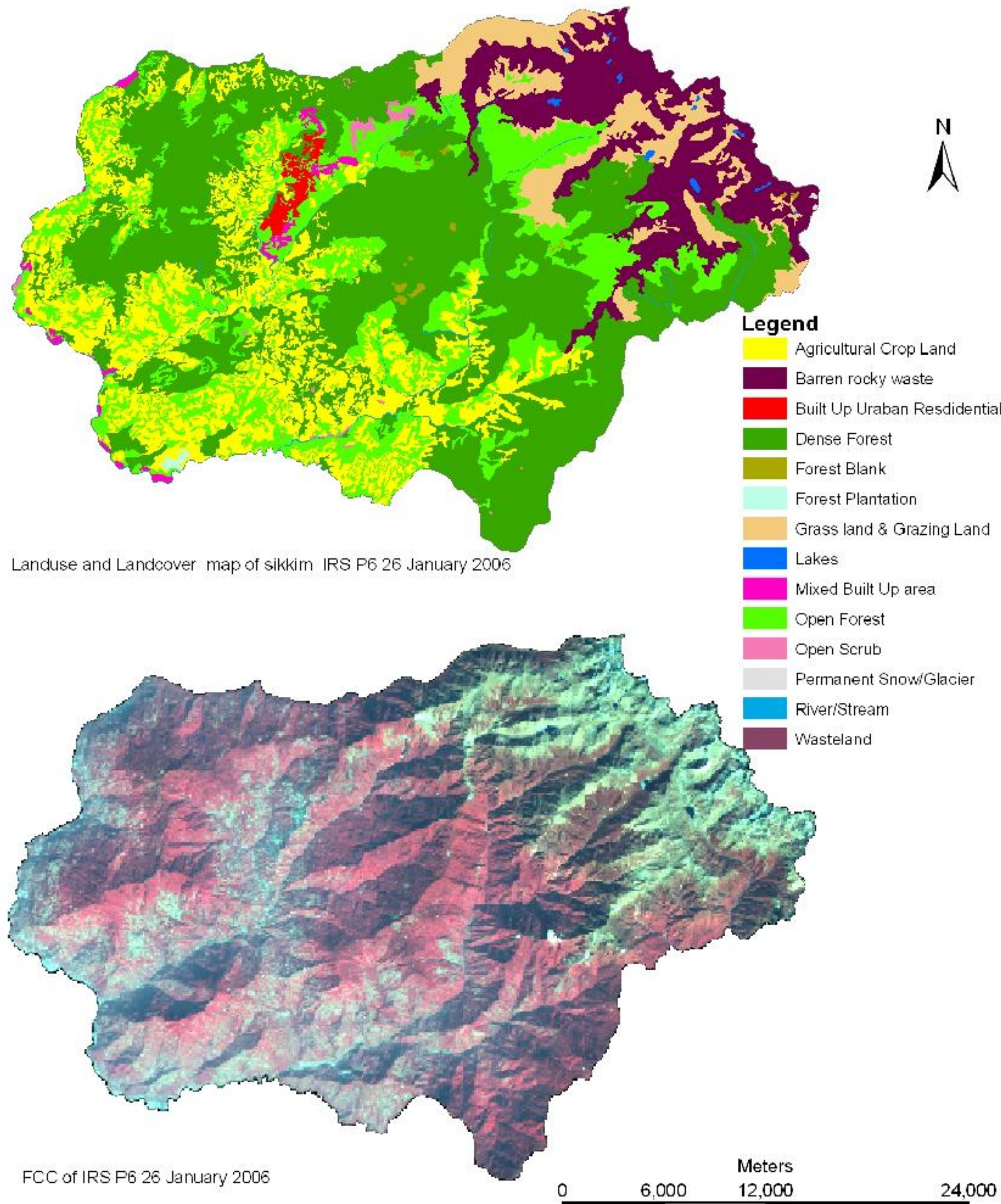

Fig. 3. A. False Color Composite of IRS P6 January 2006 of East Sikkim;**B.** Landuse and Landcover Map of East Sikkim

The total study area was mapped and classified into 13 land use types using IRS P6 Raw Satellite Image. The total geographical area of East district of Sikkim is 95400 ha, of which 40124 ha is under Dense Forest, which is slightly over 42 % of total area of East district; 17160 ha land is under Agricultural cropland, which is nearly 18% of the district's area. Similarly, 18509 ha of land was classified as Open Scrub land which is over 19 % of the total area. This is followed by 10874 ha (i.e. 11 %) area under Barren Rocky wasteland.

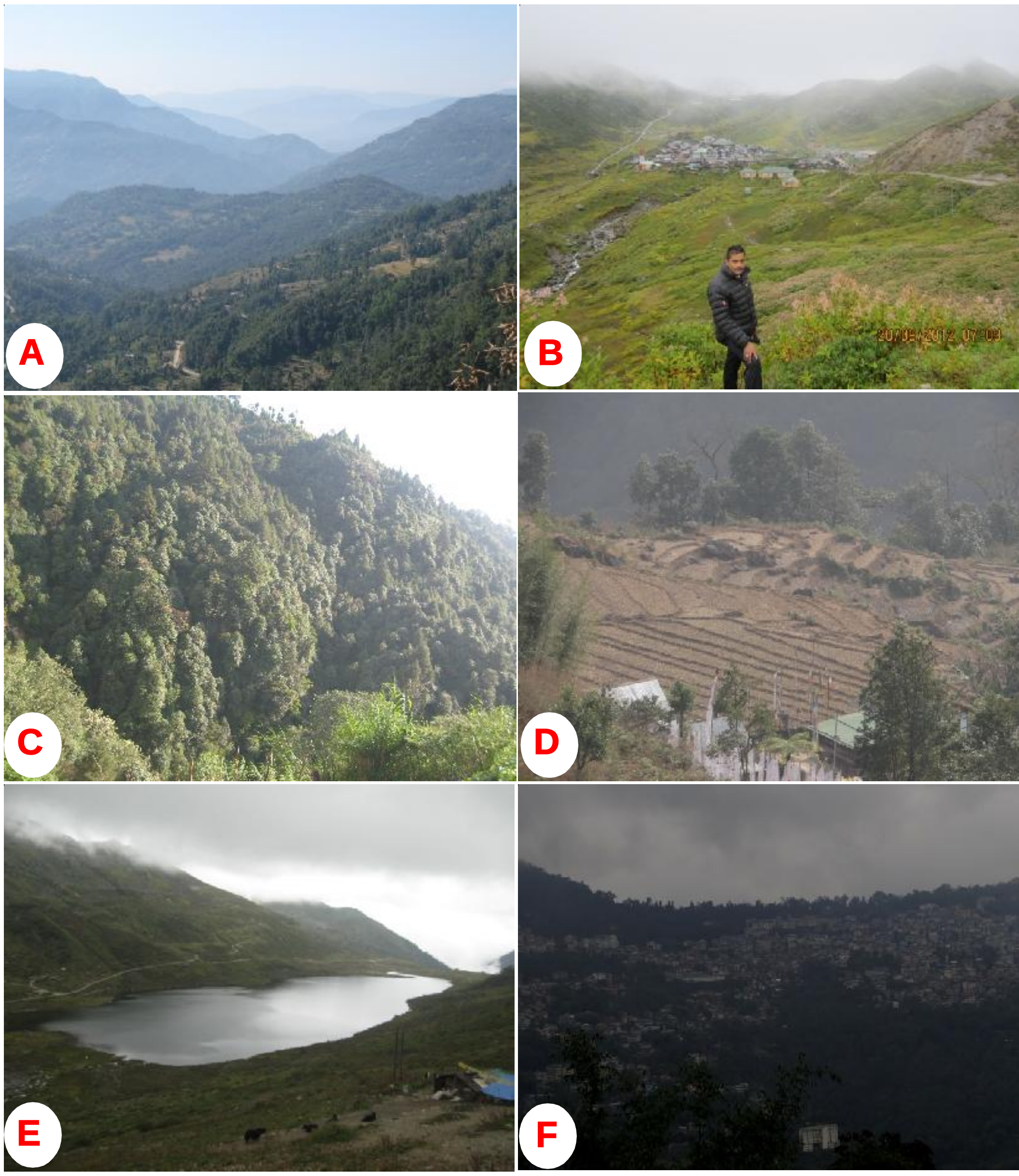

PLATE - I. Snaps on different land features of East District of Sikkim: A. Open Forest with Agricultural land; **B.** Alpine Grass Land and Grazing Land; **C.** Dense Forest; **D.** Agriciltural Land; **E.** Kupup Lake of East Sikkim; **F.** Built up urban Residential area

Also, 6226 ha or 6 % area was classified as Grassland and Rangeland. Other land use types were classified as Built up Urban Residential, Forest Blank, Forest Plantation, Lakes, Mixed Built up area, Permanent Snow/Glacier, River/Stream and Wasteland and each of them contribute less than 1% of total geographical area of East Sikkim (Table 1).

Precision, as it pertains to agreement between observers (interobserver agreement), is often reported as a kappa statistic (Cohen 1960). Kappa is intended to give the reader a quantitative measure of the magnitude of agreement between observers. Accuracy assessment was done following Kappa Statistics method (Table 2).

Table 1. Land use and Land cover type of East Sikkim with area

Sl. No.	**Land use Type**	**Area in Ha.**	**% of Area**
1.	Agricultural Crop Land	17160	17.99
2.	Barren rocky waste	10874	11.40
3.	Built Up Urban Residential	701	0.73
4.	Dense Forest	40124	42.06
5.	Forest Blank	233	0.24
6.	Forest Plantation	98	0.10
7.	Grassland & Grazing Land	6226	6.53
8.	Lakes	165	0.17
9.	Mixed Built Up area	641	0.67
10.	Open Scrub	18509	19.40
11.	Permanent Snow/Glacier	20	0.02
12.	River/Stream	642	0.67
13.	Wasteland	7	0.01
	Total	**95400**	**100.00**

Table 2. Accuracy assessment table using Kappa statistics

	Agricu-lture	Built up	Forest	Alpine	Waste-land	Snow & glacier	Water bodies	**TOTAL**
Agriculture	**22**	1	1	0	0	0	0	24
Built up	1	**17**	0	0	1	0	0	19
Forest	0	0	**19**	1	0	0	0	20
Alpine	1	1	1	**10**	1	1	0	15
Wasteland	1	1	2	1	**13**	1	1	20
Snow glacier	0	0	0	1	0	**13**	2	16
Water bodies	0	0	0	0	0	1	**14**	15
TOTAL	25	20	23	13	15	16	17	**129**

Kappa assessment Sum of the observation on which the class occur/total no. of Observation x 100

$$\frac{108}{129} \times 100 = 83.72$$

The overall accuracy assessment of vegetation classification of East Sikkim is 83.72%

[*Abbreviations*
SER -State of the environment report
ISE -Indian state of Environment
TIFF-Tagged image file format
IRS- Indian Remote Sensing]

CONCLUSION

In this study the Land-use and land-cover pattern of east Sikkim using IRS LISS III imagery was studied and showed the natural vegetation cover is restricted to 42% of the area of the East District of Sikkim as it was on January 26, 2006. On the other hand, settlements has covered 1 % area, and the total land used for cultivation is 18 %. This is little old data, but the modification of natural habitat is taking place very fast and, it is expected that the present scenario will be little different, with much more areas now urbanized and occupied for cultivation, industry, etc.

This picture is not impressive as it translate the too much of anthropogenic pressure of the survival of extremely rich biodiversity of Sikkim Himalaya, which is a part of the Himalaya Hotspot for Biodiversity Conservation. It is now important for planners and policy makers to decide wheather the Sikkim biodiversity will preserved in which way. The pictures showed the changes are not restricted only to the previous city areas, even the land-use is quite fast even in remote areas and numerous new townships are appearing.

So, the present set of generated data will be helpful for better modeling and forecasting the land-use and land-cover change over the time. This will also speak for the direct and indirect impact on environment, which are expected cause due to rampant change in land-use pattern.

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RESEARCH ARTICLE

Assessing the Priorities for Sustainable Forest Management in the Sikkim Himalaya, India: A Remote Sensing Based Approach

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Abstract Sikkim is a small, mountainous, Indian state (7,096 km^2) located in the eastern Himalayan region. Though a global biodiversity hotspot, it has been relatively less studied. A detailed forest type, density and change dynamics study was undertaken, using SATELLITE remote sensing data and intensive field verification. The landscape was found to be dominated by alpine and nival ecosystems, with a large portion above the tree line, considerable snow cover, and a sizeable area under forest cover (72%, 5,094 km^2). A total of 18 landscape components including 14 vegetation classes were delineated, with the major ones being oak forest, alpine meadow, alpine scrub, conifer forest and alder-cardamom agro-forestry. Of the 3,154 km^2 of forests below the tree line, 40% were found to be dense (>40% tree canopy cover). A sizeable portion of the non dense forests below the tree line was contributed by the degradation of oak forests, which was confirmed by change detection analysis. However on a positive front over the past decade, ban on grazing and felling of trees in forests has been implemented. In order to expand the extent of dense forests, further efforts are needed for the restoration of oak forests such as fire protection, providing alternatives to firewood use, promotion of alder-cardamom agro-forestry in the private lands and protection of the small-sized, fragmented forest patches in the subtropical belt.

Keywords Eastern Himalaya · Spatial analysis · Change detection · Vegetation mapping · Oak forest

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Introduction

Sikkim is a small north-eastern Indian state that lies between 27° 04′ 46″ to 28° 07′ 48″ N latitudes and 88° 00′ 58″ and 88° 55′ 25″ E longitudes, covering an area of just 7,096 km^2 (Fig. 1). The elevation ranges from 300 to 8,586 m, with the dominant feature being Mt. Khangchendzonga (8,586 m), the third highest peak in the world and the highest in the country. The state is a part of the eastern Himalayan region which is one of the 34 global biodiversity hotspots of the world (Myers et al. 2000; Mittermeier et al. 2004). The sharp altitudinal gradient and complex topography has manifested in 12 forest types (Table 1). It harbours nearly one third of the national flowering plants diversity, an estimated 5,000 species of flowering plants (Hajra and Verma 1996).

Remote sensing technique and associated spatial analysis tools are highly useful in conservation planning (Roy et al. 1999; Singh et al. 2002; Turner et al. 2003), landscape ecology (Quattrochi and Pelletier 1990; Roy and Tomar 2000) and assessing the impacts of climate change (Kulkarni et al. 2007). Multi-spectral and multi-temporal data obtained from satellite remote sensing allows integration of several layers and change detection more quickly and effectively (Blamont and Méring 1987). These tools are particularly useful for areas located in the Himalaya, where adequate field sampling is often negated by non-negotiable rugged terrain. The present study used satellite data and is backed by extensive field verification compared to the pervious studies (ISRO 1994; IIRS 2002; Kushwaha et al. 2005). Mapping of major forest types has been attempted using a systematic approach covering the entire state.

Our goals in this paper are threefold. First, we delineate the forest types, their density and patterns of change in vegetation cover. Secondly we provide evidence which reveals that considerable portions of the temperate and subalpine forests have been converted into thickets, scrub and blanks, and thereby adversely impacted in recent times. Thirdly we compare our assessment with contemporary studies done by various agencies. We also propose management strategies that need to be prioritized for effective conservation of forested landscapes in this global biodiversity hotspot.

Data Used and Methodology

Field Data Collection

The study area was surveyed over a 6 year period from 2003 to 2008. A total of 497 well distributed ground reference points along with attribute data on location and vegetation characteristics were recorded using a hand-held Garmin Global Positioning System (GPS; 12-channel Garmin Etrex-Summit mode). Field surveys helped in creating a database of about 400 digital photographs of the landscape which helped during visual interpretation especially of areas under shadow.

Spatial Data and Image Processing

For landcover mapping, multispectral satellite images from Indian Remote Sensing satellite (IRS-1C) LISS III data with 23 m spatial resolution, of Jan and Feb, 2002 were used. Ground control points (GCPs), covering all the landuse types as well as covering the shadow areas were collected with the help of GPS (Garmin, etrex-summit, 12 channel). The spectral signatures of GCPs sites thus collected during ground checks were used for supervised classification in Erdas Imagine (version 8.5) software using standard techniques (Roy and Tomar 2000). We identified dense forests as vegetated areas with >40% of tree canopy cover, open forests as those with 10–40% tree canopy cover, very open forests as those with 5–10% tree canopy cover, scrub as areas devoid of tree cover with less than 5% cover and blank as barren areas devoid of tree and shrub cover (FSI 2005). Total forest cover refers to the combined areas of dense, open and very open forests including alpine thickets, alpine scrub and alpine meadows in forest and private lands. Image rectification, enhancement, hybrid classification and smoothening with adequate ground truthing were carried out to map the broad landcover classes. Classification and interpretation of shadow classes was done separately. For areas with deep shadows support of ground truthing, aerial photographs and digital photographs were also taken. For delineation of oak and conifer forests, band 4 (1.55–1.70 μ m wavelength range) was found to be very useful. The mixing of classes was reduced by masking the forest and non forest areas separately into 6 elevation zones (0–1,000 m, 1,000–1,500 m, 1,500–2,000 m, 2,000–2,500 m, 2,500–3,000 m and greater than 3,000 m). For the areas above 3,000 m, the Jan image was used since the Feb image showed extensive seasonal snow cover. Thereafter reclassification was carried out using a subset of the landcover categories which were known to occur in a given elevation zone was then done. This was followed by manual recoding to remove the drop lines, clouds and their shadow. Finally a mosaic of these 12 separately classified images was done to obtain a composite image, and finally area statistics were calculated after normalization. This hybrid approach, combining digital supervised classification, reclassification using elevation and visual interpretation resulted in the final 21 broad landcover classes. Quality of the classifica-

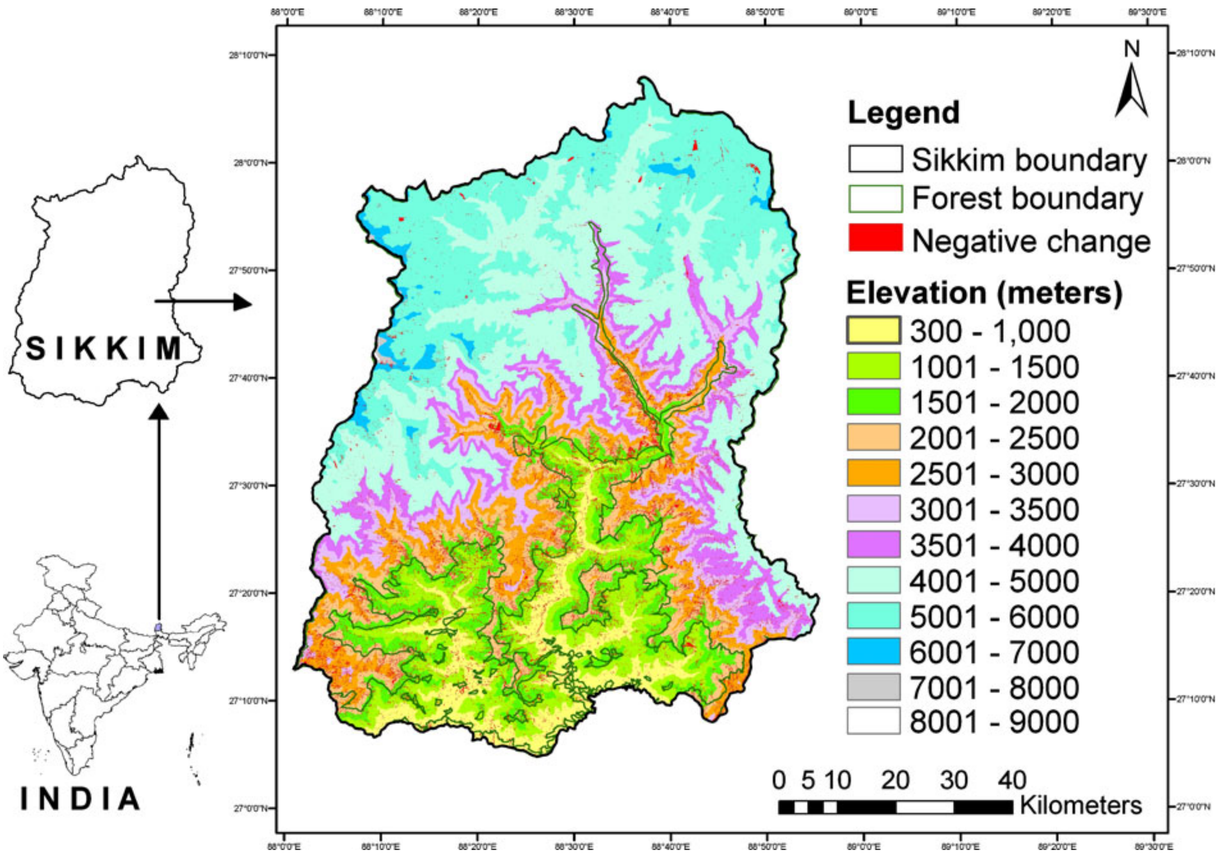

Fig. 1 Map showing the spatial distribution of areas with more than 10% decrease in NDVI (shown in red) between 1977 and 2000 along with Reserve Forest (RF) boundary and elevation zones in Sikkim, Eastern Himalaya, India

tion was found using the accuracy assessment option of the classifier module. ArcGIS (version 9) was used for integration of the various layers on a GIS platform.

Temporal Change Detection

The georeferenced Landsat time series data of 23rd January, 1977 (NASA Landsat Program 1977) and 26th December, 2000 (NASA Landsat Program 2000) were used for temporal change detection. Atmospheric correction was performed with Idrisi Kilimanjaro (v14) using the ATMOSC module. All imagery was corrected using the cos(t) model with input parameters reported in the metadata supplied by Landsat (Chavez 1996). The 30 m resolution Landsat ETM+ (2000) image was degraded to 60 m using the utilities option in the image interpreter module of Erdas to match with the Landsat MSS (1977) image. NDVI was calculated for each of the images using the spectral enhancement option, followed by change detection using the utilities option in the image interpreter module of Erdas (Lillesand and Kiefer 2000). The 2000 image had less snow cover in the alpine zone especially in the greater Himalayan portion. Because of this reduction in winter snow cover, the alpine vegetation that was concealed under snow in the older image was visible in the new image, causing the NDVI to show a positive bias in the snow covered areas. There was variation in the shadow intensity as well, with the 2000 image showing lighter shadows as compared to the 1977 image. Change detection in shadow areas was seriously hampered by variability in shadow intensity along with low spectral reflectance of vegetation. Hence all shadow areas were erroneously classified as a positive change (i.e. gain in vegetation cover) between the 1997 and 2000. To overcome these challenges inferences from change detection analysis using NDVI were drawn only from the negative changes highlighted in the map, since the positive changes could be due to reduction in shadow

Table 1 Details of forest types found in Sikkim, Eastern Himalaya, India (Adapted from Grierson and Long (1983), Champion and Seth (1968))

S. no.	Forest type adapted from Grierson and Long (1983)	Characteristic species	Altitude range	Forest type adapted from Champion and Seth (1968)	
1	Sal (*Shorea robusta*) forest	*Shorea robusta, Terminalia myriocarpa, Schima wallichii, Phyllanthus emblica, Mallotus philippensis, Bombax ceiba*	300–900	3C/Cia	East Himalayan sal forests
2	Chir pine (*Pinus roxburghi*) forest	*Pinus roxburghi, Woodfordia fruticosa, Phoenix acaulis*	500–900	$9/C_{1b}$	Himalayan chir pine forests
3	Subtropical forest	*Terminalia myriocarpa, Alstonia grandis, Duabanga grandiflora, Tetrameles nudiflora, Dillenia pentagyna, Ailanthes grandis*	300–900	$3C/C_{3b}$	East Himalayan moist deciduous forest
4	Warm broad-leaved forest	*Schima wallichii, Engelhardia spicata, Macaranga nepalensis, Castanopsis indica, Spondias axillaris, Ostodes paniculatus*	900–1,700	$8B/C_1$	East Himalayan sub-tropical wet hill forest
5	Alder forest	*Alnus nepalensis*	1,500–2,000	$12/IS_1$	Alder forest
6	Evergreen Oak forest	*Castonopsis* sp., *Quercus* sp., *Michelia* sp., *Juglans regia, Symplocos* sp., *Acer campbellii*	1,700–2,800	$11B/C_1$	East Himalayan wet temperate forests
7	Dwarf bamboo thicket	*Arundinaria maling, Thamnocalamus aristata, Thamnocalamus spathiflorus*	2,600–3,100	$12/DS_1$	Montane bamboo brakes
8	Mixed conifer forest	*Tsuga dumosa, Quercus pachyphylla, Larix griffithiana, Picea smithiana*	2,700–3,100	$12/C_{3a}$	East Himalayan moist temperate forest, East Himalayan dry temperate coniferous forest, Larch forest
9	Conifer forest	*Abies densa, Juniperus recurva, Betula utilis, Sorbus macrophylla, Prunus cornuta*	2,800–3,700	$13/C_6$, $14/C_2$	East Himalayan sub-alpine forests
10	Alpine thicket	*Rhododendron* sp., *Betula utilis, Acer* sp.	3,500–4,500	$15/C_1$	Birch/Rhododendron scrub
11	Alpine scrub	*Juniperus* sp., *Rhododendron* sp., *Caragana* sp., *Ephedra gerardiana*	4,000–5,500	$15/C_2$, $16/C_1$, $16/E_1$	Dwarf *Rhododendron* scrub, Dry alpine scrub, Dwarf Juniper scrub
12	Alpine meadow	*Kobresia* sp., *Carex* sp., *Stipa* sp., *Poa* sp.	4,000–5,500	$15/C_3$	Alpine pastures

intensity or decrease in snow cover between the two images.

Results

Landcover Types

About 79% of the geographical area of the state has been classified as reserve forests having a total extent of 5,589 km^2. However of this only 2,292 km^2 (41%) occurs below the tree line. The reserve forests occurred in 58 discrete patches comprising of one large chunk with an extent of 5,385 km^2 (Fig. 1). The next big patch was the Fambong lho with an area of 55 km^2. The mean area of the reserve forest patches is 95±707 km^2 which indicates a large variation. However without these two large polygons the extent of the remaining 56 reserve forest polygons reduced to 88 km^2 and the mean area to 1.6±2.4 km^2.

About 47% (3,323 km^2) of the geographical area of the state is above the tree line which is at 3,800± 200 m. The forest cover including alpine thickets, alpine scrub and alpine meadows stood at 72% (5,094 km^2) of the geographical area. The forest cover when calculated for the area below the tree line (3,783 km^2) increased to 76% (2,893 km^2) of which 23% occurs outside reserve forests. The final classified image of the study area had 16 classes or landscape components (Table 2, Fig. 2), with the dominant ones being oak forest (16.15%), alpine scrub (13.53%), alpine meadow (13.44%), conifer forest (11.02%), agriculture (8.33%), cardamom-alder agro-forestry (6.51%), mixed conifer (6.35%) and a high proportion (14.73%) of snow.

Forest Density

Of the forests below the tree line, 40.2% (1,268 km^2) were found to be dense (>40% canopy cover), 26% (820 km^2) open (10 to 40% canopy cover), 10.3% (326 km^2) very open (5 to 10% canopy cover), 15.2% (479 km^2) thickets, 4.2% (133 km^2) scrub (< than 5% canopy cover) and 4.1% (128 km^2) blank (Fig. 3, Table 2). *Shorea robusta* (sal) forests (91%), mixed conifer forests (90%), subtropical forests (68%) and warm broad-leaved forests (64%) were found to be the most non dense. Oak forests contributed significantly (32%, 608 km^2) to the total non dense forests below the tree line. Subtropical forests that have a total extent of 110 km^2 are the only natural forests that occur mostly (80%) outside reserve forests. Forests which are most extensive in non reserve forest lands are the cardamom-alder agro-forests with an extent of 272 km^2 and comprise 17% of the total forests in private lands.

Temporal Change Detection

Out of a total 7,096 km^2 of the state's area, 317 km^2 (4.57%) was found to be impacted by a decrease of greater than 10% in NDVI (Fig. 1, Table 3). This decrease was found to be 209 km^2 (3.8%) in reserve forest area and 108 km^2 (6.9%) in other areas. However, this change was not uniform, for instance, as much as 30 km^2 (12.7%) of the reserve forest area between 1,500 to 2,000 m, 61 km^2 (12.1%) between 2,000 to 2,500 m and 54 km^2 (9.9%) between 2,500 to 3,000 m showed a decline in forest cover, while less than 1.5% of the area in the zone above 3,000 m showed a negative change.

Table 2 Broad landcover types, their density and extent (in km^2) in Sikkim, Eastern Himalaya, India

Landcover type	Extent in km^2							
	Dense	Open	Very open	Thicket	Scrub	Blank	Total	% of Total
Alpine meadow							953.36	13.44%
Alpine scrub							959.56	13.53%
Alpine thicket							260.04	3.66%
Conifer forest	449.94	304.01	0.00	28.21	0.00	0.00	782.16	11.02%
Mixed conifer forest	46.13	90.71	0.00	256.27	0.00	57.62	450.72	6.35%
Oak forest	538.50	213.52	169.89	176.64	0.00	47.58	1146.13	16.15%
Alder forest	141.18	131.31	110.55	78.85	0.00	0.00	461.88	6.51%
Warm broad-leaved forest	51.64	29.11	16.87	39.08	3.88	2.93	143.50	2.02%
Subtropical forest	35.01	50.18	16.17	0.00	8.53	0.00	109.89	1.55%
Sal forest	5.39	1.44	12.83	10.72	10.02	19.76	60.15	0.85%
Agriculture							591.99	8.34%
Rock							101.32	1.43%
Sand							37.16	0.52%
Lake							27.98	0.39%
Snow							1045.59	14.73%
Total	1250.43	740.21	326.00	590.84	24.14	188.94	7096.00	100%

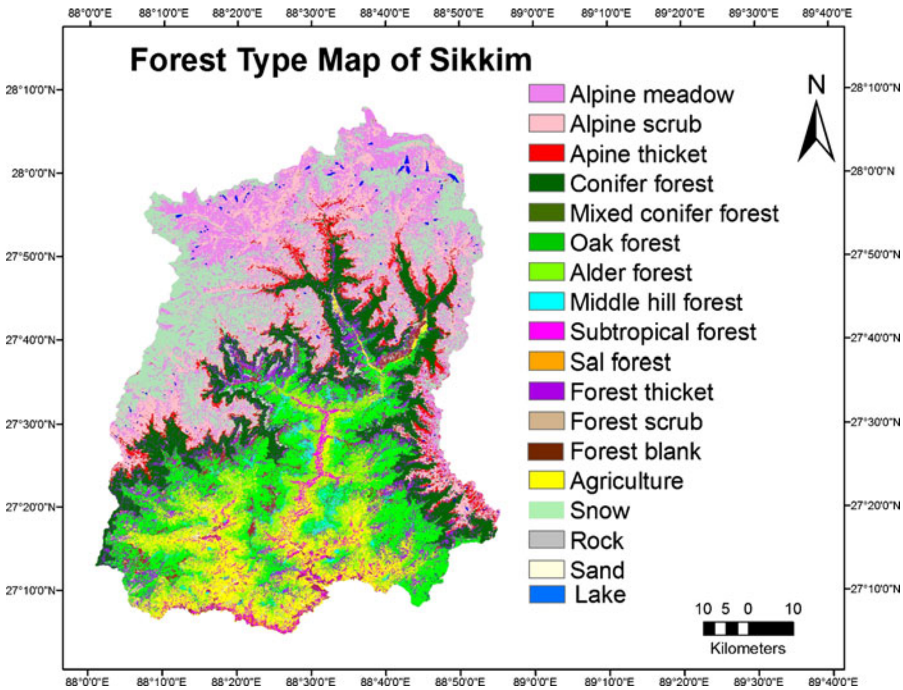

Fig. 2 Forest type map of Sikkim, Eastern Himalaya, India

Discussions

Mountain regions like Sikkim pose several challenges for the natural resource managers and ecologists in terms of understanding linkages between the landscape features and spatio-temporal changes in the composition and extent of vegetation caused by both natural and anthropogenic factors. A substantial proportion of the Eastern Himalaya remains largely inaccessible for physical verification as many areas are far from roads, not easily approached on account of un-forded rivers and steep terrain. Despite the

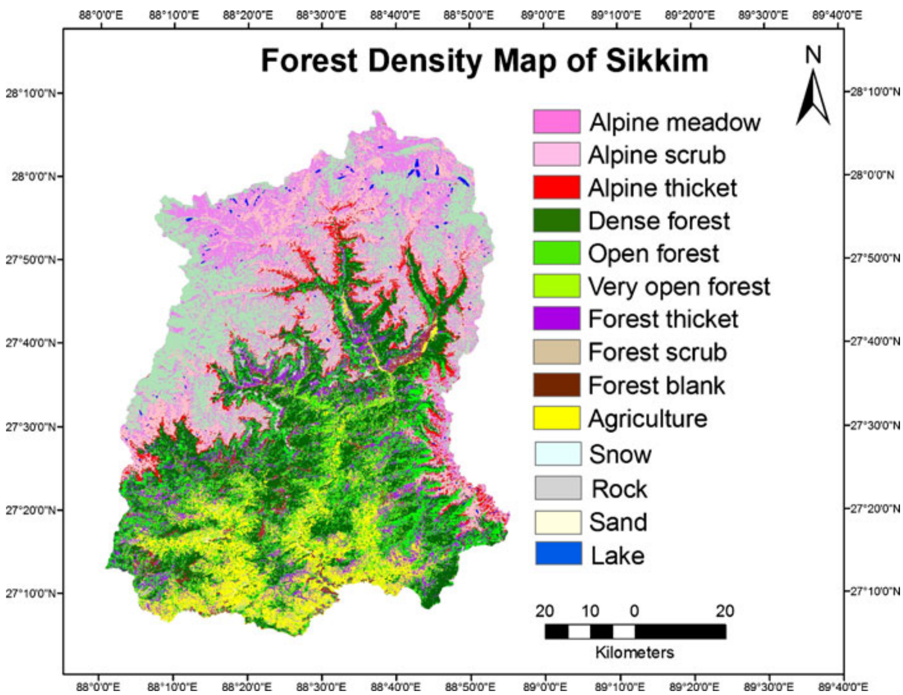

Fig. 3 Forest density map of Sikkim, Eastern Himalaya, India

Table 3 Extent of area (in km^2) with more than 10% decrease in NDVI between 1977 and 2000 presented altitude wise in Sikkim, Eastern Himalaya, India

Elevation	300–1,000 m		1,000–1,500 m		1,500–2,000 m		2,000–2,500 m		2,500–3,000 m		>3,000 m		Total	
Area in km^2	RF	Non RF	RF	Non RF	RF	Non RF	RF	Non RF	RF	Non RF	RF	Non RF	RF	Non RF
Total area	66.74	361.09	23.71	606.08	233.26	478.35	507.71	92.88	542.32	18.77	4140.37	24.72	5514.10	1581.90
Negative change	3.77	20.88	2.37	35.12	29.65	41.24	61.34	9.00	53.66	1.36	57.90	0.69	208.70	108.29
% Negative change	5.65%	5.78%	9.99%	5.80%	12.71%	8.62%	12.08%	9.69%	9.89%	7.27%	1.40%	2.77%	3.78%	6.85%

advantages of remote sensing tools, relief-induced factors limit utilization of potential of these tools (Buchroithner 1995). Reflected signal values carry high variability and distortion caused by terrain complexity, shadow effects and cloud and snow cover. Persistent cloud cover during the summer months and snowfall in winter create only a small window of 2–3 months in early winter when the alpine zone can be adequately remotely sensed by satellites. Though these challenges result in certain uncertainty in the accuracy of vegetation classification, careful choice of the images, hybrid classification procedure and few post processing steps could overcome some of these problems. Extensive field surveys of vegetation structure and knowledge of altitudinal variation in major formations coupled with intensive ground truthing proved necessary to enhance the accuracy of classification. The classification accuracy of the various landuse types using the above approaches was found to be 86.32% (Table 4).

The reserve forest area of 5,589 km^2 was reasonably close to the recorded reserve forest area 5,451 km^2. The FSI (2005) study is based on 23.5 m resolution IRS P6 satellite data of December 2004, while our study is based on 23 m resolution IRS-1C satellite data of February 2002, hence the source and resolution of the two datasets are quite similar. The area under dense forests as per our study comes to only 1,268 km^2. FSI (2005) assessed the area under very dense (498 km^2) and moderately dense forests (1,912 km^2) in the state to be significantly higher at 2,410 km^2. Our assessment is nearer to other contemporary, satellite data based forest mapping studies like Pandit et al. (2007), who assessed extent of dense forests to be 1,040 km^2 based on the satellite image of the year 2000. Other studies by Kushwaha et al. (2005) in the south west portion of Sikkim also highlight the fragmentation of temperate forests. Earlier studies by ISRO (1994) using 72.5 m IRS-1A satellite data assess the extent of dense forests in the state to be 975 km^2.

Due to the steep elevation gradient the various vegetation classes were found to be telescoped together making the landscape heterogeneous. 56 of the 58 reserve forest polygons are considerably small (mean extent of 1.6 km^2), and comprise just 1.6% (88 km^2) of the total reserve forest area. These are distributed in the lower elevation, having S*horea robusta* (sal), subtropical forests and warm broad leaved forests as the dominant landuse and sur-

Table 4 Classification accuracy of the various landuse types as indicated by the confusion matrix

Class name	Reference totals	Classified totals	Number correct	Producers accuracy	Users accuracy
Alpine meadow	13	13	13	100.00%	100.00%
Alpine scrub	5	5	5	100.00%	100.00%
Alpine thicket	9	8	7	77.78%	87.50%
Conifer forest	33	35	28	84.85%	80.00%
Mixed conifer forest	25	19	18	72.00%	94.74%
Oak forest	250	245	230	92.00%	93.88%
Alder forest	23	22	15	65.22%	68.18%
Middle hill forest	33	34	26	78.79%	76.47%
Subtropical forest	8	12	6	75.00%	50.00%
Sal forest	52	48	45	86.54%	93.75%
Forest thicket	61	56	50	81.97%	89.29%
Forest scrub	8	14	7	87.50%	50.00%
Forest blank	8	14	6	75.00%	42.86%
Agriculture	38	35	33	86.84%	94.29%
Snow	12	10	9	75.00%	90.00%
Rock	2	5	1	50.00%	20.00%
Sand	2	2	1	50.00%	50.00%
	497	497	429	86.32%	86.32%

rounded by agricultural fields. There is an urgent need to protect and regenerate these small sized, fragmented forests, as they are susceptible to encroachment and degradation. Out of the 15 forest classes, 3 classes namely *sal* forest, subtropical forest and warm broad-leaved forest were found to have a limited extent (area less than 145 km^2) and relatively higher degree of degradation. Protection of these forests is critical to prevent the loss of the characteristic biodiversity that they possess.

Cardamom farming is a perennial, low-volume, high-value, non-perishable, cash crop and it demands less nutrients and other inputs in comparison to other crops. Alder forest occurs in private lands and is grown as a shade tree for large cardamom—a valuable native horticulture plant (Sharma et al. 2000). In this zone, these forests have a sizeable extent of 272 km^2 which can be potentially increased to 462 km^2 by encouraging this landuse to bring more and more areas under forest cover and also to have an eco-friendly buffer to shield the temperate oak forests.

During the last three decades of the 20th century, 317 km^2 of degradation has taken place, with the impacts mostly concentrated (196 km^2, 62%) in the temperate oak forests, which have been converted into thickets, scrub and blank areas. This degradation was caused mainly due to open grazing, forest fires, selective felling of commercially important mature trees from forests and clear felling of temperate forests for meeting the demand for timber, firewood and charcoal. Thickets of secondary, unpalatable shrubs and bamboos have increased substantially in these degraded forests. Since 1995, several conservation initiatives have been taken up like implementation of the ban on open grazing in reserve forests and ban on green felling of trees in forests.

The main cause of degradation and fragmentation of the temperate oak and subalpine conifer forests is the heavy dependence for firewood and timber, high grazing pressure, vulnerability to forest fire, poor natural regeneration and naturally slow growing nature. While impacts of pastoralism on these forests has been substantially reduced with the removal of about 10,000 cows along with the 500 herders between 2001 and 2006 (Tambe and Rawat 2009), reducing firewood extraction by local communities and road construction labour force and preventing forest fire still needs to be prioritized. Chettri et al. (2006) documented that there is an unregulated extraction of firewood from the forests of the state, and estimated the annual dependence per rural household to be 6–8 tonnes (dry weight). Greater emphasis is needed for promoting solar water heaters, LPG and ensuring access to alternate and cheap forms of energy and fuel efficient devices will help in substantially reducing the pressure on these forests. Also there is a pressing need to take up a long term restoration program to artificially regenerate these slow growing temperate and sub-alpine conifer forests.

Unlike in other parts of the country, the long dry winter from December to March is the major fire season in the state. Offlate incidence of forest fires in temperate forests which are unaccustomed to forest fire is increasing. There is a pressing need for a greater dissemination of mountain specific fire management technology using participatory approaches.

Conclusions

To conclude, we propose the following priorities for forest management in the Sikkim Himalaya. Firstly initiate a long term restoration program for the degraded oak and conifer forests. Secondly expand the extent of dense forests by reducing the pressure from firewood extraction, grazing and fire hazard. The extent of dense forests jointly with forest cover should be used as an impact indicator. Thirdly take special steps to protect and regenerate the several small-sized, fragmented forest patches in the lower belt. Fourthly promote alder-cardamom agro-forestry in the private lands as an eco-friendly buffer and lastly protect rare forest types (sal forests, subtropical forests and warm broad leaved forest) which are being increasingly degraded and under danger of losing their characteristic biodiversity.

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