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.

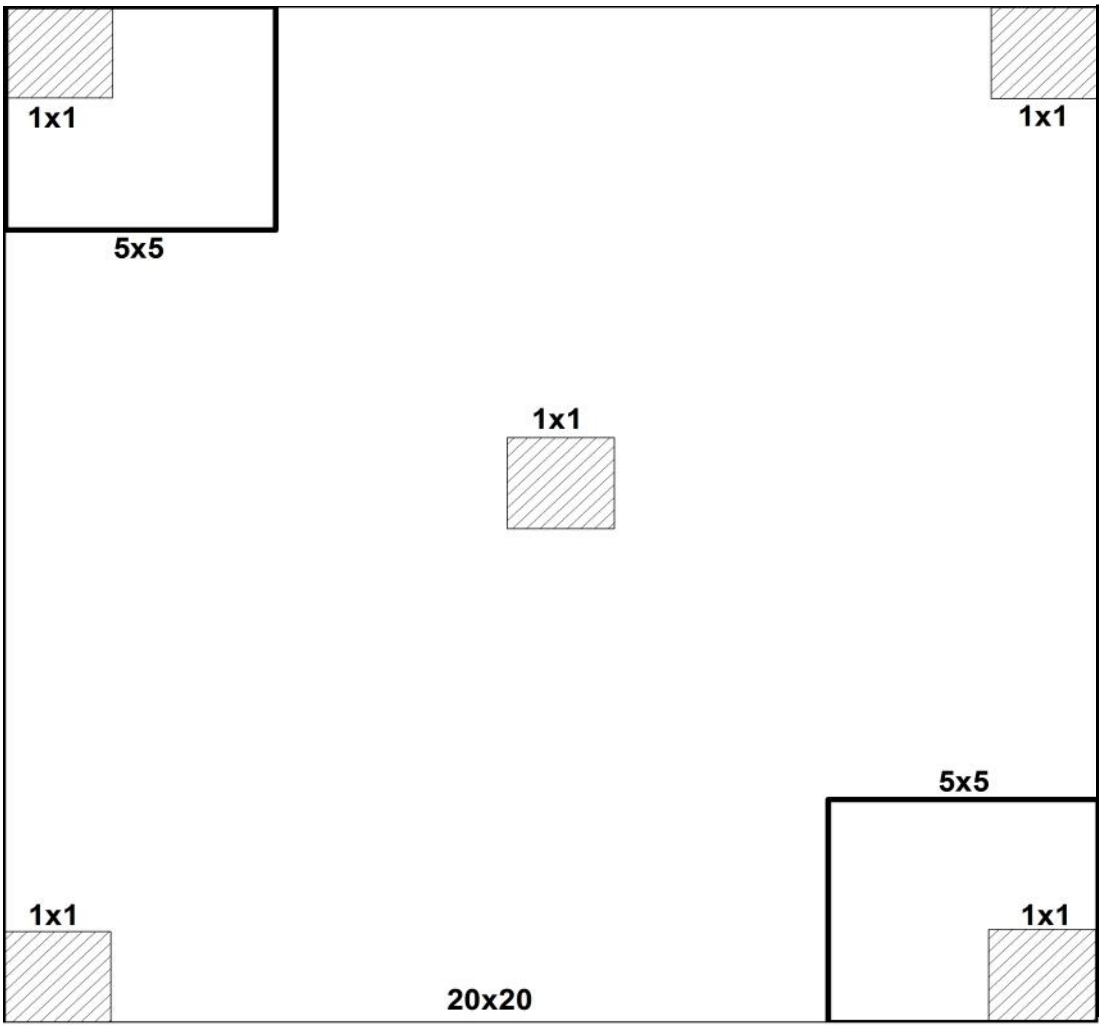

Fig. 4.1. Nested Quadrat design (20x20m for trees and lianas, 5x5m for shrubs and 1x1 m for herbs)

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.