Plant Diversity and Regeneration Status in Kandi Range of Kamraj Forest Division of Kashmir

Hillal Ahmad Rather
(2010-328-D)

Faculty of Forestry

Faculty of Postgraduate Studies

Sher-e-KashmirUniversity of Agricultural Sciences & Technology of Kashmir

2014

Plant Diversity and Regeneration Status in Kandi Range of Kamraj Forest Division of Kashmir

Hillal Ahmad Rather
(2010-328-D)

Thesis

Submitted to

Faculty of Forestry

Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir
in partial fulfilment of requirement for the award of the degree of

Doctor of Philosophy in Forestry

2014

DEDICATE MY THESIS

to

The light which lit up every nook and corner of my life

"FAMILY"

and

To serve whom is my dream

"FACULTY OF FORESTRY, SKUAST-K

&

J&K FOREST DEPARTMENT"

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Forestry, Campus Wadura, Sopore-193201

Certificate – I

This is to certify that the thesis entitled **"Plant Diversity and Regeneration Status in Kandi Range of Kamraj Forest Division of Kashmir"**submitted in partial fulfilment of the requirements for the award of the degree of**Doctor of Philosophy in Forestry**,to the Faculty of Postgraduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, is a record of bonafide research work carried out by**Mr. Hillal Ahmad Rather (Regd. No. 2010-328-D)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation have duly been acknowledged.

Prof. (Dr.) T. H. Masoodi
Chairman
Advisory Committee

Endorsed

Dean,
Faculty of Forestry

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Forestry, Campus Wadura, Sopore-193201

Certificate – II

We, the members of the Advisory committee of **Mr. Hillal Ahmad Rather (Regd. No. 2010-328-D)**, a candidate for the degree of **Doctor of Philosophy in Forestry**, have gone through the manuscript of the thesis entitled, **"Plant Diversity and Regeneration Status in Kandi Range of Kamraj Forest Division of Kashmir"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of degree.

Advisory Committee

Chairman	**Prof. (Dr.) T. H. Masoodi** Faculty of Forestry, SKUAST-Kashmir
Members	
	Prof. (Dr.) N.A. Masoodi Ex-Dean, Faculty of Forestry, SKUAST-Kashmir
	DR. S. A. MIR Head, Division of Statistics, SKUAST-Kashmir
	PROF. (DR.) TAHIR ALI Head, Division of Soil Science, SKUAST-Kashmir
Dean PG Nominee	**Prof. (Dr.) Mushtaq Ahmad** Dean Faculty of Agriculture, SKUAST-Kashmir

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Campus Wadura, Sopore-193201
-::o::-

Certificate – III

This is to certify that the thesis entitled **"Plant Diversity and Regeneration Status in Kandi Range of Kamraj Forest Division of Kashmir"** submitted by **Mr. Hillal Ahmad Rather (Regd. No. 2010-328-D)** to the Faculty of Postgraduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy in Forestry** was examined and approved by his Advisory Committee and external examiner on **06th December, 2014**.

Chairman
Advisory Committee

External Examiner
(Dr. Kulraj Singh Kapoor)
Scientist-F and Group Co-ordinator (Res.)
HFRI, Shimla (H.P)-171009

Dean,
Faculty of Forestry

Director Education
SKUAST-Kashmir

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Forestry, Campus Wadura, Sopore-193201

Name of the student	:	**Mr. Hillal Ahmad Rather**
Registration No.	:	2010-328-D
Major subject	:	Forestry
Minor subjects	:	Soil Science and Environmental Science
Major advisor	:	**Prof. (Dr.) T. H. Masoodi** Faculty of Forestry, SKUAST-K
Title of the Thesis	:	**"Plant Diversity and Regeneration Status in Kandi Range of Kamraj Forest Division of Kashmir"**

ABSTRACT

Changes in vegetation composition and structure with respect to altitude were investigated in Kandi Range of Kamraj Forest Division. The Forest dominated by conifers viz. *Cedrus deodara* and *Pinus wallichiana* are located between an altitude of 1600 m to 2800 m amsl. The vegetation sampling was done by quadrat method and the sample quadrats were located by systematic random sampling method. Forty eight (48) vertical transects (20 m x 50 m) running parallel to each other were defined within the study area and the quadrats were located along transects. Altogether 96, 192 and 192 (480) quadrats for trees, shrubs, grasses and herbs were sampled. Three soil samples were collected from each of transect from its four corners to form a composite sample which were analyzed for some physico-chemical attributes. Number of individuals of each tree, shrub and grass and herb species, diameter of trees at breast height (each individual tree), number of seedlings and saplings of tree species were recorded in each quadrat. Various community attributes (e.g. importance percentage, species diversity index, richness index, concentration of dominance) and population characteristics (e.g. frequency, density & basal area) were analyzed.

Soil was slightly acidic with mean soil pH value of 6.15. The water holding capacity of the soil was 34%. Soil carbon, available nitrogen, phosphorus and potassium levels were 1.93, 256, 7.92 and 271% respectively. Significant

variations were seen among these parameters on different aspects along the altitudinal gradient and the corresponding soil depth. In general, soil fertility was high at the higher altitudes, where thick organic surface layers with a dense network of roots were prevailing, in contrast to the thin layers at lower altitude. The taxonomic compendium of the plant community of Kandi Forest Range included a total of 61 plant species (5 trees, 17 shrubs and 39 grasses and herbs) belonging to 53 genera and 25 families. *Pinus wallichiana* was the dominant tree species and *Cedrus deodara* was the co-dominant species. Among the shrubs *Indigofera heterantha* represented the entire altitudinal range, while *Viburnum nudum* was restricted to the higher elevation only. Similarly, among the undergrowth species *Ranunculus hirtellus* and *Cuminum cyminum* were the most dominant. The total plant density declined from 2,00,912 to 1,70,490 individual's ha^{-1} with increasing elevation between 2000 m and 2800 m.

Concerning patterns of richness and diversity index along the altitudinal gradients was strongly influenced by aspect and generally exhibited a bi- modal structure for trees (*Cedrus deodara* and *Pinus wallichiana*). The overall Simpson's Index of Dominance (0.445) was less than Shannon Wiener's Index (0.718). The overall species richness index of the forest (1.886) was relatively low, which might be due to anthropogenic factors such as illicit logging and fire wood collection. These results further indicate that the structural and floristic variability observed in the studied forest are produced by a combination of different climates (altitude, aspect and edaphic characters) and randomly expressed local processes (e.g. excessive deforestation and unbalanced recruitment of deodar) interacting across a complex physical landscape and thus supporting a hypothesis that species distribution is related to microhabital conditions.

The illicit felling in the Kandi Forest has resulted in the loss of basal area which together with decrease in density has in turn contributed to decrease in the importance of two conifers. These results on status of deforestation indicate that Kandi forest had been subjected to massive logging with population of *Pinus wallichiana* being much more exploited over the entire forest range. This situation has favoured the profuse recruitment of deodar which exhibited good status of regeneration as compared to fair to poor for *Pinus wallichiana.* Thus, in order to balance the composition of conifers in the study area, planting of *Pinus wallichiana* seedlings needs to be undertaken on priority to restrict its complete removal from the area and conversion of mixed coniferous forest to pure deodar forest in the near future.

Keywords: Physicochemical properties, Diversity, deforestation, regeneration, Kandi forest range, *Pinus wallichiana* and *Cedrus deodara*.

Signature of Student
Dated : _____

Signature of Major Advisor
Dated: _____

ACKNOWLEDGEMENT

All Praise to Almighty Allah, the most gracious, charitable, merciful and the most beneficent who gave me enough courage and valiancy to bring out this manuscript

At the outset I must put on record that this work has set the foundation of my research career in the field of forestry. Though only my name appears on the cover of this dissertation, I have not travelled alone in a vacuum in this journey. This thesis has been kept on track and been seen through completion with the support and encouragement of numerous people including my well-wishers, my friends, colleagues and various institutions. I owe my gratitude to all those people who have made this dissertation possible and because of whom my Doctorate experience has been one that I will cherish forever.

At this moment of accomplishment, first of all I take this opportunity to express my homage and sincere gratitude and indebtedness to my Worthy Chairman of Advisory Committee- Dr. T. H. Masoodi, professor Faculty of Forestry, Wadura, SKUAST-Kashmir for his valuable guidance, constant encouragement, support and affection during the period of my research and preparation of this thesis. Dr. Masoodi sets high standards for his students and guides them to meet those standards in principle. In addition to guiding this research, the opportunities that Professor Masoodi provided to broaden my professional experience and prepare me for future challenges are gratefully acknowledged. It has been an honour to be his Ph.D. student. His untiring efforts and deep involvement have led to the initiation and successful completion of this study. No words can be adequate to express my gratitude to him. Working under his expert guidance was an experience that I shall always cherish.

I express my heartful thanks to Professor N.A. Masoodi (Co-Advisor) Ex. Dean, Faculty of Forestry Wadura, SKUAST-Kashmir, Dr. S.A Mir, Head, Division of Statistics, SKUAST-Kashmir; Dr. Tahir Ali, Professor & Head, Division of Soil Science, SKUAST-Kashmir and Professor Mushtaq Ahmad (Dean PG Nominee), Dean Faculty of AgricultureWadura, SKUAST-Kashmir, Shalimar.

I rejoice to express with deep sense of gravitated indebtedness, thanks to Professor M.Y. Zargar, Dean, Faculty of Forestry, SKUAST-Kashmir, for his cooperation, guidance and encouragement during this research work.

Most of the results described in this thesis would not have been obtained without a close collaboration with few laboratories. I owe a great deal of appreciation and gratitude to Dr. Shoukat Ara, Associate Professor, Division of Environmental Sciences, SKUAST-K,, Dr. G.I Hassan, Associate Professor Quality control laboratory SKUAST-K,, Dr G R Najar, Associate Professor, Division of Soil Sciences, SKUAST-K and Dr. Irshad University of Kashmir for identifying and classifying the plant taxa collected across the selected forest range.

I put across my appreciation and respect to Dr. K.N. Qaisar, Dr. S.A. Gangoo, Dr. P. A. Khan, Dr. P.A. Sofi and Dr. Gh. Mohi-ud-din Bhat for their valuable guidance, suggestions and cooperation during my stay at Faculty of Forestry. I am deeply grateful to them for long discussions that helped me sort out the technical details of my work.

I express my sincere thanks to Mr. Manzoor A. Rather, Mr. Ishtiyak Ahmad, Mr. Ab Kareem, Mr. Quadoos, Mr. Gh. Qadir, Mr. Shabir A. Mir , Mr. Gh. Mohi-ud-din, Mr. Mehraj-ud-din, Mr. M Maqbool, Mr. Idrees A, Mr. Basharat Ahmad and other field and

supporting staff of Faculty of Forestry for their timely cooperation and help during this research work.

A journey is easier when you travel together. Interdependence is certainly more valuable than independence. This thesis is the result of many of my friends who were always there when I really needed. All of them have helped me stay sane through these difficult years. To name them all here is difficult. However some of them viz. Dr. Mumtaz Majid, Mr. Altamash Bashir, Dr. Gh. Irshad Hassian, Dr. Rayees, Dr. Sheeraz, Dr. Imtiyaz Pom, Dr. Aflaq, M.Younus Mir, Dr. Shakeel Samoon, Dr. Sajid Maqsood Rather, Fayaz ahmad, Dr. Malik, Aasif Aziz, Shameez, Dr. Javid, Abid Ahmad Lone, Hilal Budgami, Javaid Iqbal, Sohail Ahmad, Altaf ahmad, Showket Ahmad, Mr. Nazir Ahmad Ladakhi, Dr Aijaz Ahmad, Mr. hillal Ahmad Naseer Ahmad and Mr Majid Ali deserve a place to acknowledge their support that helped me overcome setbacks and stay focused during my study. I greatly value their friendship and deeply appreciate their belief in me. I regret for all those who cared for me but not have got a mention. Nevertheless none shall ever be forgotten.

I am also grateful to Mr. M. Ayoob (DFO) Mr. Miya javid (Conservator) Kamraj Forest Division, Mr. Ab. Majeed and Mr Ab. Ahad Range officersof Kandi Forest Range, office staff viz. Mr. Mushtaq Ahmad, Mr. Shahbaz Ahmad, Mr. Gh. Nabi, and field staff viz. Mr. late Ab Majeed, Mr. Jaffer ahmad, Mr. M. Sultan Hajam, and Mr. Fayaz Ahmad of this Range without whom the successful compilation of this research project would not have been possible.

I express my sincere thanks to Dr. Sb. (Mungloo) and his family members who have provided me the night staying facility and food items during my research project in the vicinity of Kandi forest range.

I express my heartful thanks to Mr. Mushtaq Ah. Mrs Shahida Parveen, Mohammad Sami, Mohammad Basit and other relatives who have supported me during this project.

Special thanks are due to Mr. Musadiq Rashid, Mr. Javid Iqbal and Mr. Younus Ahmad of M/s Anmol Computers, Duroo Sopore for composing this manuscript and giving it a final shape.

I am highly thankful to Mrs. Naseema Masoodi for her help during the course of this study. I reciprocate with thanks the affection and blessing bestowed upon me by her.

Last but not the least and most importantly, none of this would have been possible without the love and patience of my family. My immediate family, to whom this dissertation is dedicated to, has been a constant source of love, concern, support and strength through all these years. I would like to express my heart-felt gratitude to my loving Mother, brothers, my Deedi (Yusma),Deedi, nephews, nieces, sahba, shahid Hamid, dada, mosa, beta, mama gee, GH nabi war, bilal, shahzad and other relatives. All of them have aided and encouraged me throughout this endeavour. I have to give a special mention for the support given by my elder brother Mr. M Shafi Rather and his wife Jabeena Begum. I warmly appreciate their generosity and parental touch extended to me throughout my life.

Hillal Ahmad Rather

Place: Wadura, Sopore
Date:

CONTENTS

Chapter	Particular	Page No.
1.	INTRODUCTION	1-7
2.	REVIEW OF LITERATURE	8-53
3.	MATERIALS AND METHODS	54-69
4.	EXPERIMENTAL FINDINGS	70-116
5.	DISCUSSION	117-147
6.	SUMMARY AND CONCLUSION	148-156
	LITERATURE CITED	I - XLVII

List of Tables

Table No.	Particulars	Page No.
1.	General characteristics of the Kandi forest range.	56
2.	Mean monthly meteorological data of District Baramulla for the year 2011 & 2012.	58
3.	Physical properties of Kandi Forest soils at different aspects of 1600-2800m amsl altitude.	71
4.	Chemical Properties of Kandi Forest soils at different aspects of 1600-2800m amsl altitude.	76
5.	Species composition of various altitudes and aspects of Kandi Forest Range.	81-82
6.	Summary of community structure of Trees across the available aspects along an altitudinal gradient in Kandi forest range.	84
7.	Importance Value Index (IVI) of Trees across the available aspects along an altitudinal gradient in Kandi forest range.	87
8.	Summary of community structure of Shrubs across the available aspects along an altitudinal gradient in Kandi forest range.	89
9.	Importance Value Index (IVI) of Shrubs across the available aspects along an altitudinal gradient in Kandi forest range.	92
10.	Summary of community structure of Herbs and Grasses across the available aspects along an altitudinal gradient in Kandi forest range.	95-97
11.	Importance Value Index (IVI) of Herbs and Grasses across the available aspects along an altitudinal gradient in Kandi forest range.	100-102

12.	Diversity indices of trees, shrubs, herbs and grasses across the available aspects along an altitudinal gradient in Kandi forest range.	104
13.	Overall diversity index (H), Concentration of dominance (C), Richness index (R) and Evenness Index (E) of different life forms across different altitudes of Kandi forest range.	106
14.	Overall diversity index (H), Concentration of dominance (C), Richness index (R) and Evenness Index (E) of trees, shrubs and grasses and herbs in Kandi forest range.	106
15.	Overall diversity index (H), Concentration of dominance (C), Richness index (R) and Evenness Index (E) of aspects in Kandi forest range.	108
16.	Index of similarity and dissimilarity co-efficient of Tree across the available aspects along an altitudinal gradient in Kandi forest range.	108
17.	Index of similarity and dissimilarity co-efficient of shrubs across the available aspects along an altitudinal gradient in Kandi forest range.	110
18.	Index of similarity and dissimilarity co-efficient of herbs and grasses across the available aspects along an altitudinal gradient in Kandi forest range.	110
19.	Deforestation status of Kandi forest range at different altitudes.	112
20.	Deforestation status of *Cedrus deodara* and *Pinus wallichiana* in Kandi forest range.	113
21.	Regeneration status of *Cedrus deodara* and *Pinus wallichiana* species across the available aspects along an altitudinal gradient in Kandi forest range.	115
22	Pearson correlation coefficient between different vegetation and soil parameters.	142

List of Figures

Figure No.	Particulars	After page No.
1.	Photograph of Kandi forest range showing location of sampling points	54
2.	Aspects on latitudinal and longitude gradients in Kandi forest range	55
3.	Importance Value Index (IVI) of Trees across the available aspects along an altitudinal gradient in Kandi forest range	87
4.	Importance Value Index (IVI) of Shrubs across the available aspects along an altitudinal gradient in Kandi forest range	92
5.	Importance Value Index (IVI) of Herbs and Grasses across the available aspects along an altitudinal gradient in Kandi forest range	102
6.	Deforestation status of Kandi forest range at different altitudes	113
7.	Regeneration status of *Cedrus deodara* and *Pinus wallichiana* in Kandi forest range	114
8.	Regeneration status of *Cedrus deodara* species on different altitudes of study area	115
9.	Regeneration status of *Pinus wallichiana* species on different altitudes of study area	115
10.	Summary of Topographic, phyto-sociological and edaphic characteristics of Kandi forest range	149

List of Plates

Plate No.	Particulars	After page No.
1.	Map of the Kandi forest range	54
2.	Soil analysis	60
3.	locating sampling points by GPS and recording of phyto-sociological data	63
4.	Sampling layout	64
5.	Deforestation status of study area	67
6.	Tree species in Kandi Forest Range	83
7.	Shrub Species in Kandi Forest Range	88
7a.	Shrub Species in Kandi Forest Range	89
7b	Shrub Species in Kandi Forest Range	90
8.	Herb and Grass Species in Kandi Forest Range	93
8a	Herb and Grass Species in Kandi Forest Range	94
8b.	Herb and Grass Species in Kandi Forest Range	97
8c.	Herb and Grass Species in Kandi Forest Range	98
8d.	Herb and Grass Species in Kandi Forest Range	99
9	Deforestation status of study area	111
10	Regeneration status of study area	114

Chapter – 1

INTRODUCTION

Forests occupy the central importance in ecology and as such need to be quantified for their variability to describe ecosystems, the functional attributes of which are enhanced by the occurrence of varied edaphic and meteorological features (Chersetl, 1989). These ecosystems provide niches for large number of species with greater variability in life traits and strategies like dispersal, regeneration, establishment and growth (Lavorel *et al*., 1997). Thus, forests with high diversity perform various life support functions than monotonous environments (Monica *et al*., 1993). The composition and structure of these forests is an important indicator for understanding qualitative stages of succession which in turn can be used to evaluate the extent and status of natural regeneration (Myneni *et al*., 1997; Schwartz, 1999; Romshoo *et al*., 2002). Species composition is derived from behaviour and ecological attributes of a forest which varies from one habitat to another with their spatial and temporal distribution pattern providing vital inputs for bio-prospecting (Scheiner, 1992; Nautiyal *et al.*, 1999). Both these dimensions, consider species with regard to its autoecology and morphology which provide information on the underlying mechanism of species assemblages (Kolasa and Rollo, 1991; Alard and Pondivigne, 2000). It is in this endeavour that the management and utility of forests require accurate information on their compositional dimensions and spatial distribution (Noss, 1990; Tilman *et al*., 1997; Lu *et al*., 2004).

The interest in community structure has traditionally focused to define a forest in terms of its economic importance. The significance of this natural resource to ecology is very important being most obvious physical representation of terrestrial ecosystems that acts as a habitat within which energy flows from one component to another. These forests contribute not only to the production objectives, but also to the biodiversity and environmental conservation. The plant community of a region and its composition as a function of time, altitude,

latitude, aspect and slope thus not only determines the microclimate and energy budget, but also influences various edaphic and hydrological characters (Tappeiner and Cernusca, 1996; Ilorker *et al.*, 2001; Kumar *et al.*, 2004).

The community structure is a basic component of an ecosystem, the structure of which is the integrated exhibition of rank, function and developmental trends of various species living and interacting within that habitat (Zhang, *et al*., 2007). The Community structure is thus, directly regulated by species diversity and is the biological basis to maintain ecosystem processes (TilmanDowning, 1994, Zhang *et al*., 2004). Species richness, seral stage and the community stability are the important parameters characterizing a community (Liyun *et al*., 2006). While species richness is a simple stability of seral stage and easily interpretable indicator of biological diversity (Peet andVeblen, 1974), it is in turn influenced by many types of topographical changes and climatic variables (Sagar *et al*., 2003; Ellu and Obua, 2005; Sharma *et al*., 2009a). Generally, it can be noticed that mountain ecosystems usually have distinct biological communities and high level of endemism due to their topography (Gairola *et al*., 2008). The distribution of mountain vegetation is strongly influenced by the climatic parameters such as temperature, precipitation, wind and insolation. These components characteristically change rapidly for mountain regions over very short distances both along the vertical and horizontal gradients. Other factors such as soils, postglacial succession and human disturbances also affect the vegetation pattern (Krauchi*et al*.,2000).

The nature of ecological communities is a fundamental issue in ecology and understanding the forest structure is a pre-requisite to describe various ecosystem processes so as to model the dynamics of forests (Elourard *et al*., 1997). Many ecologists have considered communities as integrated (possibly discrete) entities with emergent structure and function shaped by species interactions and co-evolution (Drake, 1990; Dolezal and Srutek, 2002). The study of species diversity is helpful to understand community composition and its

structure and development (Li & Zhou, 2002). The functional consequences of species diversity determine the organismal traits, which in turn influence the ecosystem processes. The components of species diversity that determine the expression of these traits includes the number of species present (species richness), their relative abundance (species evenness), presence of the particular species (species composition), the interactions among species (non-additive effects), and the temporal and spatial variation in these ecosystem attributes. In addition to its effects on current functioning of ecosystems, species diversity also influences the resilience and resistance of ecosystems to environmental changes (Chapin *et al*., 2000).

Altitude and aspect plays an additional role in determining the temperature regime and atmospheric pressure of any site and as such within one altitude; the cofactors, like topography, aspect, inclination of slope and soil type affect the forest composition (Shank and Noorie, 1950) and as well as the species richness and their dispersion behavior Ellu and Obua (2005). The distribution of species and their richness pattern are also largely regulated by physiographic factors (Sharma *et al*., 2009a, 2009b). This type of ecological knowledge can prove to be fundamental for conservation and sustainable utilization of forests, and may help policy makers for drafting management plans for fragile mountain ecosystems.

Soils are the productive potential of forests. They are non-renewable components of our renewable resources. Soil fertility, the ability of the soil to provide plants with the nutrients they required, is a complex phenomenon. It is determined by soil chemistry, organic matter content, moisture, aeration, microbial activity and temperature. All these variables interact and influence each other. Additional complications arise from the fact that fertility is more closely related to the balance of different nutrients and to their rate of circulation within the ecosystem, than to the absolute levels of nutrients in the soil.

The growth and reproduction of forests cannot be understood without the

knowledge of soil. The importance of soil is that it acts as reservoir of nutrients and moisture for ecosystem productivity, which has been recognized since the beginning of the forest management (Schlesinger *et al*., 1990). The soil and vegetation inherit a complex interrelation due to their simultaneous development over a long period of time. The vegetation influences the chemical and physical properties of soil and rejuvenates its fertility to a great extent. The selective absorption of nutrient elements by different tree species and their capacity to return them to the soil brings about many biological and chemical changes in soil properties (Singh *et al*., 1986). Thus the concentration of elements in the soils is a good indicator of their availability to plants and their bio-cycling in the soil-plant system (Pandit and Thampan, 1988). Forests as such will have a greater influence on soil conditions than most other plant dominated ecosystems, due to a well-developed ‘‘O’’ horizon, moderating temperature and humidity at the soil surface, input of litter with high lignin content, high total net primary production and high water and nutrient flow (Binkley and Giardina, 1998). The different tree species in a forest can differ significantly in their influence on physicochemical properties of the soil which are in turn important for the growth of the plants (Augusto *et al*., 2002). Therefore, knowledge about soil chemical reactions and processes within the forest soil is an essential co-factor for developing innovative resource management strategies and understanding and regulating the behavior of the terrestrial ecosystem at regional and global scales (Schnitzer, 1986).

Forests around the world have undergone severe disturbances due to anthropogenic factors. Exponential increase in human population has caused migration into forested zones to facilitate economic activities (farming, grazing and establishment of settlements and industries). These disturbances have often resulted in habitat fragmentation, change in species composition soil degradation and nutrient losses (Dinesh *et al*., 2003; Armenteras *et al*., 2003; Dale and Pearson, 1997). The habitat fragmentation in turn enforces negative impact on species richness by reducing the probability of successful dispersal and

establishment (Gigord *et al*., 1999) and lowering down the capacity of a patch of habitat to sustain a resident population (Iida and Nakashizuka, 1995).

The term regeneration refers to processes including production, dispersal and germination of seeds and the subsequent establishment of seedlings. It is the most important process to maintain the stable age structure of the plant species in a community, affected directly or indirectly by various climatic as well as edaphic factors (Singh and Singh 1992). The issue of regeneration is mainly important for those forests which are under various anthropogenic pressures such as timber mining, grazing and trampling, etc (West *et al*., 1981).

The successful establishment of seedlings and their survival and the growth is a complex phenomenon because plant ecology, environmental factors and many random events play significant and deterministic roles for inducing natural regeneration in forests. Moreover, the regeneration of any species is confined to a peculiar range of habitat conditions, the extent of which is a major determinant of its geographic distribution (Grubb, 1977). The population structure of a species in a forest is characterized by the presence of sufficient population of seedlings, saplings and adults that determine its regeneration behaviour and the future composition of a community (Austin, 1977). Regeneration status of trees can therefore, be predicted by the age and structure of their populations (Khan, *et al*., 1987; Tripathi and Khan, 2007).

The study of regeneration of trees has important implications for the management of natural forests and is one of the thrust areas of research in modern ecology as studies have shown that regeneration of tree species in a forest is affected by its canopy density, soil moisture, cation exchange and anthropogenic pressures (Sukumar *et al*., 1997; Murthy *et al*., 2002). However, the role of other functional dimensions of a forest ecosystem is still unexplored.

The State of Jammu and Kashmir; with a total reporting area of 10.138 million ha inside the line of control, forms one of the important phyto-geographical and phyto-sociological regions in the North western Himalaya. The

State is known for its rich biodiversity and for this reason it has been designated as the **"Biomass State"** (Anonymous, 2010). The vale of Kashmir is bestowed diversified land use systems with forests occupying central place. Out of the total geographical area of 15,948 Km^2, about 51% (8128 km^2) is occupied by demarcated forests. However, only 3296 km^2 of these demarcated forests sustains very dense and moderately dense forests whereas more than 60% (4832 km^2) has been rendered degraded and classified as open forests (Anonymous, 2011). The valley of Kashmir is asymmetrical with 187 km diagonal length and considerably varying breadth, being highest 115.8 km along the latitude of Srinagar (Kaul, 1977). The diversified land-forms and relief in Kashmir supports an array of forest types. The high altitude landscape comprises varied ecosystems, the most important being temperate and sub-alpine forests and alpine pastures. These ecosystems harbour rich biodiversity and represent one of the most important, fragile and distinct life support systems distributed in two prominent bio-geographic zones viz. the Trans-Himalaya and the Himalayan zone. Both these zones represent a store house of many natural resources the important being the large number of plant species, rich pastures and ample quantity of fresh water. The collection and use of many of these economically valuable plants and their products (food, fodder, fiber, medicinal and aromatic plants) has been the main economic activity of local communities for from an immorable period of time.

Kamraj Forest Division is situated in twin district of Baramulla and Kupwara between 34^0 $16^/$ to 34^0 $42^/$ N latitude and 74^0 $02^/$ to 74^0 $32^/$ E longitude.It is represented on the survey of India's sheet no's 43J/2, J/3, J/6, J/7, J/10 and J/11. Spread over an area of 58230 ha (582.30Km^2) the altitude of this Forest Division varies between 1600 m –3845m amsl. The Kamraj Forest Division is composed of four ranges viz: Kandi, South Lolab, North Lolab and Naihari and extend from Watlab ridge in District Baramulla to Panzgam in Kandi rangeof District Kupwara (Anonymous, 1981).

The present investigation was carried out in Kandi Forest Range which

comprises the outer slopes in the south of this forest Division. The terrain of this forest range is precipitous only in the upper ridges east of Zaloora and is steep to gentle in general. The impact of geological formation on the flora of the range is quite vivid. The presence of dry type of deodar and kail on the Cambrian areas is due to adverse bedding dip. In outer Kandi range the biotic interferences in the past have led to the devastation of the forest cover and with accelerated erosion, the top soil is almost eroded. Despite these ecological constraints, this has never been explored for its community attributes along the local topographic features.

With the abovefacts in mind the present study was carried in this forest range to explore its present status of floristic composition, diversity attributes and some physico-chemical characterists of soil along a vertical gradient. The present study was also taken up to generate a valuable data on extent of deforestation and regeneration of dominant conifers clothing this forest range. The datagenerated from this study can be used to formulate management policies and land use planning for this Forest Range which forms important water shed of Wular Lake. The study was undertaken with following specific objectives:-

1. **To assess some soil Physico-chemical properties of Kandi Range along the altitudinal gradient.**
2. **To explore community structure and plant diversity of Kandi Range along the altitudinal gradient.**
3. **To study the extent of deforestation of the selected Forest Range and,**
4. **To evaluate the regeneration status of dominant conifer tree species in the selected Forest Range.**

Chapter – 2

REVIEW OF LITERATURE

2.1. Soil characterisation

Slope, altitude and pattern of rainfall largely govern qualitative and quantitative distribution of forest species in the Himalayan regions. Soil plant interaction also has specific effects. The types of species, which establishes on soil, affect nature and properties of soil. Effects of altitude on soil properties has been studied by Legarda *et al*. (1973) who reported that organic matter, total nitrogen and exchangeable potassium increased with altitude between 1000 to 4000 m, while clay percentage, exchangeable calcium , exchangeable magnesium, tended to decrease.

From the studies of cold temperate zone plants, particularly conifers (Kaufmann ,1975; Running and Reid, 1980), it is known that even in soils near field capacity, water uptake may extend through spring and into early summer in temperate zone coniferous forests with persistent snow cover. The herbaceous flowering plants are known to prefer rich organic matter, higher amount of available nutrients, moisture, temperature (10-20^0 C) and high light intensity (Collins *et al*., 1985).

A study was conducted in Himachal Pradesh to observe the effect of altitude (from 800-2,865 m amsl) on the organic carbon, pH, total ammonical nitrate and nitrogen by Minhas and Bora (1982). They concluded that organic carbon and total and available nitrogen increased with altitude pattern. Similar, study was conducted in North-western Himalaya and the result show that the humus in high altitude soil profile is over whelmingly fulvic with fractions associated with free sesquioxides predominating. Further, the humic acid molecule has a low degree of condensation and thus they are closed to fulvic acid. The humus in middle altitude soil profile is less fulvic and it shows an increase in frictions associated with divalent cations. Fulvic acid frictions associated with

highly mobile sesquioxide decrease considerably and homic acid molecule becomes more condensed (Dhir, 1967 and 1973).

Soil characteristics of varying altitudes (140 m -3615 m amsl) in the eastern Himalayan in relation to vegetation have been reported by Gangopadhyay *et al*.(1990) although all the soils studied were derived from Darjeeling gneiss and schists consisting of sand stone and quartizes, the soil differences have been assigned to variation in the climatic conditions and vegetation cover. Organic carbon, total N, humus carbon, humic acid carbon and fulvic acid carbon contents of the soils were highly significantly positively correlated with altitude, while CEC showed lower significant positive relation. The value of pH, exchangeable Ca^{+2}, Mg^{+2} and K^{+} showed negative correlation with altitude, while clay contents showed non-significant positive correlation.

2.1.1. Physico-chemical properties

Physical and chemical properties of soils have been used to evaluate the ecological functioning of the forest soils. Forest soils are important for maintaining the normal cycling and make soil physicochemical conditions favourable for plant growth (Bargali *et al*., 1998).Buckman and Brady (1967) suggested that the chemical and physical properties of soils are largely controlled by clay and humus as it acts as the centre of activity around which chemical reactions and nutrient exchange occurs.

2.1.1. Physical properties

2.1.1.1.Bulk density

Soil compaction is evaluated in several ways. The most common way is by measuring soil bulk density. Soil bulk density is defined as the mass of a unit volume of dry soil in which both solids and pore space are included in the volume measurement (Brady and Weil, 2002). Bulk density influences the root penetration, availability of nutrients, water and oxygen for plant and porosity of soil thereby affecting the success of a plant. Eden *et al*., (1991) reported that

bulk density increases over time after conversion of forests by clear-cutting or burning to pastures. Increase in bulk density after clear-cutting has been reported by several workers (Hajabbasi *et al*., 1997; Schwendenmann, 2000; Lister *et al*., 2004) due to susceptibility of the soil to compaction and trampling compaction by logging machinery for forest harvesting (Schmidt *et al*., 1996), and due to the decrease in organic matter by reduced litterfall (Bargali *et al*., 1998).

Tiwari *et al*, (2013) who recorded bulk density of different forest tree species and the values observed were 1.74, 1.58 and 1.72 (*Pinus wallichiana*), 1.37, 1.58 and 1.49 (*Cedrus deodara*) and 1.34, 149 and 1.79 (Mixed Forest) gm cm^{-3} at 0-15, 15-30 and 30-45 cm soil depth respectively. But, soil bulk density values of temperate forests of Nanda Devi Biosphere Reserve ranged between 1.14 to 1.91 gm cm^{-3}. Zarin et al. (1998) found that median bulk density values were lowest for the 0-10 cm depth in coniferous forest soils and highest for the 10-40 cm depth in moorland soils. Bisht and Lodhiyal, (2005) reported soil bulk density values in the range of 0.95-1.20 g cm^{-3} in the coniferous forest of central Himalaya (Kumaon). Bulk density of forest soils reported by Page-Dumroese *et al*. (1999) was 1.10 and 1.24 mg m^{-3} at 0 to 10 cm and 1.11 to 1.21 mg m^{-3}at 10 to 20 cm. However, low average values (1.05 mg m^{-3}) of bulk density were reported by DeLong *et al*, (2011). Neeraj *et al*, (2001) studied the effect of altitude and aspect on bulk density in mid elevation forests of Central Himalaya (India) and the values recorded were 1.0 and 1.2 (1300-1500 m), 1.0 and 1.2 (1500-1800 m) and 1.1 and 1.3 g cm^{-3} on East and West aspects respectively.

Bulk density was observed under different land uses in foothills of Siwaliks in N-W India and the barren lands showed the highest values (1.47 to1.60 g cm^{-3}), followed by cultivated unmanaged (1.46 to 1.58 g cm^{-3}), cultivated well-managed lands (1.34 to 1.54 g cm^{-3}) and least in those of forest lands (1.32 to 1.52 g cm^{-3}) (Gupta *et al*, 2010). Tate *et al*, (2004) observed that soil surface

bulk density was 16 to 22 percent lower under canopy cover compared to open grasslands, and was greater at grazed sites than at non-grazed sites.

2.1.1.2. Electrical conductivity (EC)

Electrical conductivity of grassland soils of Yusmarg (Kashmir) showed variation between 150µS/cm at non-fenced grazing area in December to that of 290µS/cm at commercial/ tourist area in June. Generally, it is believed that higher the concentration of ions in the soil solution, more is its electrical conductance. Therefore, the higher value at commercial/ tourist area in June could possibly be attributed to the presence of higher amounts of calcium, magnesium and potassium ions at the site. The result further revealed that average EC at Fenced meadow and Transition zone /edge between a coniferous forest and a meadow was 235 and 214 µS/cm respectively (Moieza *et al*., 2012). EC did not vary significantly under different land−uses at varying soil depths. Although, the higher values of EC under tree based land−use system, as compared to arable land has been reported by Pal (2013). Bhat (2001) while working on apple orchard soils of Kashmir valley reported that the electrical conductivity of surface soils was in normal range.

The electrical conductivity varied from 0.08 to 0.16, 0.14 to 0.15 and 0.06 to 0.21 dSm^{-1} in low, karewa and high altitude soils of Kashmir respectively (Sheikh, 2006). In an experiment conducted by Qazi and Ashok (2008) in the catchment area of the world famous Dal Lake, the EC values recorded were 161 and 137 μScm^{-1} (*Pinus wallichiana*) and 169 and 135 μScm^{-1} (*Cedrus deodara*) at 0-10cm and 10-20cm soil depths respectively. Ganai (2001) reported that the electrical conductivity of saffron growing soils of Kashmir valley ranged from 0.09 to 0.32 dSm^{-1} with mean value was 0.16 dSm^{-1}. Anjum (2007) observed mean EC value were 0.12 dSm^{-1} on surface and 0.16 dSm^{-1} on subsurface layers, showing an increased trend with depth in some orchard soils of Kashmir. Rao *et al.* (2008) observed that electrical conductivity values ranged from 0.01 to 0.04 dSm^{-1} in surface horizons and 0.02 to 0.12 dSm^{-1} in sub-surface horizons

respectively and also showed a variation down the slope gradient. Similarly, Dhale and Prasad (2009) found a variation in the electrical conductivity which ranged from 0.15 to 0.40 $dSm^{-1}$and 0.15 to 0.54 dSm^{-1} in the surface and sub-surface horizons of the analysed pedons, respectively. Wani *et al.* (2009) observed that soils of Tsari-Shrief watershed had normal electrical conductivity. In an experiment conducted in lower munda watershed soils which reveals that soil had normal range of electrical conductivity, also there was a slightly increase in the value with the increase in soil depth across the profile (Dandroo, 2001).

2.1.1.3. Soil reaction (pH)

In different studied the Grassland Soils of Yusmarg (Kashmir), soil pH values ranges between 5.90 - 6.23 and all examined sites were found to be slightly acidic to acidic, but lowest pH values at Site 4 can be attributed to the presence of pine needles which contribute in increasing the soil acidity when they are decomposed. Moieza *et al*. (2012). Higher levels of organic matter result in a greater number of cation exchange sites which tend to decrease the pH (Naiman *et al*., 1994). The presence of higher content of organic matter in the soil can be another passible reason for lowering of the pH (Hodges, 1996). The acidic soil may be due to the acids released by the decomposition of organic residues obtained from forest vegetation. Richter *et al*. (1988) found that very dilute soil solutions (conductivity of soil solution of 2mS/m) declined by about 0.3 units in pH when measured in a stronger salt solution (0.01M $CaCl_2$), whereas soils with higher salt concentration (conductivity >5mS/m) showed no further effect of added salt on pH. Tilki and Fisher (1988) reported that the root tolerance to acidity differs widely among plant species, but it appears that many tree species are relatively tolerant to acid conditions. Blake *et al*. (1999) depicted that pH decreased from 6.2 - 3.8 in naturally regenerated woodland and from 5.2-4.2 in unlimed grassland due to acid deposition. Binklay *et al*. (1989) also reported decrease in soil pH of about 0.3 to 0.8 units in 20 years in an old-field plantation of loblolly pine but attributed it to reduction in base saturation

of the exchange complex. Contribution of vegetation through fall to soil pH was studied by Reynolds *et al*. (1989). Falkengren-Grerup (1987) studied the long term changes in soil pH in 22 forest soils from southern Sweden and observed that the top soil has become more acidic probably due to acid deposition.

Tiwari *et al*. (2013) recorded soil pH of different forest tree species. Highest values (5.76) were recorded in *Abies pindrow* followed by *Cedrus deodara* (5.33), Mixed Forest (5.50) and *Pinus wallichiana* (5.09) percent. Drohan and Sharp (1997) also reported reduction in forest soil pH due to acid deposition. They reported 3 times greater H ions flux beneath larch than that of Sitka spruce indicating that larch is more acidifying than spruce. Inter species differences in soil pH in a mixed forest were also reported by Finzi*et al*. (1998) and Matsuura *et al*. (2001). Gupta, (1980) reported that the pH range of Koyhikerh and Mecleodganj soil profiles from northwest Himalaya of Kangra reflecting good growth of *Cedrus deodara* was 4.8 to 5.3 and 6.2 to 8.2 respectively. The author also found that in case of *Pinus roxburghii*, it was from 7.1 to 8.3 for Bankhandi and 5.5 to 6.0 for Norpur soil profile and has also reported that *Cedrus deodara* and *Pinus roxburghii* have been found to grow well even on clay and sand clay-loam soil of northwest Himalaya.

Anderson *et al*. (2004) observed lowest soil pH under scot pine and spruce than other two groups arollo pine and larch and aspen and birch. Similarly, Xu*et al*., 2006also reported that Grand fir and Norway spruce acidified soil more than oak and beech. Various studied have shown that tree species litter quality changes soil pH differently with increasing acidity for coniferous species and decreasing acidity for deciduous and herbaceous litter (Sariyildiz *et al*., 2005). However, application of wood ash (Jacobson *et al*., 2003) and liming (Hwang and Son, 2006) to the forest soils had led to the increase in pH significantly.

The soils on hill tops and hill side are slightly acidic with pH varying from 6.11 to 6.50, whereas those on the ravenous area, piedmont plain and alluvial plain were slightly alkaline to alkaline with range of 7.55 to 8.57 (Sitanggang *et al*., 2006). Slightly acidic to alkaline pH was observed in karewa soils of Kashmir region (Kirmani, 2004). Takahashi*et al*. (2001) found that soils in the coniferous forests of Japan are mostly acidic. Similarly, pH in the range of 5.5 - 6.5 was reported by Bisht and Lodhiyal (2005) in coniferous forests of central Himalaya. In an experiment soil pH of alpine sites ranges 4.0 to 6.0 which are lower than that reported for oak and pine forest sites (6.0 to 6.3) in the lower elevations (Singh and Singh 1987).

The influence of slope, aspect and altitude on soil characteristics in Garhwal Himalayas observed the surface soils of north facing pedons had higher pH values (6.3 to 6.7) as compared to south facing pedons (5.4 to 6.0). The maximum difference in surface and sub-surface horizons were found on higher altitude of north aspects (Verma *et al.* 2008). The higher value of pH is attributed to leaching of salts to subsurface horizons (Ram *et al*., 2010). Sub-surface soil pH was more acidic under teak plantation compared to soil pH under shifting cultivation (Walia and Chamuah, 1992).

2.1.1.4. Water Holding Capacity (WHC %)

Whittaker (1965) observed that the distribution of tree, shrub and herb diversities has been found to be affected by the presence of different soil moisture regimes and infact site quality has been related primarily to soil moisture and nutrients (Lowry, 1975). High moisture regimes have been reported to favor the growth of seedlings in temperate forests (Khan and Tripathi, 1989).

WHC values of Puri Temperate forests (Uttarakhand) were recorded as 68.02, 77.91 and 88.81 (Undisturbed site); 66.87, 76.98 and 72.84 (Moderately disturbed site) and 75.80, 73.08 and 90.15 (Highly disturbed site) at 0-10, 10-20 and 20-30 cm soil depth respectively (Bisht and Bhatt, 2010). Tiwari *et al*, (2013) recorded water holding capacity of different forest tree species and the values

observed were 36.50, 49.17, 47.38 and 44.78 % under *Pinus wallichiana*, *Cedrus deodara*, *Abies pindrow* and Mixed Forest respectively at 0 to 45 cm soil depth. In another study on soil physical variability in relation to soil erodibility under different land uses in foothills of Siwaliks in N-W India was conducted by Gupta *et al*., (2010), the result reveal that WHC (%) ranged from 21.9 to 32.2, 30.5 to 40.5, 35.4 to 47.5 and 35.3 to 47.3 in soils of barren, cultivated unmanaged, cultivated well managed and forest lands respectively.

In Mandal subalpine forests WHC were 85.55, 96.62 and 65.94 (Undisturbed site), 64.15, 92.34 and 74.90 (Moderately disturbed site) and 85.56, 95.50 and 75.26 (Highly disturbed site) percent were recorded at 0-10, 10-20 and 20-30 cm soil depth respectively (Bisht and Bhatt, 2010).

An experiment conducted in foot hills of Pir Panjal and Siwalik (Rajouri) Range of Jammu and Kashmir Himalaya and WHC was recorded on different altitude of north aspect. The observation recorded were 20.40, 19.50 and 19.28 (500-700 m asl), 19.40, 19.56 and 19.78 (700-900) and 20.15, 19.80 and 19.80 (900-1200 m asl) % at 0-10, 10-20 and 20-30 cm soil depth respectively (Dangwal *et al*., 2012). Neeraj *et al*, (2001) studied the effect of altitude and aspect on WHC in mid elevation forests of Central Himalaya (India) and the values recorded were 43.7 and 29.8 (1300-1500 m asl), 37 and 40 (1500-1800 m asl) and 25.1 and 28.3 (1800- 2000 m asl) % on East and West aspects respectively.

2.1.2. Chemical properties

2.1.2.1. Calcium carbonate ($CaCo_3$)

The soil nutrients Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} are supplied to plants in large measures in exchangeable forms. Exchangeable macronutrients (Ca, Mg, K and Na) are of great importance of plant nutrition and because of their impact on the ecosystem health and as good indicators of the ecosystem responses to environmental changes such as climate change, acid deposition and other human disturbances. Reduction in exchangeable base cations in coniferous

forest soils has been reported from North America (Drohan and Sharp, 1997; Likens and Bormann, 1999), Europe (Egli, 1998, Blake *et al*., 1999) and Asia (Takahashi *et al*., 2001) mainly due to the acid deposition, leaching, uptake by forest vegetation and forest harvesting. Hence, decrease in base cation nutrients is geographically widespread.

Likens *et al*. (1977) reported that weathering of calcium and magnesium bearing minerals represents an important inputs of these nutrients in many terrestrial ecosystem, satisfying 35 percent of calcium and magnesium required for the annual growth of some temperate forests. Haghnia and Pratt (1988) evaluated the effect of exchangeable magnesium on the accumulation of sodium and potassium in soils. The result showed that as the ratio of magnesium to calcium increased the exchangeable sodium and potassium were more competitive against magnesium than against calcium. Jacabson *et al*. (2004) reported increase in the base cation content of the humus layer in coniferous forests after application of wood ash. A study was conducted in Push Ziarat South Waziristan, Pakistan by Shahid *et al*. (2010) and found that $CaCo_3$ at Eastern aspect was 5.00 and 4.80 (2500 and 2630 m asl altitude) and at North aspect 4.4 and 5.40 (2350-2500 and 2500-2620 m asl altitude) percent and results further depicts that on South aspect 4.51 (2650-2730 m asl altitude) percent $CaCo_3$ was recorded.

Results of Nykvist, (1998) reveal that exchangeable calcium to be only a minor part of the total storage of calcium in the soil. According to him, most calcium is bound in organic compounds, calcium-containing silicates and carbonates. The author also reported that low amount of exchangeable calcium in soil from other parts of the world indicates that the calcium content of the soil can be an initial factor influencing forest production in other rain forest area as well. The main reason for the low content of local calcium in the soil is that the bedrock consists of interbedded sandstones, siltstones and shales with low calcium contents.

The results of lacustrine belt of Kashmir valley reported 0 to 1.40 per cent $CaCO_3$ in surface and 0 to 17.80 per cent $CaCO_3$ in subsurface horizon of the pedons (Kirmani, 2004). The free $CaCO_3$ was observed in all the soils examined and the content ranged from 5.0 to 100 g kg^{-1}. The highest content was found in pedon on piedmont plain (P_4) followed by pedons on ravinous area (P_3) and alluvial plain (P_8), respectively (Sitanggang *et al.*, 2006). The $CaCO_3$ content varied from 0.85 to 1.83 g kg^{-1} (plains), 0.53 to 1.40 g kg^{-1} (uplands) and 0.50 to 0.85 g kg^{-1} (hill slope). Subsurface horizons showed higher content of $CaCO_3$ as compared to surface horizons (Rao *et al.*, 2008). $CaCO_3$ was not found in the surface horizons of any profile studied. However, as compared to surface horizons traces to 7 per cent was observed in subsurface horizons. Also, it was found higher in profiles facing north than south facing pedons (Bhat, 2010).

In an experiment conducted by Subbaiah and Manickam (1992) it was observed that $CaCO_3$ content varies from 0.5 to 48.2 per cent and increase with depth and also concluded that soils derived from lime charged granite-gneiss, lime-charged shales show higher $CaCO_3$ content, while as soils derived from granite shows least $CaCO_3$ content. Ahmad (2003) reported an increased trend in the calcium carbonate content with the increasing depth of soil.

The results of an experiment conducted by Wani (1994) in karewa soils of Kashmir shows that $CaCO_3$ content ranged from 1.00 to 5.50 percent. Farida (1997) observed that $CaCO_3$ content varies from 0.20 to 0.40, 1.40 to 1.90 and 0.50 to 0.80 per cent in high altitude karewa and valley basin soils of Kashmir, respectively. Walia *et al.* (1999) revealed that $CaCO_3$ ranged from 0.45 to 13.7 per cent in some soils of Ladakh. Bhat (2001) while working on apple orchard soils observed that in surface soils the calcium carbonate content ranged from 4.1 to 4.3 per cent with a mean value of 4.2 per cent and in sub-surface it varied from 4.2 to 4.7 per cent with a mean value of 4.4 per cent. In Kashmir the average value of calcium carbonate was 1.79 per cent (Sofi, 2001).

2.1.2.2. Organic carbon

In the past, SOC concentration was primarily measured to evaluate soil ‘‘quality’’ (Gregorich *et al*. 1994; Pierce and Munson 2000; Shukla *et al*. 2006). Presently, carbon (C) storage is also studied, in the context of greenhouse gas balance assessment, and how soil C dynamics exerts its influence on the global C cycle (Tremblay *et al*. 2006; Ouimet *et al*. 2007). The potential of using SOC both as an indicator of soil quality and a broader indicator of ecosystem response to environmental changes has reinforced the importance of having appropriate techniques to accurately measure SOC concentrations and to adequately predict C storage in soils.

Forest ecosystems contribute a lot of organic matter to soil in the form of leaves, twigs, stems, flowers and fruits, which after decomposition by microorganisms (Waksmann*et al*., 1928) result in the formation of organic carbon and release of different nutrients (Schnitzer, 1991). The nature and amount of organic carbon produced after decomposition of litter depends on the dominating tree species present (Vogt *et al*., 1986; Fu *et al*., 2004) and the characteristics of the area (Liski and Westman, 1997; Zhong and Qigua, 2001; Cauteaux *et al*., 2001; Koch and Makeschin, 2004), which regulate the physical, chemical and biological properties of soils (Trasar-Cepeda *et al*., 1998). According to Lal, (2005) the soil organic carbon values in forest soils may range from 0 percent in very young soils to as much as 50 percent (w/w) in some organic or wetland soils, with most soils containing between 0.3 and 11.5 percent in the surface 20 cm of mineral soil.

Depthwise distribution of organic carbon was studied in Tarai region of West Bengal. Organic carbon decreased with depth in tea gardens and forest areas. However, no consistent pattern of distribution was observed in profiles of cultivated lands (Saha*et al.*, 2000). The organic carbon content of 0.37 to 4.11 per cent was observed in profiles of forests, pasture, orchard and arable lands of Lower Munda Watershed soils in south Kashmir (Dandroo, 2001).The average

values for organic carbon for different slopes under forest land use at the surface and subsurface soils were 2.31 and 1.86 per cent (Ajaz, 2003).

Khademi and Mermut (2003) observed a varied organic carbon content in the Argids of Iran. The organic carbon content ranged from 0.50 to 11.7 g kg^{-1} of soils, which showed a decreasing trend, with the depth of the pedon. Soil organic carbon content has been shown to be related to particle size distribution. The organic carbon content in the Neogal Watershed of Northwest Himalayas varied from 3.2 to 9.5 g kg^{-1} of soil. Also, the organic carbon content showed a definite relationship with the slope and altitude of the area, besides the type of vegetation (Sharma *et al.*, 2004).

According to Patil and Prasad (2004) organic carbon varied from 33 to 2 g kg^{-1} with depth, being higher in surface than in sub-surface horizons. Also topography, slope and type of vegetation showed a definite relationship. The organic carbon content of Kiar-Nagali Micro watershed in Himachal Pradesh varied from 11.7 to 23.5 g kg^{-1} in surface and 4.5 to 16.2 g kg^{-1} in sub-surface soils, respectively (Tripathi *et al.*, 2006). Singh *et al.* (2006) observed that organic carbon was higher in surface layers as compared to sub-surface layers. There is a significant difference between the soil organic carbons content of varied landuses; forest land use had higher organic carbon content than cultivated landuse (Wills *et al.*, 2007). Najar *et al.* (2009) while studying the effect of aspect and slope on some apple orchard soils of valley, observed higher content of organic carbon in northern facing pedon as compared to southern facing pedons.

The organic carbon in Punjab soils ranged from 0.55 to 1.53 per cent with a mean of 0.65 per cent. This may be due to repeated application of FYM dozes and due to decomposition of organic residues (Bali *et al.*, 2010). Organic carbon content was found higher in the northern aspect pedons than the southern facing pedons. Also, it decreased with the increase in soil depth in both the aspects (Bhat, 2010).

2.1.2.3 Available Nitrogen

Nitrogen is an essential element for forest growth, and usually acts as a limiting factor for the productivity of forest ecosystems. It is estimated that more than 90 % of the soil N reserves are in the soil organic pool and acts as a potential source of soil available N through mineralization. The processes of N uptake by vegetation and return to soils as litter periodically is one of the basic features of forest ecosystems (Chen *et al*., 2000b). Soil N availability and net N mineralization and nitrification rates have been found to vary with tree species composition in temperate and boreal forests (Bargali *et al*., 1998; Zhong and Makeschin, 2004).

Waksman et al. (1928) remarked that the nature of friction of nitrogen in forest soil has remained very vague, since neither Azotobacter nor legume bacteria are found to occur to any extent in these soils especially in the ‘’raw humus soils’’. The authors suggested that most of the nitrogen in the soils of coniferous forests has been deposited in precipitation.

Vitousek, (1982) noted that for both coniferous and deciduous species, the efficiencies of nitrogen conversion in the production of biomass was greater for site of lower than higher fertility status, which he attributed to increased re-absorption of nutrients from foliage before abscission, and to a greater capacity of foliage on poor sites to fix C per unit N compared to foliage from nutrient rich soils.

The forest surface soils are generally higher in N levels as compared to sub-surface soils as has been studied by different wokers in India and abroad (Mandal *et al*., 1990). Verma *et al*. (1990) reported that the available nitrogen content ranged from 36.0 to 205.0 ppm with a mean value of 118.0 ppm in some alluvial soils of Kashmir. Sharma and Bhandari (1992) observed that available nitrogen content ranged from 92 to 231and 27 to 210 ppm with a mean value of 158 and 138 ppm in the surface and sub-surface soils, respectively in Himachal Pradesh. The available nitrogen content of some apple orchard soils of valley

varied from 56 to 140 and 22 to 118 ppm in the surface and sub-surface horizons, respectively (Mushki, 1994).

Vogt *et al*. (1986) reported that evergreen forests had higher root mass and turnover and greater circulation of N in the forest floor. According to them one annual litter fall input of N may be retained in the forests in floor for more than 20 years in boreal and 10 years in cold temperate forests in contrast to less than 2 years for tropical forests. The potential N mineralization and nitrification linearly increase with field age, and standing crop of plant biomass has been reported to be highly correlated to pools and rates of N-cycling (Zak *et al*., 1990).

Schreiber *et al*. (1990) observed that a single storm leached 0.23 % of the N as NH^{4+} and NO_3^- from loblolly pine forests. The maximum leaching by rainfall would occur with warm temperature and low intensity rainfall. Losses of NO_3^- were associated with Ca^{2+} and Mg^{2+} in non-acidified soil types and with Al_3^+ in the acidified soils(Duffy and Schreiber, 1990). Berg and Verhoef, (1998) observed that nitrogen saturated coniferous forests in the Netherlands has been transformed into an “open flow” system, in which the ammonia is transformed into NO_3^- N which is leached into the ground waters. Papke and Papen, (1998) pined that NO emitted from the soil to the atmosphere was produced almost exclusively in the organic layers of the forest soil. Watmough and Dillon, (2004) calculated the input and output budgets of nutrients over a 17 years period for a coniferous catchment and found that over 80 % atmospheric N input was retained in the catchment, indicating that this catchment has not reached N saturation. In a recent study, Jussy *et al*. (2004) measured the N deposition, N transformation and N leaching in acid forests soils and stated that the amounts of nitrogen annually mineralized and nitrified were positively correlated.

Paul and Beauchamp (1996) observed no increased net N mineralization in the manured soil than in the control or fertilized soil. It was pointed out

that although mineralization rates were higher in manured soil but N immobilization or N losses through denitrification were also higher. Recent studies suggest that nitrate added to the soil is immobilized rapidly and the processes may include abiotic pathways. Gurtevik *et al*. (2004) observed that both vegetation and fertilization increased field net N mineralization, and there was a strong positive interaction betweenthe treatments. They suggested that vegetation derived labile C is an important driver for net N mineralization.

The available nitrogen content in surface soils varies from 131.6 to 193.2 ppm with a mean value of 164.7 ppm, whereas, in subsurface soils it varied from 61.6 to 137.2 ppm with a mean value of 89.9 ppm in the cherry growing soils of Kashmir (Dar, 1996). Ganai (2001) reported available nitrogen content in the range of 124.54 to 336.63 kg ha^{-1} with a mean value of 238.82 kg ha^{-1} in saffron growing soils of Jammu and Kashmir. Available nitrogen content showed decreasing trend with depth and ranged from 82 to 150 ppm in surface soils and 30.1 to 93.0 ppm in valley basin apple orchard soils of Kashmir (Najar, 2002).

2.1.2.4 Available Phosphorus

Troug (1947) reported that phosphorus is available over a narrower range of pH than nitrogen, availability declines above pH 7.5 and below pH 6.5 with maximum availability at about 6.5. According to him, in acid soils (pH less than 5.0), phosphorus in the H_2PO_4- form reacts with iron and aluminum to form insoluble compounds and above pH 6.0 it reacts with calcium to form insoluble calcium phosphate, although there is generally no amount of free calcium in the soil until the pH rises to 7.0 or above. As a result of these processes, phosphorus is found only at very low levels in the soil solution and many forest plants depend upon mycorrhizal fungi to obtain the phosphorus they need. The author also found that phosphorus can exist in a number of organic forms including chelates of iron and aluminum phosphate and these may increase its availability to plants. Likens *et al*. (1977) found that the

weathering mineral phosphates of calcium, iron and aluminium provide an important source of phosphorus for plant growth.

In natural ecosystems, the concentration and chemical nature of soil organic phosphorus (P_o) are mainly determined by a combination of major soil forming factors like time, parent material climate topography and organisms (Smeck, 1985). The long term dynamics of Phosphorus in the soil environment is said to be closely related to the dynamics of organic C, N and S (Sood and Kanwar, 1986; Stewart and Tiessen, 1987). The combination of physical, chemical and biological processes controls the balance between P_o immobilization and P_o mineralization. Plant not only take up P from the soil but also exert significant effects on soil P availability and dynamics through litter fall, root turnover and exudation and specific interactions with microbes in the rhizosphere (Gressel *et al*., 1996).

Antoo (2000) while studying the command area soils of Zangir found that phosphorus content ranged from 12.90 to 16.70 ppm with a mean value of 15.01 ppm. The available phosphorus content in the surface and sub-surface layers of karewa soils ranged from 12.0 to 19.10 ppm and 8.0 to 17.20 ppm, respectively (Najar, 2002). The available phosphorus content of forest soils of Kashmir ranged medium to high (Amarjit, 2004).

Mandal *et al*. (1990), while studying the forest sites of the eastern Himalaya, reported the distribution of phosphorus fallowed no definite trend, though soils at higher altitude showed higher available phosphorus content. The authors also found that the content of easily soluble or available phosphorus (P_2O_5) varies in virgin forest soils from 10ppm-200ppm. Cole *et al*. (1990) found that the response of a forest to nutrient and moisture stresses is reflected in nutritional, physiological and structural changes that include efficiency of nutrient use, translocation and cycling of nutrients, transpiration, retention of foliage, below-ground and above ground allocation of carbon, as well as structural development of the forest stand and its growth characteristics.

Mushki (1994) observed that available phosphorus in some apple orchard soils of Kashmir ranged from 10 to 20 and 9 to 26 ppm in the surface and sub-surface layers, respectively. Khan *et al.* (1997) reported that available phosphorus was high in the surface and decreased downwards in the soil profiles. Farida (1997) observed that the available phosphorus content vaied from 16.8 to 19 ppm in karewa soils of Kashmir.

Dwivedi *et al.* (2005) reported that the available phosphorus ranged from 2.35 to 25.66 and 2.5 to 137.4 kg ha^{-1} in the surface soils of Leh and Kargil districts of Jammu and Kashmir, respectively. All the soils under study contained high available phosphorus ranging between 25.8 and 77.4 kg ha^{-1}, with a maximum coverage value of 47.4 kg ha^{-1} under agriculture soils, followed by wastelands (44.5 kg ha^{-1}) and hops (44.1 kg ha^{-1}), and a minimum of 38.1 kg ha^{-1} under forest land use (Kumar *et al.*, 2006).

Vogt *et al*. (1986) observed that mean P concentration did not revealed significant difference between the tropical (0.05-0.11 %), warm temperate (0.06-0.09 %), cold temperate (0.01-0.12 %) and boreal (0.08 %) forests. Reynolds et al. (1989) observed that release of P was more under Larch than the Sitka spruce. However, Saetre*et al*. (1999) observed no difference in P mineralization rates between mixed and spruce stands. Chen *et al*. (2000a) also observed low P_o in coniferous forests stands than in the adjacent grasslands. Smal and Olszewska (2008) observed that total and available P content in the humus horizon in forest soils decreased with stand age, with higher values in young stands.

The available phosphorus content varies from 12.0 to 42.6 kg ha^{-1}. The highest mean phosphorus of soil was found in Kiar and Nagali-II (Tripathi *et al.*, 2007). Sharma *et al.* (2008) noticed a range of 9.38 to 84.9 kg ha^{-1} averaging to 37.3 kg ha^{-1} for available phosphorus in the Amritsar, Punjab. Singh and Bansal, (2009) reported that available P in Barpur alluvial soil series of Indo-Gangatic Plains ranged from 9.0 to 153 mg ka^{-1} in surface soil samples.

2.1. 2.5. Available Potassium

The mineral potassium (exchangeable K) is found in soluble form in all parts of plants, and is responsible for the carbohydrate and protein formations. Potassium activates the enzymes of the plants, which in turn help in the metabolism of the plants, starch synthesis, nitrate reduction, and also plays a role in sugar degradation. Potassium performs very vital processes like regulating transpiration and respiration, influencing enzyme action, and synthesis of carbohydrates and proteins, etc. (Brady, 1996). The decrease of K is caused by leaching and drainage, which results in the destruction of vegetation (Basumatary and Bordoloi, 1992).

Since exchangeable K in soil largely depends on the composition of parent rock material, no specific reason can be assigned to its differential quantities at different altitudes and sites in various parts of Uttarakhand Himalaya. Total soil K varied on different altitudes and the higher content of available K was found in surface soil in the form of exchangeable K, which may later convert into the soil solution (Dimri *et al*., 2006). Although Gupta and Sharma, (2008) argued that the K is not much influenced by soil organic matter because it is not the direct supplier of K. The findings of Basumatary and Bordoloi, (1992) and Boruah and Nath (1992) reasoned that a layer of organic matter significantly improves the retention of K in the soil. Gupta and Sharma, (2008) also showed that N and organic C were positively correlated, chiefly because all these attributes are intimately linked with soil humus. Hebel, (1995) reported very high amount of exchangeable potassium coming from the decomposition of crop residue. According to him, the high available potassium under pasture could have been contributed by animal waste.

A study in moist temperate valley slopes of Garhwal Himalaya, India was conducted by Gairola *et al*. (2012) to record available Potassium at different forest types (Mainly Abies pindrow, Mixed Abies pindrow and Conifer mixed broad–leaved forests) at three soil depths (0-10, 11-30 and 31-60cm) in each

forest type, decreasing trend (125, 80 and 57 ppm) in 1st and 3rd (75, 52 and 40 ppm), but in 2nd (42, 90 and 60 ppm) increasing trend with respect to soils depths was observed. Rao *et al*. (2008) reported that the available potassium in the surface samples of Ramachandrapuram, Mandal soils in the range of 135 to 320 kg ha^{-1} with a mean value of 237 kg ha^{-1}.

Kaushal *et al*. (1997) also observed that soils under Deodara forests in Northwest Himalaya (HP) were high in available K, Na, Ca and Mg. Many authors have reported increase in K values with increase in altitude in the Garhwal Himalaya (Jha *et al*., 2002; Dimiri *et al*., 2006). An experiment was conducted in foot hills of Pir Panjal and Siwalik (Rajouri) Range of Jammu and Kashmir Himalaya and available Potassium was recorded on different altitude of Northern aspect, the values obtained at Hill base 102,126 and 136 (500-700 m asl), Hill slope 98, 110 and 127 (700-900) and Hill top 136, 121 and 153 (900-1200 m asl) kg ha^{-1} at 0-10, 10-20 and 20-30 cm soil depth respectively, However the results depict that increasing trend was found in the values with respect to soil depth and altitude except in Hill top were decreasing trend 10-20 cm was recorded (Dangwal *et al*., 2012). Similar trend were also recorded in temperate forests of Uttarakhand and values of available Potassium were 224, 174 and 280 (Undisturbed site), 174, 205 and 224 (Moderately disturbed site) and 173, 224 and 207 (Highly disturbed site) kg ha^{-1} at 0-10, 10-20 and 20-30 cm soil depth respectively (Bisht and Bhatt, 2010).

Farida, (1997) observed that the available potassium varied from 156.0 to 180.0 ppm in karewa soils of Kashmir valley. Wani *et al.* (2007) reported that the soils of Zanigir Command Area of north Kashmir were medium in available potassium, ranging from 134-158 mg kg^{-1}. Nazir and Wani(2009) observed that the plant available potassium in some soils of Kashmir valley ranged from 0.10 to 0.37 $cmol_c$ kg^{-1}soil with a mean value of 0.23 $cmol_c$ kg^{-1} soil. Wani, (2005) while working on the potassium dynamics of some soils of Kashmir valley reported that

available potassium varied from 0.17 to 0.435, 0.141 to 0.179 and 0.120 to 0.230 $cmol_c\ kg^{-1}$ in high, mid and low altitude soils, respectively.

Dar (1996) observed that the available potassium content in the cherry orchard soils of Kashmir ranged between 135 to 205 ppm with a mean value of 168.3 ppm in the surface and from 80 to 17 ppm with a mean value of 118.8 ppm in subsurface soils. The available potassium ranged from 11 to 496 and 103 to 861 mg kg^{-1} in soil surface sample of Leh and Kargil districts of Jammu and Kashmir respectively (Dwivedi *et al.*, 2005) and specific potassium ranged from 0.019 to 0.90 $cmol_c\ kg^{-1}$ in surface soils and 0.030 to 0.060 $cmol_c\ kg^{-1}$ in subsurface soils.

2.2.Vegetation studies

The nature of ecological communities is a fundamental issue in ecology. Many have considered communities as integrated, possibly discrete entities with emergent structure and function shaped by species interactions and co-evolution (Drake, 1990). The study of species diversity is helpful to understanding community composition, structure, change and development (Li & Zhou, 2002). Moreover, species diversity is affected by multi-environmental factors (Gaston, 2000, Lan, 2003 and Tang, 2004) especially by the altitudinal gradient. The altitudinal gradient is an important factor affecting species composition and structure (Whittaker, 1972). The change of abiotic condition (e.g. Climate, soil and Temperature) along with the altitudinal gradient affects species composition and distribution.The vegetation diversity of forest ecosystems of Himalaya is influenced by topography, soil, climate and geographical location of the region. There is a great diversity in the floristic pattern due to altitudinal variation and rainfall (Arora, 1995). The relationship between vegetation and altitude has been studied since the early 19th century (Kala & Mathur, 2002). Climatic and soil factors are deemed to be primary determinants of change in species composition and community structure in mountains (Whittaker, 1975).

Forest structure and composition are strongly correlated with the environmental factors, such as climate and topography (Schall&Pinaka, 1978, Wright,1983 and Currie, 1991) while, vegetation within a forest is greatly affected by differences in the microclimate, aspect and altitude (Chaudhary, 1999 and Pande *et al*.,2002). Structural and functional analysis of natural plant communities provide a valuable sources of information for understanding relationship between plant form, vegetation structure and environment (Parsons, 1976). Species diversity has functional consequences, because the number and kinds of species present in any area determine the organismal traits, which influence ecosystem processes. Species diversity reflects species richness and evenness and expresses differences of community structure, community composition and community habitat conditions (Lan, 2003). Species composition and diversity vary from one habitat to another within the communities exposing identical physiognomic characteristics (Nautiyal *et al.*, 1999). Understanding of forest structure is a pre-requisite to describe various ecological processes and also dynamics of forests (Elourard et al., 1997).

2.2.1. Vegetation structure

The industrial age in the world history ushered in the commercial exploitation of natural resources at a scale that has threatened the resource base itself. Nearly one species is becoming extinct per day somewhere on this earth and it has been estimated that by the turn of the century about a million species would have become extinct, if no remedial action is taken (Khoshoo, 1984).

In the last few decades there has been a worldwide attention for the conservation of the habitat and biotic forms and several of the plants are marked as endangered, vulnerable and rare, etc.(Lucas and Synge 1978; Nayar and Sastry 1987). The increase in human population in the last few decades, demanding developments in various spheres, has resulted directly or indirectly in the sudden and of the far reaching disturbances in natural ecosystems (Jain and Sastry 1980;

Gaur 1982). This has caused increased environmental stress on the plants and led some of them at the edge of extinction.

Original habitats of several plant species have been so disturbed that it has almost forced them to disappear. According to an estimate of the threatened plant committee of the IUCN about 10 % (20,000 – 30,000 species) of the world flowering plants are reported to be dangerously rare or under threat (Lucas and Synge, 1978).

The vegetational growth efficiency of the regions depends upon the type, quantity and stratification of vegetation. Therefore, for any study on ecology of these areas, quantitative evaluation of its vegetation is a pre- requisite. The quantitative study on structure of vegetation is called phytosociology, the principal aim of which is to describe the vegetation, explain or predict its pattern and classify it in a meaningful way. It is also considered as a basic biological science to be applied for the concept and realization of land management (Singh et al., 1991).

Different workers have studied the Himalayan regions vegetation for its quantitative and qualitative characters (Saxena and Singh, 1982; Singh and Singh, 1987; Khanduri *et al*., 2002). Gadgil and Mehar-Homji (1990) have broadly classified the higher plant vegetation of Chopta and Tungnath region as temperate mixed oak and coniferous forest. More than 270 vascular plant species were reported by Semwal and Gaur (1981) from the same region.

Altitude variation and direction has been seen to affect the tree diversity in Garhwal Himalaya region of Uttaranchal; wherein tree density was comparatively high at 1800 m elevation in east facing aspect (Kumar *et al*., 2006;Devlal and Sharma, 2008). With the change in environmental conditions the vegetation cover reflects several changes in its structure, density and composition (Gaur, 1982). A plant community can be defined as a collection of plant species growing together in a particular location that show a definite association or affinity with each other (Mueller – Dombois and Ellenberg, 1974).

Each of the individuals within the community has large measure of its structural and functional individualism and has more or less different ecological amplitude and modality (Singh and Joshi, 1979). The species diversity reflects the gene pool and adaptation potential of the community (Odum, 1971). The variation in floristic richness from region to region, within the Northern Andes is positively correlated with habitat area; it is also suggested that variation in habitat area and isolation during and since the Pleistocene period may have influenced current pattern of species richness (Simpson, 1974).

Maximum species numbers (47) were observed in the moderately grazed plot and only 30 species were observed from protected plot. This indicates that controlled biotic interference enhanced species diversity. On the other hand, on the grazed site, only 16 species were recorded. Thus, over grazing reduces the species diversity (Itow, 1963; Misra, 1968).Harper (1969) also reported that moderate grazing increased species diversity.

Anitha *et al.*, (2010) reveals that structure, function, and ecosystem services of any forest depend on its species richness, diversity, dominance, and the patterns of changes in the assemblages of tree populations over time. The data on species diversity, community composition, and regeneration status of tropical forests in a human-dominated landscape in the Western Ghats of southern India and the enumeration of 40 plots (50m x 20m) results a total of 106 species of trees, 76 species of saplings and 79 species of seedlings. Detrended Correspondence Analysis (DCA) ordination of the tree populations yielded five dominant groups, along disturbance and altitudinal gradients on the first and second axes respectively. Abundant species of the area such as *Albiziaamara, Nothopegiaracemosa and Pleiospermumalatum* had relatively few individuals in recruiting size classes. Our data indicate probable replacement of rare, localized, and old growth ‘specialists’ by disturbance-adapted generalists, if the degradation is continuing at the present scale.

Species richness is the simplest way to describe community and regional diversity (Magurran, 1988) and this variable numbers of species is the basis for many ecological models and community structure (MacArthur and Wilson, 1967).

Evergreen forests are richer in species than deciduous forests, and within the evergreen forests, there is a decending gradient of species richness from low to medium and high elevation evergreen forests. This species richness also varies from site to site with in the same forest type depending on the parameters such as topography, light exposure etc.(Nayar, 1996). In the forested landscapes of Western Ghats, species richness has been assessed to be 100 – 174 species (Pascal, 1988) in low elevation evergreen forests, around 90 – 126 in medium elevation evergreen forests (Ganesh *et al*., 1996) between 90 to 100 species in high elevation evergreen forests (Pascal, 1986) generally less than 50 species in moist deciduous forests, and less than 30 in dry deciduous forests.

Pascal (1986) had reported that the species richness of medium elevation evergreen forests of Western Ghats ranged from 90 – 126, while in the sacred groves in the similar vegetation under disturbed condition the species richness was higher (156). The species richness varied according to the disturbance gradient in the different stands. The mildly disturbed stands showed the highest species richness (54 of 51 genera). The species richness was lowest (16 of 16 genera) in the highly disturbed stand. The undisturbed stand had 47 species of 42 genera while in moderately disturbed stand 42 species of 36 genera were found. The Shannon diversity was recorded highest in undisturbed stand and lowest in highly disturbed stand. The value of concentration dominance was similar in undisturbed stand. The similarity index values were higher in undisturbed and minimum in highly disturbed stand (Bhuyan *et al*., 2003).

In 0.1 ha plot in Uttara Kannada, there is almost steady increase in the number of tree species with increase in the percentage of evergreenness in the population. The species diversity index as computed by Shannon – Weiner index is low (less than 3) if ever greenness is less than 40 percent. The one hectare plots

in Uttara Kannada shows that, the number of tree species is lower if percentage of ever greenness is less than 50. Maximum mean species number (54) and highest value of H (4.72) occur between 80 – 90 per cent. There is a decline in species number at the intermediate stage is obviously due to many semi evergreen to deciduous species mingling with large number of evergreen species. However, some kind of disturbance in the forest ecosystems is necessary to maintain such large number of species but this value addition is due to arrival of alien species from other forest types. Unchalli in Uttara Kannada and a gallery of forest situated in the deep gorge of the Aghanashini river had highest number of tree species (60) in one ha sample (H' 4.81) of the total population of 476 individuals, 88 percent are evergreen species (Chandran and Gadgil,1993).

Importance Value Index decreased rapidly in steps, values below 25 (out of 200) are obtained from the second species onwards, less than 15 at the fifth and less than five after the tenth species on wards. The rare species (less than three individuals per hectare) comprise nearly two third of the species enumerated (58). The most common families are also those which have the highest IVI, Dipterocarpaceae (IVI =63.3 out of 200), Myristicaceae (35.9) and Fabaceae (23.2). The dominant species were Vateria indica (IVI = 46), Myristica dactyloides (24.6), Humboldtia brunonis (17.6) and Dipterccarpus indicus (15.0). The first three species represented nearly 45 per cent of trees, accounting for 16.7, 14.9 and 13.2 per cent respectively. These three species together contributed more than half of the basal area (Pascal and Pelisser, 1996).

Raghu, (2003) has reported 191 plant species distributed over 58 families in evergreen forests of Gerusoppa region of Uttara Kannada district. Among the different altitudinal zones, altitude between 250 – 350 m amsl was found to be richest in species composition followed by the second altitudinal gradient between 150 – 250 m amsl (128 species) Members of Lauraceae, Rubiaceae, Euphorbiaceae, Fabaceae, Ebenaceae, Myrtaceae, and Rutaceae families were the most dominant floristic elements in this region.

Santhosha, (2005) had reported that, the high elevation evergreen forests were richer and diverse as compared to medium elevation evergreen forests. Forests in the eastern aspect were more diverse than the western aspect. There was no significant difference in the high and medium elevation evergreen forests. In recent past detailed study on morpho-physiological attributes of various low and high altitude species along an altitude gradient in Garhwal Himalaya were conducted by Nautiyal and Purohit, (1980) and Todaria and Purohit, (1979). Based on the results, these workers have proposed that high altitude species have higher resistance to environmental stresses than low land species.

2.2.2. Population structure and floristic diversity:

The species in a community grow together in a particular environment because they have similar requirement for existence in terms of environmental factors such as light, temperature, water drainage and soil nutrients (Mueller – Dombois and Ellenberg 1974; Ter Braak 1987). They share the ability to tolerate the activities of animals and human such as grazing, burning, cutting and trampling. However, the tolerance for the environment by different species would be different and each will have a definite tolerance range. If the species grow in association with each other, many of them should have similar although rarely identical response to the prevailing environmental conditions. The most important structural property of a community is a definite quantitative relationship between abundant and rare species. The study of floristic composition and phytosociological attributes are useful for comparing one community with the other from season to season and year to year (Singh, 1976).

The mean density of 851 trees ha^{-1} were noticed in tropical evergreen forest of Sengaltheri, Western Ghats of Tamil Nadu is comparable to the mean density of 419 trees / ha for Western Ghats, closed canopy evergreen forest (Parthasarthy, 2001; Ghate *et al*. 1998) and that of high elevation forests of kalakkad 716 stems / ha (Parthasarthy, 2001) and Kakachi with 583 stems / ha (Ganesh*et al*., 1996).

The basal area values of Sengaltheri, mid elevation forests in Kalkad Mundanthari Tiger Reserve (KMTR) was well within the range of tropical wet forests; 25.5 m^2 in Rio Xingu, Brazil (Campbell *et al*.,1992) 82.76 m^2 in the tropical rain forests of Reunion islands to 94.6 m^2/ha in the high elevation forest of Kalakkad (Parthasarthy, 1999).

In the southern Western Ghats and that of Uppangala, Central Western Ghats had 635 stems/ha (Pascal and Pelissier, 1996). In 0.6 ha area, 347 trees in logged area and 1991 trees in 3.12 ha. In case of unlogged area with a total different species of 111 in kadamakal forest in Kodagu of which 58 were represented by less than two individuals/ha (Pelissier, 1998). Stand density and basal area of forests with dbh10cm were slightly lower in logged compartment, that is 578 stems/ha, 34.8m^2/ha than in the unlogged compartment, that is, 606 stems/ha and 39.3m^2/ha. The difference in density and basal area is due to felling as proposed by Loffer in 1989.

Tree density and basal area of the tree species has been observed to be influenced by the varied altitudinal zones as the density of tree species varied from 280 to 410 trees per hectare. Highest tree density was reported from the altitudinal zone between 250 – 350 m amsl (410/ha) followed by 350 to 450 m amsl (314.8/ha). Highest basal area of tree species was reported from the altitude between 350 – 450 m amsl (26.24 m^2/ha) followed by 250 to 350m amsl (22.4m^2) (Raghu, 2003).

In the forests of Arunchal Pradesh the highest stand density (5452 stems per hectare) was recorded in the undisturbed stand and lowest (338 stems per hectare) in moderately disturbed stand. The basal area recorded was highest in undisturbed stand (104.60 m^2 per hectare) and lowest in moderately disturbed stand (18.60 m^2 per hectare) (Bhuyan *et al*., 2003).

2.3. Deforestation

Deforestation is the removal or damage of vegetation in a forest to the extent that it no longer supports its natural flora and fauna. In other words,

deforestation can be defined as the transformation of forest land to non-forest uses where forest land includes lands under agro-forestry and shifting cultivation, and not simply closed canopy primary forests (FAO/UNEP, 1982). However, this definition does not include "logging". More inclusive was Myers's 1980 definition, where deforestation refers, "generally to the complete destruction of forest cover through clearing for agriculture. But, the FAO's latest definitions (1993) defines forests as "ecosystems with a minimum of 10 % crown cover of trees and/or bamboo, generally associated with wild flora, fauna, and natural soil conditions, and not subject to agricultural practices" and deforestation as a "change of land use with a depletion of tree crown cover to less than10 % crown cover". Saxena and Nautiyal (1997) asserts that selective logging does not "lead to forest clearance and does not constitute deforestation", whereas Norman Myers (1980 and 1993) thinks that logging is crucial because, although it may only affect a small proportion of trees per hectare, it damages wide areas and is the precursor of penetration by the forest farmers.

Logging does not necessarily cause deforestation. However, logging can seriously degrade forests (Putz *et al*., 2001). Logging in Southeast Asia is more intensive and can be quite destructive. However, logging provides access roads to follow-on settlers and log scales can help finance the cost of clearing remaining trees and preparing land for planting of crops or pasture. Logging thus catalyzes deforestation (Chomitz *et al*., 2007). Fuelwood gathering is often concentrated in tropical dry forests and degraded forest areas (Repetto, 1988 & 1990; Rowe *et al*., 1992).

Deforestation has many far-reaching consequences. The environmental functions and services of the forest ecosystem are reduced or even lost, depending on the extent of deforestation (Sponsel *et al*., 1996). Forests contain numerous species of flora and fauna and protect the soils from heavy rainfall and its effects on erosion. It reduces biological diversity and increases soil erosion and the

siltation of rivers and streams and can endanger hydroelectric dams, agricultural irrigation systems, and other technological and economic facilities (Bruijnzeel, 1991). Moreover, deforestation also means the loss of other renewable natural resources such as valuable non-timber forest products and ecotourism value of the area.

The major part of economic literature on the topic still uses panel data from old periods 1960-1995 (Pfaff, 1999; Andersen *et al*., 2002) or cross-section from the 2000 (Arima *et al*., 2007). The first group brings up typical explanatory variables such as population (Andersen, 1996; Kirby *et al*., 2006), roads (Andersen, 1996; Pfaff,1999), cattle herd (Reis and Guzman, 1992,Andersen and Reis, 1997; Prates, 2008) and rainfall (Margulis, 2003; Arima *et al*. 2007; Aguiar *et al*. 2008), according to them these are the causes of deforestation. But other recent researchs reveal that these drivers may not be the actual causes of deforestation. Pfaff (1999) finds population to be endogenous. Other studies show that causality, from roads to deforestation could be more intense in the opposite direction and that their effects depend on where the roads are built (Andersen *et al*., 2002; Weinhold and Reis, 2008). The second group brings up variables which are more relevant for my analysis. The effects of differences in prices paid to producers is found to influence deforestation by Arima *et al*. (2007) cross-section wise and with a short panel by Prates, (2008) using a short panel from 2000 to 2004. Prates (2008) also find credit availability to fuel deforestation. For old periods, using less robust proxies, Andersen (1996) found it to explain deforestation from 1975 to 1985. The presence of protected areas is believed by many authors, using different methodologies, to decrease fire incidence or deforestation (Arima *et al*., 2007; Aguiar *et al*., 2008).

There are not any econometric studies which focus on the effectiveness of the ibama fighting illegal deforestation. The first attempt is made by Barreto *et al*. (2009), who estimate how high the deforestation rates would be without the

measures taken by ibama in 2008. The author argues that the difference to the observed values corresponds to its effectiveness.

According to Global Forest Resources Assessment (2005) the agriculture sector accounted for just over half of the deforestation in 2005 the result of forests having been cleared for pasture or crops. The remainder was caused by urban development, transportation corridors, and recreation (19 %); hydroelectric development (10 %); the forest sector (10 %); and other natural resource extraction industries (8 %). About two third of this deforestation occurred in Canada's boreal forest, mainly in areas in Alberta, Saskatchewan, and Manitoba forest.

Rapid deforestation is taking place in the Terai because forests are being converted into agriculture land. During the 1950s, the migration of people from the hills and mountains to the Terai was remarkable. "During the period between-1965-1979, exploitation of forests took place at the rate of about 700 ha per year which decreased to 12000 ha per year after 1979. The annual rate of deforestation between the period- 1964-1986 was 0.41%" (Rajbhadari, 2000).

2.3.1 Causes of Deforestation

2.3.1.1 Encroachment

Iftekhar and Hoque (2005) say that encroachment is an important cause of deforestation and forest degradation in Bangladesh. The forests are depleting mainly due to illegal logging and conversion to non-forestry uses. In their writing, limited land availability and unemployment have been identified as the major proximate causes of encroachment and they also predicts that if no measures are adopted within next three decades the existing natural forests might be encroached.

Haque (1995) shows that the illicit felling is done by the poor villagers, who usually work for the illegal traders, local influential leaders and forest land encroachers. The main cause of depletion of sal forest was due to the land

clearance for agriculture and forest land encroachment. The almost half of the total Sal forest has been already depleted. The remaining patches are in poor condition, degraded and in the process of depletion.

Millions of people live on the tropical forest with less than a dollar a day where a third of a billion are estimated to be foreign settlers. However, as the land degrades people are forced to migrate, exploring new forest frontiers increasing deforestation (Wilkie *et al*., 2000; Amor, 2008; Amor and Pfaff, 2008).

2.3.1.2 Ruthless Profit-making

Ahmed (2002) identifies ruthless profit-making as the main cause for the depletion of forest resources. Due to unethical profit motive, forest cover, timber, fuel wood, forest food, medicinal plants and wildlife are decreasing gradually. He also showed that some specific plant species like blackberry, tamarind, wild apple, sal, gojari, gorjon, boyar etc are becoming rare day by day. Ahmed (2002) also finds that illicit felling, theft and encroachment are very significant causes of deforestation and forest degradation in Dhaka, Sylhet, Bandarban, Rajshahi, Mymensingh and Tangail district.

2.3.1.3 Land rights and land tenure.

Cultivators at the forest frontier often do not hold titles to land (absence of property rights) and are displaced by others who gain tenure over the land they occupy (Mather, 1991; Deacon, 1999; Sands, 2005). This means they have to clear more forest to survive. Poorly defined tenure is generally bad for people and forests (Chomitz *et al*., 2007). In many countries government have nominal control of forests but are too weak to effectively regulate their use. This can lead to a tragedy of the commons where forest resources are degraded. In frontier areas deforestation is a common practice and legalized way of declaring claim to land and securing tenure (Schneider, 1995).

2.3.1.4. Mining

Mining is very intensive and very destructive (Mather, 1991; Sands, 2005). The area of land involved is quite small and it is not seen as a major cause of primary deforestation. Mining is a lucrative activity promoting development booms which may attract population growth with consequent deforestation. The deforestation rate due to mining activities in Guyana from 2000 to 2008 increased 2.77 times according to an assessment by the World Wildlife Fund-Guianas (Staff, 2010). Similarly, in the Philippines, mining along with logging, has been among the forces behind the country's loss of forest cover: from 17 million hectares in 1934 to just three million in 2003 or an 82 per cent decline (Docena, 2010). Nearly 2,000 hectares of tropical forest in the Municipality of Coahuayana in the State of Michoacán (south-western Mexico) will completely be destroyed by mining iron minerals planned by the Italo-Argentine mining company TERNIUM (Anonymous, 2008).

Nyamagari hills in Orissa India currently threatened by Vedanta Aluminum Corporation's plan to start bauxite mining will destroy 750 hectares of reserved forest (Griffiths and Hirvela, 2008). Massive and unchecked mining of coal, iron ore and bauxite in Jharkhand, India has caused large scale deforestation and created a huge water scarcity (Anonymous, 2011b). In return for US$3.8 billion of investment, the agreements between the State government of Jharkhand, India and mining companies, there will be a massive land acquisition which will deforest no less than 57,000 hectares of forest and displace 9,615 families, many of them located in legally protected Scheduled Areas set aside for indigenous peoples in the State (Mullick and Griffiths, 2007).

2.3.1.5. Militarization

Militarization in any part of the world leads to greater amount of deforestation by the way of firing, drills, blasts, construction, utilization of forest flora and fauna and generation of waste material. This phenomenon is present in Chittagong hill forest areas. The militarization in the hill tracts is also responsible

for the deforestation of those areas. Participants from FGDs and interviews reported that, huge amount of forest had been cleared by the military for making of their camp, training centre and infrastructural development. It is found from the field that, firing range which is built by the military is another reason for deforestation. Gain, (2003) says that out of 46,000 acres in the Tangail part of the Modhupur forest 1,000 acres to the Air Force.

It is well established that military operations caused deforestation during the Vietnam War and elsewhere. More recently, linkages have been documented between the civil war in Myanmar and the timber trade between Myanmar and Thailand. Myanmar regime sells timber to the Thais to finance its civil war against the Karen hill tribe. Forest destruction in El Salvador has resulted from war. Apart from military involvements in wars, the role of military in deforestation has been documented in Southeast Asia and South America (Mather, 1991; Sands, 2005). The authors also observed that role of powerful military in Brazilian politics are a major cause of Amazonian forest destruction.

2.3.2. Effects of Deforestation:

Deforestation has direct impact on tree diversity according to Myers, (1993) the numbers of large environmental problems are primarily due to deforestation: excessive run-off, soil erosion, lowered water tables, desertification and biodiversity losses. Many plant species are threatened with extinction due to loss and fragmentation of habitats, over-exploitation and introduction of invasive species (Joshi *et al*., 2003). Deforestation gives rise to a whole host of problems such as soil erosion, silting of river beds, flooding, drought and loss of agricultural and forest productivity (Rajbhandari, 2000). In Nepal, major forest habitats of the terrestrial ecosystems harbour and sustain the immense biodiversity. Around 29 % of the total land area is covered by forest in the country, whereas the deforestation rate is around 1% per annum.

It is essential to distinguish between microclimates, regional climate and global climate while assessing the effects of forest on climate (Gupta *et al*.,

2005) especially the effect of tropical deforestation on climate (Dickinson, 1981). Deforestation can change the global change of energy not only through the micrometeorological processes but also by increasing the concentration of carbon dioxide in the atmosphere (Pinker, 1980) because carbon dioxide absorbs thermal infrared radiation in the atmosphere. Moreover, deforestation can lead to increase in the albedo of the land surface and hence affects the radiation budget of the region (Charney, 1975; Rowntree, 1988; Gupta *et al*., 2005). Deforestation affects wind flows, water vapour flows and absorption of solar energy thus clearly influencing local and global climate (Chomitz *et al*., 2007). Deforestation on lowland plains moves cloud formation and rainfall to higher elevations (Lawton *et al*., 2001). Deforestation disrupts normal weather patterns creating hotter and drier weather, thus; increasing drought and desertification, crop failures, melting of the polar ice caps, coastal flooding and displacement of major vegetation regimes. In the dry forest zones, land degradation has become an increasingly serious problem resulting in extreme cases in desertification (Dregne, 1983).

Global warming or global change includes anthropogenically produced climatic and ecological problems such as recent apparent climatic temperature shifts and precipitation regimes in some areas, sea level rise, stratospheric ozone depletion, atmospheric pollution and forest decline. Tropical forests are shrinking at a rate of about five per cent per decade as forests are logged and cleared to supply local, regional, national and global markets for wood products, cattle, agricultural produce and biofuels (Anon., 2007; 2010).

Joshil and Kumar (2008) studied the effects of deforestation on species composition of forest floor vegetation between the elevations of 1850-2000 m in Kumaun Himalaya. The species composition changed ji-om forested site to totally deforested site. The moderate level of disturbance increased the species richness (25 to 31 species), but severe disturbance caused a drastic reduction (12 species). Species diversity decreased with increasing level of disturbance (3.82 in forested site to1.51 in deforested site). Erect forbs were the dominant growth forms in

forested site and grasses and sedges showed dominance in partly deforested and totally deforested sites.

On the contrary, when trees are felled and the root mats are destroyed, the soil is subject to soil erosion by the full force of the rains. Heavy rain removes nutrients by washing away the thin top layer of soil and by leaching nutrients deep into the sub-soil thus making it unavailable to plant roots. In the process, it compact the soil and squeezes out the air pockets. Air is as much important to soil quality as mineral nutrients and compacted soil poses serious threat to environment in the form of land degradation (Karpagam, 1991).

In the fragile area like the Shiwaliks of Nepal, deforestation enhances run-off, formation of gullies and occurrence of debris flow, landslides and flooding. As around 77 % of the total land area is occupied by mountains and high Himalayas in Nepal, the vegetation cover plays a crucial role for the supply of water source i.e. natural wells and streams. However, the rate of deforestation in Nepal is quite severe i.e. around 1.6 % per annum (Joshi *et al*., 2003) and high timber price is an important driving variable in deforestation. Forests provide a range of goods and services to the people. In economic analysis, these goods and services are generally divided into use values (physical goods and recreational benefits) and non-use values (the ecological functions) according to Grimble and Laidlaw, (2002).

2.3.3. Strategies to reduce deforestation

Many international organizations including the United Nations and the World Bank have begun to develop programmes to curb deforestation mainly through Reducing Emissions from Deforestation and Forest Degradation (REDD) which use direct monetary or other incentives to encourage developing countries to limit and/or roll back deforestation. Significant work is underway on tools for use in monitoring developing country adherence to their agreed REDDS targets (Chomitz et al., 2007).

The provision of protected areas is fundamental in any attempt to conserve biodiversity (Myers, 1994; Myers and Mittermeier, 2000; Nepstad *et al*., 2006). Protected areas alone, however, are not sufficient to conserve biodiversity. They should be considered alongside, and as part of a wider strategy to conserve biodiversity. The minimum area of forest to be protected is generally considered to be 10 per cent of total forest area. It is reported that 12.4 per cent of the world's forest are located within protected areas. Tropical and temperate forests have the highest proportions of their forests in protected areas and boreal forests have the least. The Americas have the greatest proportion while Europe the least proportion of protected areas (Anon., 2010).

The most serious impediment to sustainable forest management is the lack of dedicated forests specifically set aside for timber production. If the forest does not have a dedicated long-term tenure for timber production then there is no incentive to care for the long-term interests of the forest. FAO, (2001) found that 89 per cent of forests in industrialized countries were under some form of management but only about six per cent were in developing countries. If 20 per cent could be set aside, not only could timber demand be sustainably met but buffer zones could be established to consolidate the protected areas. This would form a conservation estate that would be one of the largest and most important in the world (Anon., 2001a).

In order to promote sustainable forest management, it must be sustainable ecologically, economically and socially. Achieving ecological sustainability means that the ecological values of the forest must not be degraded and if possible they should be improved. This means that silviculture and management should not reduce biodiversity, soil erosion should be controlled, soil fertility should not be lost, water quality on and off site should be maintained and that forest health and vitality should be safeguarded. However, management for environmental services alone is not economically and socially sustainable. It will not happen until or unless the developing nations have a reached a stage of

development and affluence that they can accommodate the costs of doing so. Alternatively, the developed world must be prepared to meet all the costs (Chomitz et al., 2007; Anon., 2010; 2011a). There are vast areas of unused land as discussed earlier some of which is degraded and of low fertility. Technological advances are being made to bring this land back into production. This should be a major priority since a significant proportion of cleared tropical forest will eventually end up as degraded land of low fertility.

Strong and stable government is essential to slow down the rate of deforestation considered that half of the current tropical deforestation could be stopped if the governments of deforesting countries were determined to do so FAO, (2010). Land reform is essential in order to address the problem of deforestation. However, an enduring shift in favour of the peasants is also needed for such reforms to endure (Colchester and Lohmann, 1993). A means must be found to reconcile conservation and development by involving local/indigenous populations more closely in the decision-making process and by taking the interactions between 'societies' and forest resource more fully into account (Chakravarty *et al*., 2008). A priority is to fund and coordinate basic monitoring on the rate, location and causes of global deforestation and forest poverty along with the impacts of project and policy interventions. Without this information, policy makers are flying blind and interest groups lack a solid basis for dialogue (Chomitz et al., 2007).

2.4. Regeneration Studies

Regeneration is a critical phase of forest management because it maintains the desired number of a species in a community. For healthy regeneration, it is important that a large number of seedlings should survive. The presence of adequate number of seedlings, saplings and distribution of boles reveal good regeneration potential (Pande, 2000).Hole, (1914) probably was the first person to carry out first systematic study on regeneration. Since then the problem of regeneration was studied by many workers. For example Ralhan *et al*. (1985) and

Singh *et al*. (1990) had studied seed characteristics of a number of Himalayan conifers (*Pinus roxburghii*, *Cedrus deodara*, *Cupressus torulosa* and *Abies pindrow*).

The successful regeneration of a tree species depends on its ability to produce large number of seedling and the ability of seedlings and saplings to survive and grow (Good and Good, 1972). However, the presence of sufficient number of seedlings, saplings and young trees is greatly influenced by interaction of biotic and abiotic factors of the environment (Howards, 1973,Muller – Dombois *et al*. 1980, Akshamit and Irving 1984, Khan *et al*. 1986). However, in spite of research done by these workers, our understanding of various aspects of tree regeneration in Himalaya is still far from adequate lack of the data on population dynamics of trees based on the long term field observation is a major weakness of the studies on reproductive strategies of the species.

Some of the above mentioned studies deal with the population structure, regeneration dynamics, appropriate seed collection and handling techniques under variable climatic conditions of the Garhwal Himalayan Forests (Bhatt, 2007). Primary information on the species composition, diversity and regeneration of certain Indian Central Himalayan Forests has also been recorded by various workers (Negi, 1979; Ralhan, 1982;Singh and Singh, 1992). In fact, most studies on sub- alpine forests have reported poor seedling recruitment in under stories of undisturbed old growth forests (Coates, 2002; Mori and Takeda, 2004). The problem of inadequate natural regeneration of kharsu oak (Quercus semecarpifolia) has attracted particular attention and has long been reported by various workers (Saxena *et al*., 1984 , Singh & Singh 1987, Masaki *et al*. 1992, Negi and Naithani 1995, Metz 1997 and Vetaas 2000). Several reasons such as erratic seed production, defoliation, acorn herbivory, browsing damaged to seedlings, decreased or increased fire frequency and extensive lopping have been found to be responsible for poor development of seedlings (Saxena *et al*. 1984, Singh & Singh 1987 and Masaki *et al*. 1992).

2.4.1 Biotic and Abiotic studies:

As mentioned earlier, the wealth of the forest depends on the potential of regenerative status of species composing of forests stand, in space and time. But mountain forests are facing a very serious problem of insufficient regeneration (Krauchi *et al*., 2000). Regeneration of tree species is greatly influenced by interaction of biotic and abiotic factors of the environment (Boring *et al*. 1981, Aksamit and lrving 1984, Khan et al., 1986). These factors affect the recruitment, survival and growth of tree seedlings and sprouts. Several types of biotic and abiotic disturbances such as land use practices, structure and composition of the atmosphere and climate are responsible for causing damage to biodiversity. In particular, anthropogenic activities in the forms of commercial harvesting, over exploitation of forests for fodder, fuel wood and uncontrolled grazing have been cited as some of the most important reasons for forest degradation, including oak (Singh and Singh 1992, Singh, 1998).The intensity, magnitude and frequency of disturbances also determine the structure and composition of plant communities in the forest ecosystem (Armesto and Pickett 1985, Khan *et al*., 1987). Increased resources dependency by communities on surrounding forests has affected the status of highly preferred species (Awasthi *et al*. 2003). Their repeated lopping and poor regeneration not only checks the growth of the trees but also affect the available biomass. It also favours the growth of thorny and unpalatable species (Upreti *et al*. 1985). The disturbances have a negative impact disrupting the climate and making it unstable (Clements, 1936).

The abiotic and biotic disturbances in the form of grazing, browsing, fire have attracted the attention of various workers. Agni *et al*. (2000) assessed the regeneration pattern, tree diversity and qualitative characters of forests in the tarai-bhabhar belt of Kumaon Himalaya. They found low regeneration in all the important dominant species case by repeated burning by the forest department and severe biotic pressure by both wild and domestic animals.

Regeneration largely depends on the ability of young seedlings to survive, which are especially vulnerable. An important cause of the seedling mortality is attack by predators. At the earliest stages of seed, animals may eat their cotyledons and rob the seedlings of their reserve. Later on, herbivour mammals may eat the whole seedlings before it becomes woody. For this region, exclusion of mammals from the forests can significantly reduce seedling mortality rates (Osunkoya *et al*. 1992; Turner 2001).

The growth rate and species composition of the natural regeneration are also determined by the light conditions (Ammer, 1996). Another important cause of low regeneration is the disturbances of ground flora (Murali*et al*., 1996). A successful forest tree regeneration strategy requires a number of consideration including seed production, seed size, dispersal mechanisms, under story tolerance or shade tolerance, growth rate longevity, tree crown architecture, resistance to insects and pathogens, biomass production and requirement (Barnes *et al*., 1998).

Favourable local factors such as low temperature, variation in rainfall, high humidity, ferruginous soils with fair amount of clay and silt offers optimum condition for establishment of natural regeneration species (Thangam, 1982). Other researchers have found that the species competition, seed dispersal limitation, fire and soil nutrient defency are the major barriers of natural regeneration (Hooper *et al.*, 2005).

Furthermore, shrub cover often plays a vital role in increasing regeneration rate. For example, Garcia *et al*. (2000) found that *Taxus baccata* saplings suffered serious herbivory damage when unprotected by shrubs, resulting in low regeneration. It was found that shrubs provided the best habitats for seedling establishment and sapling survival and growth. Shrubs serve the purpose of fences that protect plants from herbivores (Tittensor, 1980; Hulme, 1996). They also serve as the main microsites for the recruitment, not only for the early establishment but also for the long term survival of seedling (Gomez-Aparicio *et al*., 2004). Strong nurse plant relationship between saplings and shrubs was also

suggested by Callaway (1995). As the shrubs are main regeneration niches, they should be used as transplanting microsites that facilitate the establishments of recruites (Gomez-Aparicio *et al*., 2004).

Canopy opening also play a significant role in the proper establishments of seedlings. Partial canopy opening may induce seedlings establishment in the sub-alpine region. For example, continuous regeneration was observed under Betula Utilis own canopy (Shribeta *et al*., 2007).this was supported by the findings of Thadaniand, Ashton, (1995), who observed that high tree basal area and dense canopy cover does not promote satisfactory establishment of seedling of oaks and its associates and its own understory.

Shimizu, (1984) stated that the gaps were necessary for the growth of seedlings and juveniles, although they do not promote germination of seeds and establishment of seedlings and also found that the importance of canopy gaps in regeneration differs among various types of forests, varying with the structure of the forest, characteristic of the component species, the physical environment of the habitat, the quality and quantity of disturbances etc. Gaps in the canopy may be in part responsible for creating the microsites in the plant community.

2.4.2. Richness diversity and structure of regeneration

Regeneration status of trees can be predicted by the age structure of their populations (Marks, 1974; Veblen *et al*., 1979 and Khan *et al*., 1987). Presence of sufficient number of seedlings and young trees in a given population indicates successful regeneration (Saxena and Singh, 1984). Regeneration of tree species is greatly influenced by the interaction of biotic and abiotic factors of the environment (Boring *et al*., 1981; Lange and Graham, 1983; Aksmit and Irving, 1984; Khan *et al*.,1986). These factors may affect the recruitment, survival and growth of tree seedlings and sprouts.

The successful regeneration of a tree species depends on ability to produce sufficient number of seedlings, saplings to survive. However the presence of sufficient number of seedlings, saplings and young trees is greatly influenced by

interaction of biotic and abiotic factors of the environment (Akasmith and Irving, 1984; Khan *et al*., 1987). Moreover, the intensity of magnitude and frequency of disturbances also determine the structure and composition of plant communities in the forest ecosystem (Khan *et al*., 1987).

The rain forests are climatic climax. In India these forests are not very extensive but are found locally in small pockets in the Western Ghats, in the lower part of eastern Himalayas and in Andaman and Nicobar islands. Normally in forests, when mature tree die they are replaced by younger generation of the same or other species and thus the species diversity in the ecosystem is maintained. The process of natural regeneration in tropical forests is no doubt exceedingly complex, and though its practical importance to the forester is obvious, yet surprisingly very little is known about it (Richards, 1952).

The regeneration of different size classes was found to vary in scared groves, natural forests, but there was no regeneration in coffee plantations. The distribution of different size classes of regeneration in case of sacred groves was normally distributed compared to natural forests. In case of natural forests the distribution of different size classes is not normal was not, which is an indication of some disturbance (Devkumar *et al*., 2007).

Even though the percentage contribution of seedlings by different tree species to general stocking is very low as they show a specific trend, some being very low and some very high. Around 68 species figured in field count of which identified 54 species belonging to 32 families. From this only 5 species contributed more than five per cent remaining 39 species had less than one per cent regeneration. Difference in frequency and abundance of seed production, difference germination of seeds and establishment of regenerates could be some of the reasons for lack of regeneration of all the species. The analysis of regeneration count carried in the evergreen forests of Makutta indicated that crop density between 60 to 80 per cent favoured regeneration than fully covered areas. Also it is seen that regeneration gets reduced as the slope increases and this

phenomenon is very much pronounced in steep slopes. It was very glaring that regeneration of many primary species is poorly represented, which directly reflects on the scarcity of seed bearers (Sha, 1989).

Out of 47 tree species in the undisturbed stand only 26 were found to be regenerating in tropical evergreen forests of Arunachal Pradesh. Thirteen species showed good regeneration (predominance of saplings and seedlings) which contributed more than 90 per cent to the total density of species. Eight species had fair regeneration and five species showed poor regeneration. In mildly disturbed stand out of 54 tree species 37 were found regenerating, of which, 15 species had good regeneration, eight showed fair regeneration and 14 had poor regeneration. Out of 42 species in moderately disturbed stand, 22 were found regenerating and good regeneration was recorded in nine species, seven species showed fair regeneration and six species has poor regeneration and no regeneration was recorded on highly disturbed stand (Bhuyan *et al*., 2003).

In the high elevation evergreen forests of Talakavery wildlife sanctuary, regenerates in the classs II, III and IV were deficient and the story was dominated by life forms other than tree species. Whereas in medium elevation evergreen forests the understory was dominated by regenerates of tree species, which could be attributed to higher disturbance in high altitude evergreen forests (Santhosha, 2005).

In a 3.12 hectare study area in evergreen forest of Uppangala, Kodagu district, 1981 trees of ≥ 30 cm were counted. The mean density was 635 trees per hectare and basal area of 123.8 m^2, that is, 39.7 m^2 per hectare. The distribution of girth class was followed the classic negative exponential pattern commonly found in undisturbed rain forests (Pascal and Pelisser, 1996).

The stand density and basal area of adult (6cm diameter) in three stands varied greatly along the disturbance gradient. Maximum density was recorded in undisturbed stand (904/ha) and minimum in disturbed stand (564/ha). Basal area ranged from 6.04 m^2/ha (disturbed stand) to 12.55 m^2/ha (undisturbed) showing

significant differences among three stands. Distribution of stems in various diameter classes in seedlings (0 – 2 cm), saplings (2 – 6 cm) and trees (>6 cm) in the total population of the species showed significant differences among the stands. The density of seedlings was highest in moderately disturbed stands (296/ha) and lowest in disturbed stands (264/ha), while the density of saplings did not vary largely (332/ha in disturbed stands to 384/ha in undisturbed stand) among three stands (Rai and Proctor, 1986). Rajwar *et al*. (1999) studied the density of seedlings & saplings and measured the regeneration potential of an oak forest of Garhwal Himalaya. Among 15 species, he has recorded 88 % of the tree species in seedling stage while sapling percentage was further reduced and some of the species were even not observed in seedling stage.

A total of 13,393 trees of ≥30 cm girth trees were enumerated in 30 hectares area. The stand density of each hectare varied considerably. In a total of 14 hectares tree density was greater than the mean density of 446 stems per hectare. The mean stand basal area was 36.26 m^2 per hectare. In the 30 hectare plot, 13 hectares had a basal area greater than the mean stand basal area. Based on their contribution to the basal area of the stand, *Dipterocarpus indicus* ranked first with 124.64 m^2 (in 30 hectare) followed by *Poeciloneuron indicum* (79.27 m^2). A total of 10 species in the study area contributed 48 per cent of stand basal area (Ayappa and Parthasarth, 1999).

The reverse J shaped population structure of trees exhibited in tropical evergreen forest of Tamil Nadu and is confirmed with the many of the forest stands in Western Ghats such as Kakachi (Ganesh *et al*, 1996), Uppangala (Pascal and pelissaer, 1996), Mylodas – Courtallam Reserve forest (Parthasarthy, 2001) and high elevation forests of Kalkad (Parthasarth, 1999).The girth class frequency distribution of trees reveals that 52 per cent of the forest stand was formed by the lower girth class (30 – 60 cm gbh) and with increasing girth class the number of individuals decreased exponentially. Trends in basal area contribution of girth

classes reveal a step – wise increase in basal area with increasing girth class that peaked at 150 cm gbh thereafter decreased (Ayappa and Parthasarthy, 1999).

The species richness and abundance decreased with increasing girth class. The lowest girth class (30-60 cm gbh) contributed 89 per cent of species richness and decreased gradually with increasing tree size class. The lowerstory tree *Drypetes longifolia* dominated the 30-60 cm girth class and 90 cm girth class followed by *Poeciloneuron indicum* (150 to 180 and 210 cm girth class), *Dipterocarpus indicus* (240 – 480 cm and 600 cm gbh) and *Bombax ceiba* (10 and 570 cm girth class) (Ayappa and Parthasarthy, 1999).

The species density and diversity index consistently decreased with increase in stem size class from 30 cm gbh to 210 cm gbh, except in the last class of 210 cm gbh. The lowest size class captured 89 per cent of species richness, 54 per cent of the forest stand density and there was a 5 fold decrease in richness and about a 40 fold decrease in density in 180 – 210 cm gbh (Parthasarthy, 2001).

Tree stand density and species richness consistently decreased in the forests of Arunachal Pradesh with increasing the girth class of tree species from 20 to more than 200 cm girth. The highest tree stand density species richness were recorded in medium girth class (15 – 110 cm) in all stands in undisturbed stand the highest tree stand density was found in the 111 to 140 cm girth class. While mildly disturbed stands the 51 – 80 girth recorded the highest stand density. In the highly disturbed stand no trees recorded more than 140 cm girth. The highest contribution of tree stand density per girth class to the total tree density in undisturbed, mildly disturbed and moderately disturbed stands was recorded in the 51 to 80cm girth class (4731 and 28 per cent), while in the highly disturbed stand it was maximum (54 per cent) in the 81 to 110 cm girth class. *Dipterocarpus macrocarpus, Shorea assamica, Mesua, Castanopsis indica, Canarium resiniferum* and *terminalia chebula* the dominant species represent at least at one or two life stages in all forest stands (Bhuyan *et al*., 2003).

In the evergreen forests of Uttarakannada, the highest basal area of 62.81 m^2/ha is found in Karikan a well preserved sacred forest, rich in Dipterocarpus indicus. This forest has no history of logging and probably indicates that, similar kind of forests found in southern Western Ghats, would have vanished from major part of Uttarakannda. Devanagadde, with basal area 60 $m^2ha^{-1}$is another good patch of forests without any logging history. The basal area of stems in Yana 54 m^2ha^{-1} was mainly due to sustainable number of palm *Corypha umbraculifera*. In most other reserve forests the basal area ranges between 35 – 45 m^2ha^{-1}(Ayappa and Parthasarthy, 1999).

The studies undertaken in the worked and unworked high elevation evergreen forests of Kodagu indicated that, unworked areas have relatively higher species richness (85) compared to worked areas (82) and also the basal area of stems was also relatively higher in unworked forests (51.75 m^2) compared to worked area (43.60 m^2). With respect to dominant tree species as per the Importance value index, there was no much difference between worked and unworked forests, that is, out of ten dominant trees, seven were common to worked and unworked forests (Kushalappa and Kushalappa, 1998).

Chapter – 3

MATERIALS AND METHODS

This chapter provides relevant information of the study area with respect to its location, accessibility, geology, climate and biotic interferences and as well as the details of various materials and methods used to achieve the aims and objectives of this study. The methods used employ an "accepted paradigm" for the analysis of plant community data which is unfolded through subsequent analysis to effectively reveal the key features of vegetation structure. The links to specific environmental variables have been deduced by measuring, simulating and estimating candidate variables and then numerically correlating them with vegetation data by using techniques specifically designed for this type of work.

3.1. Study site

The details of the study site are presented under the following sub headings (Plate. 1).

3.2. Selection criteria

The criterion used for selecting Kandi Forest Range for exploration of vegetation structure was.

1. The site exhibited an altitudinal range in the order of at least one kilometer. Through this range it was likely that at least one major change in canopy species would be clearly assessable.
2. The site enabled transects to be extended in the study area with minimal variation in topography apart from that occurring over the length of the transect itself.
3. The site lied on a uniform and representative geological substrate.
4. The site possessed both undisturbed and disturbed paths, but was generally free from agricultural operations.

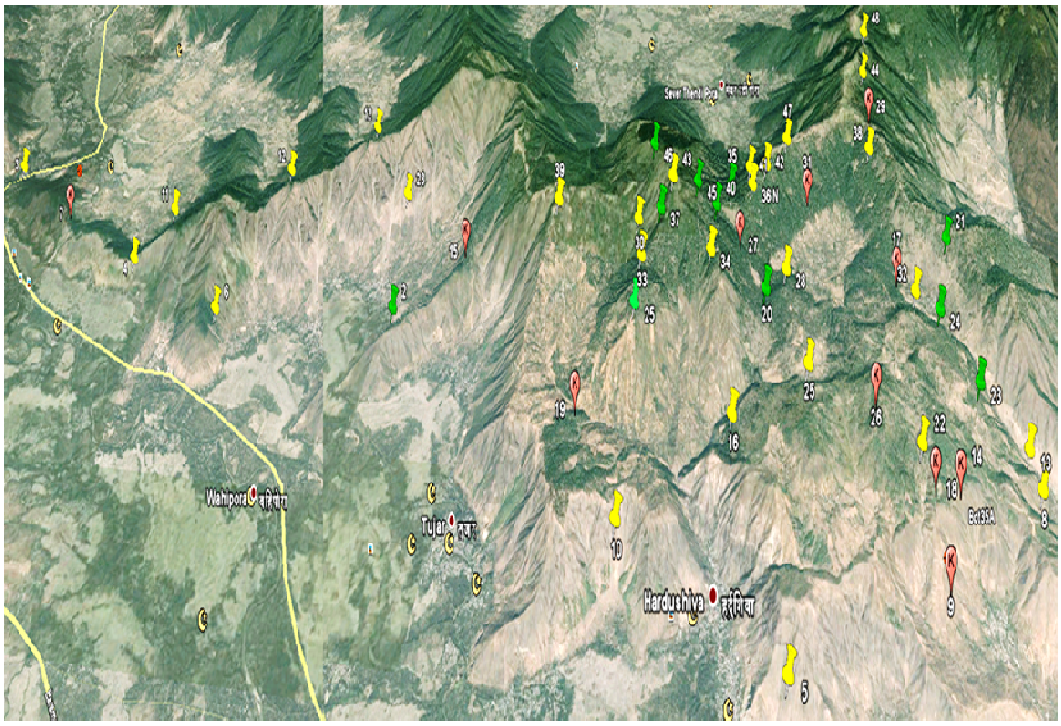


Fig.1.Photograph of Kandi forest range showing location of sampling points.

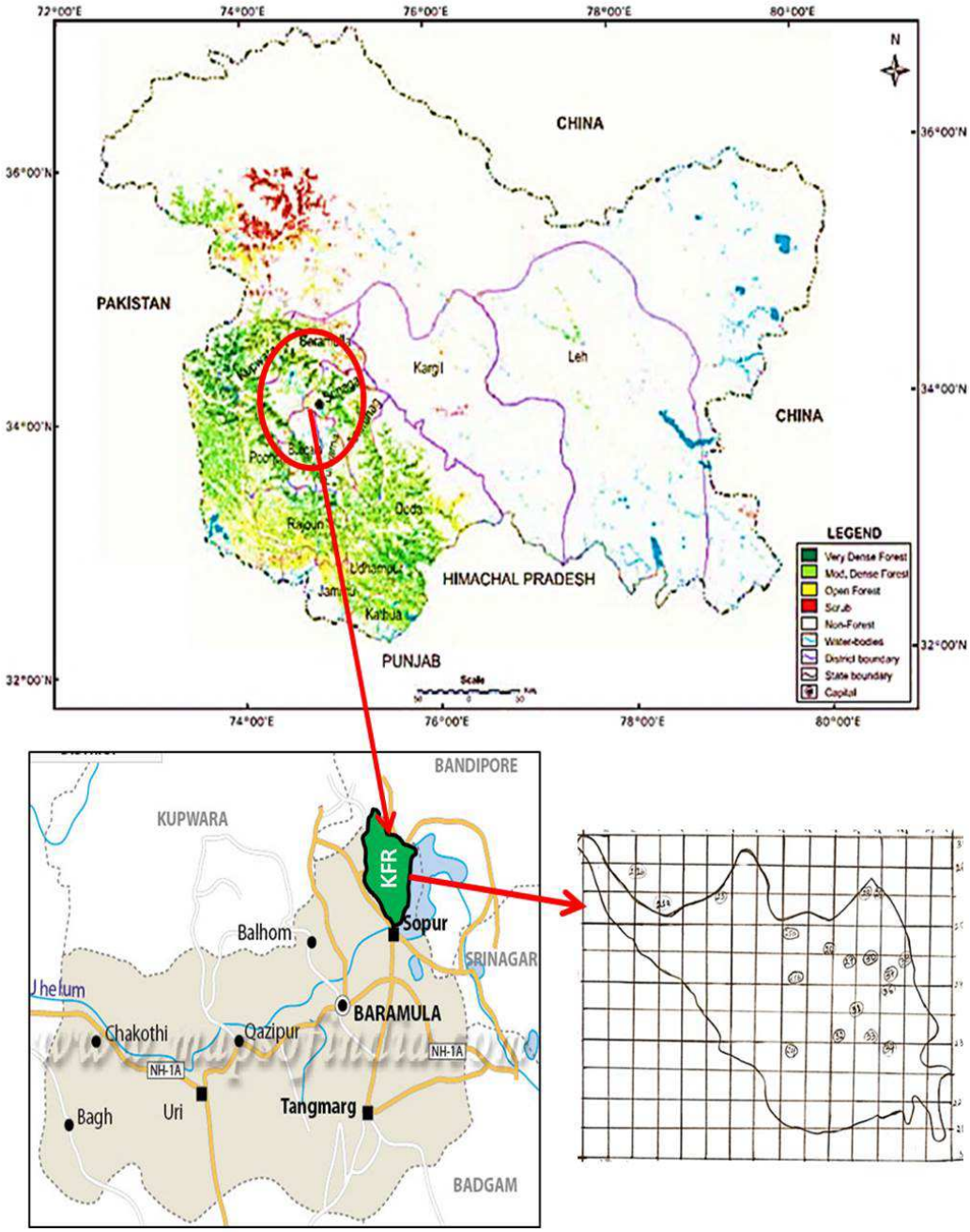


Plate: 1. Map of the Kandi forest range

3.3.Location and Access

The Kandi forest range of Kamraj forest Division in Kashmir lies between the geographical coordinates of 34^0 21´ to 34^0 26.05´ N latitude and 74^0 21´ to 74^0 32´ E longitudes (Table. 2). This Forest Range is spread over an area of 100.69 km^2 which extends from an elevation of 1600 m at the floor of the North Western valley where river Phoru and Kandi nalla forms the boundary up to 2800m at the ridge. The areas in the valley floor have gentle slope and as it progresses the upper areas become undulating with steeper slope. There are also some rock outcrops that vertically rise from the slopes near the ridge. The access of the forest range is possible via two/four wheel drive tracks that extend along the ridges in Northern and Southern aspects. The road to the upper part of the Forest Range often remains blocked for some periods due to freezing of snow during winter.The area of the forest range which is inaccessible for vehicle movements have some established tracks (Fig. 2 & 3).

3.4. Geology and soil

Geologically, the Kandi Forest Range is located in the inner reaches of the Himalaya. It is dominated by the shale/slate types of rocks which reflect the lithology of underlying sediments. The various geological formations formed within the Kandi forest range included Karewas and alluvium, Triasics, Panjal series, Nutnusa formation and Sagipora formation with limestone, slate, lava flows and highly friable arenaceous shale as their lithology.The area is characterized by alluvium soils in the lower elevations and lacustrian at higher elevations. In general the soils are moderately fertile and owing to lower clay content retain less water and show tendency for good drainage. The pH is close to neutral and is buffered by the limestone. The soils tend to be fairly stable, and are not prone to large-scale or frequent surface erosion or landslides. The soil type is suitable for forestry activities, as long as the silviculture and management regimes are appropriately chosen (Table. 1).

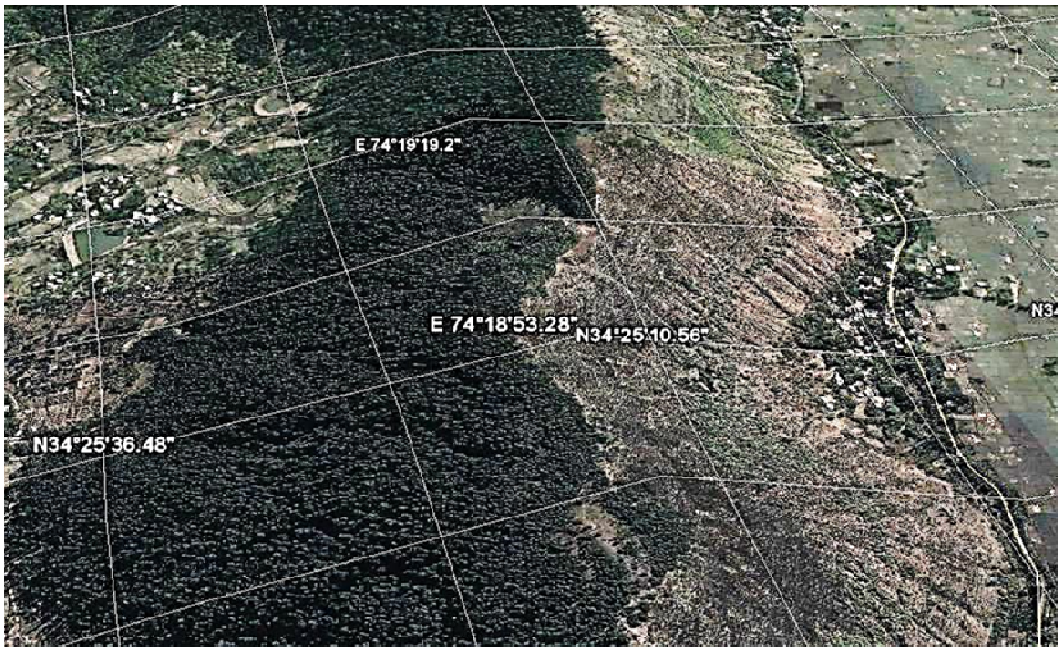


Fig.2. Aspects on latitudinal and longitude gradients in Kandi forest range

Table. 1. General characteristics of the Kandi forest range

Altitudinal Range (m)	Aspect	Latitude	Longitude	Geological formation	Lithology	Slope
1600-2000 (Lower)	S	34^0 22′ 11″	74^0 30′ 35″	a. Karewas and alluvium	a. Recent alluvial deposits	Gentle
	S	34^0 19′ 58″	74^0 19′ 35″			
	S	34^0 21′ 59″	74^0 27′ 40″			
	S	34^0 23′ 16″	74^0 30′ 24″			
	S	34^0 22′ 36″	74^0 29′ 18″			
	S	34^0 22′ 40″	74^0 25′ 56″			
	S	34^0 23′ 1″	74^0 29′ 13″			
	NW	34^0 24′ 15″	74^0 43′ 43″	b. Panjal series (Carboniferous)	b. Valconic lava flows, slate tuffs.	Steep
	NW	34^0 26′ 8″	74^0 17′ 6″			
	NW	34^0 25′ 34″	74^0 18′ 17″			
	NW	34^0 23′ 27″	74^0 30′ 18″			
	NW	34^0 24′ 41″	74^0 23′ 33″			
	N	34^0 24′ 28″	74^0 21′ 1″	c. Nutnusa & Sagipora formation	c. Highly friable arenaceous shale	Moderately steep
	N	34^0 25′ 27″	74^0 19′ 59″			
	N	34^0 26′ 4″	74^0 21′ 34″			
	N	34^0 23′ 22″	74^0 27′ 5″			
2000-2400 (Middle)	NW	34^0 24′ 53″	74^0 29′ 44″	a. Panjal series (Carboniferous)	a. Valconic lava flows,slate tuffs.	Moderately gentle
	NW	34^0 23′ 13″	74^0 29′ 13″			
	NW	34^0 24′ 17″	74^0 29′ 27″			
	N	34^0 23′ 20″	74^0 25′ 22″			
	N	34^0 23′ 40″	74^0 27′ 56″			
	N	34^0 24′ 28″	74^0 27′ 43″			
	NE	34^0 24′ 37″	74^0 29′ 6″	b. Triasics	b. Massive grey lime stone shales.	Steep
	NE	34^0 24′ 20″	74^0 27′ 28″			
	NE	34^0 24′ 16″	74^0 29′ 13″			
	E	34^0 22′ 50″	74^0 28′ 50″			
	E	34^0 23′ 58″	74^0 29′ 50″			
	E	34^0 23′ 25″	74^0 28′ 40″			
	E	34^0 24′ 41″	74^0 27′ 10″			
	E	34^0 35′ 24″	74^0 25′ 52″			
	E	34^0 23′ 1″	74^0 29′ 13″			
	E	34^0 25′ 31″	74^0 28′ 21″			
2000-2800 (Upper)	SW	34^0 24′ 53″	74^0 29′ 44″	a. Panjal series (Carboniferous)	a. Valconic lava flows,slate tuffs.	Moderately gentle
	SW	34^0 23′ 13″	74^0 29′ 13″			
	SW	34^0 24′ 17″	74^0 29′ 27″			
	SW	34^0 23′ 20″	74^0 25′ 22″			
	NW	34^0 23′ 40″	74^0 27′ 56″			
	NW	34^0 24′ 28″	74^0 27′ 43″			
	NW	34^0 24′ 37″	74^0 29′ 6″			
	NW	34^0 24′ 20″	74^0 27′ 28″			
	NW	34^0 24′ 16″	74^0 29′ 13″			
	N	34^0 22′ 50″	74^0 28′ 50″	b. Triasics	b. Massive grey lime stone shales.	Steep
	N	34^0 23′ 58″	74^0 29′ 50″			
	N	34^0 23′ 25″	74^0 28′ 40″			
	NE	34^0 24′ 41″	74^0 27′ 10″			
	NE	34^0 35′ 24″	74^0 25′ 52″			
	NE	34^0 23′ 1″	74^0 29′ 13″			
	NE	34^0 25′ 31″	74^0 28′ 21″			

3.5. Rainfall

The precipitation varies greatly along the elevation and increases with the increase in altitude. The average annual precipitation of the area varies from 500 mmto 833mm. While summers are drier with occasional rains, the winter however, witnesses a frequent snowfall. Due to absence of high mountainous ranges there is hardly any perpetual snow. The main drainage is southerly through Kandi nalla which is seasonal in nature and joins Phoru at Nutnusa.

3.6. Climate

The climate of the selected Forest Range is moderate with harsh winter and hot & dry summer. The range of elevation greatly affects the climate: in the bottom of the Forest Range, the summers are hot (25° C is common) and the winters fairly cold (often below -3° C); at the ridge top the climate is alpine, with mild summers and severe winters due to freezing temperature. The area experiences frost at high altitudesduring late autumn (Table. 2).

3.7. Forest management and silviculture system followed.

The silvicultural system applied in the selected Forest Range during the last management plan period (1965-66 to 1974- 75) was shelter wood uniform/ compartment system. The Forest range is presently managed in accordance with the Forest and Nature Conservation Rules modified in the year 2000. This management plan has adopted ban on green felling and the removal of timber is restricted to fallen trees only, the transportation of which is easier being practiced with gravity line system from the inaccessible areas. This system has facilitated regeneration of major conifer species to balance the economic and ecological prospectives of the forest management.

3.8. Biotic interferences

Thus, due to the presence of some villages in the forest fringes and gujjars inside the forest, a large chunk of forest land has been lost to agricultural operations. The menace of encroachment is marching ahead through the villagers

Table. 2. Mean monthly meteorological data of District Baramulla for the year 2011 & 2012

Month	2011			2012		
	Max temp	Min temp	Rf (mm)	Max temp.	Min Temp	Rf (mm)
JAN	7.64	-2.74	54.20	4.90	-3.13	60.20
FEB	9.65	1.52	100.10	9.38	0.18	78.70
MAR	16.75	4.93	100.80	16.19	4.61	58.00
APR	18.79	7.02	105.60	19.99	8.19	82.70
MAY	27.41	12.60	16.20	Missing	Missing	Missing
JUN	30.32	16.65	27.00	27.34	14.12	27.10
JUL	29.72	18.32	28.30	30.81	18.63	12.10
AUG	30.19	18.08	68.40	29.93	19.09	26.60
SEP	27.82	14.07	46.50	26.53	14.48	106.20
OCT	22.68	6.95	29.10	21.44	5.79	10.80
NOV	16.15	2.78	24.10	17.19	1.56	11.70
DEC	10.14	-1.83	33.10	9.11	-0.44	27.10

encroach the forest land along the fringes. The Gujjars have devastated huge area along the upper altitudes. The forest range is highly vulnerable to grazing by cattle and sheep. The unlimited and unrestricted grazing has affected the forest adversely. The refracted area along the southern slope is subjected to intensive grazing and thus makes conditions unfavorable for regenerationto come up. Illicit felling of trees which has reached its zenith is another serious damage done to forests. The trees are also subjected to most serious damage in the form of girdling, debarring, scoring and heavy lopping before being ultimately felled.

3.1.1Soil analysis:

A total of 48 composite soil samples were collected (at two depths viz. 0-15 and 15-30 cm) from the study area. The soil samples were air dried and processed through 2mm sieve whilst twigs, roots and gravels were removed. The sieved fraction of soil was homogenized and used for analysis of different physico-chemical parameters as per standard procedures described by Jackson (1967) and Misra (1968).

3.1.2 Physical properties

3.1.2.1. Bulk Density (BD)**:**

Bulk Density is the ratio of the oven-dry mass of the solids to the volume (the bulk volume includes the volume of the solids and of the pore space) of the soil. It was analyzed following the method of Gupta, (2002). Measuring cylinder of 100 ml was weighed and filled with soil with continuous tapping of the bottom of cylinder until soil volume of 100ml was obtained. Then the weight of the cylinder containing soil was recorded. The procedure was replicated thrice and average weight was taken. The bulk density of the soil samples was calculated by the formula:

$$\textbf{Bulk Density } (g/cm^3) = \frac{\text{Dry weight of soil sample (g)}}{\text{Volume occupied by the same soil sample } (cm^3)}$$

3.1.2.2. Electrical conductivity (μScm^{-1})

The conductivity of soil samples was measured at 20^0C with the help of a digital CD-601 conductivity meter (Milwaukee). Twenty five gram(25g) of air dry soil sample was thoroughly mixed with 50 ml of distilled water (1:2 w/v) and conductivity of the soil samples was recorded after 30 minutes. The conductivity meter was calibrated before use with standard 0.01M potassium chloride solution. The results were expressed as $\mu S/cm$ at 20^0C.

3.1.2.3. Soil pH

The pH of soil samples was measured at 20^0C with the help of a digital pH meter (model AP x 175 E/C). Twenty five gram(25g) of air dry soil sample was thoroughly mixed with 50 ml of distilled water (1:2 w/v) and pH of the soil samples was taken after 30 minutes. The pH meter was calibrated before use with standard pH buffers (pH 4 and pH 7).

$$\text{Soil pH}=\log \frac{1}{H^+}=-\log\left(H^+\right)$$

H^+ is expressed as g ions/lt.

3.1.2.4. Water holding capacity (WHC %)

The maximum water holding capacity of soil is the amount of water taken up by unit weight of dry soil, when immersed in water in standardized conditions. This amount of water is equal to the volume of pores (Misra, 1968).

$$WHC=\frac{w_2-w_3-w_4}{w_3-w_1}\times 100$$

W_1= weight of box and filter paper (Whatman NO. 1 filter paper),

W_2 = Blotting paper weight after 12-16 hours of surfacing drying,

W_3 = Oven dry (105^0C for 24 hours) weight of box

W_4 = Amount of water absorbed by filter paper.

Stratified Sampling						
Altitudinal Range (m)	Aspects					
	S	SW	NW	N	NE	E
1600-2000	+	-	+	+	-	-
2000-2400	-	-	+	+	+	+
2400-2800	-	+	+	+	+	-

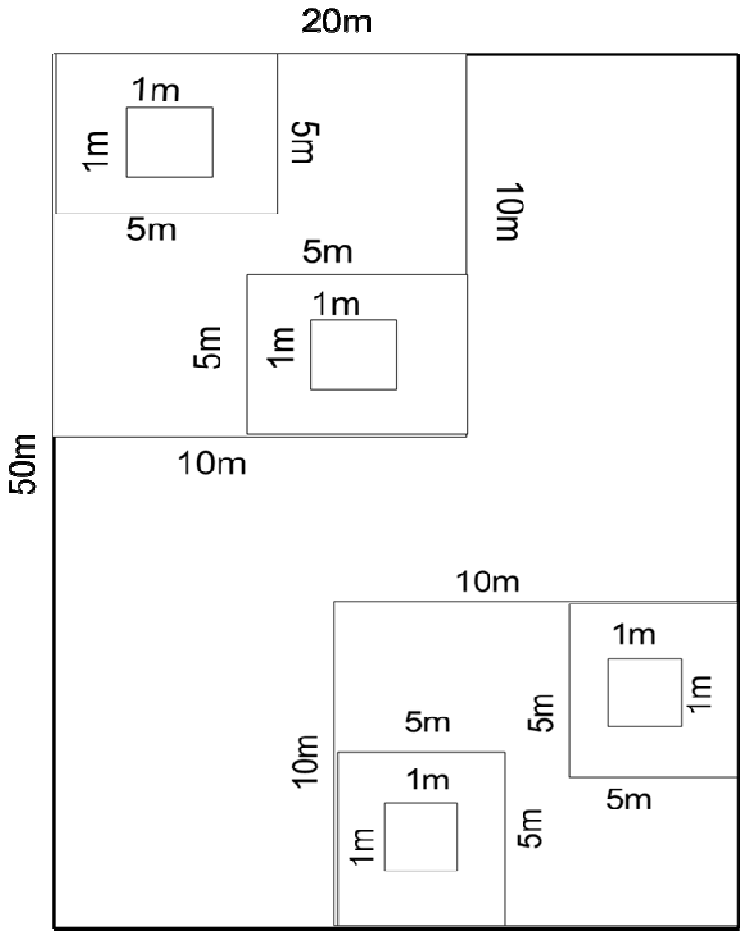


Plate. 2. Sampling layout

3.1.3. Chemical properties of soil

3.1.3.1 Calcium Carbonate ($CaCO_3$ %)

Rapid titration Method was used for the determination of calcium carbonate of soil (Puri, 1930). The soil suspension was titrated against the 0.5N sulphuric acid in the presence of bromothymol blue and brocresol green indicator. Calcium sulphate was added as flocculating agent in order to make the colour change distinct. Calcium sulphate also ensures uniform conditions throughout the reaction. Aluminum chloride lowers the pH of the soil suspension to the point where the indicators show their acidic colour (yellow).

3.1.3.2 Organic carbon (%)

Organic carbon (OC)was estimated by wet combustion method prescribed by Walkley and Black (1934).The known weight of soil was treated with excess standard $K_2Cr_2O_7$ in presence of concentrated Sulfuric acid. The excess $K_2Cr_2O_7$ not reduced by the organic matter of the soil, was determined by back titration with standard ferrous ammonium sulfate using diphenylamine indicator. Percentage organic carbon was calculated using the following formula:

$$\textbf{Soil organic carbon } (\%) = \frac{10\ (\mathrm{B} - \mathrm{T})}{\mathrm{B}} \times \frac{0.003 \times 100}{\text{weight of soil sample}} \times 1.3$$

Where, **B**=Volume of titrant used for blank;

T=Volume of titrant used for sample.

Since it is assumed that organic carbon recovery by this method is only 77%, the Values obtained were multiplied by a correction factor of 1.3.

3.1.3.3 Available Nitrogen (kg ha^{-1})

The distillation process helps liberate ammonia which is absorbed in boric acid. The distillate is titrated with standard acid (N/10HCL) and the nitrogen is calculated using the exact titre value of the acid (Jackson, 1967). The detailed procedure is as under:

Take 5g soil in Kjeldhal tube

↓

Add a little distilled water and 25 ml $KMnO_4$

↓

Place a conical flask (250ml) containing 25ml boric acid solution in such a way that the end of condenser tube dips into the boric acid solution

↓

Connect the Kjeldhal tube to the distillation assembly add about 25ml sodium hydroxide (2.5%)

↓

Set the process time 15-18 minutes (about 150ml distillation is collected in receiving flask) Test with red litmus paper to ensure total distillation

↓

Titrate the distillation with standard 0.02N H_2SO_4 to wine red end point

Run a blank in the same way

$$\textbf{Available Nitrogen } (\textbf{kg ha}^{-1}) = \frac{(\text{sample titre} - \text{blank titre})0.02 \times 14 \times 2.24 \times 10^6}{\text{weight of soil sample(g)} \times 1000}$$

3.2.3.4. Available Phosphorus (kg ha^{-1})

Olsen's method was used to determine available phosphorus in soil samples (Olsen, 1954). The detailed procedure for estimation of available P is as under:

1g of a soil

↓

20ml $NaHCO_3$

↓

Shaking on a mechanical shaker for 30 minutes

↓

5ml extract in 25ml U/F

↓

5ml Ammonium Molibdate

↓

10ml D/W

↓

1ml stannous chloride dilute to 25ml blue colour on

spectrophotometer Reading at 660 W/I %AB

The concentrations of available phosphorus were calculated by reference to a calibration graph plotted from the standard phosphorus (KH_2PO_4) solution. Blanks were run in the same manner without soil.

3.1.3.5 Available Potassium (kg ha^{-1})

The available potassium was estimated by N-Ammonium Acetate Method, (Jackson, 1967) using Digital Flame Photometer (Model CL 22D).

Plate-:3. locating sampling points by GPS and recording of phyto-sociological data

5g soil

↓

25ml Ammonium acetate solution

↓

Shake for 5minutes

↓

Filter

↓

Feed on flame photometer

3.2.1. Vegetation structure analysis:

3.2.1.1. Sampling pattern:

A stratified random sampling method (Greig-smith, 1983 and Krebs, 1989) was employed and vegetation analysis on each altitude and aspect was replicated by laying quadrates on constant slope. This type of analysis minimizes environmental influence other than those related toaltitude and excludes historical influences such as fires which may have affected some of the given transects (Pielou, 1977). The working plan of the selected Forest Range was examined, but no two candidate sites were found sufficiently similar. Almost every altitudinal gradient varied considerably in slope and aspects and thus quadrats on a particular altitude were laid on places with similar geographical position. The study area was divided into three altitudinal gradients viz. 1600-2000m, 2000-2400m and 2400-2800m, using sampling intensity of 0.048%. Forty eight (48) sampling plots (16 at each altitude) each measuring 0.1 ha (20m x 50m) were laid on all the three altitudes (Anitha et al, 2010; Uma shanker, 2001) to study the composition and structure of vegetation. A Global Positioning System (GPS) was trailed to aid site location (latitude, longitude, altitude and aspect) of each plot (Table. 1).

Plate: 4. Soil analysis

3.2.1.2.Quadrate design and size:

At each altitude 10 x 10m quadrats were defined in 20 x 50m plot within which frequency, density and abundance of all plant species was recorded. The vegetation composition of understory species was recorded using 5x5m and 1x1m quadrats for shrubs and herbaceous vegetation respectively.

3.2.1.3. Plant Identification:

Significant taxonomic reservoirs (Willis, 1970; Costin, 1979; Norton. 1979; Mccann, 1987; Duigam, 1991 and Scarlett et al, 1992) were used for pant identification. The species lists documented by Masoodi *et al*., (2003) for the area also aided in identification of some of the plant species. Specimens difficult to identify at the species level were got identified by expert taxonomists at Sher-e-Kashmir University of Agricultural Science and Technology of Kashmir, Shalimar, Srinagar and University of Kashmir. For this purpose herbarium specimens with some distinguishing characteristics of general appearance of vegetative or reproductive material were prepared and these served as a crude basis for their identification and classification.

3.2.1.4. Phytosociology of the study area:

The various parameters of vegetation composition recorded and the procedures followed (Curtis & McIntosh, 1950) to determine them are as under.

3.2.1.4. Frequency (%):

The degree of dispersion of individual species (Frequency) expressed in terms of its percentage occurrence in the study area was calculated as:

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

3.2.1.5. Density:

The Density as the numerical strength of a species was determined as:

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

3.2.1.6. Abundance:

The number of individuals of different species in the community per unit of area was calculated as:

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

The spatial distribution pattern of various species at different altitudinal gradients was obtained using ratio of abundance to frequency (A/F) with values of <0.025 indicating regular distribution, 0.025 – 0.050 denoting random distribution and >0.050 reflecting contagious distribution (Curtis andCottom,1956).

3.2.2.1. Relative frequency, Density and Dominance (%):

The Relative values of frequency (RF), Density (RD) and Dominance (RDO) were determined as:

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

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

$$\textbf{Relative Dominance (\%)} = \frac{\text{Total basal cover of the species}}{\text{Total basal cover of all species}} \times 100$$

Mean Basal area $= \pi(d^2/4); \pi = 3.14$; d = Diameter at breast height (1.37 m)

Total Basal Area =Mean Basal Area * Density

3.2.2.2. Importance Value Index (IVI):

This index is used to determine the overall importance of each species in the community structure. The IVI for tree species was calculated by summing up

the relative values of frequency, density and basal area (Misra, 1968) and IVI for shrubs and herbs was obtained by summing the relative values of frequency and density (Bharali et al., 2011).

3.2.3. Diversity indices:

3.2.3.1 Species diversity index:

The species diversity index was determined by using Shannon-Wiener's ($H^{/}$) index (Margalef, 1968).

$$\textbf{Shannon-Wiener index } (\mathbf{H}^{/}) = -\sum_{i=1}^{s} \langle (Ni/N) \text{ In } (Ni/N) \rangle$$

Where, $\mathbf{N_i}$= IVI of species i and **N** = Total IVI of all the species.

3.2.3.2 Concentration of dominance(C) was calculated by using Simpson's index of dominance (Simpson, 1949):

$$\boldsymbol{C} = \sum_{i=1}^{s} (Ni/N)^2$$

Where, **C** = Concentration of dominance, **Ni and N** are same as species diversity index.

3.2.3.3. Species richness index (R) was calculated following (Margalef, 1958)

$$R = \frac{S-1}{\text{In } N}$$

3.2.3.4. Species evenness index (E) was estimated as per Hill (1973)

$$E = \frac{H}{\text{In } S}$$

Where, **S=** total number of species,

N= total number of individuals of all the species,

H= Species diversity index.

3.2.4. Index of similarity and dissimilarity between different altitudes were calculated by using following formula (Misra, 1989).

Plate: 5. Deforestation status of study area.

3.2.4.1. Index of similarity (S):

$$s = \frac{2C}{A + B}$$

Where,

A= Number of species in community A,

B= Number of species in community B,

C= Number of species common to both communities.

3.2.4.2. Index of dissimilarity:

$$\textbf{Index of dissimilarity} = 1 - S$$

3.3.Deforestation status of Kandi forest range:

The status of deforestation was studied in terms of Importance Value Index (IVI) of dominant conifer species (*Cedrus deodara* and *Pinus wallichiana*) in deforested area and core forested areas (Bhat, 2007). Ten quadrates of definite size (10 x10m) were laid at each area for the purpose of enumerating the deforestation status of the selected forested range.

3.4. Natural regeneration status of dominant conifers of Kandi Forest Range:

The regeneration status of the Kandi range was determined as per the procedure followed by Uma Shankar (2001) and Anitha, *et al.* (2010).The conifer species (Kail pine and deodar) thus recorded in the forest was categorized into three groups viz:

1. Individuals with > 11cm girth at breast height (1.3 m) and >2 meter height were considered as **tree.**
2. Individuals having 1 – 11 cm collar girth and 0.5 - ≤ 2 meter height were considered as **saplings**
3. Individuals ≤ 1 cm collar girth and ≤ 0.5 cm height were recorded as **seedlings**.

The quadrates laid for recording the phytosociology of the entire area

were used to study the regeneration status of the selected and forest range.

The regeneration status of selectedspecies assessed on the basis of phytosociological data (Uma Shankar, 2001) was classified into the following categories:

a. **Good:** if present in seedling > sapling > mature strata.

b. **Fair:** if present in seedling > sapling < mature strata.

c. **Poor:** if a species survives only in the sapling stage, but not as seedlings (even though saplings may be less than, more than, or equal to mature).

d. **None:** if a species is absent both in sapling and seedling stages, but present as mature; and,

e. **New:** if a species has no mature, but only sapling and/or seedling stages.

3.9. Data Analysis

The data collected in the field was analysed using Microsoft Excel (Office 2010). The soil data was subjected to the statistical analysis following the standard procedures (Gomez and Gomez, 1984). The variation between various factors and there interaction were tested at 0.05 percent level of significance as followed by Gomez and Gomez, (1984). The statistical analysis of data was carried out using the software statistica - AG, licensed to RRS Faculty of Agriculture, SKUAST-K, Wadura campus Sopore (193201). A two-tailed Pearson correlationcoefficient was calculated between various phytosociological and soil physico-chemical parameters using SPSS-16 software(SPSS Inc., Chicago, IL, USA).

Chapter – 4

Experimental findings

4.1.Soil Analysis

The results of some soil physico-chemical characteristics on various aspects (South, South West, North West, North, North Eastern and East) along the three altitudinal gradient viz.1600-2000, 2000-2400 and 2400-2800m asl are presented under following main headings.

4.1.1. Physical Properties

4.1.1.1. Soil Bulk Density (BDg cm^{-3})

The results on bulk density are summarized in table (3). The values calculated exhibited significant differences between the aspects and soil depths. The mean soil bulk density values on lower altitudinal range (1600-200 m) were 1.38, 1.30 and 1.25 g cm^{-3} on Southern, North Western and Northern aspects respectively. The mean BD value of Southern aspect was significantly ($p \leq 0.05$) different from the other aspects which were however non-significant with each other. Contrary to this bulk density values with respect to soil depths were significant. The mean interaction values between aspects and soil depths for soil bulk density were maximum (1.42 g cm^{-3}) on Southern and minimum (1.21 g cm^{-3}) on Northern aspect at lower altitudinal gradient for 15-30 and 0-15cm soil depths respectively.

The mean bulk density values at middle altitudinal range (2000-2400 m) were in order of 1.29, 1.32, 1.29 and 1.27 g cm^{-3} on Eastern, North Western, Northern and North Eastern aspects respectively. Again, the BD values differed and increased significantly ($p \leq 0.05$) with an increasing soil depth. Mean bulk density values for aspects were also significant with each other. Interaction values between aspects and soil depths ranged between 1.18 (0-15cm) to 1.36 g cm^{-3}(15-30cm) at between the aspects along the altitudinal gradient.

Table: 3. Physical properties of Kandi Forest soils at different aspects of 1600-2800m amsl altitude

Parameters	Soil Depths	Altitudes (m)																						
		1600-2000							2000-2400								2400-2800							
		Aspects				C.D ($p \leq 0.05$) (SEM)			Aspects					C.D ($p \leq 0.05$) (SEM)			Aspects					C.D ($p \leq 0.05$) (SEM)		
		S	NW	N	Mean	A	D	A×D	E	NW	N	NE	Mean	A	D	A×D	SW	NW	N	NE	Mean	A	D	A×D
Bulk Density	**0-15**	1.35	1.28	1.21	**1.28**	**0.05**	**0.02**	**0.07**	1.24	1.30	1.25	1.18	**1.24**	**0.02**	**0.06**	**0.08**	1.27	1.37	1.31	1.33	**1.32**	**0.03**	**0.07**	**0.01**
(g cm^{-3})	**15-30**	1.42	1.33	1.30	**1.35**	**(0.02)**	**(0.01)**	**(0.02)**	1.33	1.35	1.32	1.36	**1.34**	**(0.01)**	**(0.02)**	**(0.03)**	1.33	1.32	1.36	1.34	**1.34**	**(0.01)**	**(0.03)**	**(0.04)**
Mean		**1.38**	**1.30**	**1.25**	**1.31**				**1.29**	**1.32**	**1.29**	**1.27**	**1.29**				**1.30**	**1.35**	**1.34**	**1.34**	**1.33**			
EC (µScm^{-1})	**0-15**	80	93	90	**88**	**2.3**	**0.81**	**3.26**	105	111	103	99	**104**	**0.82**	**2.3**	**3.26**	84	89	87	85	**86**	**0.82**	**2.30**	**3.26**
	15-30	99	116	105	**107**	**(0.82)**	**(0.29)**	**(1.15)**	124	132	134	124	**128**	**(0.28)**	**(0.82)**	**(1.15)**	110	108	107	118	**111**	**(0.29)**	**(0.82)**	**(1.16)**
Mean		**89**	**104**	**97**	**97**				**115**	**122**	**119**	**112**	**116**				**97**	**99**	**97**	**102**	**98**			
pH	**0-15**	6.99	5.70	5.57	**6.09**	**0.05**	**0.02**	**0.07**	5.82	6.03	6.10	5.90	**5.96**	**0.01**	**0.03**	**0.05**	5.93	6.00	6.16	6.07	**6.04**	**0.03**	**0.07**	**0.10**
	15-30	7.23	5.97	6.01	**6.40**	**(0.02)**	**(0.01)**	**(0.02)**	6.11	6.31	6.33	6.08	**6.21**	**(0.01)**	**(0.01)**	**(0.02)**	6.17	6.30	6.33	6.2	**6.25**	**(0.01)**	**(0.03)**	**(0.04)**
Mean		**7.11**	**5.83**	**5.79**	**6.24**				**5.96**	**6.17**	**6.22**	**5.99**	**6.08**				**6.05**	**6.15**	**6.24**	**6.13**	**6.14**			
WHC (%)	**0-15**	19	41	43	**34**	**1.45**	**0.53**	**2.12**	36	39	37	39	**38**	**0.69**	**1.96**	**2.77**	40	39	42	39	**40**	**0.82**	**2.31**	**3.26**
	15-30	21	36	34	**30**	**(0.53)**	**(0.19)**	**(0.75)**	31	32	32	31	**31**	**(0.25)**	**(0.69)**	**(0.98)**	31	31	33	33	**32**	**(0.29)**	**(0.82)**	**(1.16)**
Mean		**20**	**38**	**38**	**32**				**34**	**36**	**34**	**35**	**34**				**36**	**35**	**38**	**36**	**36**			

S=South; NW=North West; N= North; NE=North East; E = East; SW= South West; A= Aspect; D= Depth; A×D= Aspect × Depth; Values in Parentheses are SEM.

The mean bulk density values on upper altitudinal range (2400-2800 m) were 1.30, 1.35, 1.34 and 1.34 g cm^{-3} on South Western, North Western, Northern and North Eastern aspects respectively. The mean bulk density values increased significantly with an increasing soil depth. The bulk density values with respect to aspects were non-significant ($p \leq 0.05$) with exception to South Western aspect on upper altitude. The interaction values were minimum (1.27 g cm^{-3}) at South Western aspect and maximum (1.37 g cm^{-3}) on North Western aspects at a soil depth of 0-15 cm on upper altitude.The altitudinal variation in BD was 1.5% between lower & middle, 3% between middle & upper and 1.5% between lower & upper altitudes.

4.1.1.2. Electrical Conductivity (EC μScm^{-1})

The results (Table. 3) show that the mean values of Electrical Conductivity on lower altitudinal gradient (1600-2000 m) were 89, 104 and 97μScm^{-1} on Southern, North Western and Northern aspects respectively. The mean values of EC recorded at lower altitude were significantly different between the two soil depths.The mean values of interaction between aspects and soil depths for soil ECranged between 116 μScm^{-1}on North Western aspect to 80 μScm^{-1} on Southern aspectat 15-30 and 0-15cm of soil depth respectively.

The variation in EC was also evident on middle altitudinal range of 2000-2400m asl. The average values of EC at this altitude were in order of 115, 122, 119 and 112 μScm^{-1} on Eastern,North Western, Northern and North Eastern aspects respectively. Again EC exhibited significant variation between aspects and soil depth with mean EC values of 104 &128 at 0-15 and 15-30cm. Interaction values for EC between aspect andsoil depthwere maximum (134 μScm^{-1}) on Northern and minimum (99μScm^{-1}) on North Eastern aspects at 15-30 and 0-15 cm of soil depths respectively.

The mean EC values on the available aspects at the upper altitudinal range (2400-2800m) were 97, 99, 97 and 102 on South Western, North Western, Northern and North Eastern aspects respectively. The EC values increased

significantly on all the available aspects along the soil depth with mean maximum interaction value of 118 μScm^{-1} on North Eastern aspect and minimum value of 84 μScm^{-1}on South Western aspects ata soil depth of 15-30 and 0-15cm respectively.The altitudinal variation in EC was 3% between lower & middle, 1% between middle & upper and 2% between lower & upper altitudes.

4.1.1.3. Soil pH

Data in table (3) depicts that mean soil pH values on lower altitudinal range (1600-2000 m) were 7.11, 5.83 and 5.79 on Southern, North Western and Northern aspects respectively. The pH value of Southern aspect was significantly ($p \leq 0.05$) different from the other aspects which in turn were non-significant with each other. The mean values of soil pH were 6.09 & 6.40 at 15-30 to 0-15cm. The interaction values of soil pH between aspects and soil depths was maximum (7.23) on Southern and minimum (5.57) on Northern aspect on lower altitudinal gradient at 0-15 and 15-30cm of soil depths respectively.

The mean pH values at middle altitudinal range (2000-2400 m) were in order of 5.96, 6.17, 6.22 and 5.99 on Eastern, North Western, Northern and North Eastern aspects respectively. Again the bulk density values differed and increased significantly ($p \leq 0.05$) with an increasing soil depthon all the available aspects. Interaction values of soil pH at this altitude ranged between 6.33 (15-30cm)to 5.82 (0-15cm) on Northern and Eastern aspects respectively.

The mean pH values on upper altitudinal range (2400-2800 m) were 6.05, 6.15, 6.24 and 6.13 on South Western, North Western, Northern and North Eastern aspects respectively. The pH values increased significantly ($p \leq 0.05$) with an increasing soil depth. Similarly, the pH values recorded on South Western and Northern aspects were significantly different from the other aspects, with North Western and North Eastern aspects being non-significant between themselves at this altitudinal range. The interaction value for soil pH was minimum (5.93)on South Western aspect and maximum (6.33) on North Western aspect at 15-30 and 0-15cm soil depths respectively.The altitudinal variation in soil pH was 6%

between lower & middle, 5% between middle & upper and 11% between lower & upper altitudes.

4.1.1.4. Water Holding Capacity (%)

The mean values of Water Holding Capacity (WHC)on lower altitudinal gradient (1600-2000 m) were 20, 38 and 38 % on Southern, North Western and Northern aspects respectively (Table. 3). The interaction values for WHC between aspects and soil depths ranged between 43% on Northern aspect to 21% on Southern aspectat a soil depth of 0-15and 15-30 cm respectively.

The WHC of soil differed significantly on both the soil depths at middle altitudinal range (2000-2400 m). The mean values of WHC at this altitude were in order of 34, 36, 34 and 35 on Eastern,North Western, Northern and North Eastern aspects respectively. WHC on North Western aspect was significantly different from all the aspects with exception to North Eastern aspect. The differences in WHC between other aspects were non-significant with each other. Interaction values of WHC between aspect andsoil depth was maximum (39%) and minimum (31%) on North Eastern aspects at 15-30 and 0-15 cm of soil depth.

The examination of data (Table. 3) further reveals that mean WHC values on the available aspects at the upper altitudinal range (2400-2800m) were 36, 35,38 and36 on South Western, North Western, Northern and North Eastern aspects respectively. Except for Northern aspect, the differences in WHC between aspects were non-significant ($p \leq 0.05$). The interaction values of WHC between aspect and soil depths were maximum (42%) on Northern aspect and minimum (31%) on South Western aspect at a soil depth of 0-15 and 15-30 cm respectively.The altitudinal variation in WHC was 6% between lower & middle, 5% between middle & upper and 11% between lower & upper altitudes.

4.1.2. Chemical Properties of Soil

4.1.2.1. $CaCo_3$ (Percent)

Data in table (4) depicts that mean $CaCo_3$ values on lower altitudinal range (1600-2000 m) were in order of 1.39, 1.32 and 1.29 percent on North

Western, Southern and Northern aspects respectively. The mean values of $CaCo_3$ were significantly ($p \leq 0.05$) different between two depths at various aspects. The interaction values between aspects and soil depths for $CaCo_3$ were maximum (1.41%) on North Western and minimum (1.26%) on Northern aspect at lower altitudinal gradient for 15-30 and 0-15 cm soil depths respectively.

The $CaCo_3$ values at middle altitudinal range (2000-2400 m) were in order of 1.34, 1.39, 1.37 and 1.34 percent on Eastern, North Western, Northern and North Eastern aspects respectively. Again, the bulk density values differed and increased significantly ($p \leq 0.05$) with an increasing depth on all the available aspects with exception at North Eastern and Eastern aspects were the difference was non-significant. Interaction values of $CaCo_3$ranged between 1.42% (15-30cm)to 1.28% (0-15cm) on North Western and North Eastern aspects respectively.

The mean $CaCo_3$ values on upper altitudinal range (2400-2800 m) were 1.58, 1.56, 1.48and1.48% on South Western, North Western, Northern and North Eastern aspects respectively. Although $CaCo_3$ values increased with an increasing depth, the differences were non-significant ($p \leq 0.05$) for all the aspects except at South Western aspect were differences were significant. The interaction values of $CaCo_3$ between aspects and soil depths were minimum (1.44%)onNorth Eastern aspect and maximum (1.62%) on South Western aspects at 0-15 and 15-30 cm of soil depth respectively. The altitudinal variation in $CaCo_3$ was 0 % between lower & middle, 11 % between middle & upper and 11% between lower & upper altitudes.

4.1.2.2. Organic Carbon (OC %)

The results on OC are summarized in table (4). The results reveal that mean values of OCon lower altitudinal gradient (1600-2000 m) were 0.92, 1.94 and 2.6 percent on Southern, North Western and Northern aspects respectively. The mean values of OC along the soil depths were 1.45 and 1.41 percent at a soil depth of0-15 and 15-30 cm respectively. The maximum and minimum

Table: 4. Chemical Properties of Kandi Forest soils at different aspects of 1600-2800m amsl altitude

Parameters	Soil Depths	Altitudes (m)																						
		1600-2000							2000-2400								2400-2800							
		Aspects				C.D ($p \leq 0.05$) (SEM)			Aspects					C.D ($p \leq 0.05$) (SEM)			Aspects					C.D ($p \leq 0.05$) (SEM)		
		S	NW	N	Mean	A	D	A×D	E	NW	N	NE	Mean	A	D	A×D	SW	NW	N	NE	Mean	A	D	A×D
$CaCo_3$(%)	0-15	1.27	1.38	1.27	**1.33**				1.31	1.36	1.34	1.28	**1.32**				1.55	1.54	1.45	1.44	**1.50**			
	15-30	1.37	1.41	1.32	**1.39**	**0.05 (0.02)**	**0.02 (0.01)**	**0.07 (0.02)**	1.37	1.42	1.40	1.39	**1.40**	**0.03 (0.01)**	**0.07 (0.03)**	**N.S (0.04)**	1.62	1.58	1.51	1.52	**1.56**	**0.03 (0.01)**	**0.08 (0.03**	**N.S (0.03)**
Mean		**1.32**	**1.39**	**1.29**	**1.36**				**1.34**	**1.39**	**1.37**	**1.34**	**1.36**				**1.58**	**1.56**	**1.48**	**1.48**	**1.53**			
OC(%)	0-15	0.93	1.97	2.73	**1.45**				2.47	2.18	2.62	2.30	**2.39**				2.31	2.26	2.12	2.55	**2.31**			
	15-30	0.91	1.91	2.47	**1.41**	**0.10 (0.04)**	**0.04 (0.01)**	**0.15 (0.05)**	2.15	1.84	2.29	1.96	**2.06**	**0.07 (0.03)**	**0.21 (0.07)**	**0.29 (0.11)**	1.95	1.86	1.77	2.28	**1.97**	**0.11 (0.03)**	**0.28 (0.13)**	**0.39 (0.14)**
Mean		**0.92**	**1.94**	**2.6**	**1.43**				**2.31**	**2.01**	**2.46**	**2.13**	**2.22**				**2.13**	**2.06**	**1.95**	**2.42**	**2.14**			
Av. N (kg/ha)	0-15	173	276	304	**224**				311	324	278	310	**306**				294	318	296	331	**310**			
	15-30	136	218	257	**177**	**1.15 (0.41)**	**0.41 (0.14)**	**1.63 (0.58)**	259	269	244	268	**260**	**0.82 (0.29)**	**2.31 (0.82)**	**3.26 (1.15)**	249	258	257	279	**261**	**0.82 (0.29)**	**2.31 (0.82)**	**3.26 (1.16)**
Mean		**155**	**247**	**281**	**200**				**285**	**297**	**261**	**289**	**283**				**272**	**288**	**277**	**305**	**285**			
Av. P (kg/ha)	0-15	4.53	7.32	8.30	**5.93**	**0.12 (0.41)**	**0.04 (0.14)**	**0.16 (0.58)**	11.77	10.19	12.43	13.01	**11.85**	**0.09 (0.03)**	**0.27 (0.09)**	**0.38 (0.13)**	12.17	9.42	10.44	12.89	**11.23**			
	15-30	2.97	4.48	5.58	**3.73**				6.53	6.83	9.43	7.33	**7.53**				8.13	6.37	5.76	8.72	**7.25**	**0.12 (0.04)**	**0.34 (0.12)**	**0.47 (0.17)**
Mean		**3.75**	**5.90**	**6.94**	**4.82**				**9.17**	**8.53**	**10.97**	**10.17**	**9.69**				**10.15**	**7.90**	**8.10**	**10.81**	**9.24**			
Av. K (kg/ha)	0-15	211	255	272	**224**	**1.15 (0.41)**	**0.41 (0.14)**	**1.63 (0.58)**	312	297	302	305	**304**	**0.82 (0.29)**	**2.31 (0.82)**	**3.26 (1.15)**	310	331	310	316	**317**			
	15-30	194	239	252	**225**				291	280	292	264	**282**				291	273	245	287	**274**	**0.82 (0.29)**	**2.31 (0.82)**	**3.26 (1.16)**
Mean		**203**	**247**	**262**	**224**				**302**	**289**	**297**	**285**	**293**				**301**	**302**	**278**	**302**	**295**			

S =South; NW=North West; N= North; NE=North East; E = East; SW= South West; A= Aspect; D= Depth; A×D= Aspect × Depth; Values in parentheses are SEM, Av.= available

interaction values for OC between aspect and soil depths were 2.73% on Northern aspect and 0.91% on Southern aspectat the soil depth of 0-15 and 15-30 cm respectively.

The values of OC on middle altitude (2000-2400 m) were in the order of 2.31, 2.01, 2.46 and 2.13 percent on Eastern,North Western, Northern and North Eastern aspects respectively. Organic Carbon exhibited significant change with respect to soil depths with mean values of 2.39 and 2.06 % at a soil depth of 0-15 and 15-30 cm respectively. The interaction value of OC between aspect andsoil depth at this altitude was maximum (2.62%) on Northern aspect and minimum (1.84%) on North Western aspects at the soil depth of0-15 and 15-30 cm respectively.

The OC values on the available aspects at the upper altitudinal range (2400-2800m) were 2.13, 2.06, 1.95 and 2.42 on South Western, North Western, Northern and North Eastern aspects respectively. The OC content decreased with increase in soil depth with values recorded at 0-15cm being 15 % higher than that in 15-30cm of soil depth. The interaction values of OC between aspect and soil depths were maximum (2.55%) on North Eastern aspect and minimum (1.77%) on Northern aspects at the soil depth of 0-15 and 15-30 cm respectively.The altitudinal variation in OC was 36 % between lower & middle, 4 % between middle & upper and 33% between lower & upper altitudes.

4.1.2.3. Available Nitrogen (N kg ha^{-1})

The results on available N are summarized in table (4). The mean values of available N on lower altitudinal range (1600-2000 m) were 155, 247 and 281 kg ha^{-1} on Southern, North Western and Northern aspects respectively. The data further reveals that available N values increased significantly ($p \leq 0.05$) with increase in respective soil depth from 244(kg/ha)in 0-15 to 177(kg/ha)in 15-30cm. The interaction values between aspects and soil depth for available N were maximum (304kg ha^{-1}) on Northern and minimum (136kg ha^{-1}) on Southern aspect at 0-15and 15-30 cm of soil depth.

The available N values at middle altitudinal range (2000-2400 m) were in order of 285, 297, 261, 289 and 283 kg ha^{-1} on Eastern, North Western, Northern and North Eastern aspects respectively. Again the available N values differed significantly ($p \leq 0.05$) with an increase in soil depth. The interaction values of available N between soil depths and aspects ranged between 324 kg ha^{-1}(0-15cm) to 244kg ha^{-1} (15-30cm) atNorth Western and Northern aspects respectively.

The mean available N values on upper altitudinal range (2400-2800 m) were 272, 288, 277, 305 and 285 kg ha^{-1} South Western, North Western, Northern and North Eastern aspects respectively. Again, the depth wise difference in available N was significant ($p \leq 0.05$) with respective average values of 310 & 261 kg ha^{-1} at 0-15 and 15-30 cm. The interaction value of available N was minimum 249 kg ha^{-1} on South Western aspect andmaximum (331kg ha^{-1}) on North Eastern aspect at 15-30 and 0-15 cm of soil depth. The altitudinal variation in available N was 29 % between lower & middle, 1 % between middle & upper and 33% between lower & upper altitudes.

4.1.2.4. Available phosphorus (kg ha^{-1}**)**

Results presented in table (4) reveals that mean values of available P at lower altitudinal gradient (1600-2000 m) were 3.75, 5.90 and 6.94kg ha^{-1} on Southern, North Western and Northern aspects respectively. The maximum and minimum depth wise values for available Pwere 5.93 and 3.73 kg ha^{-1} at a soil depth of 0-15and 15-30 cm respectively. The interaction values of available P between soil depths and aspects were maximum (8.30kg ha^{-1}) on Northern aspect and minimum (2.97kg ha^{-1}) on Southern aspect at a soil depth of 0-15and 15-30 cmrespectively.

The mean values of available P on middle altitude (2000-2400 m) were in the order of 9.17, 8.53, 10.97 and 10.17kg ha^{-1} on Eastern,North Western, Northern and North Eastern aspects respectively. Available P exhibited significant ($p \leq 0.05$) change with respect to soil depths with mean values of 11.83 and 7.53 % at a soil depth of 0-15 and 15-30 cm respectively. The interaction

values between aspect andsoil depthforavailable P was maximum (13.01kg ha^{-1}) and minimum (7.33kg ha^{-1}) onNorth Eastern aspect at 0-15 and 15-30 cm of soil depths respectively.

The mean available P values on the available aspects at the upper altitudinal range (2400-2800m) were in order of 10.15, 7.90, 8.10 and 10.81kg ha^{-1} onSouth Western, North Western, Northern and North Eastern aspects respectively. Available P decreased significantly ($p \leq 0.05$) with respect to soil depths from 11.23 to 7.25 % in 0-15 and 15-30 cm respectively. The interaction values between aspect and soil depths for soil available P were significantly different with maximum availability (12.89 kg ha^{-1}) on North Eastern aspect and minimum (5.76kg ha^{-1}) on Northern aspects at a soil depth of 0-15 and 15-30 cm respectively. The altitudinal variation in available P was 50% between lower & middle, 5 % between middle & upper and 48 % between lower & upper altitudes.

4.1.2.3. Available Potassium (K kg ha^{-1})

Data in table (4) depicts that mean available K values on lower altitudinal range (1600-2000 m) were 203, 247 and 262kg ha^{-1} on Southern, North Western and Northern aspects respectively. The mean values ofavailable K recorded with respect to soil depths were significantly ($p \leq 0.05$) different with maximum and minimum figures of 225 & 224%at a soil depth of 15-30 cm and 0-15cm respectively.The mean interaction values between aspects and soil depths for available K were maximum (272kg ha^{-1}) on Northern aspect and minimum (194kg ha^{-1}) on Southern aspect at a soil depth of 0-15 and 15-30 cm respectively.

The mean available K values at middle altitudinal range (2000-2400 m) were in order of 302, 289, 297 and 285kg ha^{-1} on Eastern, North Western, Northern and North Eastern aspects respectively. Again, the available K value differed and increased significantly ($p \leq 0.05$) with an increasing depths from 304 to 282 kg ha^{-1}in 0-15 and 15-30 cm respectively. Interaction values ranged from a highest of 312kg ha^{-1}(0-15cm)to a lowest value of 264 kg ha^{-1} (15-30cm) on Eastern and North Eastern aspects respectively.

The available K values on upper altitudinal range (2400-2800 m) were 301, 302, 278 and 302 on South Western, North Western, Northern and North Eastern aspects respectively. The available K values decreased significantly ($p \leq 0.05$) from 317 kg ha^{-1} in 0-15 cm to 274 kg ha^{-1} in 15-30cm of soil depth. The interaction values for available K were minimum(245kg ha^{-1}) onNorthern aspect and maximum (331kg ha^{-1}) on North Western aspects at 15-30 and 0-15 cm of soil depth respectively.The altitudinal variation in available K was 23% between lower & middle, 1% between middle & upper and 24% between lower & upper altitudes.

4.2. Floristic composition

The vegetation survey conducted indicated that the area is floristically rich, supporting many plant species, of diverse taxonomic and ecological significance. The data presented in table (5) shows that the selected forest range hosts 25 families (23 Angiosperms and 02 Gymnosperms), 53 Genera (50 Angiosperms and 03Gymnosperms) and 61 species (58 Angiosperms and 03 Gymnosperms). Out of the 61 species identified in the study area 39, 17 and 5 were herbs, shrubs and trees respectively.Rosaceae was the dominant family with 15 species followed by the Asteraceae (7), Lamiaceae (5), Poaceae (4), Fabaceae (4), and Caryophyllaceae (3) Pinaceae (2), Geraniaceae (2) and Ranunculaceae (2). Families with only one species were Adoxaceae, Apiaceae, Apocynaceae, Berberidaceae, Boraginaceae, Cupressaceae, Hypericaceae, Juglandaceae, Moraceae, Oleaceae, Onagraceae, Oxalidaceae, Plantaginaceae, Scrophulariaceae and Violaceae.

The vertical distribution of flora in the study area depicts that altitudinal range of 1600-2000 m represented maximum number of species (44) belonging to 23 families. The number of families and species for other two altitudinal ranges was in the order of 19 & 43 at 2000 -2400 m and 15& 32 at 2400 – 2800 m respectively. The species which were present throughout the vertical range of the selected forest included *Asterspp, Erigeron spp. Indigofera heterantha, Thymus serpyllum, Cedrus deodara, Pinus wallichiana, Plantago lanceolate, Viola odorata, Festuca pratensis ,Lolium perenen., Cotoneaster accuminatus, C. falconeri, Crataegus ambigua,*

Table:-5. Species composition of various altitudes and aspects of Kandi Forest Range.

Family	Division	class	Species	Habitat	Altitude		
					Lower	Middle	Upper
Adoxaceae	**Angiosperms**	**Dicot**	***Viburnum nudum L.***	**S**	-	-	+
Apiaceae			***Cuminum cyminum L.***	**H**	+	-	-
Apocynaceae			***Nerium indicum Mill.***	**S**	+	-	-
Asteraceae			***Artimesa absinthum L.***	**H**	-	+	-
			Aster spp.	**H**	+	+	+
			Chrysanthemum spp.	**H**	-	+	+
			Cichorium intybus L.	**H**	+	-	-
			Erigeron spp.	**H**	+	+	+
			Matricaria chamomilla L.	**H**	+	+	-
			Picris hiercioides L.	**H**	+	-	-
Berberidaceae			***Berberis lycium Royle***	**S**	+	+	+
Boraginaceae			***Cynoglossum glochidiatum Wall. exBenth.***	**H**	+	+	+
Caryophllaceae			***Dianthus angulatus Royle ex Benth.***	**H**	-	+	+
			Lychnus coronaria	**H**	-	+	+
			Silene spp.	**H**	+	-	-
Cupressaceae	**Gymnosperms**	**Pinopsida**	***Juniperus communis L.***	**S**	+	-	-
Fabaceae	**Angiosperms**	**Dicot**	***Indigofera heterantha Wall.***	**S**	+	+	+
			Lespedeza cuneata (Dum.Cours.) G.Don.	**H**	+	+	+
			Robinia pseudoacacia L.	**T**	+	+	-
			Trifolium repens L.	**H**	+	+	-
Geraniaceae			***Geranium rotundifolia L.***	**H**	-	+	+
			Geranium wallichianum Oliv.	**H**	-	+	+
Hamamelidaceae			***Parrotiopsis jacquemantiana (Decne) Rehd.***	**S**	+	+	-
Hypericaceae			***Hypericum perfoatum L.***	**H**	+	-	-
Juglandaceae			***Juglans regia L.***	**T**	+	-	-
Lamiaceae			***Clinopodium vulgare L.***	**H**	+	+	-
			Marrubium vulgare L.	**H**	+	-	-
			Rabdosia rugosa thumb.	**S**	+	-	-
			Scutellaria prostrate L.	**H**	-	+	+
			Thymus serpyllum L.	**H**	+	+	+

Cont…..

Family	Division	Class	Species	Habitat	Altitude		
					Lower	Middle	Upper
Moraceae	**Angiosperms**	**Dicot**	***Morus spp.***	**T**	+	-	-
Oleaceae			***Jasminum officinale L.***	**S**	+	-	-
Onagraceae			***Epilobium spp.***	**H**	-	+	+
Oxalidaceae			***Oxalis corniculata L.***	**H**	+	+	-
Pinaceae	**Gymnosperms**	**Pinopsida**	***Cedrus deodara (Roxb.)G. Don***	**T**	+	+	+
			Pinus wallichiana A. B. Jackson	**T**	+	+	+
Plantaginaceae	**Angiosperms**	**Dicot**	***Plantago lanceolata L.***	**H**	+	+	+
Poaceae		**Monocot**	***Bothriochloa pertusa***	**G**	-	+	+
			Cynodon dactylon (L). pers.	**G**	+	+	-
			Festuca pratensis (huds)	**G**	+	+	+
			Lolium perenen L.	**G**	+	+	+
Ranunculaceae		**Dicot**	***Anemone tetrasepala***	**H**	+	-	-
			Ranunculus hirtellus	**H**	-	+	+
Rosaceae		**Monocots**	***Cotoneaster accuminatus lindl.***	**S**	+	-	-
			Cotoneaster falconeri Medik	**S**	+	+	+
			Cotoneaster horizantalis decne	**S**	+	-	-
			Crataegus ambigua A. K. Becker	**S**	+	+	+
			Crataegus songarica K.Koch	**S**	+	+	+
			Fragaria nubicola lindl Xx lacaita	**H**	+	+	+
			Geum coccineum	**H**	-	+	+
			Geum elatum L.	**H**	+	+	+
			Geum spp.	**H**	-	+	+
			Potentilla reptens L.	**H**	-	+	+
			Potentilla spp.	**H**	-	+	+
			Rosa brunonii LINDL	**S**	+	+	-
			Rosa canina L.	**S**	-	+	-
			Rosa webbiana Wall. Ex. Royle	**S**	+	+	-
			Rubus armeniacus focke	**S**	+	-	-
Scrophulariaceae			***Verbascum Thapsus L.***	**H**	+	+	+
Violaceae			***Viola odorata L.***	**H**	+	+	+
Total Species					**44**	**43**	**32**
Total Families					**23**	**19**	**15**

T= Tree; S= Shrub; H= Herb; G=Grasses; + = Present; - = Absent

C. songarica and *Verbascum thapsus*. The species which exhibited limited distribution to lower altitudinal range of 1600 – 2000 m included *Cuminum cyminum, Nerium indicum, Cichorium intybus, Cirsium falconeri, Picris hiercioides, Silene spp, Juniperus communis, Hypericum perfoatum, Juglans regiaspp, Marrubium vulgare, Rabdosia rugosa, Morus spp, Jasminum officinale, Anemone tetrasepala, Cotoneaster accuminatus, C. horizantalis* and *Rubusarmeniacus*. While *viburnum nudum* was restricted at upper altitudinal gradient of 2400 – 2800m, *Artimesa absinthum* was constrained in the middle altitudinal range of 2000 – 2400m.

4.2.1. Community structure:

4.2.1.1. Trees:

The data on community structure of trees is presented in table (6). The vegetation analysis of the study area shows that the altitudinal gradient of 1600-2000 m was represented by South, North West and North aspects. While North West and North aspects comprised two species viz. *Cedrus deodara*and *Pinus wallichiana,* Southern slopes were represented by three hard wood species viz. *Juglans regiaJuglans regia, Robinia pseudoacacia* and *Morusspp*. The middle altitudinal range of 2000- 2400 m was represented by four aspects; viz. east, North West, North and North East, which comprised three species viz. *Cedrus deodara, Pinus wallichiana* and *Robinia pseudoacacia* with latter one being present only on North Eastern aspect. The upper altitudinal gradient of 2400 – 2800 m represented four aspects viz. South West, North West, North and North East all of which comprised only two tree species viz. *Cedrus deodara* and *Pinus wallichiana*.

The data in table (6) further manifests that; except for North Western aspect at an altitudinal range of 1600 – 2000 m, *Pinuswallichiana* was the most dominant tree species at each of the three altitudinal gradients. The respective highest and lowest density of 683 and 60 individual's ha^{-1} (trees>11cm gbh) for this species was recorded on North Eastern and North Western aspects at an altitude of 2400-2800 and 1600-2000 m amsl. *Cedrus deodara* was the second dominant tree species with respective highest and lowest density of 558 and 83

Plate-6: Tree species in Kandi Forest Range

Table:-6. Summary of community structure of Trees across the available aspects along an altitudinal gradient in Kandi forest range.

Altitude (m)	Species	Aspects																													
		S					SW					NW					N					NE					E				
		F	D	A	A/F	TBC	F	D	A	A/F	TBC	F	D	A	A/F	TBC	F	D	A	A/F	TBC	F	D	A	A/F	TBC	F	D	A	A/F	TBC
1600-2000	*Cedrus deodara*	-	-	-	-	-	-	-	-	-	-	90	540	2.80	0.03	69.19	79	558	3.00	0.03	38.23	-	-	-	-	-	-	-	-	-	-
	Pinus wallichiana	-	-	-	-	-	-	-	-	-	-	20	60	0.80	0.04	4.51	56	573	3.38	0.05	59.04	-	-	-	-	-	-	-	-	-	-
	Juglans regia	14	29	0.33	0.02	0.81	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Robinia pseudoacacia	14	36	0.36	0.03	0.47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Morus spp	21	36	0.50	0.02	0.66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total	**49**	**101**	**1.19**	**0.07**	**1.94**						**110**	**600**	**3.6**	**0.07**	**73.7**	**135**	**1131**	**6.38**	**0.08**	**97.27**										
2000-2400	*Cedrus deodara*	-	-	-	-	-	-	-	-	-	-	33	67	0.67	0.02	6.52	58	383	2.00	0.03	26.26	58	267	1.83	0.03	7.76	36	264	1.71	0.05	8.63
	Pinus wallichiana	-	-	-	-	-	-	-	-	-	-	58	167	1.17	0.02	5.41	58	500	3.17	0.06	11.22	83	683	3.67	0.04	25.30	57	329	1.93	0.03	25.5
	Robinia pseudoacacia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	67	0.67	0.02	1.51	-	-	-	-	-
	Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**91**	**234**	**1.84**	**0.04**	**11.93**	**116**	**883**	**5.17**	**0.09**	**37.48**	**174**	**1017**	**6.17**	**0.09**	**34.57**	**93**	**593**	**3.64**	**0.08**	**34.13**
2400-2800	*Cedrus deodara*	-	-	-	-	-	33	133	1.33	0.04	16.75	31	175	1.75	0.06	18.38	42	83	0.50	0.01	5.93	62	367	1.92	0.03	17.70	-	-	-	-	-
	Pinus wallichiana	-	-	-	-	-	75	367	2.00	0.03	81.87	75	450	2.38	0.03	10.89	67	450	2.67	0.03	55.90	75	400	2.33	0.03	34.74	-	-	-	-	-
	Total	**0**	**0**	**0**	**0**	**0**	**108**	**500**	**3.33**	**0.07**	**98.62**	**106**	**625**	**4.13**	**0.09**	**29.27**	**109**	**533**	**3.17**	**0.04**	**61.83**	**137**	**767**	**4.25**	**0.06**	**52.44**	**0**	**0**	**0**	**0**	**0**

S = South; SW = South West; NW = North West; N= North; NE = North East; E = East; F=Frequency (%); D=Density (ha^{-1}); TBC= Total Basal Cover (m^2 ha^{-1}); A=Abundance; A/F= Abundance Frequency Ratio

individual's ha^{-1} at lower and upper altitudinal ranges on Northern slopes. *Juglans regia* and *Morusspp* which were found restricted to Southern slope at 1600-2000 m altitude exhibited respective density values of 29 and 36 trees ha^{-1}. *Robiniapseudoacacia* displayed density values of 36 and 67 tree ha^{-1} at Southern and North Eastern aspects at altitudinal gradients of 1600-2000 and 2000 – 2400 m respectively.

The frequency of the existent tree species varied on all the aspects at each of the three altitudinal gradients (Table.6). The frequency of *Juglans* and *Morusspp* was 29 and 36 percent respectively. *Robiniapseudoacacia* exhibited frequency values of 36 and 33 percent on Southern and North Eastern aspects at the altitudinal gradients of 1600-2000 and 2000-2400m respectively. *Cedrusdeodara* displayed maximum frequency values of 90 percent on North Western aspect at an altitudinal range of 1600- 2000 m. *Pinuswallichiana* was the most frequent tree species on the entire area and exhibited higher frequency than *Cedrusdeodara* on the altitudinal ranges of 2000-2400 and 2400 – 2800m amsl. The maximum and minimum frequency values (83 and 78.75%) displayed by this species were recorded on North Eastern and Northern aspects at middle and lower altitudinal gradients.

The examination of data (Table.6) shows that the abundance of tree species also varied on all the available aspects along the altitudinal gradients. The critical examination of the data envisages that *Pinuswallichiana* and *Cedrusdeodara* are the most abundant tree species in the entire forest range. While *Pinuswallichiana* exhibited highest abundance values of 3.67 onNorth Eastern aspect at an altitude of 2000-2400 m followed by 3.38 on Northern aspect at 1600 – 2000 m,*Cedrusdeodara* was the second abundant species and displayed abundance values of 3.00 and 2.80 on North and North Western aspects at an altitude of 1600-2000 m. *Robiniapseudoacacia* demonstrated abundance values of 0.67 and 0.36 on North Eastern and Southern aspects at an altitudinal gradient of 2000 – 2400 m and 1600 – 2000 m respectively. *Juglans regia* representing only Southern slopes at an altitude of 1600-2000m recorded a lowest abundance value of 0.33.

The data on abundance to frequency ratio (Table.6) depicts that the distribution of tree species did not vary to a great extent along the altitudinal gradients. The highest A:F ratio of 0.06 was exhibited by *Pinuswallichiana* and *Cedrusdeodara* on Northern and North Western aspects at an altitude of 2000-2400 and 2400-2800m respectively thus representing a limited contagious pattern of distribution at these two places in the entire forest range. The distribution pattern for these two species varied from regular on North Western and Northern aspects at an altitude of 2000 – 2400 and 2400-2800m to random on all other available aspects at each of the three altitudes. The broadleaved tree species representing the selected forest, exhibited a general preponderance of more regular and random distribution pattern and the data apparently shows that the present pattern of distribution is regular for *Juglans regia* and *Morus spp* and random for *Robiniapseudoacacia*.

The data in table (6) manifests major differences in basal area of trees on each altitudinal gradient. While *Pinus wallichiana* exhibited highest total basal area of 81.87 m^2 ha^{-1} on South Western slopes at an altitude of 2400 – 2800 m, *Cedrusdeodara* displayed maximum total basal area values of 69.19 m^2 ha^{-1} on North Western aspect at an altitudinal range of 1600 – 2000m. The total basal area values for these two species on other available aspects ranged between 5.93 to 38.23 m^2 ha^{-1} for *Cedrusdeodara* and 4.51 to 59.01 m^2 ha^{-1} for *Pinuswallichiana*. The total basal area values for *Juglans regia* and *Morus spp* were 0.81 and 0.66 m^2 ha^{-1} respectively. *Robiniapseudoacacia* exhibited maximum and minimum basal area values of 1.51 and 0.47 m^2 ha^{-1} on North Eastern and Southern aspects at an altitude of 2000 – 2400m and 2400 – 2800 m respectively.

The examination of data (Table. 7 and Fig. 3) reveals profound variation in IVI values of trees over the entire range of altitudinal gradients. At lower altitude, maximum IVI was exhibited by *Cedrus Deodara* (266%) on North

Table:-7. Importance Value Index (IVI) of Trees across the available aspects along an altitudinal gradient in Kandi forest range.

Altitude (m)	Species	Aspects																							
		S				SW				NW				N				NE				E			
		RF	RD	RDO	IVI	RF	RD	RDO	IVI	RF	RD	RDO	IVI	RF	RD	RDO	IVI	RF	RD	RDO	IVI	RF	RD	RDO	IVI
1600-2000	***Cedrus deodara***	-	-	-	-	-	-	-	-	82	90	94	**266**	58	49	39	147	-	-	-	-	-	-	-	-
	Pinus wallichiana	-	-	-	-	-	-	-	-	18	10	6	**34**	42	51	61	153	-	-	-	-	-	-	-	-
	Juglans regia	29	29	42	99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Robinia pseudoacacia	29	36	24	88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Morus spp	43	36	34	113	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total	**100**	**100**	**100**	**300**	**-**	**-**	**-**	**-**	**100**	**100**	**100**	**300**	**100**	**100**	**100**	**300**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
2000-2400	***Cedrus deodara***	-	-	-	-	-	-	-	-	36	29	55	120	50	43	70	163	33	26	22	82	39	45	25	109
	Pinus wallichiana	-	-	-	-	-	-	-	-	64	71	45	180	50	57	30	137	48	67	73	188	61	55	75	191
	Robinia pseudoacacia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	7	4	**30**	-	-	-	-
	Total		**-**	**-**	**-**	**-**	**-**	**-**	**-**	**100**	**100**	**100**	**300**	**100**	**100**	**100**	**300**	**100**	**100**	**100**	**300**	**100**	**100**	**100**	**300**
2400-2800	***Cedrus deodara***	-	-	-	-	31	27	17	74	29	28	63	120	39	16	10	64	45	48	34	127	-	-	-	-
	Pinus wallichiana	-	-	-	-	69	73	83	226	71	72	37	180	61	84	90	**236**	55	52	66	173	-	-	-	-
	Total					**100**	**100**	**100**	**300**	**100**	**100**	**100**	**300**	**100**	**100**	**100**	**300**	**100**	**100**	**100**	**300**	**-**	**-**	**-**	**-**

RF= Relative Frequency; RD= Relative Density; RDO= Relative dominance ; IVI= Importance Value Index ; S =South; SW= South WestNW=North West; N= North; NE=North East; E = East

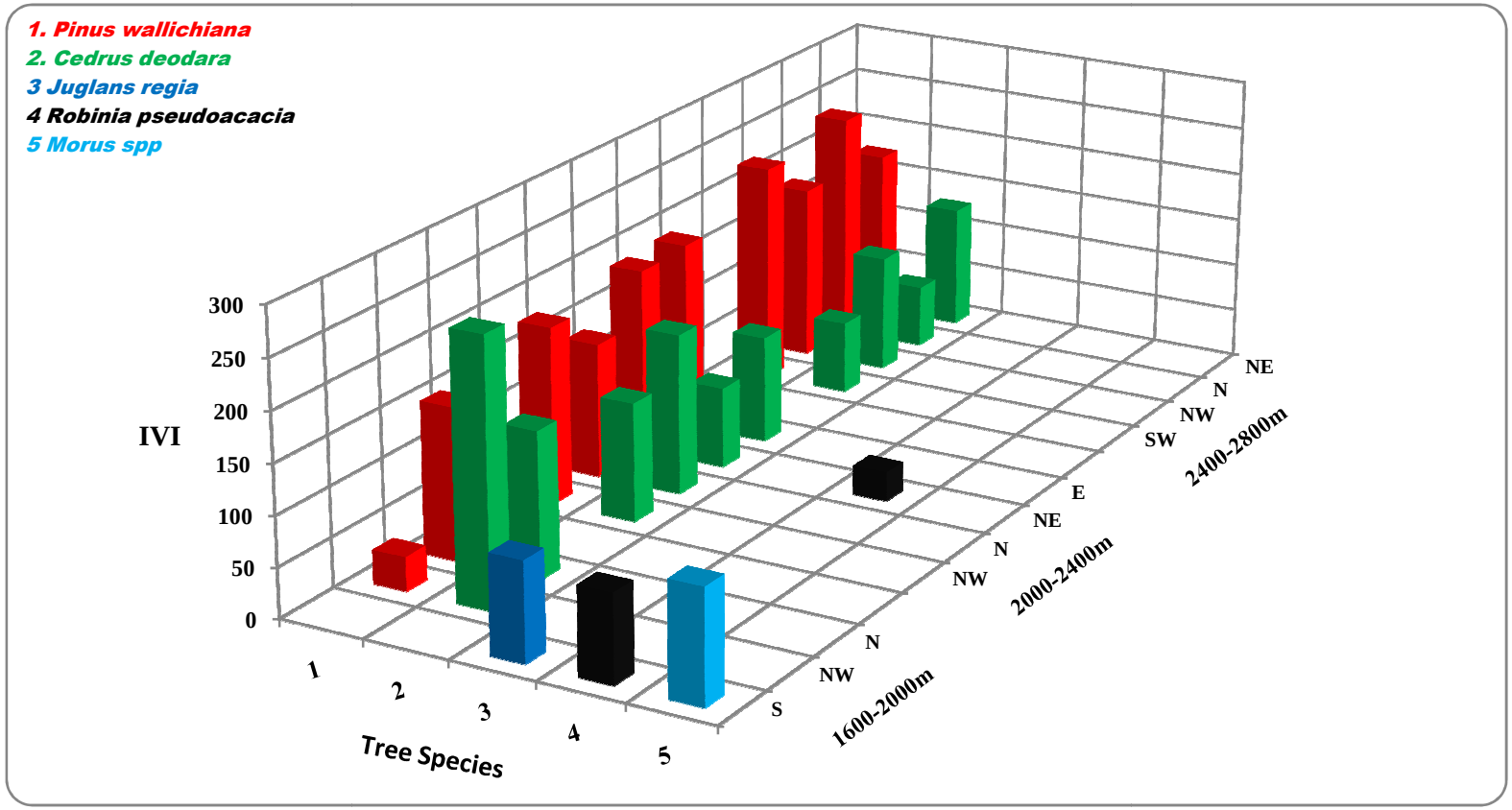


Fig.: 3. Importance Value Index (IVI) of Trees across the available aspects along an altitudinal gradient in Kandi forest range.

Western aspect followed by *Pinus wallichiana* (153%) on Northern aspects and *Morus spp*. (113%) on Southern aspect. At middle altitudinal range of 2000-2400 m *Pinus wallichiana* was dominant species and recorded highest IVI values 191%, 188%, 180% and 163% on Eastern, North Eastern, North Western and Northern aspects respectively. *Cedrus deodara* was co-dominant and exhibited IVI values of 163% and 120% on Northern and North Western aspects respectively. The least IVI value of (30%) was exhibited by *Robinia pseudoacacia* on North Eastern aspect. Similarly, the upper altitudinal range of 2400-2800 m was also dominated by *Pinus wallichiana* with IVI values of 236% and 226% and 180% on Northern, South Western and North Western aspects respectively. *Cedrus deodara* exhibited IVI values of 64%, 74% and 120% on Northern, South Western and North Western aspects at upper altitudinal range.

4.2.1.2. Shrubs

The data on community structure of shrubs is presented in table. 8. The vegetation analysis of the study area reveals that while North Western aspect at an altitude of 1600-2000 m was comprised of thirteen species viz.*Berberis lycium, Cotoneaster accuminatus, Cotoneaster horizantalis, Crataegus ambigua, Indigofera heterantha, Jasminum officinale, Juniperus communis, Nerium indicum, Parrotiopsis jacquemantiana, Rabdosia rugosa, Rosa brunonii, Rosa webbiana* and *Rubus armeniacus,* the Northern aspect represented nine species viz.*Berberis lycium, Cotoneaster accuminatus, Crataegus ambigua, Indigofera heterantha, Jasminum officinale, Nerium indicum, Parrotiopsis jacquemantiana, Rabdosia rugosa*and*Rosa brunonii*. The Southern aspect comprised seven species namely *Berberis lycium, Cotoneaster falconeri, Crataegus songarica, Indigofera heterantha, Parrotiopsis jacquemantiana, Rosa brunonii* and *Rosa webbiana*.

The middle altitudinal range of 2000- 2400 m was represented by nineteen species. The Northern aspect comprised of seven species viz. *Cotoneaster falconeri, Crataegus ambigua, Crataegus songarica, Indigofera heterantha,*

Plate-7: Shrub Species in Kandi Forest Range

Table:-8. Summary of community structure of Shrubs across the available aspects along an altitudinal gradient in Kandi forest range

Altitude (m)	Species	Aspects																			
		S				NW				N				NE				E			
		F	D	A	A/F	F	D	A	A/F	F	D	A	A/F	F	D	A	A/F	F	D	A	A/F
1600 - 2000	***Berberis lycium***	7	44	0.21	0.03	30	260	0.8	0.03	50	552	1.38	0.03	-	-	-	-	-	-	-	-
	Cotoneaster accuminatus	-	-	-	-	20	260	1.4	0.07	13	200	1	0.08	-	-	-	-	-	-	-	-
	Cotoneaster falconeri	29	256	0.95	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cotoneaster horizantalis	-	-	-	-	10	100	0.5	0.05	-	-	-	-	-	-	-	-	-	-	-	-
	Crataegus ambigua	-	-	-	-	60	680	2.27	0.04	38	324	1.63	0.04	-	-	-	-	-	-	-	-
	Crataegus songarica	7	44	0.21	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Indigofera heterantha	43	500	2.57	0.06	25	320	1.9	0.08	25	224	1.63	0.07	-	-	-	-	-	-	-	-
	Jasminum officinale	-	-	-	-	35	340	0.93	0.03	19	252	0.83	0.04	-	-	-	-	-	-	-	-
	Juniperus communis	-	-	-	-	15	140	0.47	0.03	-	-	-	-	-	-	-	-	-	-	-	-
	Nerium indicum	-	-	-	-	25	400	1.5	0.06	19	300	1	0.05	-	-	-	-	-	-	-	-
	Parrotiopsis jacquemantiana	25	416	1.68	0.07	35	580	2.43	0.07	50	824	2.81	0.06	-	-	-	-	-	-	-	-
	Rabdosia rugosa	-	-	-	-	25	180	0.7	0.03	44	424	1.75	0.04	-	-	-	-	-	-	-	-
	Rosa brunonii	4	44	0.43	0.11	35	320	1.8	0.05	38	324	1.58	0.04	-	-	-	-	-	-	-	-
	Rosa webbiana	4	28	0.29	0.07	15	100	0.33	0.02	-	-	-	-	-	-	-	-	-	-	-	-
	Rubus armeniacus	-	-	-	-	10	280	1.4	0.14	-	-	-	-	-	-	-	-	-	-	-	-
	Total	**119**	**1332**	**6.34**	**0.40**	**340**	**3960**	**16.43**	**0.70**	**296**	**3424**	**13.61**	**0.45**	**0**	**0**	**0**	**0**	**-**	**-**	**-**	**-**
2000 -2400	***Berberis lycium***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	82	1.21	0.06
	Cotoneaster falconeri	-	-	-	-	33	50	1	0.03	83	433	5.75	0.07	33	50	1	0.03	36	129	1.42	0.04
	Crataegus ambigua	-	-	-	-	-	-	-	-	17	33	0.67	0.04	-	-	-	-	-	-	-	-
	Crataegus songarica	-	-	-	-	-	-	-	-	25	75	1	0.04	-	-	-	-	-	-	-	-
	Indigofera heterantha	-	-	-	-	50	117	1.56	0.03	67	283	4.5	0.07	75	233	3.44	0.05	29	118	1.83	0.06
	Parrotiopsis jacquemantiana	-	-	-	-	17	58	1.17	0.07	17	50	1	0.06	-	-	-	-	39	154	2.2	0.06
	Rosa brunonii	-	-	-	-	-	-	-	-	17	25	0.5	0.03	-	-	-	-	-	-	-	-
	Rosa canina	-	-	-	-	8	25	1	0.12	17	33	0.67	0.04	17	42	0.83	0.05	-	-	-	-
	Rosa webbiana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	29	0.57	0.04
	Total	**-**	**-**	**-**	**-**	**108**	**250**	**4.73**	**0.25**	**243**	**932**	**14.09**	**0.35**	**125**	**325**	**5.27**	**0.13**	**139**	**512**	**7.23**	**0.26**
2400 -2800	***Cotoneaster falconeri***	-	-	-	-	25	106	1.89	0.08	-	-	-	-	33	142	2.42	0.07	-	-	-	-
	Crataegus ambigua	-	-	-	-	17	33	0.67	0.04	-	-	-	-	-	-	-	-	-	-	-	-
	Crataegus songarica	-	-	-	-	-	-	-	-	-	-	-	-	13	38	0.5	0.04	-	-	-	-
	Indigofera heterantha	-	-	-	-	8	50	2	0.24	-	-	-	-	4	29	1.17	0.28	-	-	-	-
	Viburnum nudum	-	-	-	-	-	-	-	-	67	633	6.33	0.09	17	121	1.21	0.07	-	-	-	-
	Total					**50**	**189**	**4.56**	**0.36**	**67**	**633**	**6.33**	**0.09**	**67**	**330**	**5.3**	**0.46**	**-**	**-**	**-**	**-**

Plate-7 a: Shrub Species in Kandi Forest Range

Parrotiopsis jacquemantiana, Rosa brunonii and *Rosa canina* fallowed by Eastern aspect with five species namely *Berberis lycium, Cotoneaster falconeri, Indigofera heterantha, Parrotiopsis jacquemantiana* and *Rosa webbiana*, North West with four species viz. *Cotoneaster falconeri, Indigofera heterantha, Parrotiopsis jacquemantiana* and *Rosa canina* and North Eastern aspect with three species viz. *Cotoneaster falconeri, Indigofera heterantha and Rosa canina.*

The upper altitudinal gradient of 2400 – 2800 m was represented by eight species. While maximum of four species viz.*Cotoneaster falconeri, Crataegus songarica, Indigofera heterantha* and *Viburnum nudum*were recorded on North Eastern aspect, the North Western aspect comprised three species namely *Cotoneaster falconeri, Crataegus ambigua* and *Indigofera heterantha*. The Northern aspect wasrepresented by only one species namely *Viburnum nudum*.

The perusal ofdata (Table. 8) revealed that maximum frequency values (60%) were recorded for*Crataegus ambigua* at North Western aspect followed by *Berberis lycium*and *Parrotiopsis jacquemantiana species* with respective frequency value of 50%on Northern aspect 43% for*Indigofera heterantha* on Southern aspects at an altitude of 1600-2000m.

*Cotoneaster falconeri*appeared to be the most frequent shrub species on Northern aspectat 2000-2400 m with highest frequency values of 83% followed by *Indigofera heterantha*with frequency of 75% onNorth Eastern aspect and *Indigofera heterantha*with frequency of 50%on North Westernaspect. *Parrotiopsis jacquemantiana*exhibited least frequency values of 39%at Eastern aspect.

At upper altitudinal range of 2400-2800 m *Viburnum nudum*appeared to be the most frequent shrub species with frequency of 67%at Northern aspect followed by *Cotoneaster falconeri*with frequency value of 33%on North Eastern aspectand *Indigofera heterantha*with frequency of 25% onNorth Westernaspect.

The examination of data(Table 8) further revealed that total density at an altitude of 1600-2000m was 3960 individuals ha^{-1}on North Western side followed

Plate-7 b: Shrub Species in Kandi Forest Range

by 3424 and 1332 individuals ha^{-1}on Northern and Southern aspects respectively. The maximum density of 824 individuals $ha^{-1}$was recorded for *Parrotiopsis jacquemantiana*on Northern aspect followed by 680 and 500 individuals $ha^{-1}$for *Crataegus ambigua* and *Indigofera heteranthaon* North Western and Southern aspects respectively.

The total density values recorded at 2000-2400m altitude were 932, 512, 633, 325 and 250 individuals ha^{-1}on Northern,Eastern, North Eastern and North Westernaspects respectively. The results further manifested that maximum density of 433 individualsha^{-1} was exhibited by *Cotoneaster falconer*on the Northern aspect, followed by 233 and 117 individuals $ha^{-1}$for *Indigofera heterantha* on North Eastern&North Western aspects respectively. *Parrotiopsis jacquemantiana* on Eastern aspect recorded a density of 154 individualsha^{-1}.

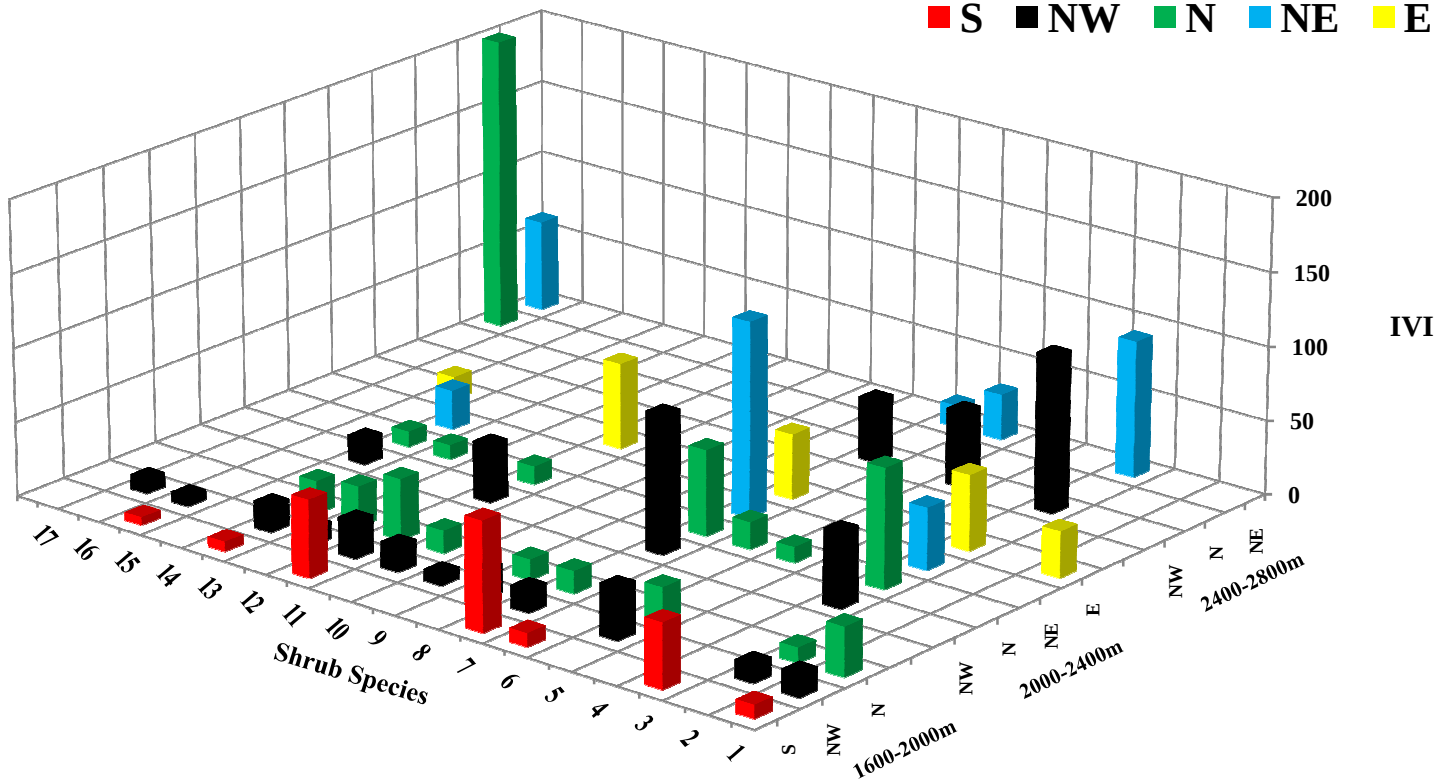
The density of shrub species (individualsha^{-1}) recorded at 2400-2800m altitude on various aspects was in order of 633 on Northern, 330 on North Eastern and 189 on North Western aspect. The highest density of 633 plants ha^{-1} was recorded for *Viburnum nudum*on Northern aspect followed *Cotoneaster falconeri*with density of 142 &106individuals ha^{-1} on North Eastern and North Western aspects respectively.

The distribution (A/F ratio) for all species at 1600-2000m altitudes was random on each of the aspects. The species at 2000-2400m altitude exhibited random distribution on Eastern, North Western and North Eastern aspects and contagious on Northern aspect. Similarly, at 2400-2800m altitude the species presented regular distribution pattern on North Westernaspect and contagious on Northern and North Eastern aspects.

The phyto-sociological data (Table 9& Fig. 4) recorded for shrub species portrays the dominance of *Indigofera heterantha* with IVI value of 73.67% on Southern aspect at an altitude of 1600-2000 m. The IVI values for other species at

Table:-9. Importance Value Index (IVI) of Shrubs across the available aspects along an altitudinal gradient in Kandi forest range.

Altitude (m)	Species	Aspects														
		S			NW			N			NE			E		
		RF	RD	IVI	RF	RD	IVI	RF	RD	IVI	RF	RD	IVI	RF	RD	IVI
1600-2000	***Berberis lycium***	5.88	3.30	9.19	8.82	6.57	15.39	16.89	16.12	33.01	-	-	-	-	-	-
	Cotoneaster accuminatus	-	-	-	5.88	6.57	12.45	4.39	5.84	10.23	-	-	-	-	-	-
	Cotoneaster falconeri	24.37	19.22	43.59	-	-	-	-	-	-	-	-	-	-	-	-
	Cotoneaster horizantalis	-	-	-	2.94	2.53	5.47	-	-	-	-	-	-	-	-	-
	Crataegus ambigua	-	-	-	17.65	17.17	34.82	12.84	9.46	22.3	-	-	-	-	-	-
	Crataegus songarica	5.88	3.30	9.19	-	-	-	-	-	-	-	-	-	-	-	-
	Indigofera heterantha	36.13	37.54	73.67	7.35	8.08	15.43	8.45	6.54	14.99	-	-	-	-	-	-
	Jasminum officinale	-	-	-	10.29	8.59	18.88	6.42	7.36	13.78	-	-	-	-	-	-
	Juniperus communis	-	-	-	4.41	3.54	7.95	-	-	-	-	-	-	-	-	-
	Nerium indicum	-	-	-	7.35	10.10	17.45	6.42	8.76	15.18	-	-	-	-	-	-
	Parrotiopsis jacquemantiana	21.01	31.23	52.24	10.29	14.65	24.94	16.89	24.07	40.96	-	-	-	-	-	-
	Rabdosia rugosa	-	-	-	7.35	4.55	11.9	14.86	12.38	27.25	-	-	-	-	-	-
	Rosa brunonii	3.36	3.30	6.66	10.29	8.08	18.37	12.84	9.46	22.30	-	-	-	-	-	-
	Rosa webbiana	3.36	2.10	5.46	4.41	2.53	6.94	-	-	-	-	-	-	-	-	-
	Rubus armeniacus	-	-	-	2.94	7.07	10.01	-	-	-	-	-	-	-	-	-
Total		**100**	**100**	**200**	**100**	**100**	**200**	**100**	**100**	**200**	**-**	**-**	**-**	**-**	**-**	**-**
2000-2400	***Berberis lycium***	-	-	-	-	-	-	-	-	-	-	-	-	15.11	16.02	**31.12**
	Cotoneaster falconeri	-	-	-	30.56	20	50.56	34.16	46.46	80.62	26.40	15.38	41.78	25.90	25.20	51.09
	Crataegus ambigua	-	-	-	-	-	-	7.00	3.54	10.54	-	-	-	-	-	-
	Crataegus songarica	-	-	-	-	-	-	10.29	8.05	18.34	-	-	-	-	-	-
	Indigofera heterantha	-	-	-	46.30	46.80	93.10	27.57	30.36	57.94	60	71.69	131.69	20.86	23.05	43.91
	Parrotiopsis jacquemantiana	-	-	-	15.74	23.20	38.94	7.00	5.36	12.36	-	-	-	28.06	30.08	58.14
	Rosa brunonii	-	-	-	-	-	-	7.00	2.68	9.68	-	-	-	-	-	-
	Rosa canina	-	-	-	7.41	10	17.41	7.00	3.54	10.54	13.60	12.92	26.52	-	-	-
	Rosa webbiana	-	-	-	-	-	-	-	-	-	-	-	-	10.07	5.66	15.74
Total		**-**	**-**	**-**	**100**	**100**	**200**	**100**	**100**	**200**	**100**	**100**	**200**	**100**	**100**	**200**
2400-2800	***Cotoneaster falconeri***	-	-	-	50	56.08	106.08	-	-	-	49.25	43.03	92.28	-	-	-
	Crataegus ambigua	-	-	-	34	17.46	51.46	-	-	-	-	-	-	-	-	-
	Crataegus songarica	-	-	-	-	-	-	-	-	-	19.40	11.52	30.92	-	-	-
	Indigofera heterantha	-	-	-	16	26.46	42.46	-	-	-	5.97	8.79	14.76	-	-	-
	Viburnum nudum	-	-	-	-	-	-	100	100	200	25.37	36.67	62.04	-	-	-
Total		**-**	**-**	**-**	**100**	**100**	**200**	**100**	**100**	**200**	**100**	**100**	**200**	**-**	**-**	**-**



1 Berberis lycium 2 Cotoneaster accuminatus 3 Cotoneaster falconeri 4 Cotoneaster horizantalis 5 Crataegus ambigua 6 Crataegus songarica 7 Indigofera heterantha 8 Jasminum officinale 9 Juniperus communis 10 Nerium indicum 11 Parrotiopsis jacquemantiana 12 Rabdosia rugosa 13 Rosa brunonii 14 Rosa canina 15 Rosa webbiana 16 Rubus armeniacus 17 Viburnum nudum

Fig.: 4. Importance Value Index (IVI) of Shrubs across the available aspects along an altitudinal gradient in Kandi forest range

this altitude were in order of 52.24% and 43.59% for *Parrotiopsis jacquemantiana* and *Cotoneaster falconeri* on Southern slopes, 40.96% for *Parrotiopsis jacquemantiana* on Northern aspect and 34.82% for *Crataegus ambigua* on the North Western side. *Berberis lycium* and *Rabdosia rugosa* were other major contributors to dominance with IVI values of 33.01 and 27.25 percent on Northern aspect.

IVI values at an altitudinal gradient of 2000-2400 m also varied for all the shrub species on each of the available aspects. *Indigofera heterantha* again proved to be the most dominant species with IVI values of 131.69, 93.10, 57.94 and 43.91% on North Eastern, North Western, Northern and Eastern slopes respectively. *Cotoneaster falconeri* was co-dominant and exhibited IVI values of 80.62, 51.09 and 50.56% on Northern, Eastern and North Western aspects respectively. The Importance Value Index of other promising species was in order of 58.14 and 38.94% for *Parrotiopsis jacquemantiana* on Eastern and North Western aspects and 31.12% for *Berberis lycium* on Eastern aspects.

The species at upper altitudinal gradient of 2400-2800 m also exhibited variation with respect to their ecological importance. *Cotoneaster falconeri* dominated North Western and North Eastern aspects with respective IVI values of 106 and 92.28%. While *Viburnum nudum* exhibited highest IVI of 200% on Northern slopes; it represented co-dominant status on North Eastern aspect with IVI of 62%. *Crataegus ambigua* represented only North Western aspect with IVI of 51.46%. The prominent IVI value of other species was in order of 42.46 and 30.92% for *Indigofera heterantha* and *Crataegus songarica* on North Western and North Eastern aspects respectively.

4.2.1.3. Grasses and Herbs

The clear shift in community structure was also observed for under growth species (Table.10). The vegetation analysis of the study area shows that the altitudinal gradient of 1600-2000 m was represented by twenty four(24) species of grasses and herbs. While Northern aspect comprised highest number (twenty)

Plate-8 : Herb and Grass Species in Kandi Forest Range

of species viz. *Anemone tetrasepala, Ciehorium intybus, Clinopodium vulgare, Cuminum cyminum, Cynoglossum glochidiatum, Fragaria nubicola, Geum elatum, Hypericum perfoatum, Lespedeza cuneata, Marrubium vulgare, Matricaria chamomilla, Oxalis corniculata, Plantago lanceolata, Silene spp, Thymus serpyllum, Verbascum thapsus, Cynodon dactylon, Viola odorata, Festuca pratensis* and*Lolium perenen*, the North Western aspect hosted eleven (11) species viz. *Anemone tetrasepala, Ciehorium intybus, Cuminum cyminum, Erigeron spp, Fragaria nubicola, Hypericum perfoatum, Lespedeza cuneata, Marrubium vulgare, Matricaria chamomilla, Picris hiercioides* and *Silene spp* and the Southern aspect recorded nine species viz. *Aster spp., Ciehorium intybus, Cuminum cyminum, Erigeron spp, Hypericum perfoatum, Picris hiercioides, Thymus serpyllum* and *Verbascum thapsus.*

The middle altitudinal range of 2000- 2400m was represented by thirty two (32) species. Maximum number of species (23) viz. *Artimesa absinthum, Chrysanthemum spp, Clinopodium vulgare, Cynoglossum glochidiatum, Fragaria nubicola, Geranium rotundifolia, Geranium wallichianum, Geum coccineum, Geum elatum, Lychnis coronaria, Matricaria chamomilla, Oxalis corniculata, Plantago lanceolata, Potentilla reptans, Potentilla spp, Ranunculus hirtellus, Thymus serpyllum, Trifolium repens, Verbascum thapsus, Cynodon dactylon, Viola odorata, Festuca pratensis, Lolium perenen*and *Bothriochloachloa pertusa*were recorded on Eastern aspect followed by North Western aspect with fifteen (15) species viz. *Artimesa absinthum, Aster spp, Cirsium falconeri, Clinopodium vulgare, Dianthus angulatus, Epilobium spp, Erigeron spp, Fragaria nubicola, Geum spp, Lespedeza cuneata, Plantago lanceolata, Potentilla reptans, Potentilla spp, Scutellaria prostrata* and*Lolium perenen*, North Eastern aspect with fifteen species namely *Artimesa absinthum, Aster spp, Cirsium falconeri, Clinopodium vulgare, Epilobium spp, Erigeron spp, Fragaria nubicola, Geum spp, Lespedeza cuneata, Plantago lanceolata, Potentilla reptans, Potentilla spp, Scutellaria prostrata, Viola odorata* and *Lolium perenen*.Northern aspect was represent by

Plate-8 a: Herb and Grass Species in Kandi Forest Range

Table:-10. Summary of community structure of Herbs and Grasses across the available aspects along an altitudinal gradient in Kandi forest range.

Altitude (m)	Species	Aspects																							
		S				SW				NW				N				NE				E			
		F	D	A	A/F	F	D	A	A/F	F	D	A	A/F	F	D	A	A/F	F	D	A	A/F	F	D	A	A/F
1600-2000	***Anemone tetrasepala***	-	-	-	-	-	-	-	-	20	8000	0.8	0.04	19	8100	1.08	0.06	-	-	-	-	-	-	-	-
	Aster spp	21	7500	1.5	0.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cichorium intybus	14	2500	0.79	0.06	-	-	-	-	20	5500	1.1	0.06	31	8800	1.42	0.05	-	-	-	-	-	-	-	-
	Clinopodium vulgare	-	-	-	-	-	-	-	-	-	-	-	-	12	6300	1.25	0.11	-	-	-	-	-	-	-	-
	Cuminum cyminum	11	3200	0.43	0.04	-	-	-	-	30	22500	2.75	0.09	31	21900	2.94	0.09	-	-	-	-	-	-	-	-
	Cynodon dactylon	-	-	-	-	-	-	-	-	-	-	-	-	12	16300	3.25	0.26	-	-	-	-	-	-	-	-
	Cynoglossum glochidiatum	-	-	-	-	-	-	-	-	-	-	-	-	19	4400	0.58	0.03	-	-	-	-	-	-	-	-
	Erigeron spp	21	16100	3.21	0.15	-	-	-	-	10	7500	1.5	0.15	-	-	-	-	-	-	-	-	-	-	-	-
	Festuca pratensis	-	-	-	-	-	-	-	-	-	-	-	-	19	29400	3.92	0.21	-	-	-	-	-	-	-	-
	Fragaria nubicola	-	-	-	-	-	-	-	-	10	4500	0.9	0.09	37	8800	1.17	0.03	-	-	-	-	-	-	-	-
	Geum elatum	-	-	-	-	-	-	-	-	-	-	-	-	12	5000	1	0.08	-	-	-	-	-	-	-	-
	Hypericum perfoatum	21	1500	3	0.14	-	-	-	-	30	11000	2.2	0.07	37	8800	1.75	0.05	-	-	-	-	-	-	-	-
	Lespedeza cuneata	-	-	-	-	-	-	-	-	30	6500	1.43	0.05	44	12500	2.17	0.05	-	-	-	-	-	-	-	-
	Lolium perenen	32	13600	1.81	0.06	-	-	-	-	-	-	-	-	25	28800	2.88	0.12	-	-	-	-	-	-	-	-
	Marrubium vulgare	-	-	-	-	-	-	-	-	30	6500	1.43	0.05	56	15600	2.08	0.04	-	-	-	-	-	-	-	-
	Matricaria chamomilla	-	-	-	-	-	-	-	-	15	4500	0.6	0.04	19	5600	0.75	0.04	-	-	-	-	-	-	-	-
	Oxalis corniculata	-	-	-	-	-	-	-	-	-	-	-	-	25	15600	1.56	0.06	-	-	-	-	-	-	-	-
	Picris hiercioides	32	6400	0.86	0.03	-	-	-	-	15	4500	0.6	0.04	-	-	-	-	-	-	-	-	-	-	-	-
	Plantago lanceolata	-	-	-	-	-	-	-	-	-	-	-	-	12	4400	0.88	0.07	-	-	-	-	-	-	-	-
	Silene spp	-	-	-	-	-	-	-	-	30	7500	1	0.03	31	8100	1.38	0.04	-	-	-	-	-	-	-	-
	Thymus serpyllum	21	12900	2.57	0.12	-	-	-	-	-	-	-	-	12	9400	1.88	0.15	-	-	-	-	-	-	-	-
	Trifolium repens	-	-	-	-	-	-	-	-	-	-	-	-	25	18800	1.88	0.08	-	-	-	-	-	-	-	-
	Verbascum thapsus	32	7100	0.93	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Viola odorata	-	-	-	-	-	-	-	-	-	-	-	-	19	18800	2.5	0.13	-	-	-	-	-	-	-	-
	Total	**205**	**70800**	**15.1**	**0.07**	**-**	**-**	**-**	**-**	**240**	**88500**	**14.31**	**0.06**	**497**	**255400**	**36.32**	**0.07**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Conti..

	Species	S	SW				NW				N				NE				E			
	Artimesa absinthum	-	-	-	-	-	-	-	-	17	4100	0.97	0.06	-	-	-	-	35	8700	1.78	0.051	25	9300	1.83	0.07
	Aster spp	-	-	-	-	-	-	-	-	17	2500	0.5	0.03	17	2500	0.5	0.03	17	2500	0.5	0.03				-
	Bothriochloachloa pertusa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	22500	2.25	0.16
	Chrysanthemum spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	15400	1.54	0.11
	Cirsium falconeri	-	-	-	-	-	-	-	-	50	14200	2.83	0.06	-	-	-	-	75	20800	3.06	0.04				-
	Clinopodium vulgare	-	-	-	-	-	-	-	-	33	5000	1	0.03	-	-	-	-	33	5000	1	0.03	11	5000	1.21	0.11
	Cynodon dactylon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	9300	1.86	0.3
	Cynoglossum glochidiatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	2500	0.33	0.03
	Dianthus angulatus	-	-	-	-	-	-	-	-	58	25800	4.44	0.08	-	-	-	-	-	-	-	-	-	-	-	-
	Epilobium spp	-	-	-	-	-	-	-	-	17	5000	1	0.1	-	-	-	-	17	5000	1	0.06	-	-	-	-
	Erigeron spp	-	-	-	-	-	-	-	-	17	19200	3.83	0.23	25	15000	3.83	0.2	16	19200	3.83	0.23	-	-	-	-
	Festuca pratensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		21	44300	6.04	0.3
	Fragaria nubicola	-	-	-	-	-	-	-	-	67	22500	3.5	0.05	33	14200	1.42	0.04	75	40000	5.58	0.07	32	10400	1.38	0.04
	Geranium rotundifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	5400	0.54	0.04
	Geranium wallichianum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	11800	1.46	0.07
2000	***Geum coccineum***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	10400	1.04	0.07
-2400	***Geum elatum***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	2900	0.57	0.08
	Geum spp.	-	-	-	-	-	-	-	-	33	8300	1.67	0.05	-	-	-	-	33	8300	1.67	0.05	-	-	-	-
	Lespedeza cuneata	-	-	-	-	-	-	-	-	17	5000	1	0.06	-	-	-	-	17	4200	0.83	0.05	-	-	-	-
	Lolium perenen	-	-	-	-	-	-	-	-	50	20000	2.67	0.05	-	-	-	-	33	38300	3.83	0.12	14	16400	1.64	0.12
	Lychnus cornaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	5000	0.5	0.04
	Matricaria chamomilla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	2500	0.5	0.07
	Oxalis corniculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	8900	0.89	0.06
	Plantago lanceolata	-	-	-	-	-	-	-	-	17	4200	0.83	0.05	-	-	-	-	17	4200	0.83	0.05	7	1800	0.36	0.05
	Potentilla reptens	-	-	-	-	-	-	-	-	17	1700	0.67	0.04	-	-	-	-	17	1700	0.67	0.04	-	-	-	-
	Potentilla spp	-	-	-	-	-	-	-	-	67	13300	2.22	0.03	67	49200	4.92	0.07	67	15000	2.44	0.04	43	28900	3.32	0.08
	Ranunculus hirtellus	-	-	-	-	-	-	-	-	-	-	-	-	58	59200	6.78	0.12	-	-	-	-	14	14300	1.43	0.1
	Scutellaria prostrata	-	-	-	-	-	-	-	-	25	12500	1.67	0.07	-	-	-	-	17	10800	2.17	0.13	-	-	-	-
	Thymus serpyllum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	14	6800	0.68	0.05
	Trifolium repens	-	-	-	-	-	-	-	-	-	-	-	-	25	8300	1.11	0.04	-	-	-	-	25	19600	2.14	0.09
	Verbascum thapsus	-	-	-	-	-	-	-	-	-	-	-	-	25	10800	1.44	0.06	-	-	-	-	11	7900	1.05	0.1
	Viola odorata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	15000	1.5	0.05	21	17100	2	0.1
	Total									**502**	**163300**	**28.8**	**0.06**	**250**	**159200**	**20**	**0.08**	**502**	**198700**	**30.69**	**0.06**	**375**	**278400**	**34.56**	**0.09**

Conti..

	Species	S				SW				NW				N				NE				E			
	Aster spp	-	-	-	-	-	-	-	-	21	4500	0.67	0.03	21	4200	0.83	0.04	11	2100	0.4	0.04	-	-	-	-
	Bothriochloachloa pertusa	-	-	-	-	11	19200	2.1	0.19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chrysanthemum spp	-	-	-	-	17	20400	2	0.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cynoglossum glochidiatum	-	-	-	-	7	2500	0.33	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dianthus angulatus	-	-	-	-	-	-	-	-	50	25300	4	0.08	-	-	-	-	-	-	-	-	-	-	-	-
	Epilobium spp	-	-	-	-	-	-	-	-	21	6100	1.3	0.06	-	-	-	-	25	7300	1.2	0.05	-	-	-	-
	Erigeron spp	-	-	-	-	-	-	-	-	33	22000	3.5	0.11	33	18500	4	0.12	33	20200	4	0.12	-	-	-	-
	Festuca pratensis	-	-	-	-	25	45400	6.16	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Fragaria nubicola	-	-	-	-	32	9400	1.54	0.05	60	21200	3	0.05	25	11700	1.2	0.05	70	39300	6	0.09	-	-	-	-
	Geranium rotundifolia	-	-	-	-	11	4900	0.36	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Geranium wallichianum	-	-	-	-	21	11800	1.46	0.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2400 - 2800	*Geum coccineum*	-	-	-	-	7	8500	0.68	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Geum elatum	-	-	-	-	7	2900	0.57	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Geum spp	-	-	-	-	-	-	-	-	25	7200	1	0.04	-	-	-	-	33	7500	1.42	0.04	-	-	-	-
	Lespedeza cuneata	-	-	-	-	-	-	-	-	21	4700	1.27	0.06	-	-	-	-	21	5300	1.04	0.05	-	-	-	-
	Lolium perenen	-	-	-	-	21	15000	1.54	0.07	47	19100	2.5	0.05	-	-	-	-	33	36500	3.5	0.11	-	-	-	-
	Lychnus cornaria	-	-	-	-	17	5300	1.05	0.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Plantago lanceolata	-	-	-	-	14	5000	0.87	0.06	17	4000	1.1	0.06	-	-	-	-	17	3500	0.65	0.04	-	-	-	-
	Potentilla reptens	-	-	-	-	-	-	-	-	11	1400	0.66	0.06	-	-	-	-	11	1500	0.5	0.05	-	-	-	-
	Potentilla spp	-	-	-	-	43	32400	3.32	0.08	63	11200	2	0.03	63	45000	4.4	0.07	58	14500	2.22	0.04	-	-	-	-
	Ranunculus hirtellus	-	-	-	-	21	17500	1.64	0.08	-	-	-	-	50	58100	6.24	0.12	-	-	-	-	-	-	-	-
	Scutellaria prostrata	-	-	-	-	-	-	-	-	33	13300	3	0.09	-	-	-	-	21	12300	2.5	0.12	-	-	-	-
	Thymus serpyllum	-	-	-	-	11	5000	0.54	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Verbascum thapsus	-	-	-	-	7	4600	0.51	0.07	-	-	-	-	33	13400	2.22	0.07	-	-	-	-	-	-	-	-
	Viola odorata	-	-	-	-	14	14000	1.46	0.1	-	-	-	-	-	-	-	-	27	14200	1.42	0.05	-	-	-	-
	Total					**286**	**223800**	**26.13**	**0.09**	**402**	**140000**	**24**	**0.06**	**225**	**150900**	**18.89**	**0.08**	**360**	**164200**	**24.85**	**0.07**				

Plate-8 b: Herb and Grass Species in Kandi Forest Range

seven(7) speciesviz. *Aster spp, Erigeron spp, Fragaria nubicola, Potentilla spp, Ranunculus hirtellus, Trifolium repens* and *Verbascum thapsus*.

The upper altitudinal gradient of 2400 – 2800 m hosted twenty five (25) species. The maximumnumber (17) of speciesviz. *Chrysanthemum spp, Cynoglossum glochidiatum, Fragaria nubicola, Geranium rotundifolia, Geranium wallichianum, Geum coccineum, Geum elatum, Lychnis coronaria, Plantago lanceolata, Potentilla spp, Ranunculus hirtellus, Scutellaria prostrata, Thymus serpyllum, Verbascum thapsus, Viola odorata, Festuca pratensis, Lolium perenen and Bothriochloachloa pertusa*were recorded on South Western aspect followed by twelve (12) species namely *Aster spp, Dianthus angulatus, Epilobium spp, Erigeron spp, Fragaria nubicola, Geum spp, Lespedeza cuneata, Plantago lanceolata, Potentilla reptans, Potentilla spp, Scutellaria prostrata* and*Lolium perenen* on North Western aspect, twelve (12) speciesviz. *Aster spp, Epilobium spp, Erigeron spp, Fragaria nubicola, Geum spp, Lespedeza cuneata, Plantago lanceolata, Potentilla reptans, Potentilla spp, Scutellaria prostrata, Thymus serpyllum, verbascum thapsus, Viola odorata and Lolium perenen* were recorded on North East aspect and six (6) species namely *Aster spp, Erigeron spp, Fragaria nubicola, Potentilla spp, Ranunculus hirtellus and Verbascum thapsus*were recorded on Northern aspect.

The perusal of Table (10) revealed that maximum Frequency value (56%) was recorded for*Marrubium vulgare*on Northern aspect,32% for *Picris hiercioides, verbascum thapsus* and *Lolium perenen* on Southern aspect, 30% for *Cuminum cyminum, Hypericum perfoatum, Lespedeza cuneata, Marrubium vulgare* and *Silene spp* on North Western aspect and 56% for in *Marrubium vulgare* on Northern aspect at 1600-2000 m altitude.

Highest frequency values (67%) were recorded in *Fragaria nubicola* and *Potentilla spp* on North Western aspect, followed by 67% for *Potentilla spp* on Northern aspect, 75% for *Cirsium falconeri* and *Fragaria nubicola* on

Plate-8 c: Herb and Grass Species in Kandi Forest Range

NorthEastern aspect and 43% for *Potentilla spp* on Eastern aspect at an altitude of 2000-2400 m.

At upper altitudinal range of 2400-2800 m *Potentilla spp* appeared to be the most frequent undergrowth species with frequency of 43%, 63% and 63% at South Western, North Western and Northern aspects respectively.*Fragaria nubicola*exhibited a frequency value of 70%on North Eastern aspect.

The examination of data (Table. 10) revealed that total density of herbs and grasses at an altitude of 1600-2000m was 2,55,400 individuals ha^{-1} on Northern aspect followed by 88,500 and 70,800 individuals ha^{-1} on North Western and Southern aspects respectively. The maximum density of 29,400 individuals ha^{-1} was recorded for *Festuca pratensis* on Northern aspect followed by 28,800 and 22,500 individuals ha^{-1} for *Lolium perenen* and *Cuminum cyminum* on Northern and North Western aspects respectively.

The total density values recorded at 2000-2400m altitude were 2,78,400, 1,98,700, 1,63,300 and 1,59,200 individuals ha^{-1} on Eastern, North Eastern, North Western and Northern aspects respectively. The results further manifested that maximum density by undergrowth (59,200 individuals ha^{-1}) was exhibited by *Ranunculus hirtellus* on the Northern aspect, followed by 49,200 individuals ha^{-1} for *Potentilla spp* on Northern aspect and 44,300 individuals ha^{-1} for *Festuca pratensis* on Eastern aspect.

The density of herbs and grasses (individuals ha^{-1}) recorded at 2400-2800m altitude on various aspects was in order of 2,23,800 on South Western aspect, 1,64,200 on North East and 1,50,900 on North Western aspect. The highest density of 58,100 individuals ha^{-1} was recorded for *Ranunculus hirtellus* on Northern aspect followed by 45,400 individuals ha^{-1} for *Festuca pratensis* on South Western aspect and 45,000 individuals ha^{-1} for *Potentilla spp* on Northern aspect.

The results (Table.10) further manifested that ratio of abundance to frequency (A/F) on all the aspects along an altitudinal gradient of Kandi forest

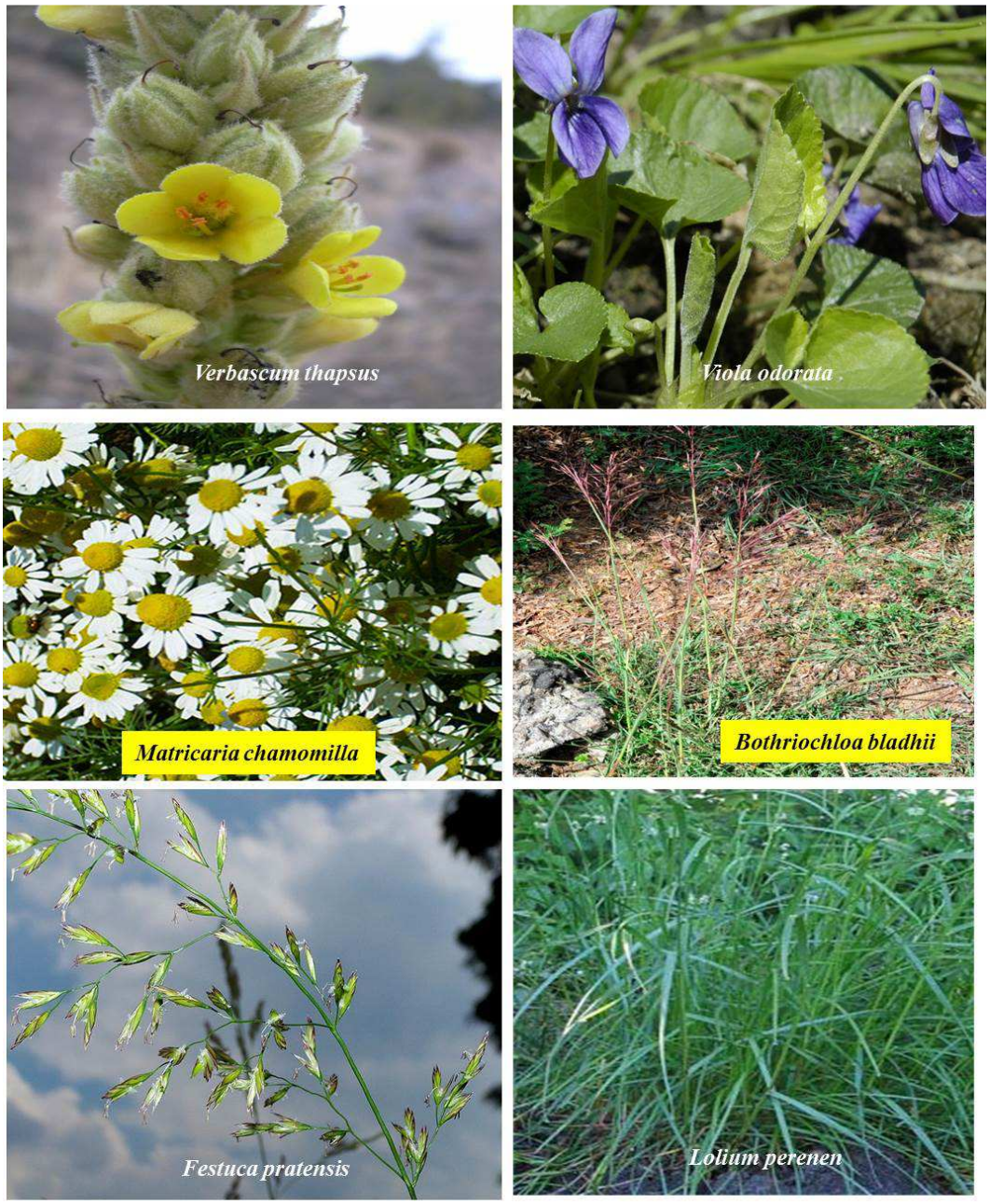


Plate-8 d: Herb and Grass Species in Kandi Forest Range

Table:-11. Importance Value Index (IVI) of Herbs and Grasses across the available aspects along an altitudinal gradient in Kandi forest range.

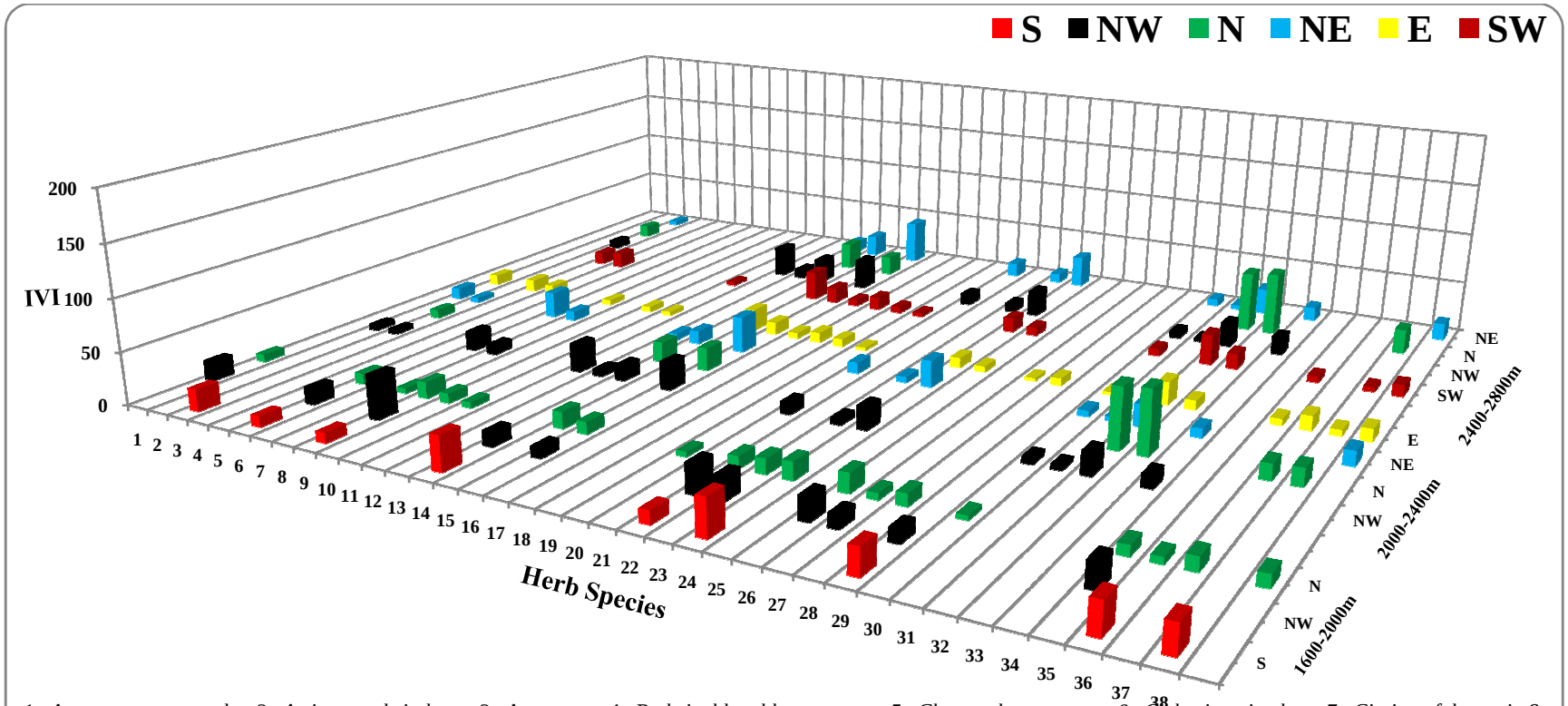
Altitude (m)	Species	Aspects																	
		S			SW			NW			N			NE			E		
		RF	RD	IVI	RF	RD	IVI	RF	RD	IVI	RF	RD	IVI	RF	RD	IVI	RF	RD	IVI
1600 -2000	***Anemone tetrasepala***	-	-	-				9.09	9.94	19.03	3.97	3.28	7.25	-	-	-	-	-	-
	Aster spp	10.24	10.59	20.84				-	-	-	-	-	-	-	-	-	-	-	-
	Cichorium intybus	6.83	3.53	10.36				9.09	6.83	15.92	6.49	3.56	10.04	-	-	-	-	-	-
	Clinopodium vulgare	-	-	-				-	-	-	2.51	2.55	5.06	-	-	-	-	-	-
	Cuminum cyminum	5.37	4.52	9.89				13.64	27.95	41.59	6.49	8.86	15.34	-	-	-	-	-	-
	Cynodon dactylon	-	-	-				-	-	-	2.51	6.59	9.1	-	-	-	-	-	-
	Cynoglossum glochidiatum	-	-	-				-	-	-	3.97	1.78	5.75	-	-	-	-	-	-
	Erigeron spp	10.24	22.74	32.98				4.55	9.32	13.86	-	-	-	-	-	-	-	-	-
	Festuca pratensis	-	-	-				-	-	-	3.97	11.89	15.86	-	-	-	-	-	-
	Fragaria nubicola	-	-	-				4.55	5.59	10.14	7.74	3.56	11.3	-	-	-	-	-	-
	Geum elatum	-	-	-				-	-	-	2.51	2.02	4.53	-	-	-	-	-	-
	Hypericum perfoatum	10.24	2.12	12.36				13.64	13.66	27.3	7.74	3.56	11.3	-	-	-	-	-	-
	Lespedeza cuneata	-	-	-				13.64	8.07	21.71	9.21	5.05	14.26	-	-	-	-	-	-
	Lolium perenen	15.61	19.21	34.82				-	-	-	5.23	11.65	16.88	-	-	-	-	-	-
	Marrubium vulgare	-	-	-				13.64	8.07	21.71	11.72	6.31	18.02	-	-	-	-	-	-
	Matricaria chamomilla	-	-	-				6.82	5.59	12.41	3.97	2.26	6.24	-	-	-	-	-	-
	Oxalis corniculata	-	-	-				-	-	-	5.23	6.31	11.54	-	-	-	-	-	-
	Picris hiercioides	15.61	9.04	24.65				6.82	5.59	12.41	-	-	-	-	-	-	-	-	-
	Plantago lanceolata	-	-	-				-	-	-	2.51	1.78	4.29	-	-	-	-	-	-
	Silene spp	-	-	-				13.64	9.32	22.95	6.49	3.28	9.76	-	-	-	-	-	-
	Thymus serpyllum	10.24	18.22	28.46				-	-	-	2.51	3.8	6.31	-	-	-	-	-	-
	Trifolium repens	-	-	-				-	-	-	5.23	7.6	12.83	-	-	-	-	-	-
	Verbascum thapsus	15.61	10.03	25.64				-	-	-	-	-	-	-	-	-	-	-	-
	Viola odorata	-	-	-				-	-	-	3.97	7.6	11.58	-	-	-	-	-	-
	Total	**100**	**100**	**200**				**100**	**100**	**200**	**100**	**100**	**200**	**-**	**-**	**-**			

Conti....

	Species	S			SW			NW			N			NE			E		
2000 -2400	*Artimesa absinthum*	-	-	-	-	-	-	3.39	2.51	5.9	-	-	-	6.97	4.38	11.35	6.67	3.34	10.01
	Aster spp	-	-	-	-	-	-	3.39	1.53	4.92	6.8	1.57	8.37	3.39	1.26	4.64	-	-	-
	Bothriochloachloa pertusa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.73	8.08	11.82
	Chrysanthemum spp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.73	5.53	9.26
	Cirsium falconeri	-	-	-	-	-	-	9.96	8.7	18.66	-	-	-	14.94	10.47	25.41	-	-	-
	Clinopodium vulgare	-	-	-	-	-	-	6.57	3.06	9.64	-	-	-	6.57	2.52	9.09	2.93	1.8	4.73
	Cynodon dactylon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.87	3.34	5.21
	Cynoglossum glochidiatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.93	0.9	3.83
	Dianthus angulatus	-	-	-	-	-	-	11.55	15.8	27.35	-	-	-	-	-	-	-	-	-
	Epilobium spp	-	-	-	-	-	-	3.39	3.06	6.45	-	-	-	3.39	2.52	5.9	-	-	-
	Erigeron spp	-	-	-	-	-	-	3.39	11.76	15.14	10	9.42	19.42	3.19	9.66	12.85	-	-	-
	Festuca pratensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.6	15.91	21.51
	Fragaria nubicola	-	-	-	-	-	-	13.35	13.78	27.12	13.2	8.92	22.12	14.94	20.13	35.07	8.53	3.74	12.27
	Geranium rotundifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.73	1.94	5.67
	Geranium wallichianum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.6	4.24	9.84
	Geum coccineum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.73	3.74	7.47
	Geum elatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.87	1.04	2.91
	Geum spp.	-	-	-	-	-	-	6.57	5.08	11.66	-	-	-	6.57	4.18	10.75	-	-	-
	Lespedeza cuneata	-	-	-	-	-	-	3.39	3.06	6.45	-	-	-	3.39	2.11	5.5	-	-	-
	Lolium perenen	-	-	-	-	-	-	9.96	12.25	22.21	-	-	-	6.57	19.28	25.85	3.73	5.89	9.62
	Lychnis coronaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.73	1.8	5.53
	Matricaria chamomilla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.87	0.9	2.76
	Oxalis corniculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.73	3.2	6.93
	Plantago lanceolata	-	-	-	-	-	-	3.39	2.57	5.96	-	-	-	3.39	2.11	5.5	1.87	0.65	2.51
	Potentilla reptans	-	-	-	-	-	-	3.39	1.04	4.43	-	-	-	3.39	0.86	4.24	-	-	-
	Potentilla spp	-	-	-	-	-	-	13.35	8.14	21.49	26.8	30.9	57.7	13.35	7.55	20.9	11.47	10.38	21.85
	Ranunculus hirtellus	-	-	-	-	-	-	-	-	-	23.2	37.19	60.39	-	-	-	3.73	5.14	8.87
	Scutellaria prostrata	-	-	-	-	-	-	4.98	7.65	12.63	-	-	-	3.39	5.44	8.82	-	-	-
	Thymus serpyllum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.73	2.44	6.18
	Trifolium repens	-	-	-	-	-	-	-	-	-	10	5.21	15.21	-	-	-	6.67	7.04	13.71
	Verbascum thapsus	-	-	-	-	-	-	-	-	-	10	6.78	16.78	-	-	-	2.93	2.84	5.77
	Viola odorata	-	-	-	-	-	-	-	-	-	-	-	-	6.57	7.55	14.12	5.6	6.14	11.74
	Total							**100**	**100**	**200**	**100**	**100**	**200**	**100**	**100**	**200**	**100**	**100**	**200**

Conti....

	Species	S			SW			NW			N			NE			E		
	Aster spp	-	-	-	-	-	-	5.22	3.21	8.44	9.33	2.78	12.12	3.06	1.28	4.33	-	-	-
	Bothriochloachloa pertusa	-	-	-	3.85	8.58	12.43	-	-	-	-	-	-	-	-	-	-	-	-
	Chrysanthemum spp	-	-	-	5.94	9.12	15.06	-	-	-	-	-	-	-	-	-	-	-	-
	Cynoglossum glochidiatum	-	-	-	2.45	1.12	3.56	-	-	-	-	-	-	-	-	-	-	-	-
	Dianthus angulatus	-	-	-	-	-	-	12.44	18.07	30.51	-	-	-	-	-	-	-	-	-
	Epilobium spp	-	-	-	-	-	-	5.22	4.36	9.58	-	-	-	6.94	4.45	11.39	-	-	-
	Erigeron spp	-	-	-	-	-	-	8.21	15.71	23.92	14.67	12.26	26.93	9.17	12.3	21.47	-	-	-
	Festuca pratensis	-	-	-	8.74	20.29	29.03	-	-	-	-	-	-	-	-	-	-	-	-
	Fragaria nubicola	-	-	-	11.19	4.2	15.39	14.93	15.14	30.07	11.11	7.75	18.86	19.44	23.93	43.38	-	-	-
	Geranium rotundifolia	-	-	-	3.85	2.19	6.04	-	-	-	-	-	-	-	-	-	-	-	-
	Geranium wallichianum	-	-	-	7.34	5.27	12.62	-	-	-	-	-	-	-	-	-	-	-	-
2400	***Geum coccineum***	-	-	-	2.45	3.8	6.25	-	-	-	-	-	-	-	-	-	-	-	-
-2800	***Geum elatum***	-	-	-	2.45	1.3	3.74	-	-	-	-	-	-	-	-	-	-	-	-
	Geum spp	-	-	-	-	-	-	6.22	5.14	11.36	-	-	-	9.17	4.57	13.73	-	-	-
	Lespedeza cuneata	-	-	-	-	-	-	5.22	3.36	8.58	-	-	-	5.83	3.23	9.06	-	-	-
	Lolium perenen	-	-	-	7.34	6.7	14.05	11.69	13.64	25.33	-	-	-	9.17	22.23	31.4	-	-	-
	Lychnis coronaria	-	-	-	5.94	2.37	8.31	-	-	-	-	-	-	-	-	-	-	-	-
	Plantago lanceolata	-	-	-	4.9	2.23	7.13	4.23	2.86	7.09	-	-	-	4.72	2.13	6.85	-	-	-
	Potentilla reptans	-	-	-	-	-	-	2.74	1	3.74	-	-	-	3.06	0.91	3.97	-	-	-
	Potentilla spp	-	-	-	15.03	14.48	29.51	15.67	8	23.67	28	29.82	57.82	16.11	8.83	24.94	-	-	-
	Ranunculus hirtellus	-	-	-	7.34	7.82	15.16	-	-	-	22.22	38.5	60.72	-	-	-	-	-	-
	Scutellaria prostrata	-	-	-	-	-	-	8.21	9.5	17.71	-	-	-	5.83	7.49	13.32	-	-	-
	Thymus serpyllum	-	-	-	3.85	2.23	6.08	-	-	-	-	-	-	-	-	-	-	-	-
	verbascum thapsus	-	-	-	2.45	2.06	4.5	-	-	-	14.67	8.88	23.55	-	-	-	-	-	-
	Viola odorata	-	-	-	4.9	6.26	11.15	-	-	-	-	-	-	7.5	8.65	16.15	-	-	-
	Total				**100**	**100**	**200**	**100**	**100**	**200**	**100**	**100**	**200**	**100**	**100**	**200**			



1. Anemone tetrasepala, 2. Artimesa absinthum, 3. Aster spp, 4. Bothriochloachloa pertusa, 5. Chrysanthemum spp, 6. Cichorium intybus, 7. Cirsium falconeri, 8. Clinopodium vulgare, 9. Cuminum cyminum, 10. Cynodon dactylon, 11. Cynoglossum glochidiatum, 12. Dianthus angulatus, 13. Epilobium spp, 14. Erigeron spp, 15. Festuca pratensis, 16. Fragaria nubicola, 17. Geranium rotundifolia, 18. Geranium wallichianum, 19. Geum coccineum, 20. Geum elatum, 21. Geum spp, 22. Hypericum perfoatum, 23. Lespedeza cuneata, 24. Lolium perenen L., 25. Lychnis coronaria, 26. Marrubium vulgare, 27. Matricaria chamomilla, 28. Oxalis corniculata, 29. Picris hiercioides, 30. Plantago lanceolata, 31. Potentilla reptans, 32. Potentilla spp, 33. Ranunculus hirtellus, 34. Scutellaria prostrata, 35. Silene spp, 36. Thymus serpyllum, 37. Trifolium repens, 38. verbascum thapsus, 39. Viola odorata

Fig.:5. Importance Value Index (IVI) of Herbs and Grasses across the available aspects along an altitudinal gradient in Kandi forest range.

Range indicate a varieddistribution pattern of herbaceous vegetation. The distribution pattern was random and contagious on southern aspect, regular, contagious and random on North Western side and contagious and random onNorthernaspect at an altitude of 1600-2000m. At 2000-2400m altitude the values with respect to A/F ratioon Eastern, North Western and Northern depicted random and contagious pattern of distribution but on North Eastern aspect the species exhibited only random distribution pattern. Similarly, at 2400-2800m altitude the examination of A/F ratio values indicated random and contagious distribution pattern on North Western and North Eastern and contagious pattern on Northern aspect.

The examination of data (Table. 11 and Fig.5) reveals profound variation in IVI values of herbaceous vegetation over the entire range of vertical topographic gradient. At 1600-2000m altitude maximum IVI(41.59%)was exhibited by*Cuminum cyminum*on North Western aspect followed by *Lolium perenen* with IVI of 34.82 & 16.88% onSouthern and Northern aspects respectively. At middle altitudinal range of 2000-2400 m *Ranunculus hirtellus*recorded highest IVI value of 60.39% on Northern aspect followed by *Fragaria nubicola*, *Dianthus angulatus*and *Potentilla spp* with IVI values of 35.07, 27.35 and 21.85% on North Eastern, North Western and Easternaspects respectively. Similarly, the upper altitudinal range of 2400-2800 presented almost identical order with highest IVI value of 60.72% for*Ranunculus hirtellus*on Northern aspect followed by *Fragaria nubicola,Dianthus angulatus*and *Potentilla spp*with IVI values of 43.38%, 30.51% and 29.51% on North Eastern, North Western and South Western aspects respectively.

4.2.1.4 Diversity index and Concentration dominance

The data on diversity indices as indicated by Shannon-wiener function (H′) is presented in table (12). The degree of variability in diversity (H′maximum) for trees varied between 0.177-0.364 on various aspects at an altitude of 1600-2000 m, 0.293-0.337 at 2000-2400 m and 0.259-0.341 at 2400-2800 m. The highest and lowest diversity of 0.364 and 0.177 was recorded on Southern and North western slopes at an altitude of 1600-2000m. The diversity

Table:-12. Diversity indices of trees, shrubs, herbs and grasses across the available aspects along an altitudinal gradient in Kandi forest range.

Altitude (m)	Plant Category	Aspect	Diversity index (H)	Concentration of Dominance (C)	Richness index (R)	Evenness Index (E)
1600-2000	Trees	South	0.364	0.112	0.433	0.33
		North West	0.177	0.399	0.156	0.25
		North	0.216	0.250	0.142	0.31
	Shrub	South	0.221	0.037	0.834	0.10
		North West	0.188	0.007	1.449	0.07
		North	0.234	0.015	0.983	0.11
	Herb	South	0.234	0.014	0.716	0.11
		North West	0.221	0.012	0.878	0.09
		North	0.149	0.003	1.526	0.05
2000-2400	Trees	North West	0.337	0.260	0.183	0.48
		North	0.331	0.252	0.147	0.48
		North East	0.293	0.234	0.289	0.27
		East	0.328	0.269	0.157	0.47
	Shrub	North West	0.309	0.082	0.543	0.22
		North	0.225	0.038	0.878	0.12
		North East	0.290	0.165	0.346	0.26
		East	0.306	0.046	0.641	0.19
	Herb	North West	0.169	0.006	1.166	0.06
		North	0.247	0.030	0.501	0.13
		North East	0.167	0.006	1.148	0.06
		East	0.130	0.003	1.755	0.04
2400-2800	Trees	South West	0.279	0.314	0.161	0.40
		North West	0.337	0.260	0.155	0.48
		North	0.259	0.332	0.159	0.37
		North East	0.341	0.256	0.151	0.49
	Shrub	North West	0.338	0.131	0.382	0.31
		North	0	1.000	0	0
		North East	0.300	0.085	0.517	0.22
	Herb	South West	0.157	0.005	1.299	0.07
		North West	0.195	0.010	0.928	0.08
		North	0.206	0.010	0.419	0.14
		North East	0.192	0.011	0.916	0.06

Index (H′) for Shrubs varied between 0.188 - 0.234 at 1600-2000 m, 0.233 – 0.309 at 2000-2400 m and 0 – 0.300 at 2400-2800 m. the diversity of undergrowth species also varied along an altitudinal gradient. The maximum diversity (H′) was 0.247 at 2000-2400 m (Northern), 0.234 at 1600-2000m (Southern) and 0.206 at 2400-2800 m (Northern). The minimum diversityfor grasses and herbs was in order of 0.149 (Northern), 0.130 (Eastern) and 0.157 (South Western) at 1600-2000 m, 2000-2400 m and 2400-2800 m of altitudinal gradient respectively. The overall diversity of trees, shrubs and grasses &herbs (Table. 13) in the selected forest range was in order of 0.293, 0.237 and 0.189.

The results on concentration of dominance (C) reveals that maximum values with respect to this index for trees were0.396 (North Western)at1600-2000 m, 0.303(South Western) at 2400-2800 m and 0.278 (Northern) at 2000-2400 m of altitude. The minimum 'C' values for trees were 0.112 (Southern), 0.145 (North Eastern) and 0.255 (Northern) on 1600-2000, 2000-2400 and 2400-2800 m of altitude respectively. The concentration of Dominance for Shrubs varied from a maximum of 1.00 (Northern) at 2400-2800m altitude followed by 0.165 (North Eastern) at 2000-2400 and 0.037 (Southern) at 1600-2000m altitude to minimum values of 0.007 (North Western), 0.038 (Northern) and 0.085 (North Eastern) on 1600-2000, 2000-2400 and 2400-2800m of altitude respectively. Peak valuesof concentration of dominance for grasses & herbs were0.030 (Northern)at2000-2400 m followed by 0.014 (Southern) at1600-2000 m and 0.011 (North Eastern) at 2400-2800m of altitude with minimum values of0.003 (Northern), 0.003 (Eastern) and 0.005 (South Western) on 1600-2000, 2000-2400 and 2400-2800 m of altitude respectively. The overall concentration of dominance (C) of trees, shrubs and herbs (Table.13) in the Kandi forest range was in order of 0.266, 0.169 and 0.010.

4.2.1.5. Species Richness and Evenness:

Data on species Richness (R) and Evenness (E) is presented in table (12). The sequence in term of species richness of the Kandi forest range included a

Table: 13. Overall diversity index (H), Concentration of Dominance (C), Richness index (R) and Evenness Index (E) of trees, shrubs and grasses and herbs in Kandi forest range.

Plant Category	Diversity index (H)	Concentration of Dominance (C)	Richness index (R)	Evenness Index (E)
Trees	0.293	0.266	0.198	0.386
Shrubs	0.237	0.169	0.663	0.156
Herbs	0.189	0.010	1.024	0.081
Total	**0.718**	**0.445**	**1.886**	**0.623**

Table: 14. Overall diversity index (H), Concentration of Dominance (C), Richness index (R) and Evenness Index (E) of different life forms across different altitudes of Kandi forest range.

Altitude (m)	Life form	(H)	(C)	(R)	(E)
Lower	Tree	0.252	0.254	0.244	0.297
	Shrub	0.214	0.020	1.089	0.093
	Herb	0.201	0.010	1.040	0.083
Total		**0.668**	**0.283**	**2.372**	**0.473**
Middle	Tree	0.322	0.254	0.194	0.428
	Shrub	0.283	0.083	0.602	0.198
	Herb	0.178	0.011	1.143	0.073
Total		**0.783**	**0.348**	**1.939**	**0.698**
Upper	Tree	0.304	0.291	0.157	0.435
	Shrub	0.213	0.405	0.300	0.177
	Herb	0.188	0.009	0.891	0.088
Total		**0.704**	**0.705**	**1.347**	**0.699**

larger representation of undergrowth, shrubs and trees. The maximum richness (R) values for trees were0.433 (Southern) at1600-2000 m, 2.78 (North Eastern) at 2000-2400 m and 0.161 (South Western) at 2400-2800 m of altitude. The lowest values of tree richness were 0.142 (Northern), 0.147 (Northern) and 0.151 (Northern) on 1600-2000, 2000-2400 and 2400-2800 m of altitudes respectively. The maximum species richness for shrubs was in order of 1.449 (North Western) at 1600-2000 m, 0.878 (Northern) at 2000-2400 m and 0.382 (North Western) at 2400-2800 m of altitude. On the other hand the minimum values for shrub richness were 0.834 (Southern), 0.346 (North Eastern) and 0.00 (Northern) on 1600-2000, 2000-2400 and 2400-2800 m of altitude respectively. The species richness index (R) for herbs varied greatly with highest value of 1.755(Eastern) at 2000-2400 m of altitude followed by a minimum and maximum range of 0.716 - 1.526 at1600-2000 m and 0.419 - 1.299 at 2400-2800 m of altitude. The overall richness (Table. 12) of Kandi forest range was in order of grasses & herbs (1.024) >shrubs (0.663) and >trees (0.198).

The maximum evenness (E) valuefor trees was0.51 (Northern) at1600-2000 m followed by 0.50 (Eastern) at 2000-2400 m and 0.49 (North Eastern) at 2400-2800 m of altitude. Similarly, the minimum evenness for trees was in order of 0.26 (North Western), 0.28 (North Eastern) and 0.38 (Northern) at 1600-2000, 2000-2400 and 2400-2800m of altitudes respectively. The Evenness Index (E) for shrubs wasmaximum (0.31) on North Western aspect at 2400-2800 m of altitude followed by 0.26 (North Eastern) at 2000-2400 m and 0.11 (Northern) at 1600-2000m of altitude. The minimum values for this index were 0.07 (North Western), 0.12 (Northern) and 0.22 (North Eastern) on 1600-2000, 2000-2400 and 2400-2800m of altitudes respectively. The evenness values of grasses and herbs varied greatly. While Peak valuesof evenness index (E) for grasses & herbs were0.14 (Northern) at2400-2800 m, 0.13 (Northern) at2000-2400 m and 0.11 (Southern) at 1600-2000 m of altitude, the minimumevenness values for herbs were 0.05 (Northern), 0.04 (Eastern) and 0.06 (North Eastern) on 1600-2000,

Table: 15. Overall diversity index (H), Concentration of Dominance (C), Richness index (R) and Evenness Index (E) of aspects in Kandi forest range.

Aspects	Diversity index (H)	Concentration of Dominance (C)	Richness index (R)	Evenness Index (E)
S	0.273	0.054	0.661	0.18
SW	0.218	0.160	0.730	0.235
NW	0.252	0.216	0.584	0.205
N	0.233	0.116	0.594	0.213
NE	0.264	0.126	0.561	0.226
E	0.255	0.106	0.851	0.233
Mean	**0.249**	**0.130**	**0.664**	**0.216**

Table:-16. Index of similarity and dissimilarity co-efficient of Tree across the available aspects along an altitudinal gradient in Kandi forest range.

Altitude (m)		**1600-2000**		
1600-2000	**Aspects**	**North West**		**North**
	South	0 (1)		0 (1)
	North West	-		1 (0)
Altitude (m)		**2000-2400**		
2000-2400	**Aspects**	**North West**	**North**	**North East**
	East	1 (0)	1 (0)	0.80 (0.20)
	North West	-	1 (0)	0.80 (0.20)
	North	-	-	0.80 (0.20)
Altitude (m)		**2400-2800**		
2400-2800	**Aspects**	**North West**	**North**	**North East**
	South West	1 (0)	1 (0)	1 (0)
	North West	-	1 (0)	1 (0)
	North	-	-	1 (0)

Altitude (m)	**2000-2400**	**2400-2800**
1600-2000	0.75 (0.25)	0.57 (0.43)
2000-2400	-	0.80 (0.20)

Note: Values in parentheses are index of dissimilarity.

2000-2400 and 2400-2800 m of altitude respectively. The overall evenness index of trees, shrubs and grasses &herbs in the selected forest range was in order of 0.386, 0.156 and 0.081 respectively.

4.2.1.6. Similarity and dissimilarity Index's

The data on similarity and dissimilarity Index of trees, shrubs and grasses & herbs recorded on the available aspects along an altitudinal gradient of Kandi forest range are presented in table (16 to 18).The results derived from binary data of vegetation analysis of trees reveal that the altitudinal gradients differed in their composition. The altitudinal range of 1600-2000 m was 75% and 57% similar to middle and higher altitudinal gradient with respect to composition of trees species. The similarity co-efficient between middle and higher altitudes was 80%.While comparing various aspects, the analytical calculations revealed that southern slopes at lower altitude were completely dissimilar to North Western and Northern aspects in tree composition. Contrary to this the available aspects at middle and upper altitudinal gradients exhibited almost similar tree composition pattern.

The co-efficient of similarity for shrubs was 50% between Southern & North Western and Southern & Northern aspects but 82% between North Western & Northern aspects at an altitudinal gradient of 1600-2000 m. Similarity, co-efficient of shrubs on various aspects at the middle altitude was in order of 67% between Eastern & North Western, 50% between Eastern & Northern, 75% between North Western & Northern, 86% between North Western & North Eastern and 60% between Northern & North Eastern aspects. The aspect at higher altitudinal gradient presented a different view with Southern & North Western, Southern & North Eastern and North Western & Northernaspects being completely dissimilar with each other. On the other hand North Western & North Eastern and Northern & North Eastern aspects depicted 43 and 60 % dissimilarity with each other. The analysis of data further revealed that various altitudinal gradients also differed with respect to similarity in species composition of shrubs.

Table:-17. Index of similarity and dissimilarity co-efficient of shrubs across the available aspects along an altitudinal gradient in Kandi forest range.

Altitude(m)		1600-2000		
	Aspects	North West		North
1600-2000	South	0.50 (0.50)		0.50 (0.50)
	North West	-		0.82 (0.18)
Altitude (m)		**2000-2400**		
	Aspects	North West	North	North East
2000-2400	East	0.67 (0.33)	0.50 (0.50)	0.50 (0.50)
	North West	-	0.75 (0.25)	0.86 (0.14)
	North	-	-	0.60 (0.40)
Altitude (m)		**2400-2800**		
	Aspects	North West	North	North East
2400-2800	South West	0 (1)	0 (1)	0 (1)
	North West	-	0 (1)	0.57 (0.43)
	North	-	-	0.40 (0.60)

Altitude (m)	2000-2400	2400-2800
1600-2000	0.67 (0.33)	0.40 (0.60)
2000-2400	-	0.57 (0.43)

Note: Values in parentheses are index of dissimilarity.

Table:-18. Index of similarity and dissimilarity co-efficient of herbs and grasses across the available aspects along an altitudinal gradient in Kandi forest range.

Altitude (m)		1600-2000		
	Aspects	North West		North
1600-2000	South	0.48 (0.52)		0.33 (0.67)
	North West	-		0.58 (0.42)
Altitude (m)		**2000-2400**		
	Aspects	North West	North	North East
2000-2400	East	0.37 (0.63)	0.33 (0.67)	0.37 (0.63)
	North West	-	0.36 (0.64)	0.93 (0.07)
	North	-	-	0.36 (0.64)
Altitude (m)		**2400-2800**		
	Aspects	North West	North	North East
2400-2800	South West	0.28 (0.72)	0.26 (0.74)	0.34 (0.66)
	North West	-	0.44 (0.56)	0.92 (0.08)
	North	-	-	0.44 (0.56)

Altitude (m)	2000-2400	2400-2800
1600-2000	0.54 (0.46)	0.46 (0.54)
2000-2400	-	0.46 (0.54)

Note: Values in parentheses are index of dissimilarity.

While altitudinal gradient of 1600-2000 m was 67 & 40 % similar to middle and upper altitudinal ranges, the similarity co-efficient between middle and upper altitudinal gradient was 57%.

The similarity co-efficient for grasses and herbs are presented in table (18). The data recorded reveals that the similarity in undergrowth composition at lower altitudinal range was 48% between Southern & North Western, 33% between Southern & Northern and 58% between North Western & Northern slopes. While comparing various aspects at middle altitudinal range the similarity co-efficient between Eastern & North Western, Eastern & Northern, Eastern & North Western, Northern & North Western and North Eastern & Northern were in order of 37, 33, 37, 36 and 36 % respectively. On the other hand the similarity co-efficient for grasses &herbs between North Eastern & North Western was 93%. The aspects on the upper altitudinal range also presented anidentical view with similarity co-efficient of 28% between South Western & North Western, 26% between South Western & Northern, 34% between South Western & North Eastern, 44% between North Western and Northern, 92% between North Western & North Eastern and 44% between Northern & North Eastern aspects.Likewise the similarity co-efficient for ground flora between various altitudes was in order of 54, 46 and 46% between lower & middle, lower & higher and middle & higher altitudinal gradients respectively.

4.3. Deforestation status

The results on deforestation status of dominant conifer tree species Kandi forest range was studied by comparing its phyto-sociological status in core (Undisturbed) and degraded forest (Subject to illicit felling) patches. The examination of data (Table. 19 and 20; Fig. 6) reveals that the total frequency values of the two conifer species varied from 95% in degraded to 112% in core forest zone. While *Cedrus deodara* exhibited frequency values of 38 & 53%, *Pinus wallichiana* recorded frequency of 57 & 59% in deforested and core forest patches respectively. The altitudinal variation in frequency was concomitant with

Plate :9. Deforestation status of study area

Table: 19. Deforestation status of *Cedrus deodara* and *pinus wallichiana* in Kandi forest range.

Parameters	*Cedrus deodara*		*Pinus wallichiana*		Total	
	Deforested area	Core forest area	Deforested area	Core forest area	Deforested area	Core forest area
Frequency	38	53	57	59	95	112
Density	181	310	250	439	431	749
Total basal area (TBA)	18	38	28	41	46	79
Importance valu index (IVI)	127	141	173	159	300	300

TBA = Total basal area; IVI = Importance value index

Table. 20: Deforestation status of Kandi forest range at different altitudes.

Altitude (m)	Species	Deforested area							Core forest area						
		F	D	BA	RF	RD	RDO	IVI	F	D	BA	RF	RD	RDO	IVI
1600-2000	*Cedrus deodara*	45	270	35	52.94	69.23	79.3	201	43	304	37	58.21	51.97	63.79	174
	Pinus wallichiana	40	120	9	47.06	30.77	20.7	99	31	281	21	41.79	48.03	36.21	126
Total		**85**	**390**	**44**	**100**	**100**	**100**	**300**	**74**	**585**	**58**	**100**	**100**	**100**	**300**
2000-2400	*Cedrus deodara*	34	165	8	36.96	39.95	32.87	110	55	341	29	45.08	37.75	41.43	124
	Pinus wallichiana	58	248	15	63.04	60.05	67.13	190	67	563	41	54.92	62.28	58.57	176
Total		**92**	**413**	**23**	**100**	**100**	**100**	**300**	**122**	**904**	**70**	**100**	**100**	**100**	**300**
2400-2800	*Cedrus deodara*	37	108	11	33.04	21.95	16.28	71	61	285	47	43.88	37.54	43.52	125
	Pinus wallichiana	75	383	58	66.96	77.85	83.73	229	78	473	61	56.19	62.34	56.48	175
Total		**112**	**492**	**69**	**100**	**100**	**100**	**300**	**139**	**758**	**108**	**100**	**100**	**100**	**300**
Average		**96**	**432**	**45**	**100**	**100**	**100**	**300**	**112**	**749**	**79**	**100**	**100**	**100**	**300**

F=Frequency (%); D=Density (ha-1); BA= Basal Area (m^2 ha^{-1}); RF= Relative Frequency; RD= Relative Density; RDO= Relative dominance; IVI= Importance Value Index

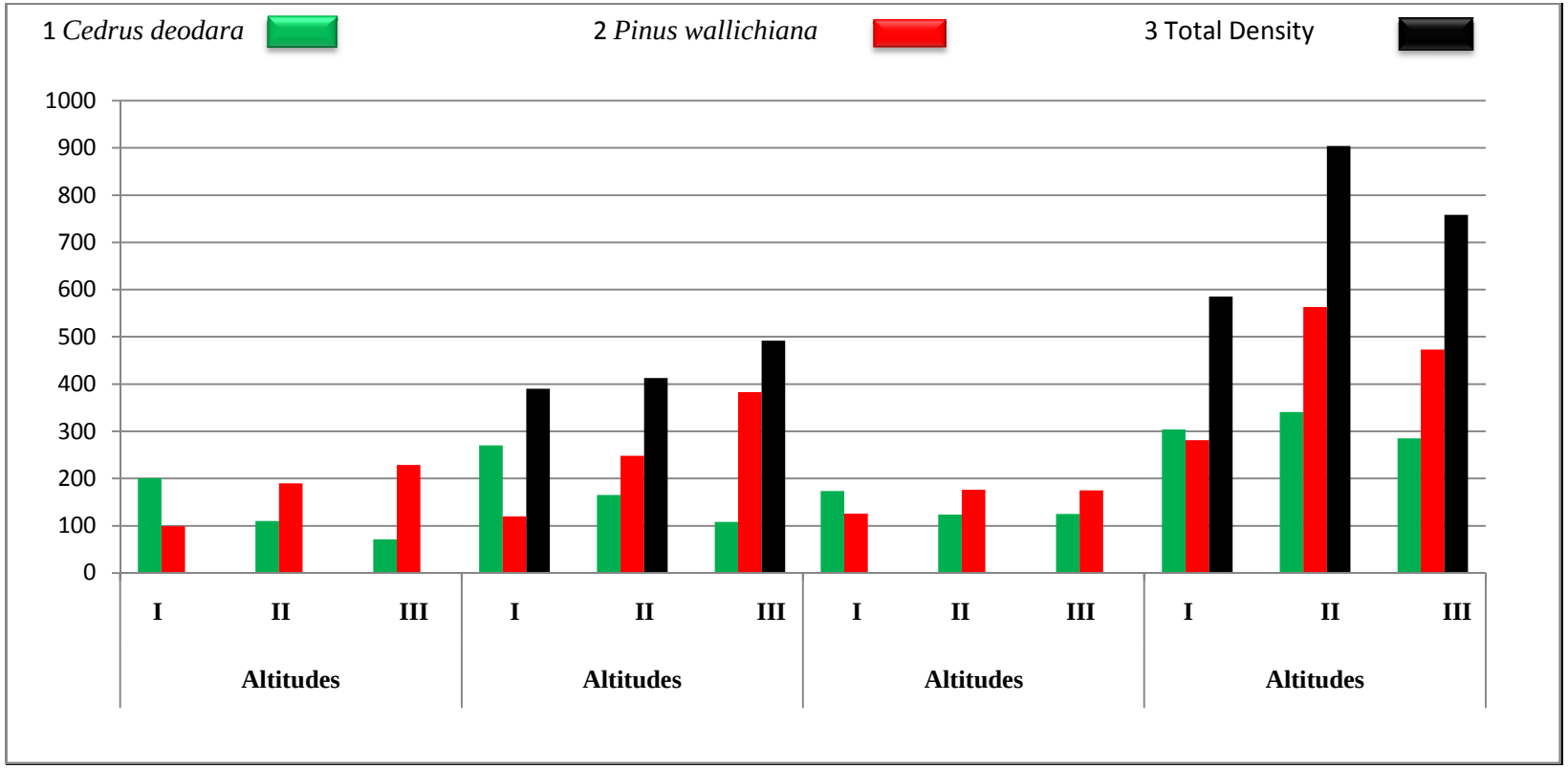


Fig.: 6. Deforestation status of Kandi forest range at different altitudes.

Totalfrequency values of *Cedrus deodara* and *pinus wallichiana* which ranged from 74 to 139% in core area to 85 to 112% in forest patches subjected to illicit felling.

The change in tree density was also consistently detected in the forest area, ranging from an average of 749 trees ha^{-1} in undistributed forest area to 431 trees ha^{-1} in patches subjected to illicit felling. The density of *Cedrus deodara* was 310 trees ha^{-1} in undistributed area as compared to 181 trees ha^{-1} in disturbed forest area. Similarly, the density of *Pinus wallichiana* varied from 439 trees ha^{-1} in core forest zone to 250 trees ha^{-1} in the forest area subjected to illicit felling. The altitudinal variation in tree density of two conifers was in order of 585, 904 and 758 trees ha^{-1} (undisturbed area) and 390, 413 and 492 trees ha^{-1} (disturbed forest patches) on 1600-2000, 2000-2400 and 2400-2800m asl of altitudes respectively.

The examination of data (Table. 20) further revealed that total basal area varied from 79 m^2 ha^{-1} in core forest area to 46 m^2 ha^{-1} in degraded forest area. The loss in basal area for *Cedrus deodara* and *Pinus wallichiana* was in order of 47 and 68 percent in forest patches subjected to illicit felling. The altitudinal variation in basal area of two conifers was in order of 58, 70 and 108 m^2 ha^{-1} (undisturbed area) and 44, 23 and 69 m^2 ha^{-1} (disturbed forest patches) on 1600-2000, 2000-2400 and 2400-2800 m altitude respectively. Similarly, the IVI values for the two species varied between degraded and undisturbed forest patches. The average IVI of *Pinus wallichiana* (166%) was higher than that of *Cedrus deodara* (134%) in both the forest zones.

4.4. Regeneration Status of conifers in Kandi Forest Range

The regeneration status of C*edrus deodara* and *Pinus wallichiana* species along the different altitudes and aspects of Kandi Forest range is summarized in table (21) and Fig. (7 to 9). The results depicted that average regeneration status was fair for *Cedrus deodara* and poor for *Pinus wallichiana* at lower altitude with respective average density of 687 and 150 seedlings ha^{-1}. While recruitment of

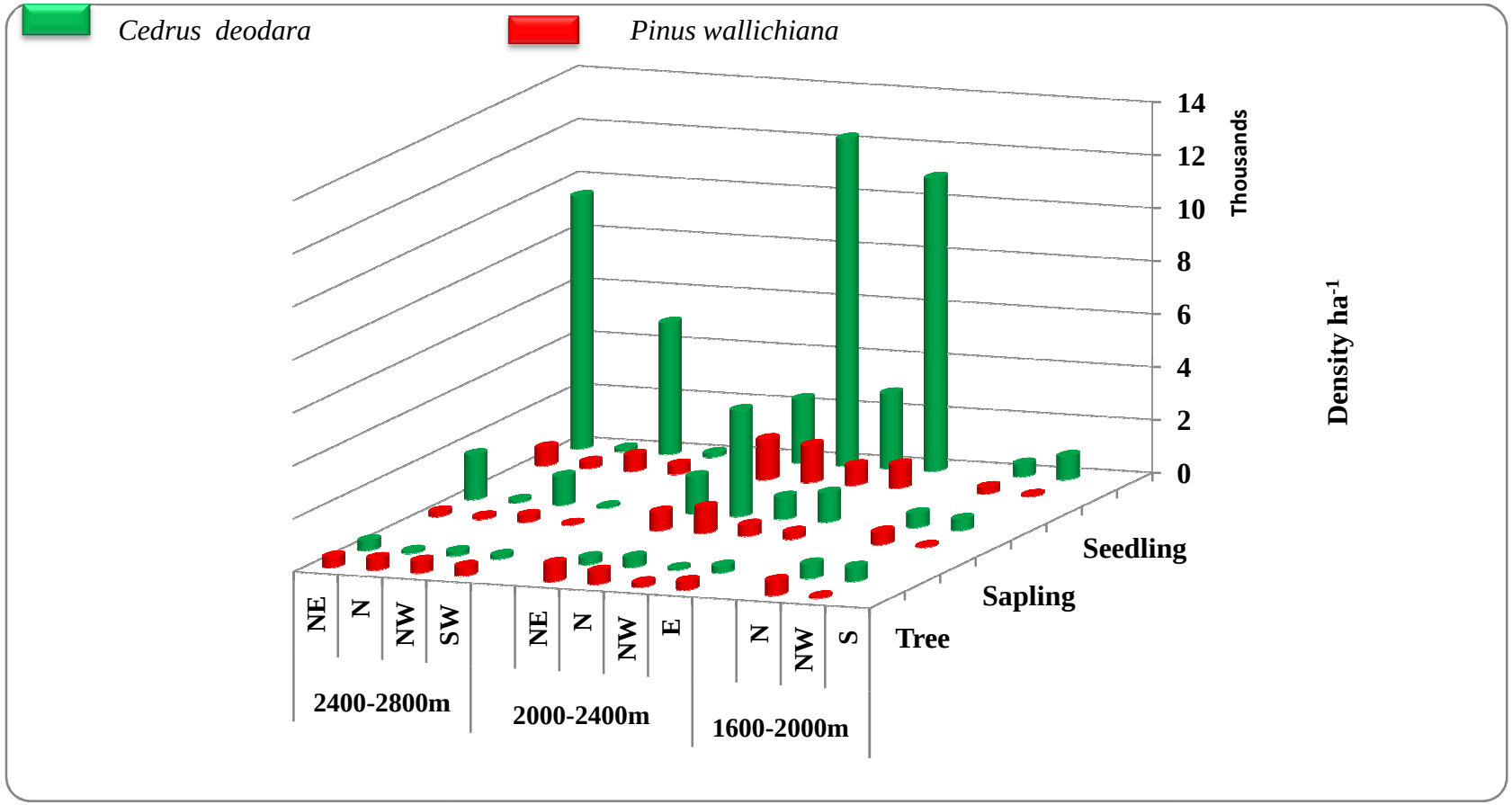


Fig. 7.Regeneration status of *Cedrus deodara* and *Pinus wallichiana* in Kandi forest range.

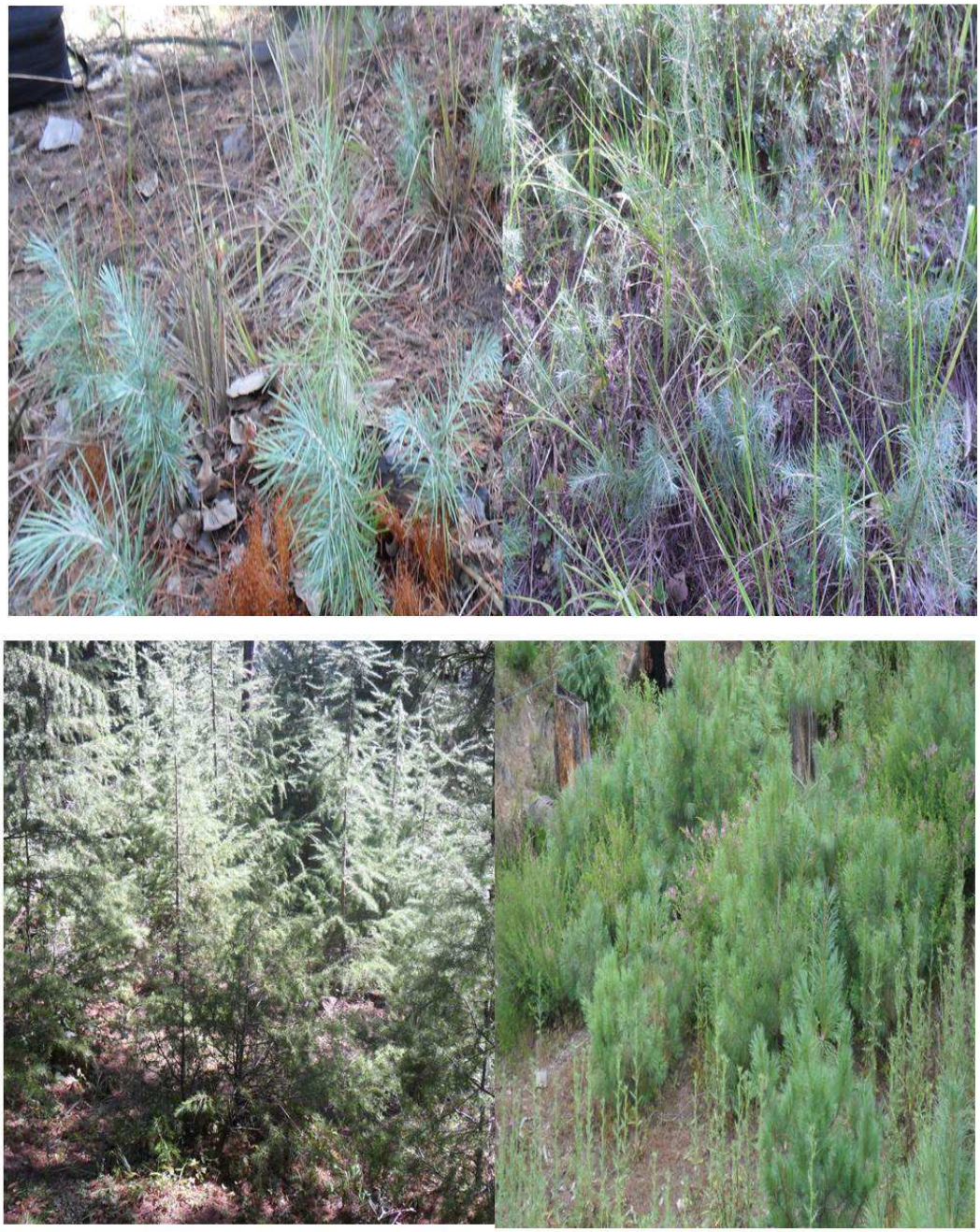


Plate: 10. Regeneration status of study area

Table:-21.Regeneration status of *Cedrus deodara* and *Pinus wallichiana* species across the available aspects along an altitudinal gradient in Kandi forest range.

Altitude (m)	Aspect	*Cedrus deodara*				*Pinus wallichiana*			
		Tree	**Sapling**	**Seedling**	**Status**	**Tree**	**Sapling**	**Seedling**	**Status**
1600-2000	SOUTH	-	-	-	-	-	-	-	-
	North West	540	420	885	Fair	60	40	55	Fair
	North	558	531	488	Poor	573	475	244	Poor
Mean		**549**	**476**	**687**	**Fair**	**317**	**258**	**150**	**Poor**
2000-2400	East	264	1100	11069	Good	329	254	886	Good
	North West	67	833	2825	Good	167	417	750	Good
	North	383	4000	12342	Good	500	983	1400	Good
	North East	267	1400	2400	Good	683	700	1517	Good
Mean		**305**	**2167**	**8604**	**Good**	**504**	**646**	**1268**	**Good**
2400-2800	South West	133	50	142	Fair	367	33	350	Poor
	North West	175	1088	4963	Good	450	263	606	Fair
	North	83	83	108	Fair	450	100	242	Fair
	North East	367	1696	9542	Good	400	179	683	Fair
Mean		**190**	**729**	**3689**	**Good**	**417**	**144**	**470**	**Fair**
Grand Mean		**348**	**1124**	**4326**	**Good**	**412**	**349**	**629**	**Fair**

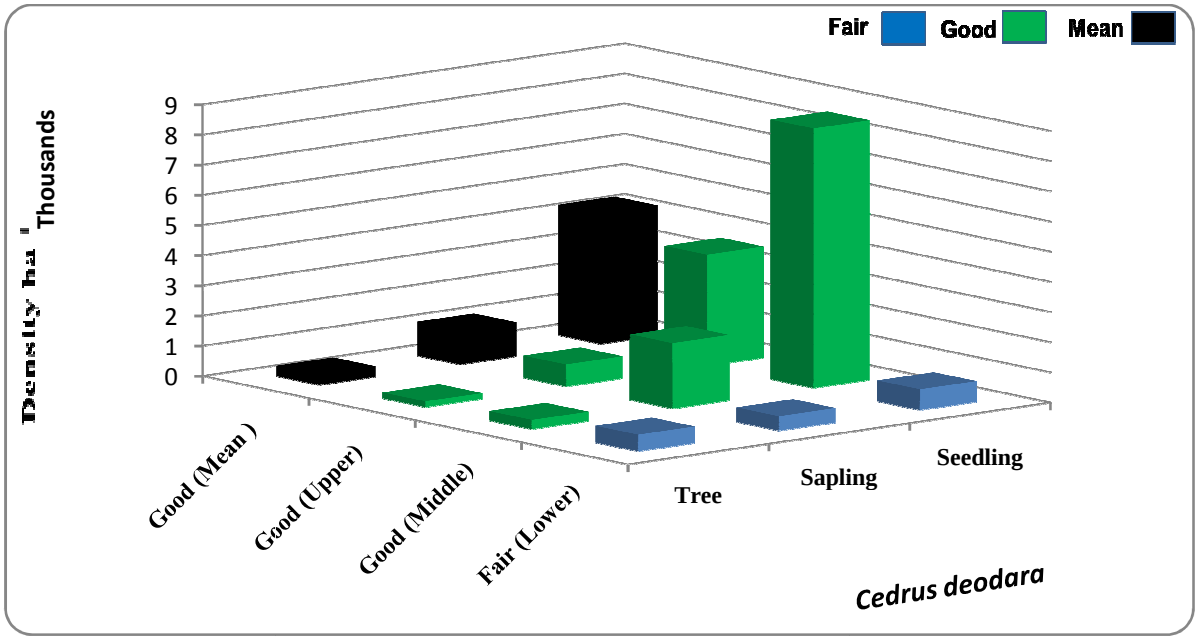


Fig.8. Regeneration status of *Cedrus deodara*species on different altitudes of study area

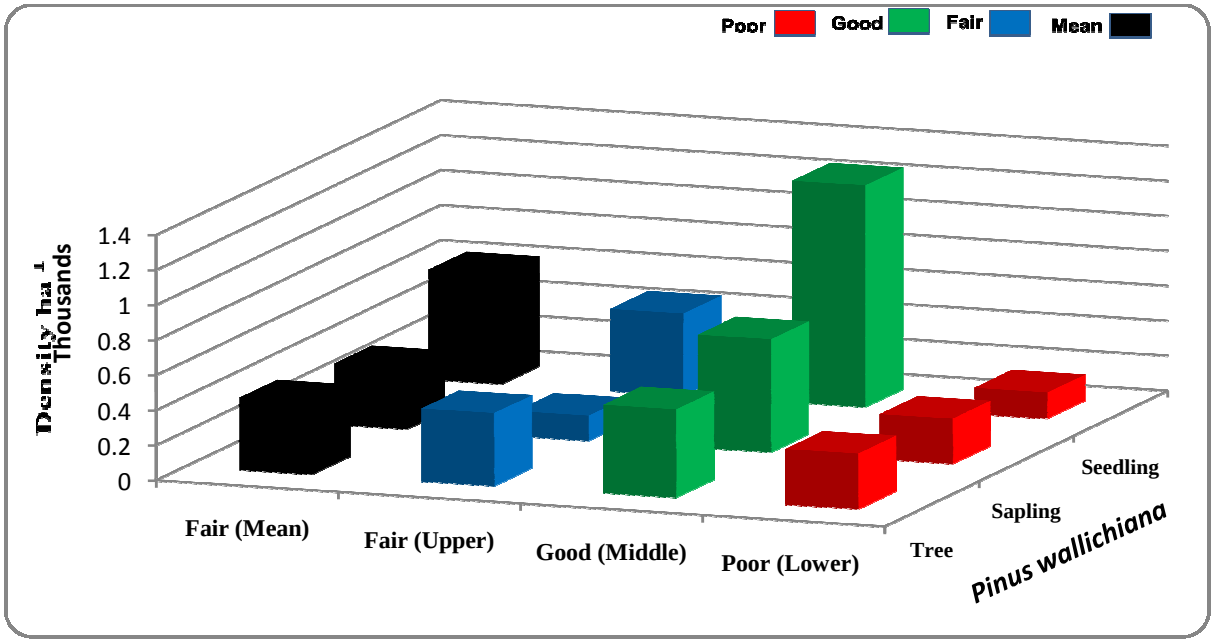


Fig.9. Regeneration status of *Pinus wallichiana* species on different altitudes of study area

Cedrus deodara was maximum (885 seedlings ha^{-1}) on North Western aspects,*Pinus wallichiana* depicted maximum density of 244 seedlings ha^{-1}on Northern slopes.

The regeneration status of *Cedrus deodara* and *Pinus wallichiana* was good at the middle altitudinal gradient. The average seedling density of *Cedrus deodara* and *Pinus wallichiana* at this altitudinal range was 8604 and 1268 seedlings ha^{-1}. While *Cedrus deodara*exhibited highest seedling density of 12342 seedlings ha^{-1} on Northern aspect, the maximum seedling density of *Pinus wallichiana*was 1517 seedlings ha^{-1} on North Eastern slopes.

The average regeneration status of *Cedrus deodara* and *Pinus wallichiana* was good and fair at upper altitudinal gradient. The average density of advance growth on this altitude was in order of 3689 and 470 seedlings $ha^{-1}$for*Cedrus deodara* and *Pinus wallichiana* respectively. *Cedrus deodara* and *Pinus wallichiana* depicted maximum regeneration of 9542 and 683 seedlings ha^{-1} on North Eastern aspects. The examination of data further reveals that the overall respective regeneration status of *Cedrus deodara* and *Pinus wallichiana* was good and fair with average seedling density of 4326 and 629 seedlings ha^{-1} respectively.

Chapter – 5

DISCUSSION

This chapter centersa debate on the results the study stated in section 4. These results recorded are interpreted and related to the literature to understand the ecological pattern of vegetation along an altitudinal gradient in the selected forest range as a whole.

The main features observed with respect to distribution of vegetation in the selected forest range clearly envisage that this ecosystem is a very complexand fragile for having varied edaphic description and topography.Besides presence of varied compositional communities, the existence of a discontinuity (on some aspects along the altitude) in the otherwise continuous altitudinal sequence of compositional change, which exhibited within the main body of vegetation, was the prominent feature of the selected forest range. The growingdemand for various resources has created disturbances in the existing forest ecosystem resulting in the deterioration of soil quality and above all loss of forest wealth. With these main features, many problems generallyconfront the management of natural resources of this region. Under these circumstances, it is always importantto adopt a holistic approach and undertake in-depth study of structure and composition of the existing vegetation and correlate it with major site specific edaphic features so as to devise a concrete management approach for conservation of natural forests.

The magnitude of compositional change along an altitudinal gradient in the selected forest stand was studied through phytosociological attributes viz. density, occurrence of the species, species abundance and total basal area are by far the most basic components of any vegetation type (Mishra *et al*., 2000). Similarly, the physiographic features such as elevation and aspect have a profound influence on the distribution, growth form and structure of tree species, as a result of which the individual species have different values for density and basal area along these geomorphic gradients (Bhatt, 2007). Therefore; in the

present study, while primary objective was to assess the community structural attributes along the altitudinal gradient, the secondary, but equally important goals were to evaluate the extent of deforestation and regeneration status and correlate structural features with some important soil physico-chemical characteristics of Kandi Forest Range. The results thus recorded are discussed under following main sub-headings.

5.1. Soil physico- chemical characteristics.

5.2Plant community composition and structure.

5.3. Extent of deforestation

5.4. Regeneration status

5.1. Soil physico-chemical properties:

5.1.1. Physical properties of soil:-

5.1.1.1. Bulk density:-

Soil compaction is evaluated in several ways. The most common one is by measuring soil bulk density. Bulk density influences the root penetration, availability of nutrients, water and oxygen for plant and porosity of soil thereby affecting the establishment and survival plants which in turn decrease the soil bulk density over time (Eden *et al*., 1991; Hajabbasi *et al*., 1997; Schwendenmann, 2000; Lister *et al*., 2004) . Tate *et al*. (2004) observed that soil surface bulk density was 16 to 22% lower under canopy cover compared to open grasslands, and was greater at grazed sites than at non-grazed sites. Zarin *et al*. (1998) found that median bulk density values were lowest for the 0-10cm depth in coniferous forest soils and highest for the 10-40cm depth in moorland soils.

The values of soil bulk density recorded in the present study reflected both altitudinal and aspect wise variation with mean values ranging between 1.38 g cm^{-3} (Southern aspect) to 1.25 g cm^{-3}(Northern aspect) on lower altitude, 1.32 g cm^{-3} (North Eastern aspect) to 1.27 g cm^{-3} (North Western aspect) on middle

altitude and 1.35 g cm^{-3} (North Western aspect) to 1.30 g cm^{-3} (South Western aspect) on upper altitude. Interaction values of bulk density with respect to aspects and soil depth ranged in order of 1.42 - 1.21 g cm^{-3} (Southern & Northern aspects), 1.36 -1.18 g cm^{-3} (North Eastern aspect) and 1.37-1.27 g cm^{-3} (North Western and Southern aspects) on lower, middle and upper altitudes respectively(Table. 3). These values on bulk density were slightly higher than the range of0.95-1.20 g cm^{-3}recorded by Bisht and Lodhiyal, (2005) in the coniferous forest of central Himalaya (Kumaon). Our values of bulk density were also in consonance with values of1.10 and 1.24 mg m^{-3} and 1.11 to 1.21 mg m^{-3}reported by Page-Dumroese et al. (1999) at a depth of 0 to 10 and 10 to 20 cm for some rocky forest soils of Western Montana.The bulk density values recorded in the present study were also more are less in the similar range of 1.0 to 1.2 (1300-1500 m), 1.0 to 1.2 (1500-1800 m) and 1.1 to 1.3 g cm^{-3} on East and West aspects of Central Himalaya (Neeraj *et al*., 2001) but lesser than reported by Tiwari *et al* (2013) who recorded bulk density values of 1.74, 1.58 and 1.72 g cm^{-3} under *Pinus wallichiana*, 1.37, 1.58 and 1.49 under *Cedrus deodara* and 1.34, 149 and 1.79 in Mixed Forests of Nanda Devi Uttarakhand at a soil depth of 0-15, 15-30 and 30-45 cm respectively.

5.1.1.2. Electrical conductivity (EC)

Soil EC is known to be influenced by a number of factors, including soil water capacity, concentration of ions in soil, type and amount of clay and soil bulk density (Brune and Doolittle, 1990). Generally, it is believed that higher the concentration of ions in the soil solution more is its electrical conductance (Moieza *et al*., 2012). The lower electrical values in soil attributes to the lesser release of ions from mineral weathering under different temperature and moisture regimes (Kaushal *et al*., 1997). The mean Electrical Conductivity values on lower, middle and upper altitudinal gradient of Kandi Forest ranged between 104 μScm^{-1}(North Western aspect) to 97 μScm^{-1}(Northern aspect), 119μScm^{-1} (Northern aspect) to 112 μScm^{-1}(North Eastern aspect) and 102μScm^{-1}(North

Eastern aspect) to 97 μScm^{-1} (Southern aspect) respectively. Interaction values of Electrical Conductivity between aspects and soil depths were in the range of 116 - 80 μScm^{-1} (Northern Western & Southern aspects), 134 -99 μScm^{-1} (Northern & North Eastern aspects) and 118-84 μScm^{-1} (North Eastern and South Western aspects) on lower, middle and upper altitudes respectively (Table. 3). Results of EC in present study were lesser than 161 and 137 μScm^{-1} under *Pinus wallichiana* and 169 and 135 μScm^{-1} under *Cedrus deodara* reportedbyQazi and Ashok (2008) at 0-10 and 10-20cm of soil depths respectively. The EC values recorded at different altitudes also fall within the range of 0 .08 to 0.16, 0.14 to 0.15 and 0.06 to 0.21 dSm^{-1} reported by Sheikh (2006) in low and high altitude soils of Kashmir respectively.

5.1.1.3. Soil pH

Higher levels of organic matter results in greater cation exchange which tends to decrease the soil pH (Naiman*et al*., 1994; Reynolds*et al*., 1989; Falkengren-Grerup, 1987). The acidic nature of the forest soil is generally attributed to the release of greater number of H ions from the decomposing resinous organic residues (Hodges, 1996) obtained from conifer forest vegetation. Tilki and Fisher (1988) reported that the root tolerance to acidity differs widely among plant species, but it appears that many tree species are relatively tolerant to acid conditions. Binklay *et al*. (1989) also reported decrease in soil pH of about 0.3 to 0.8 units in 20 years in an old-field plantation of loblolly pine but attributed it to reduction in base saturation of the exchange complex.

The mean pH values recorded in the present study (Table. 3) ranged between 7.11 (Southern aspect) to 5.83 (North Western aspect), 6.22 (Northern aspect) to 5.96 (Eastern aspect) and 6.24(Northern aspect) to 6.05 (South Western aspect) on lower middle and upper altitudinal gradient respectively. The interaction values of soil pH between aspects and soil depths ranged between 7.23- 5.57 (Southern & Northern aspects), 6.33 – 5.82 (Northern & Eastern aspects) and 6.33-5.93 (North Western and South Western aspects) on lower,

middle and upper altitudes respectively. Our values of Soil pH were on higher side than the range of 5.5 - 6.5 reported by Bisht and Lodhiyal (2005) in coniferous forests of Central Himalaya. The results of the present study are in conformity with those reported by Takahashi *et al*. (2001) from the coniferous forests of Japan. Tiwari *et al*. (2013) recorded soil pH values of 5.76 under *Abies pindrow* followed by 5.33 under *Cedrus deodara* and 5.09 under *Pinus wallichiana*. Sitanggang *et al.* (2006) has reported that the soils on hill tops and hill side are slightly acidic with pH varying from 6.11 to 6.50, whereas those on the ravenous area, piedmont plain and alluvial plain were slightly alkaline to alkaline with pH range of 7.55 to 8.57.

The influence of slope, aspect and altitude on soil characteristics is generally profound. Verma *et al*.(2008) has reported that surface soils of Northern facing pedons had higher pH values (6.3 to 6.7) as compared to Southern facing pedons (5.4 to 6.0) in Garhwal Himalayas. The maximum difference in surface and sub-surface horizons were found maximum on Northern aspects at upper altitude as compared to lower attitude. Such a variation in pH with respect to altitudes is attributed to leaching of salts to subsurface horizons (Ram *et al*., 2010). Gupta, (1980) reported that the pH range of 4.8 to 5.3 in Koyhikerh and Mecleodganj soil profiles from northwest Himalaya of Kangra reflected a good growth of *Cedrus deodara*. Various studies have shown that tree species litter quality changes soil pH differently with increasing acidity for coniferous species and decreasing acidity for deciduous and herbaceous litter (Sariyildiz *et al*., 2005; Xu*et al*., 2006).

5.1.1.4. Water Holding Capacity (WHC %)

The site quality attributes have been related primarily to soil moisture and nutrients (Whittaker, 1965; Lowry, 1975) with high moisture regimes favouring the rapid growth of trees in temperate forests (Khan and Tripathi, 1989). The mean WHC values on lower middle and upper altitudinal gradient ranged between 38 (North Western aspect) to 20 % (Southern aspect), 36 (North Western

aspect) to 34 % (Eastern aspect) and 38(Northern aspect) to 35 % (North Western aspect) respectively(Table. 3). Interaction values of WHC between aspects and soil depth were in the range of 43 - 21 % (Northern & Southern aspects), 39 – 31 % (North Eastern aspects) and 42-31 % (Northern and South Western aspects) on lower, middle and upper altitudes respectively. These data are in consonance with the WHC values of 43.7 and 29.8% (1300-1500 m asl), 37 and 40% (1500-1800 m asl) and 25.1 and 28.3% (1800- 2000 m asl) reported by Neeraj et al (2001) in the mid elevation forests of Central Himalaya. Dangwal *et al*., (2012) recorded WHC values of 20.40, 19.50 and 19.28% (500-700 m asl), 19.40, 19.56 and 19.78% (700-900) and 20.15, 19.80 and 19.80% (900-1200masl) at 0-10, 10-20 and 20-30 cm of soil depth in foot hills of Pir Panjal and Siwalik (Rajouri) Himalaya. Similarly, Tiwari et al (2013) recorded water holding capacity of 36.50, 49.17, 47.38 and 44.78 percent under *Pinus wallichiana* (Kail), *Cedrus deodara* (deodar), *Abies pindrow* (Ragha) and Mixed Forests of Himalayas at a soil depth of 0 to 45 cm. In another study on Soil physical variability in relation to soil erodibility under different land uses in foothills of Siwaliks in N-W India Gupta *et al*. (2010) reported WHC values in the range of 21.9 to 32.2, 30.5 to 40.5, 35.4 to 47.5 and 35.3 to 47.3% in barren soils, cultivated unmanaged, cultivated well managed and forest lands, respectively.

5.1.2. Chemical Properties of Soil:

5.1.2.1. Calcium carbonate ($CaCo_3$)

The soil nutrients Ca^{2+}, Mg^{2+}, $K^{+}$and $Na^{+}$are supplied to plants in large measures in exchangeable forms. Exchangeable macronutrients (Ca, Mg, K and Na) are of great importance of plant nutrition and because of their impact on theecosystem health and as good indicators of the ecosystem responses to environmental changes such as climate change, acid deposition and other human disturbances. Reduction in exchangeable base cations in coniferous forest soils has been reported from North America (Drohan and Sharp, 1997; Likens and Bormann, 1999; Courchesne et al., 2005); Europe (Egli,

1998, Blake et al., 1999) and Asia (Takahashi et al., 2001) mainly due to the acid deposition, leaching, uptake by forest vegetation and forest harvesting. Hence, decrease in base cationnutrients is geographically widespread. Results of Nykvist (1998) reveal that exchangeable calcium to be only a minor part of the totalstorage ofcalcium in thesoil. According to him, most calcium is bound in organiccompounds, calcium-containing silicates and carbonates. The author alsoreportedthat low amount of exchangeable calcium in soil from other parts of the world indicates that the calcium content of the soil can be an initial factor influencing forest production in other rain forest area as well. The main reason for the low content of local calcium in the soil is that the bedrock consists of interbedded sandstones, siltstones and shales with low calcium contents.The mean $CaCO_3$ values on lower, middle and upper altitudinal gradient ranged between 1.39 (North Western aspect) to 1.29 % (Northern aspect), 1.39 (North Western aspect) to 1.34 % (Eastern aspect) and 1.58(South Western aspect) to 1.48 % (North Western aspect) respectively. Interaction values for aspects and depths of $CaCO_3$ were in the order of 1.41 –1.26 % (North Western& Northern aspects), 1.42– 1.28 % (North Western & North Eastern aspects) and 1.62-1.44 % (South Western &North Eastern aspects) on lower, middle and upper altitudes respectively. Our surface values of $CaCO_3$ were within the range reported byKirmani, (2004) from lacustrine belt of Kashmir valley and reported 0 to 1.40 % $CaCO_3$ in surface soils but lesser than 0 to 17.80%in subsurface horizon of the pedons. Similar trend was recorded in our study that subsurface horizons showed higher content of $CaCO_3$ as compared to surface horizons. Rao *et al.*, 2008 andBhat, 2010 have advocated that profiles facing North have more $CaCO_3$content than South facing pedons. The range of $CaCO_3$ recorded in the present study is also similar to that reported by Wani, (1994) and Farida, (1997) in some karewa and valley basin soils of Kashmir. Shahid *et al*, (2010) found $CaCO_3$ values of 5.00 and 4.80%on Eastern aspect at the altitudeof 2500 to 2630 m, 4.4 and 5.40%on Northern aspect at an altitude of 2350 to 2500 and 2500-2620 m and 4.51% on Southern aspect at an altitude of 2650-2730 m.

5.1.2.2. Organic carbon (OC %)

In the past, SOC concentration wasprimarily measured to evaluate soil ‘‘quality’’ (Gregorich *et al*., 1994; Pierce andMunson 2000; Shukla *et al*., 2006).Forest ecosystems contribute a lot of organic matter to soil in the form of leaves, twigs, stems, flowers and fruits, which after decomposition by microorganisms (Waksman*et al*., 1928) result in the formation of organic carbon and release of different nutrients (Schnitzer, 1991). The nature and amount of organic carbon produced after decomposition oflitter depends on the dominating tree species present (Vogt *et al*., 1986; Fu *et al*., 2004; Hobbie *et al*., 2006) and the characteristics of the area (Liski and Westman, 1997; Grisi *et al*., 1998; Zhong and Qigua, 2001; Cauteaux *et al*., 2001; Koch and Makeschin, 2004), which regulate the physical, chemical and biological properties of soils (Trasar-Cepeda *et al*., 1998). The mean OC values on lower middle and upper altitudinal gradient ranged between 2.6 (Northern aspect) to 0.92 % (Southern aspect), 2.46 (Northern aspect) to 2.01 % (North Western aspect) and 2.42(Eastern aspect) to 2.06 % (North Western aspect) respectively(Table. 4). Interaction values of OC for aspects and depthswere in the order of 2.73 –0.91 % (Northern&Southern aspects), 2.62 – 1.84 % (Northern & North Western aspects) and 2.55 – 1.77 % (North Eastern & Northern aspects) on lower, middle and upper altitudes respectively.Our results were in consonance with the average values for organic carbon reported by Aijaz, (2003) for different slopes, under forest landuse with surface and subsurface soils exhibiting OC values of 2.31 and 1.86 % respectively.

Sharma *et al*., (2004)reported that organic carbon content in Neogal Watershed of Northwest Himalayaexhibited a definite relationship with altitude of the area, its slope and the type of vegetation.The results of the present study are further confirmed by Singh *et al.* (2006) who observed that organic carbon was higher in surface layers as compared to sub-surface layers. There is a significant difference between the soil organic carbons content of varied landuses; with

forest land use depicting higher organic carbon content than cultivated landuse (Wills *et al.*, 2007).Organic carbon content is generally higher in the Northern aspects than the South facing slopes and it decreased with the increases in soil depth on both the aspects (Bhat, 2010).

5.1.2.3. Available Nitrogen

Nitrogen is an essential element for all growth processes inplants, especially in coldregions. If it is not available, theplant remains stunted and comparatively undeveloped.Ecologists have long considered temperate forest systemsto be limited by N availability(Mitchell and Chandler, 1939; Fenn *et al*., 1998).It is estimated that more than 90% of the soil N reserves are in the soil organic poolwhich acts as a potential source of soil available N through mineralization (Cheng*et al*., 1987; Xu*et al*., 1995). The processes of N uptake by vegetation and its periodic return to soilsis one of the basic features of forest ecosystems (Chen *et al*., 2000b). Soil N availability and net N mineralization and nitrification rates have been found to vary with tree species composition in temperate and boreal forests (Bargali *et al*., 1998; Zhong and Makeschin, 2004).

Soils under higher vegetation cover accumulate higher amounts of organic matter. This is also due to the fact that nitrification rates under high vegetation cover are normally low because of the inhibition of nitrifiers by acidity (Bormann and Likens, 1979). Increase in total N content, due to higher soil organic matter under high vegetation cover , has also been reported by Zinke (1962), Patric and Smith (1975)and Maggs and Hewett (1993). The removal of the canopy has been reported to increase nitrogen mineralization by increasing soil temperature (Marks and Bormann, 1972 and Stone, 1973), by increasing the frequency and intensity of wetting and drying cycles in the forest floor (Campbell *et al*., 1972), by increasing the availability of substrate for mineralization and by decreasing resource competition between heterotrophs and mycorrhizae (Gadgil and Gadgil, 1978).

The mean available N values on lower middle and upper altitudinal gradient ranged between 281 (Northern aspect) to 155 kg ha^{-1}(Southern aspect), 297 (Northern aspect) to 261 kg ha^{-1}(North Western aspect) and 305(Eastern aspect) to 272 kg ha^{-1} (North Western aspect) respectively (Table.4). Interaction values of available N for aspects and depths were in the order of 304 to136 kg ha^{-1}(Northern&Southern aspects), 324 to 244 kg ha^{-1} (North Western& Northern aspects) and 331 to 249 kg ha^{-1} (North Eastern & South Western aspects) on lower, middle and upper altitudes respectively. The values of the available N are within the range of 36.0 to 205.0 ppm with a mean value of 118.0 ppm reported by Verma *et al*. (1990) in some alluvial soils of Kashmir. Likewise the similar trend of decrease in N with depth reported in this study is in consonance with Sharma and Bhandari, (1992) who recorded respective mean available nitrogen content of158 and 138 ppm in the surface and sub-surface soils of Himachal Pradesh. The forest surface soils are generally higher in N levels as compared to sub-surface soils (Mandal et al., 1990; Ram and Singh, 1994and Walia et al., 1996). Since availability of N depends to a large extenton the amount and properties of organic matter (De Hann, 1977), the high amount of organic matter on some aspects in the upper altitude may also be the reason fortheir richness in N as compared to loweraltitudes.

5.1.2.4. Available Phosphorus

Available P is inevitable for the vital growth processes in plants. It is observed that P is found in all terrestrial systems in the form of organic and inorganic matter, with organic P forms being major available source of this element. Soil organic matter has the inorganic form of P which is transformed into insoluble form in many soils. The rates of weathering and input levels of plant residues control phosphorus availability to plants(Brown et al. 1994). The carbon–phosphorus andnitrogen–phosphorus ratios vary according to the parentmaterial, which depends upon degree of weathering (Paul and Clark 1996). The amount of availability of Pindicates the character of soil to allow specific

plants togrow at a particular site, which is also useful to identify thevegetation type of the area. It has been reported that a largeproportion of P is stored in the forms that are unavailable toplants (Murphy, 1958), for example, H_2PO_4, whichbecomes available at low pH values and suffers from fixation by hydrous oxides and silicate minerals (Soromessaetal., 2004). Smal and Olszewska, (2008) observed that total and available P content in the humus horizon in forest soils decreases with stand age, with higher values in young stands.

The mean available P values on lower middle and upper altitudinal gradient ranged between 6.94 (Northern aspect) to 3.75 kg ha^{-1}(Southern aspect), 10.97 (Northern aspect) to 9.17 kg ha^{-1}(Eastern aspect) and 10.81(North Eastern aspect) to 7.90 kg ha^{-1} (North Western aspect) respectively. Interaction values for aspects and depths of available P were ranged in the order of 8.30 –2.97 kg ha^{-1}(Northern&Southern aspects), 13.01 – 7.33 kg ha^{-1} (North Eastern aspect) and 12.89 – 5.76 kg ha^{-1} (North Eastern & Northern aspects) on lower, middle and upper altitudes respectively (Table. 4). The values of available P recorded in the present study aresimilar to those recorded by some other investigators(Sanchez, 1976; Gilmore and Mattis, 1981; Mandal *et al*, 1990 and Chen *et al*, 2004). Dwivedi *et al.* (2005) reported that the available phosphorus ranged from 2.35 to 25.66 kg ha^{-1} in some surface soils of Jammu and Kashmir.Vogt et al., (1986) who observed that mean P concentration did not reveal any significant difference between the tropical (0.05-0.11%), warm temperate (0.06-0.09%), cold temperate (0.01-0.12%) and boreal (0.08%) forests. Our results are also supported by Chen et al. (2000) who observed low Pin coniferous forest stands than in the adjacent grasslands.

5.1.2.5. Available Potassium

The mineral potassium (Exchangeable K) is found in soluble form in all parts of plants, and is responsible for the carbohydrate and protein formations. Potassium activates the enzymes of the plants, which in turn help in the metabolism of the plants, starch synthesis, nitrate reduction, and also plays a role

in sugar degradation. Potassium performs very vital processes like regulating transpiration and respiration, influencing enzyme action, and synthesis of carbohydrates and proteins, etc. (Brady, 1996). The decrease of K is caused by leaching and drainage, which results in the destruction of vegetation (Basumatary and Bordoloi, 1992). The mean available K values on lower middle and upper altitudinal gradient ranged between 262 (Northern aspect) to 203 kg ha^{-1}(Southern aspect), 302 (Eastern aspect) to 285 kg ha^{-1}(North Eastern aspect) and 302(North Western aspect) to 278 kg ha^{-1} (Northern aspect) respectively. Interaction values for aspects and depths of available K were ranged in the order of 272 –194 kg ha^{-1}(Northern&Southern aspects), 312 – 264 kg ha^{-1} (Eastern & North Eastern aspect) and 331 – 245 kg ha^{-1} (North Western & Northern aspects) on lower, middle and upper altitudes respectively(Table. 4). The values of available K recorded in the present study were within the range 135 to 320 kg ha^{-1} (mean value of 237 kg ha^{-1})reported by Rao *et al*. (2008)in the surface soils of Ramachandrapuram, Mandal soils. The of our study area are further confirmed by Gairola *et al*. (2012) who reported that available Potassium in Conifer mixed broad–leaved forests of Garhwal Himalaya exhibited a decreasing trend (75, 52 and 40 ppm), with respect to soils depths (0-10, 11-30 and 31-60cm). The availability of K increased with increase in altitude with a significant increase on higher altitude as compared to lower. Similar results of increase in K values with increase in altitude have been reported by Jha *et al*., 2002 and Dimiri *et al*., 2006 in Garhwal Himalaya.Dangwal *et al*. (2012) reported that available Potassium on different altitude ofPir Panjal and Siwalik (Rajouri) on Northern aspect of Hill base were 102,126 and 136 (500-700 m asl), Hill slope 98, 110 and 127 (700-900) and Hill top 136, 121 and 153 (900-1200masl) kg ha^{-1} at 0-10, 10-20 and 20-30 cm of soil depth respectively.

Since availability of K in soil is largely governed the composition of parent rock material, no specific reason could be assigned to its differential quantities at different altitudes and sites in various parts of Uttarakhand

Himalaya(Dimri *et al*., 2006).These workers further noted that total soil K varied on different altitudes and the higher content of available K was found in surface soil in the form of exchangeable K. Although Gupta and Sharma (2008) argued that the K is not much influenced by soil organic matter because it is not the direct supplier of K, the findings of Basumatary and Bordoloi (1992) and Boruah and Nath (1992) reasoned that a layer of organic matter significantly improves the retention of K in the soil.Gupta and Sharma (2008) also showed that N and organic C were positively correlated, chiefly because all these attributes are intimately linked with soil humus. Hebel, (1995) reported very high amount of exchangeable potassium coming from the decomposition of crop residue. According to him, the high available potassium in pasture lands could have been contributed by animal waste.

5.2. Plant community structure and distribution pattern

The phyto-sociological analysis of forests is imperative to understand the composition and function of a particular vegetation complex. The structure and distribution of trees, shrubs and other ground flora are very sensitive to changes within a range of short distances and major factors influencing these changes are bio-edaphic. The most influential factors are those expressed in or near the soil surface. These factors exert strong influences on plant development which in turn improves the micro-habitat by regulating the community structure and ecosystem functioning (Munshower, 1993).

The holistic view of the vegetation data (Table. 5) envisages that in all 61 plant species recorded from the three altitudinal gradients belonged to 53 genera which were represented by 25 families (Table. 5). Though this number seems to be less as compared to those reported from many temperate forests (Semwal, 2010;Bharali *et al*., 2011 and Zegeye*et al*., 2011), the plant species abundancereported from the study area is much greater than that documented from ManangValley,Nepal(Ghimire*et al*., 2008), temperate/subalpine coniferous forests of Arunachal Pradesh (Behera*et al*., 2002) and temperate old growth

evergreen broad leaved forests in Japan (Manabe *et al*., 2000). Out of the total 61species recorded from the three altitudes of Kandi Range, 5 were trees, 17 were shrubs and 39 were grasses and herbs. Thus, the species composition of the vegetation in the study area followed a similar trend of grasses and herbs >shrubs >trees as reported by Dar, (2011) in Branwar temperate coniferous forests of Kashmir which comprised 5 tree, 7 shrub and 64 grass and herb species. Paul, (2008) also reported the identical trend from temperate broadleaved Rhododendron forest of Western Arunachal Pradesh, but with higher representation of trees (26), shrubs (40) and grasses and herbs (56).

The floristic composition at different altitudes varied greatly with 1600-2000m elevation comprising highest species richness of 45 species, followed by 43 at 2000-2400m and 32 at 2400-2800m (Table. 5). While tree and shrub species richness followed the order as 1600-2000m > 2000-2400m >2400-2800m altitude, the grass and herb species richness was in the order of 2000-2400 > 2400-2800 >1600-2000m altitudes. This variation in species among the different altitudes may be attributed to the aspect variation, edaphic characteristics and anthropogenic stress in the study area (Fig.3 to 5, Table 3 & 4and 21& 22). Further, while highest herb species richness at 2000-2400m elevation may be due to canopy opening in this altitudinal range, the lower species composition at 1600-2000m may be attributed to heavy deforestation and change of land use pattern in this zone. The overall pattern of species richness exhibited inverse relationship with increasing altitude. Kharkwal*et al*. (2005) and Goirala *et al*. (2008) also recorded asimilar pattern of decreasing species richness along an altitudinal gradient in temperate and alpine zone of Central and Western Himalayas respectively. Several other workers have also reported similar pattern of decreasing trend in species richness and its regulation by altitude, slope and climatic factors (Kitayama, 1992;Odlandand Birks, 1999; Ellu & Obua, 2005; Wang *et al*., 2007;Ghimire*et al*., 2008and Sharma *et al*.,2009b).

5.2.1. Frequency (%)

The frequency of the existent species varied on all the aspects at each of the three altitudinal gradients (Table 6, 8 and 10).Among the trees*Cedrus deodara* was the most recurrent (Lower and Middle altitude) species on lower altitudinal range and *Pinus wallichiana* appeared to be more frequent(Middle and Upper altitude) the main recurrent species on middle and upper altitudinal ranges. Similarly, amongst the shrub species while *Crataegus ambigua* exhibited highest frequency value of 60% on North Western slopes at lower altitudinal range, *Cotoneaster falconeri* and *Viburnum nudum* displayed maximum frequency of 83 and 67% on Northern aspect at an altitude of 2000-2400 and 2400-2800m respectively. The general pattern of frequency of all the species (all along the altitudinal gradient) particularly that of grasses and herbs envisages the occurrence of secondary succession on the entire forest range. These results corroborate with those of Soni and Vasistha (1986)who reported that any disturbance in ecology of natural forests is followed by the secondary succession with dominance of undergrowth vegetation.

5.2.2. A/F ratio:

Hubbel *et al*. (1999) reported that the dispersal limitation is an important ecological factor for controlling species distribution pattern and a connection between biotic and abiotic factors. A number of species found in the Himalayas show a varying pattern of distribution with extension of climactic gradients enabling several of them to realize their fullest range of elevational adaptability (Sharma et al, 2009b). An analysis of dispersion pattern (A/F ratio) indicated that maximum species had contagious distribution at lower, middle and upper altitudes on all the aspects except for middle and upper altitudes at north western and Northern aspects which respectively follow random distribution(Table. 6, 8 & 10). In case of shrubs a similar pattern of contagious distribution was followed in almost all aspects with exception to North Western and North Eastern aspects which followed random pattern at middle altitude. At upper altitude the North

Western aspect followed regular distribution. In case of herbs the contagious pattern of distribution was observed at all the aspects and altitudes surveyed, sampled and quantified during the period of study.

The preceding observations are supported by the studies carried out by various workers(Kumar & Bhatt, 2006 and Singh *et al*., 2009). In all the three altitudinal gradients while most of the species exhibited clump or contagious distribution, only few species showed regular and random distribution.Paul (2008) has reported clumpdistribution of plant species in temperate broad leaved Rhododendron forest of Western Arunachal Pradesh. Mehta *et al*. (1997) has reported contagious distribution from temperate forest of Garhwal Himalayas. Similarly, Semwal, (2010) has reported that although few species exhibit regular distribution but random distribution is a common feature in temperate forest of Kedarnath WildlifeSanctuary in Central Himalaya. Odum (1971) has emphasized that contagious distribution is the commonest pattern in nature, which is due to small but significant variations in the environment. The randomdistribution is found only in very uniform environmental conditions whereas, the regular distribution occurs where severe competition between the individuals exists (Panchal&Pandey, 2004).

5.2.3. Plant density

The change in density was analogous to that in frequency. The total density of trees, shrubs and grasses &herbs ranged between 101 to 1131, 189 to 3,960, and 70,800 to 2,78,400 individuals ha^{-1}. These results indicate that each of the species present has adapted to the edaphic and climatic conditions and established successfully on the available aspects along the vertical gradient. Among the tree species, while maximum density of 683 individuals ha^{-1} was exhibited by *Pinuswallichiana*on North Eastern aspect at 2000-2400m altitude, the minimum density of 29 individuals ha^{-1} was recorded for*Juglans regia* on Southern aspect at an altitude of 1600-2000m (Table. 6, 8 & 10). The density of shrubs varied with both aspects and the altitudes. *Parrotiopsis*

*jacquemantiana*recorded the highest density of 824 individuals ha^{-1} at Northern aspect at lower altitude while *Rosa canina*and *Rosa brunonii*exhibited lowest density 25 individuals ha^{-1} on North Western and Northern aspect at middle altitude. Similarly, in case of grasses and herbs, while highest density of 59,200individuals ha^{-1} was observed in *Ranunculus hirtellus* on Northern aspect at upper altitude,the lowest density of 1500 individuals ha^{-1} was recorded for *Hypericum perfoatum* and *Potentilla reptans* on Southern aspect at lower altitude and Northern aspect at upper altitude.

The density of trees recorded in the present study was less as comparable to the density values of 192 to 1852 individual ha^{-1} reported by Paul (2008) from Himalayan forests in Arunachal, 420 to 1640 individual ha^{-1} from temperate forests of Kumaon Himalayas (Saxena &Singh, 1982) and 652 to 1228 individual ha^{-1} from Garhwal Himalayas(Kumar*et al*., 2009). Many other workers have reported much higher density values. For instance Bhandari &Tiwari,(1997) reported density of 1570–1785 individual ha^{-1} from Himalayan temperate forests ofGarhwal,whileKunwar&Sharma,(2004) recorded 2090to 2100 individual ha^{-1}inDolpa District of mid-west Nepal, indicating that our study site (Kandi Forest Range) is successionally more advanced than the reported Himalayan Forests.The density of shrubs recorded in the present study is within the range of504 to 3576 individual ha^{-1} reported by Paul (2008) from temperate forest of Western Arunachal Pradesh.However, it is much lowerthan that reported by Koirala (2004) fromTinjure -Milke region, Nepal.The grasses and herbs also show a similar pattern with maximum density of 59200individualsha^{-1}being almost similar to 45,000 individuals ha^{-1}reported by Paul(2008) from Arunachal Himalaya.However, the totaldensity of grasses and herb recorded in the present study is much higher as compared to that reported by other workers from Himalayan forests (Kumar & Ram, 2005;Kharkwal&Rawat, 2010 and Uniyal, 2010). The highest density and species richness of grasses &herbs and shrubs in lower and middle altitudes respectively can be attributed to the open canopy in

Kandi Forest Range.The altitude, habitat and soil characteristics may also be the mainfactors which eventually lead to the variations in speciesdensity.

5.2.4. Basal area

Analysis of basal area (BA) of tree species (Table 6) shows that the maximum basal area of 81.87 m^2 ha^{-1} was exhibited by *Pinuswallichiana*on South Western aspect at an altitude of 2400-2800m followed by 69.19 m^2ha^{-1} for*Cedrus deodara* on North Western aspect at 1600-2000m. The minimum BA of 0.47 m^2 $ha^{-1}$was recorded for *Robinia pseudoacacia* on Southern aspectat an altitude of 1600-2000m. The total basal area of trees on lower altitudinal range varied between 1.94 to 97.27 m^2 ha^{-1}on Southern and Northern aspects respectively, 11.93 to 37.48 m^2 ha^{-1}on north western and Northern aspects at 2000-2400 m altitude and 29.27 to 98.62 m^2 ha^{-1}on north western and South Western aspects at 2400-2800 m altitude respectively. The less basal area in Southern aspect at lower altitude could be attributed to the absence of conifers and sparse distribution of other tree species on this aspect. The overall basal area of tree species was 1.40 and 2.05 times higher on upper altitudinal gradient than that of lower and middle altitudinal range. The higher basal area on 2400-2800m altitude may be attributed to the presence of higher number of individuals with larger girth and less deforestation at this elevation as compared to other altitudes.

The basal area values recorded in present study fall within the range of 9.38 to 137.45 m^2 ha^{-1} reported by Paul (2008) from Himalayan forests of Arunachal as well as 17.9 to 180.1 m^2 ha^{-1} reported from other Himalayan temperate forests(Baduni, 1996, Ghildiyal *et al*., 1998, Sharma & Baduni, 2000and Ram *et al*., 2004).While maximum basal area of 98.62 m^2 $ha^{-1}$was recorded from 2400-2800m altitude (South Western aspect), theminimum basal area of 1.94 m^2 $ha^{-1}$was recorded from lower altitudinal range of 1600-2000m (Southern aspect). The less basal area on lower altitude could be due to less density, sparse distribution of tree species and especially to the fact that the major portion of area in this altitudinal range is facing towards the South. The

higher basal area in upper altitude may be due to less impact of deforestation, higher density of trees and more favourable micro climatic and edaphic condition for growth. Moreover, the variation in basal area between all the altitudes and aspects may be due to theinfluence of anthropogenic factors and presence or absence of higher number of individuals having larger girth which contributed to the greater basal area.

5.2.5. Importance Value Index (%)

Importance Value Index indicates the dominant species and their importance in a community organization. Among the trees, the maximum IVI of 266% was recorded for*Cedrus deodara*on North Western aspect followed 236% for*Pinus wallichiana*on South Western aspectat upper altitudes and minimum of 30%*Robinia pseudoacacia* on North Eastern aspect at middle altitude. Among the shrubs *Indigofera heterantha* dominated the middle altitude with highest IVI of 131.69%on North Eastern aspect followed by *Cotoneaster falconeri* with IVI of 106.08% on North western aspectat upper altitude. The lowestIVI of 5.46% was recorded for *Rosa webbiana* on Southern aspect at upper altitude. Similarly, in case of herbs *Ranunculus hirtellus*recorded the maximum IVI of 60.72% and 60.39% on Northern aspect at upper and middle altitudinal gradients. The minimum IVI of 2.51% was recorded for*Plantago lanceolata* at middle altitude on Eastern aspect. The higher values and presence of *Ranunculus hirtellus* on middle and upper altitude may be due to the fact that this species has formed its ecological niche and out competed other species from these places.

The critical examination of table (7, 9& 11) envisages that the three altitudinal gradients varied in dominance of species with *Cedrus deodara, Indigofera heterantha* and *Cuminum cyminum*forming a dominant community on lower altitude, *Pinus wallichiana- Indigofera heterantha* and *Ranunculus hirtellus* on middle altitude and *Pinus wallichiana*, *Viburnum nudum*and*Ranunculus hirtellus* as principal association on the upper altitude. The IVI values of these

plant community associations are higher than that reported by Majila & Kala, (2010) from temperate forest of Uttarakhand on four geographical aspects.

5.2.6. Diversity index and concentration of Dominance

Species diversity is of considerable importance in the study of plant succession since variations in diversity are presumed to be positively correlated with the stability of various biotic and abiotic components of ecosystem. The diversity of vegetation patterns and the spatial variation of Shannon–Weiner index of plant communities might be the simple but effective indicator for predicting the species richness (Jiang *et al*., 2007).The values of Shannon-Wiener's diversity index ($H^{/}$) recorded for trees in the present study ranged between 0.177 on North Western slope to 0.364 on Southern aspect. The values for shrubs were in order of 0.188 on North Western aspect to 0.234 on Northern side. Similarly, the range of values for grasses and herbs fell within the range of 0.149 on Northern aspect to 0.234 on Southern aspect. The altitudinal variation in species diversity was also evident with average values of 0.252, 0.322 and 0.304 for trees, 0.214, 0.283and 0.213 for shrubs and 0.201, 0.178 and 0.188 for grasses & herbs on lower, middle and upper altitudes respectively(Table.12& 14).

The preceding results reflect that the altitude itself represents a complex combination of related variables closely correlated with numerous edaphic factors viz. soil nutrient and substrate stability (Ramsay and Oxley, 1997). Within one attribute the co-factors like topography, aspect, inclination of slope and soil type further effects the forest composition and its diversity (Holland and Steyn, 1975).The average Shannon- Wiener Index ($H^{/}$) of species diversity was 0.293, 0.237 and 0.189 for tree, shrubs and grasses and herbs (Table. 13). These values were lower than the range (1.16 to 3.4)reported for temperate forests(Knight, 1975 and Monk, 1967). Sharma *et al.* (2009a) reported that Shannon- Wiener Index (H') of species diversity to be 0.99 in *Abies pindrow* forest. Similarly, Jiangming *et al*.(2008) found Shannon- Wiener Index (H') of species diversity to be 3.48 in subalpine broadleaved forest of western Sichuan (China). In mixed

Larix chinensis forest of China, Liyun et al.(2006) found Shannon- Wiener Index (H') of species diversity to be 4.75. Comparing these values with the present study, the values of Shannon – Wiener Index (H') of species diversity were far low. This decrease in species diversity of the Kandi forest may be due to the over exploitation of trees and habitat destruction.

The range of values for diversityindex recorded in the present study falls withinthe limitsrecorded for temperateforests of Himalaya and other parts of the world (Ralhan *et al*., 1982; Upreti *et al*., 1985;Behera*et al*., 2002 and Paul, 2008). But, more than that reported by Kunwar & Sharma (2004) and Sharma *et al*. (2009a) from temperate forest of Nepal and Garhwal respectively. The low Shannon-Wiener diversity value recorded in Kandi forest range indicates that the ecological structureis less complex (Odum, 1971). The variation of Shannon–Weiner index along the altitudinal gradient also suggests an unimodal relationship between the species richness and the environmental condition withregard to altitudinal factors (Jiang *et al*., 2007).

The proceeding results not only indicate that diversity index of all the life forms decreased with increasing altitude but also varied consistently on all the aspects. Pavon *et al*. (2000) has also reported that the diversity of life form usually decreases with increasing altitude and vary few life forms remain at extreme altitudes. The variation in diversity with altitude can also be attributed to differences in resource availability on the various elevational gradients (Table. 14&15).The values for Concentration of dominance for trees ranged between 0.112 on Southern aspect at lower altitude to 0.399 on North Western aspect at lower altitude (Table. 12). With respect to shrubs the values ranged between 0.007 on Northern aspect at lower altitude to 1.00 on Northern aspect at upper altitude. Similarly, for grasses and herbs the values ranged between 0.003 on Eastern aspect at lower altitude to 0.030 on Northern aspect at middle altitude. The average values of concentration of dominance (C) for trees, shrubs and herbs were in order of 0.266, 0.169 and 0.010 respectively (Table. 12).These values are

lower thanthe species diversity for all the life forms recorded in the entire Kandi forest indicating that concentration of dominance was inversely related with species diversity index (H). These results of reduced concentration of dominance with increasing diversity have been advocated to be associated with advancement to increased stability (McNaughton, 1967). Pandey and Singh, (1985) have also reported decrease in concentration of dominance with increase in species diversity in disturbed ecosystem of Kumaon Himalaya. The values of C recorded in present study are almost in consonance withthe range recorded by Risser and Rice, (1971) and comparable with the values reported for temperate forests (Singh & Singh, 1986). Whittaker (1965) reported that the values of concentration of dominance for certain temperate vegetation ranged from 0.19 to 0.99.

5.2.8. Index of Richness and Evenness:

Species richness (an easily interpretable indicator of biological diversity) isone of the main traits of communities because it influencestheir stability, productivity, and susceptibility to invasion(Peet, 1974; Hooper *et al*. 2005; Duffy et al. 2007; Gamfeldt and Hillebrand,2008). Korner (1999) argues that elevation gradients can contribute important insights into developing a general theory of species richness. Many types of environmental changes influence the processes that can both augment or erode the diversity (Sagar *et al*. 2003). Ellu and Obua (2005) have suggested that different altitudes and slopes influence the species richness and dispersion behavior of tree species. Moreover, it has been pointed out that altitude and environmental variables are detrimental to species richness and differences in isolation period may occur according to altitude thereby forming a range of microclimates in multifaceted landscapes (Sharma *et al*., 2009a).

The analysis of data (Table 12) reveals that the maximum richness index of trees, shrubs and grasses & herbs was in order of 0.433 on Southern aspect for trees at lower altitudinal range, 1.449 on North Western aspect for shrubs at lower altitude and 1.755 on Eastern aspect for grasses & herbs at middle altitude. The

total species richness index combined for all life forms and average Margalef index of richness were 44 and 2.372 across the altitudinal gradient of 1600-2000 m asl. At the middle elevation (2000-2400 m) the species richness and Margalef indexwere 43 and 1.932 respectively. The minimum values of these parameters (32 and 1.347) were encountered at upper topographic gradient of 2400-2800m asl. A similar pattern of decrease in species richness with increase in altitude has been reported by Rawal*et al*. 1991; Rathord, 1993;Burni, 1995 and Kumar & Ram, 2005. The values of species richness index recorded in the present study fall well within the range of 1.03-1.24 for trees, 0.43-0.59 for shrubs and 1.62-2.25 for grasses and herbs reported by Sanjeeb *et al*. (2011)in Temperate mixed Rhododendron forests of Arunachal Pradesh.

Species evenness (how evenly abundance is distributed among species) is of great importance to determine the ecosystem functioning. High evenness can increase invasion resistance, below-ground productivity and reduce total extinction rates (Smith *et al*., 2004). In addition, species richness of a taxon is not only sufficient to express diversity but the equitability is also an important factor because communities vary in properties of the total importance of the species and share their functional contributions(Tilman, 2000). Where richness and evenness coincide, i.e., a high proportion of plant species in the vegetation are restricted, community of that area is supposed to have evolved through a long period of environmental stability(Zobel*et al*. 1976).The values for evenness index for trees ranged between 0.25 (North Western) to 0.49 (North Eastern) at 1600-2800m altitude (Table. 12). While evenness values for shrubsranged between 0.00 (Northern) to 0.31 (North western), the values for grasses and herbs ranged between 0.04 (Eastern) to 0.14 (Northern) along the altitudinal gradient of Kandi forest range. These results further indicate that equitability/evenness with respect to aspect and the altitudinal gradientwas 0.623 for the entire forest range. The comparatively lower value of equitability (0.177) on lower altitude indicates that the individual grass and herb species distribution is higher at this elevation. This

may perhaps be due to intermediate level of disturbance as indicated by deforestation status at this altitude (Table. 20 & 21). Kharakwal*et al*. (2013) hasattributed this situation toconditional presence or absence of functional relationship between the species. The results of the present study also conform to hypothesis of Magurran (1998)who suggested that the equitability would be lower in an area in which the species are divided amongst many genera as opposed to one in which most species belong to the same genus which may be divided amongst many families as opposed to few.

5.2.10. Similarity and dissimilarity indexes:

The similarity or dissimilarity of plant community structure and composition reflects not only the diversity of local habitat, but also the complexity of community to a certain extent (Ma, 1994). It also reflects the rate of charge of species composition along the varying topographic and environmental gradients. The dominant species changes according to their adaptability and growth requirements(Nautiyal and Bhat, 1999).The obvious environment gradients always support different species composition and richness among vegetation types at different altitudes (Chen 1964; Wang 1980). The result derived from the average value of dissimilarity indexes of respective layers at different aspects on various elevations in the present study (Table.16 to 18) reflects the heterogeneity and complexity of local habitat. The data further exposed that there existed comparatively high dissimilarity between Southern and Northern aspects for all the life forms. The overall similarity co-efficient between various elevations was in order of 75, 57 & 80 % (Trees), 67, 40 & 57 % (Shrubs) and 54, 46 & 46 % (Herbs) between lower and middle, lower and higher and middle and higher altitudinal gradients.

The preceding results suggest that the community similarity coefficients of all the altitudinal zones thus exhibited close relationship with 29% of species being common among the altitudinal gradients. These results are in agreement with Sunil *et al*. (1998) who stated that the sites at 2000and 2300 m of

altitudeexhibited similarity co-efficient of 55.64%, while the sites at 1400and 2600 m were exclusively dissimilar in species composition. The index of similarity among stands at 2100 m altitude and stands at 2140 m altitude recorded highest similarity index (85.7%) whereas stands at 2000 m altitude and 2140 m altitude had recorded lowest similarity (28.57%).

The greater dissimilarity between plant communities at lower and higher altitudes in the present study reflects a complex species composition. Low similarity between various altitudes with sudden change in species composition also reflects a striking variation in microhabitat. The severity of biotic disturbance noticed at lower and middle altitudinal zones may have contributed to such behavior of the vegetation. A similar result of altitudinal complexity of plant composition has been reported by HAO Zhan-qing*et al*. (2002) from Northern Slopes of Changbai Mountain in China and Inamati*et al*. (2005) in Devimane Ghat in Uttara Kannada, Karnataka.

5.2.11. Pearson correlation coefficient between different vegetation and soil parameters.

Correlation studies between different vegetation and soil parameters (Table. 22) revealed that the bulk density was negatively (significant) correlated with WHC, OC, available N, P, K and Evenness index, but positively (significant) correlated with pH. Electrical conductivity exhibited positive (significant) correlation with available N. pH showed Negative correlation (significant) with WHC, OC, available N, P, K and Evenness index. The water holding capacity showed positive correlation (significant) with OC, available N, P and K. Organic carbonwas positively (significant) correlated with available N, P, K and Evenness index.Available N revealed positive (significant) correlation with available P, K, and Evenness index. Similar relationship between soil variables has been reported by Gupta and Sharma, (2008) who attributed the situation to intimate link of soil characteristics with soil humus.According to Jha *et al*. (1984), if

Table: 22. Pearson correlation coefficient between different vegetation and soil parameters.

Parameters	Bulk Density (g cm^{-3})	EC (μScm^{-1})	pH	WHC (%)	CaCo3 (%)	OC (%)	Av. N (Kg/ha)	Av. P (Kg/ha)	Av. K (Kg/ha)	H	C	R	E
Bulk Density (g cm-3)	1												
EC (µScm-1)	-.737	1											
pH	.946**	-.809	1										
WHC (%)	-.913*	.701	-.972**	1									
CaCo3 (%)	-.092	-.417	-.142	.229	1								
OC (%)	-.976**	.789	-.971**	.949**	.053	1							
Av. N (Kg/ha)	-.910*	.816*	-.984**	.960**	.100	.970**	1						
Av. P (Kg/ha)	-.882*	.598	-.894*	.869*	.317	.919**	.918**	1					
Av. K (Kg/ha)	-.935**	.745	-.975**	.924**	.246	.949**	.961**	.949**	1				
H	.643	-.025	.548	-.624	-.671	-.532	-.442	-.546	-.567	1			
C	-.432	.408	-.657	.725	.423	.491	.625	.434	.575	-.447	1		
R	-.213	.189	-.093	-.099	-.010	.057	-.011	.085	.216	-.148	-.258	1	
E	-.871*	.599	-.853*	.770	.321	.855*	.840*	.947**	.945**	-.560	.344	.399	1

H= Diversity index; C = Concentration of Dominance; R = Richness index; E= Evenness Index

***. Correlation is significant at the 0.05 level**
****. Correlation is significant at the 0.01 level**

the soil is rich in SOM content, it is definitely rich in total N, P and K contents.Basumatary and Bordoloi (1992) have also supported this hypothesis and reasoned that a layer of organic matter significantly improves the retention of K in the soils. Gairola, (2012) concluded that organic C showed a positive correlation with total N (0.840), available P (0.520) and available K (0.520). There is considerable evidence that temperate broad-leaved and conifer tree species alter soil C and N dynamics (Binkely, 1995). A study by Cote et al. (2000) concluded that both organic C and N were significantly affected by factors such as stand type, stand age, and the interaction between age, species composition, and soil properties.

5.3. Deforestation status

The human induced disturbances viz. deforestation has a greater influence on the structural development of forest vegetation with important implication on for silvicultural decisions (Putz et al., 2001; Harvey and Brais, 2002; Chomitz et al., 2007). The environmental functions and services of the forest ecosystem are reduced or even lost, depending on the extent of deforestation (Sponsel et al. 1996). Moreover, deforestation also means the loss of other renewable natural resources such as valuable non-timber forest products and other ecosystem services. The data of deforestation status across the Kandi forest range (Table.20&21 and Fig. 6) clearly envisages that this forest has suffered from illicit felling (plates. 9) and remains threatened by environmentally detrimental fragmentation. This process is exacerbated by a gradually increasing population, which has extended its habitation to the forest fringe and as such puts tremendous pressure on the existing growing stock. The density of visibly cut stumps was (491ha^{-1}) in the 2ndaltitudinal zone (2000-2400 m)followed by266 ha^{-1} in the 3rdaltitudinalzone(2400-2800 m),whereas 1st altitudinal zone (1600-2000 m)recorded195 ha^{-1} cut stumps. The illicit felling in the Kandi Forest has also resulted in the loss of basal area which together with decrease in density has in turn contributed to decrease in the importance of two conifers. The data recorded

shows that the average IVI values for *Cedrus deodara* and *Pinus wallichiana* were 127 and 173 on deforested patches and 141 and 159 on silviculturally managed forest area. The decrease in IVI of the two species in deforested patches can obviously be attributed to loss in density and the basal area.

The IVI values recorded in the present study are in consonance with the values recorded by Dar, (2011) in Branwar Forests of Kashmir. Ahmed, (2002) has also confirmed that illicit felling and encroachment in forests leads to decrease in IVI of climax species. Deforestation has direct impact on tree diversity and according to Myers, (1993) the extent of catastrophic ecological problems are primarily due to deforestation which ultimately leads to desertification and loss in biodiversity with many plant species facing extinction (Joshi et al., 2003; Chomitz et al., 2007) due to loss and fragmentation of habitats and introduction of invasive species. Joshil and Kumar, (2008); while compiling the effects of deforestation on species composition in Ji-Om forests of Kumaun Himalaya, found that the pattern of the species composition changed in forested site to deforested site. The moderate level of disturbance increased the species richness (25 to 31 species), but severe disturbance caused a drastic reduction (12 species).

5.4. Regeneration Status:

Plants maintain and expand their populations in time and space by the process of regeneration. Population dynamics of plant species can be described by demographic variables such as the recruitment, mortality and growth rates of individuals (Watkinson, 1997) and the balance among these variables has been found to regulate the dynamics and the structure of a population (Kohyama and Hara, 1989). Regeneration of any species is restricted to a peculiar range of habitat conditions and the extent of those conditions is a major determinant of its geographic distribution (Grubb, 1977). The natural regeneration of a tree species howeverdependslargely on the production and germination of seeds and the establishment of seedlings and saplings (Rao, 1988).

The pattern of population dynamics of seedlings, saplings and adults of a plants species can exhibit the recruitment profile, which is used to determine their regeneration status (Bekele, 1994). A population with sufficient number of seedlings and saplings depicts satisfactory regeneration behaviour, while inadequate number of seedlings and saplings of the species in a forest indicates poor regeneration (Tripathi and Khan, 2007). The density of seedlings and saplings are considered as regeneration potential of a species. Good and Good (1972) and Duan *et al*, (2009) considered three major components viz., ability to initiate new seedlings, ability of seedlings and saplings to survive and ability of seedlings and saplings to growfor successful regeneration of a species.

The population structure of *C. deodara* and*P. wallichiana* in terms of the proportion of seedlings, saplings and adults varied greatly in the three altitudinal gradients of the study area (Table. 21; Fig. 7 to 9). The relative proportion of deodar seedlings was recorded highest in Northern aspect (middle altitude), while, it was lowest in Northern aspect (upper altitude). On the other hand, the relative proportion of saplings and adults was highest in Northern (middle altitude) and Northern (lower altitude) aspects followed by North Eastern (upper altitude) and North Western (lower altitude) aspect. The distribution of seedlings, saplings and adults along the altitudinal gradient also showed variations for *P. wallichiana*. While the number of seedlings of this pine was maximum(1517 ha^{-1}) on middle altitude (North Eastern aspect), the lowest regeneration of this species (55 seedlings ha^{-1}) was recorded at lower altitudinal gradient on North Western aspect. In Norway spruceforest of Slovenian Alps, Diaci*et al*. (2005) reported that mean seedling density of *Piceaabies*was as high as 2,23,500 individuals ha^{-1}. Comparing these values, the seedling density of conifers recorded in Kandi forest was low. In *Abies spectabilis*forest on the northern slope of the Manang valley (north-central Nepal), Acharya (2004) reported seedlingdensity of *Abies spectabilis*to be 3,923 individuals ha^{-1}which is lower than that recorded in the present study.

In general the critical examination of status of regeneration reveals that the recruitment of deodar was in the good category with few exceptions of fair and poor on some aspects of lower and higher altitude. In case of *Pinus wallichiana* the overall regeneration was in fair to poor category with exception of good status at the altitudinal range of 2000-2400m. At lower and higher altitudes the total regeneration was mostly in the category of fair. Similar results have been reported by many workers from Himalayan forests (Negi, 1979; Singh and Singh, 1992).The profuse regeneration of both the conifers can be attributed to the presence of abundant shrub cover which often plays a vital role in increasing regeneration rate (Garcia *et al*., 2000). Strong nurse plant relationship between conifer seedlings and shrubs has also been reported by Callaway, (1995). Thus since places dominated by shrubs act main regeneration niches, they should be used as transplanting microsites that facilitate the establishments of recruits of climax species (Gomez-Aparicio *et al*., 2004).

The results further indicate that the contribution of *P. wallichiana* seedlings was highest to its total population followed by adults and saplings as compared to *C. deodara* for which the order was in the sequence of seedlings > saplings > trees. Such type of variation in proportion of seedlings, saplings and adults was observed in all study stands. These differences in relative proportion of seedlings, saplings and adults among the three study stands may be due to the interactive influence of an array of biotic and abiotic factors (Khumbongmayum, *et al*., 2005). According to Jones *et al*, (1994), seedling layer in various forests differs in composition from their respective over storey. Tasfeye *et al*, (2010) also reported similar variation in seedling density among species along altitudinal gradient in dry Afromontane forests of Southern Ethiopia. The critical examination of the data clearly affirms that the seedling pool of *Cedrus deodara* were abundant with stable structure and as such its population is expected to expand in the community and replace *Pinuswallichiana* at many places in the Kandi Range Forest.

During the study, it was also observed that very few seedlings were found beneath the conifer canopy, but abundant in open places particularly in forest margins. This may be because of the reason that light and moisture are absolute requirements for germination of seeds (Blazich, 1991). The presence of larger number of deodar seedlings across the forest range might be attributed to its easy germination than seeds of kail pine which has hard seed coat that hinders its germinating capability. Similar observation was reported by Shrestha (2003) for *Quercus semecarpifolia*inthe Himalayan region. Poor to fair regeneration status of *Pinus wallichiana*was due to slow vegetative growth during the seedling stage as compared to *Cedrus deodara*(Hillal Ahmad *et al*., 2012).

Chapter – 6

Summary and conclusion

Understanding how biodiversity is organized across space and time has long been a centralfocus of ecological and bio-geographic studies. Altitudinal patterns of community composition and its richness is one ofsuch striking patterns in the landscape. But, despite its ecological importance as aheuristic natural parameter for development of ecological theories, the emergentpatterns,the mechanisms that structure it is poorly understood. This is partly because ofthe complex relationships of species to geographic locationswhich is better understood by analyzing taxonomic richness as a metrics of diversity.The current studyapplies a plant functional type approach with a main objective to determine the response of vegetation to local topographic attributes (altitude and slope) and some soil properties known to structure the variance in the relative abundance and dominance of plant species in the natural forests. The study also focuses on to determine the status of deforestation and to understand the regeneration trends so as to predict the future crop structure of the selected forest.

The thesis encompasses five chapters

Chapter Ipresentbrief overview of the ecological importance of evaluating community structure of a forest, the definition of the problem, purpose of the study and its objectives.

Chapter IIcovers the research conducted, in the country and abroad on variation in phyto-sociological aspects of community structure, deforestation status, regeneration trends and the edaphic parameters along an altitudinal gradient. The description of the natural conditions of the area where the study was conducted is rendered in **Chapter III**. The area under study is located between 34^0 21´ to 34^0 26.05´North latitude and 74^0 21´ to 74^0 32East longitude. The area in question lies between an altitudeof 1600 to 2800m asl. In general the morphogenetic types that characterize the landscape of the selected forest range are complex in structure, highlighted by medium-sized mountains with rounded

parallel ridges separated by depressions and elongated hillock relief (chine type). In terms of geography, the studied area is classified with two extreme climatic variations, the moderate summer and the harsh winter with a respectivemaximum and minimum average annual temperature of -3 ºC and 25 ºC. The area receives an average annual rainfall of 630 mm, most of which is received in the form of snowfall.The soil characteristic to this area is alluvial, shale or slate type.

Chapter IIIalso presents the research methods and the materials used to study the community structure along an altitudinal gradient of the study site.

To achieve the goal and various objectives, the observations were made in the year 2011-12 in selected forest range, during which botanical measurements were finalized and floral herbaria prepared so as to identify existing flora. The phyto-sociological study was conducted using the surveying method and the qualitative indicators identified in selected site were determined based on density, frequency and abundance of each species in the floristic structure. The soil characteristics, deforestation status and regeneration trends in the selected forest were evaluated as per standard methodology.The analytical methodology was applied in accordance with standard procedures. The data were interpreted statistically by analysis of variance.We also calculated the correlation coefficients between the soil characteristics and the diversity attributes of community structure.

Chapter IV and V present the results and discussions of the study on plant community structure, diversity attributes, deforestation statusand regeneration trends in Kandi Range of Kamraj Forest Division of Kashmir. Thesummary of these results and discussions is presented as under(Fig. 10).

- The values of soil bulk density recorded in the present study varied greatly on aspects and altitudes. While the lowest bulk density (1.25gcm^{-3})was exhibited on Northern aspect at lower altitude, themaximum bulk density (1.38gcm^{-3}) was recorded on Southern at lower altitude. Higher values on Southern aspect may be attributed to rugged nature of these slopes and lack of vegetation which in turn are responsible for reduced weathering.

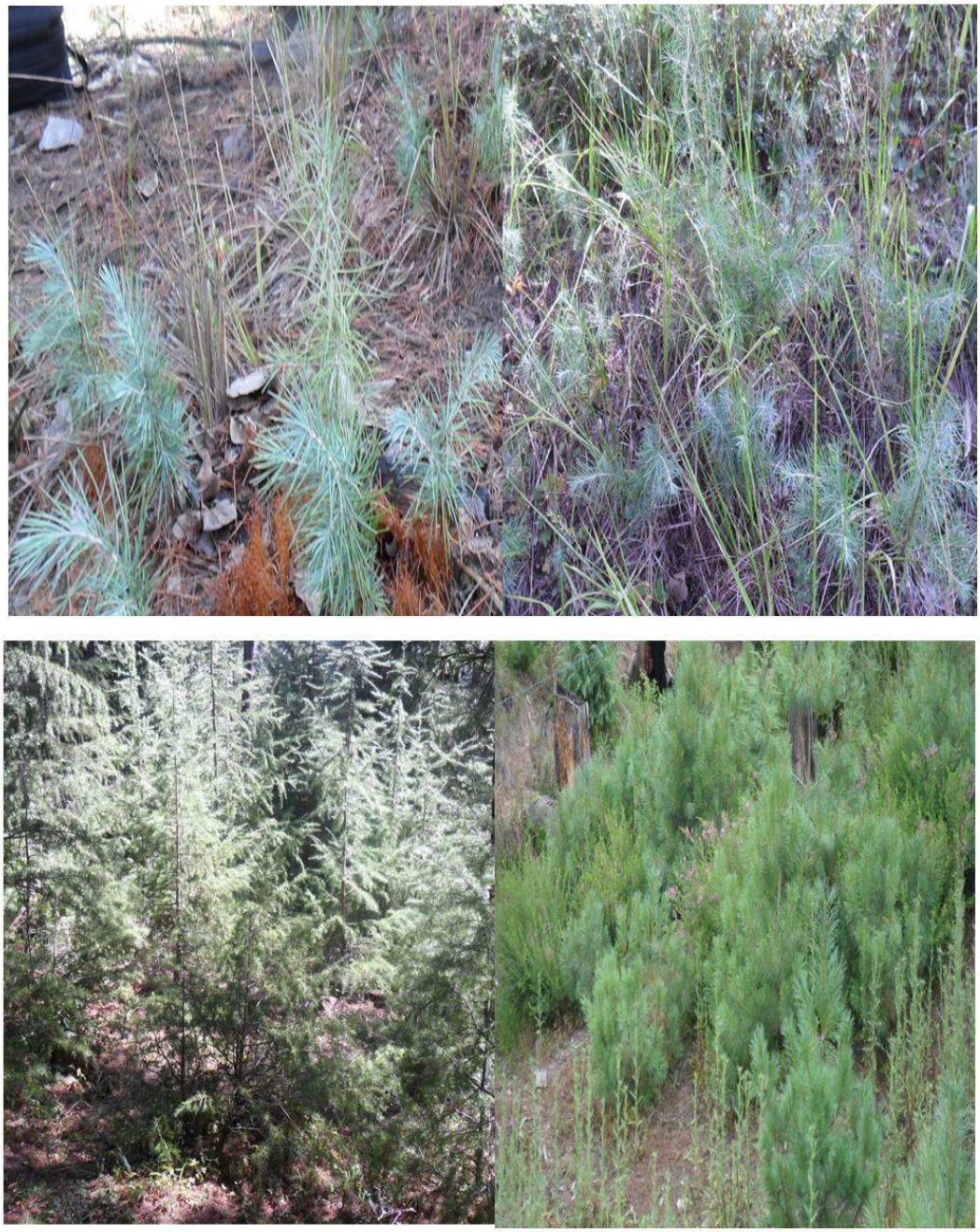


Plate: 10. Regeneration status of study area

- The results indicated a significant variation in soil electrical conductivity values across the aspects and altitudes. The lowest electrical conductivity values (97 μScm^{-1})exhibited by lower altitudinal range on Southern aspect may be attributed to the lesser release of ions on these slopes. On the other hand, the highest EC (122 μScm^{-1}) values on North Western aspect at middle altitude can be ascribed to larger amount of OM and greater release of ions upon its mineralization.
- The range of pH from 5.79 to 7.11 clearly indicated that the soil is acidic in reaction. There was not much significant variation in the pH values of different soil sample collected across the altitudinal range. While decrease in soil pH values with respect to altitude may be due to the accumulation of higher quantity of conifer litter which is generally more acidic in nature, the higher pH on Southern slopes as compared to other aspects may be attributed to the rapid decomposition of litter and the reduced tree cover.
- In the present study, the values of WHC increased with increasing altitude. The maximum water holding capacity ranged from 20% (Southern aspect)to 39 % (Northern aspect) on lower and upper attitudinal gradient respectively. The, sampling sites with higher vegetation exhibited higher capacity for holding water as compared to those with less vegetation composition. As a common phenomenon, the decrease in vegetation cover exposes the soil and increases the loss of moisture. Similarly, good vegetation cover and the subsequent accumulation of humus due to litter deposition resulted in retention of more water on northern slopes.
- The mean values of $CaCO_3$ at different altitudes recorded increasing trendand exhibited its peak on South Western aspect at upper altitudinal gradient. The decrease in base cationconcentration is geographically widespread in coniferous forests. The main reason for this low content of

$CaCO_3$ in coniferous forest soils has been ascribed to the acid deposition, leaching, uptake by forest vegetation and forest harvesting.

- The content of organic matter recorded at Northern (lower altitude), North Eastern (middle altitude) and Eastern aspects (upper altitude) aspects was higher as compared to other aspects. The upper altitudinal gradient has higher OM content as compared to lower altitudinal gradients. This may be attributed to the fact that these slopes had higher vegetation cover which added more litter the accumulation of which resulted in higher OM content as compared to warmer slopes and the lower altitude.
- The percentage of Nitrogen (N) varied from 200 to 285 % for altitudes and 155 to 305% for aspects. The higher values for available N were recorded on Northern (281%), North Western (297%) and North Eastern (305%) aspects at lower, middle and upper altitudes respectively. The difference in availability of N between the aspects along the altitudinal gradients indicated that decomposition rates were not constant which may be due to variation in microclimatic conditions as well as other soil and site properties. The removal of the canopy at some places might havealso resulted in increased nitrogencontent due to increased availability of substrate for mineralization.
- The availability of Phosphorus (P) varied from 4.82 to9.69% for altitudes and 3.75to10.81% for aspects. The higher value for available P(10.81%) was recorded on North Eastern aspect at upper altitude. On the other hand the available phosphorus was lower (3.75%) on Southern aspectswhich had less vegetation cover. It is believed that plants exert a significant effect on soil P availability and its dynamics through litter fall, root turnover, exudation and the specific interactions with microbes in the rhizosphere. Phosphorus distribution pattern also depends upon the

biochemical activity in the soil which is generally higher in soils with high OM content.

- The percentage of Potassium (K) varied from 224 to 295% for altitudes and 155 to 305%for aspects. The higher values for available K (303%) were recorded on North Eastern aspect at upperaltitude as compared to other aspects. The K content, in general, showed lower values for aspects with low tree density.
- The role of soil as controlling factor at the lower elevation could possibly be more important than at higher elevations. This was suggested by high soil fertility in all the plots and the increasing importance of the organic surface layer as nutrient supplier on sites at the higher altitudes, where thick organic surface layers with a dense network of roots were prevailing, in contrast to the thin layers at lower altitude.
- Following the processing of field data, we drafted a taxonomic compendium of the plant community of Kandi Forest Range which includes a total of 61 plant species belonging to 53 genera and 25 familiesin the Plantae world. These species included 5 trees, 17 shrubs and 39 grasses &herbsindicating that the forest range is rich in species composition. In the studyarea we found a remarkable floristic richness with majority of taxa belonging to family Rosaceae, followed by Asteraceae and Lamiaceae. The other prominent botanical families represented in study area were: Fabaceae,Poaceae,Caryophllaceae,Geraniaceae and Pinaceae.
- The higher number of plant species was recorded on lower (5 trees, 15 shrubs and 24 grasses & herbs) altitude, followed by 3 trees, 9 shrubs and 32 grasses & herbs on middle altitude and 2 trees, 5 shrubs and 25 grasses & herbs on upper altitude.
- The Kandi forest exhibited lower values for diversity index, richness index and concentration of dominance as compared to the values reported for other forests indicatingthat this forest is degraded because of lower

vegetation cover on each of the available aspects along the three altitudinal gradients which were meagerly dissimilar in vegetation composition. Concerning patterns of species richness and diversity index along the altitudinal gradients was strongly influenced by aspect and generally exhibited a bi- modal structure for trees *(Cedrus deodara* and *Pinus wallichiana*) while shrubs and other undergrowth species revealed a decreasing pattern of diversity with increase in elevation.

- The correlation between different vegetation parameters along the altitudinal gradient shows that plant diversity was positively correlated ($P<0.001$) with plant richness and negatively with concentration of dominance. Whileconcentration of dominance was negatively correlated with tree richness which was in turn positively correlated with. On the other hand the correlation between vegetation vs. soil parameters (WHC, available nitrogen, available phosphate, available potash and organic matter) were positively correlated with each other but negatively correlated with bulk density and pH.
- These results indicate the dominance of local geographical (altitude and aspect) and edaphicfeatures as drivers of species assemblage along the altitudinal gradient and partially support the hypothesis that species distribution is related to environmental conditions. Definite vegetal associations at a place are the ultimate interaction of these locality factors. The variation in the structure, composition and form are subtle even in proximally located vegetal groups. Nevertheless, other interacting factors not considered in this study could also have affected the structure and composition of the forest along the altitudinal gradient. These factors may be biological interactions, productivity and dispersal history. Unfortunately such information is not available for the study area and therefore the relative influence of these factors in shaping the current spatial patterns of structure and composition of the forest needs to be evaluated. However, some deductions are possible; for example the

decline in floristic similarity with altitude between stands suggests a role for dispersal limitation, although this could have been masked by the difference in climate along the vertical gradient.

- The data recorded shows that the average IVI values for *Cedrus deodara*and *Pinus wallichiana*were127 & 173 on deforested patches and 141 & 159 on silvicultural managed forest area. The decrease in IVI of the two species in deforested patches can obviously be attributed to loss in density and the basal area. The illicit felling in the Kandi Forest has resulted in the loss of basal area which together with decrease in density has in turn contributed to decrease in the importance of two conifers.These results on the status of deforestation indicate that Kandi forest has been subjected to massive illicit felling'swith population of *Pinuswallichiana* being much more exploited over the entire forest range.
- The examination of status of regeneration reveals that the recruitment of deodar was in the good category with few exceptions of fair and poor on some aspects at lower and higher altitude. In case of *Pinus wallichiana* the overall regeneration was in fair to poor category with exception of good status at the altitudinal range of 2000-2400m. Deodar exhibited profuse regeneration wherever the gaps were available and appears to replace the bimodal nature of Kandi forest to mono crop forest under the prevailing circumstances. The higher regeneration of deodar can be attributed to its easier nature of germination owing to soft seed coat as compared to kail pine seedswhich have hard seed coat that hinders their germinability. The presence of abundant shrub cover may also have played a vital role as nurse crop to increasing regeneration rate.
- The overall results of the present study indicate that a multitude of ecological stresses have disturbed the forest ecosystem of Kandi forest range as reflected by variability in soil characteristics and plant community organizational features. The deforestation (due to illicit felling)has not only subjected the soils prone to erosion but also lead to

loss of major plant nutrients as evidenced through their availability in the soil stratum. Similarly, the loss of vegetation has facilitated profuse regeneration to grow up because of the availability of light, space and other factors required for the establishment of new crop.

- In conclusion, it appears that the structural and floristic variability observed in the studied forest are produced by a combination of different climatic features (altitude, aspect and edaphic) and randomly expressed local processes (e.g. excessive deforestation and unbalanced recruitment of deodar) interacting across a visibly complex landscape.

Recommendations:

1. To maintain the delicately balanced ecosystem on precipitous sites no felling of what so ever kind should be carried out.
2. The potential productive areas on easy slopes; rendered non-productive by biotic pressures till today, should be given protection from such interferences. These areas should be declared as reboisement areas where Nature needs to be aided to restock them by artificial planting. These areas need protection from the illicit felling, grazing and fuel wood collection till sufficient advance growth is attained.
3. The areas which are well stocked should be managed for productive purposes with least possible disturbance to their ecosystem that could be achieved by applying silviculture system which is in conformity with the silvicultural requirements of the species.
4. The entire forest range requires intensive silvicultural treatment to regain the past glory of once comprising the best kail and deodar growing stock. Thus to balance the composition of conifers in the forest range, planting of Kail pine needs to be undertaken on priority to restrict its complete removal from the area subjected to illicit felling of this species.
5. The plantation of Robinia under taken in the forest range particularly on NE aspect needs to be replaced by the existing conifers. The southern slopes should be planted by local broadleaved species viz. Aesculus and

Prunus to hasten the succession and improve conditions for colonization and establishment of conifers.

6. More biodiversity enclosures need to be created to conserve the high value threatened species viz. *Cuminumcyminum* (Zyur), *Artemisiaabsinthium* (Tethwan), *Jasminumofficinale*(Chambayli/Yasmin), *Cotoneaster spp*(Lun) and *Berberislycium* (Kauduch/Cashmal/Kwaray) etc.
7. The grass species viz. *Festucapretensis, Trifolium repens* and *Loliumperenen* introduced in the area need to be subjected to controlled grazing to avoid their massive spread in the entire range which may out compete the growth of native flora.
8. New regeneration has been damaged by anthropogenic pressure; in this regard extension work like awareness camps/programmes on forest conservation should be started for the local people living in or near the forest. Financial assistance schemesviz. CAMPA should be strengthened to conserve the rich natural resources.
9. Some projects should be started regarding the conservation and cultivation of NWFP and especially engagement of local people in these projects should be preferred. By adapting this approach the livelihood of the local people will be sustained besides fulfilling the objective of conservation.
10. Reforms in forest department are the need of hour; in this regard some special training programs shall be started for field officers regarding the environmental and ecological importance of forests, quantification of ecosystem services and the plantation technologies to hasten the process of succession in degraded forests.

LITERATURE CITED

Acharya KP. 2004. Post Fire Natural Regeneration of Dominant Tree Species in Pisang, Manang, Nepal [M.Sc. dissertation]. Central Department of Botany, Tribhuvan University, Kathmandu.

Agni, T., Pandit, A., Pant, K., and Tewari, A. 2000.Analysis of tree vegetation in the Tarai- Bhabhar Tract of Kumaon, Central Himalaya.*Indian Journal of Forestry*, **23**(3): 252-261.

Aguiar, A.P.D., Camara, G. and Escada, M.I.S. 2007. Spatial statistical analysis of land- se determinants in the Brazilian Amazonia: Exploring intra-regional heterogeneity. *Science Direct/Ecological Modelling***209:** 169-188.

Ahmad, Z. 2003. Characterization and nutrient indexing of apple (*Malusdomestica*Borkh) orchard soils of Bangil area of Baramulla District. M.Sc Thesis submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 1-104.

Ahmed, A.I. and MahbubUddin, 2002.Baseline Socio-Economic Survey-Phase One Under Forestry Sector Project (ADB Project BAN NO.1486). Final Report. (Dhaka: Kranti Associates Ltd.).

Ajaz, S.G. 2003. Studied on soil characteristics in relation to erodibility in Dara-watershed of Dal catchment. M.Sc. Thesis submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 47-109.

Akshamit, S.E. and Irving, F. D. 1984. Prescribed burning for lowland black spruce regeneration in Northern Minnesota.*Canadian Journal of Forest Research*, **14**:107-113.

Alard, D. and Poudevigne, I. 2000. Diversity patterns in grasslands along a landscape gradient in north western France. *Journal of Vegetation Science***11**: 287-294.

Amarjit, S. 2004. Characterization and classification of some forest soils of Kashmir valley. M.Sc Thesis submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 56-63.

Ammer, C. 1996. Impact of angulates on structure and dynamics of natural regeneration of mixed mountain forests in Bavarian Alps. *Forest Ecology and Management*, **88**: 43-53.

Amor, D. 2008. Road impact on deforestation and jaguar habitat loss in the Selva Maya. Ph.D. dissertation.Ecology Department, Nicholas School of the Environment, Duke University.

Amor, D. and Pfaff, A. 2008. Early history of the impact of road investments on deforestation in the Mayan forest. Working Paper, Nicholas School of the Environment and Sanford School of Public Policy, Duke University, Durham, NC, USA.

Andersen, L.E. 1996. The Causes of Deforestation in the Brazilian Amazon.*The Journal of Environment & Development***5**: 309.

Anderson, L.E. and Reis, E.J. 1997. Deforestation, development and government policy in the Brazilian Amazon: an econometric analysis. Texto para discussao No. 513, IPEA-Instituto de Pesquisa Econômica Aplicada.

Anderson, L.E., Granger, C.W.J., Reis, E.J. and Weinhold, D. 2002. The Dynamics of deforestation and economic growth in the Brazilian Amazon.Cambridge University Press.

Anderson, M. K. Raulund-Rasmussen, K. Strobel, B. W. and Hansen, H. C. S. 2004. The effect of tree species and site on the solubility of Cd, Cu, Ni, Pb, and Zn in soils.*Water Air and Soil Pollut.,***154**: 357-370.

Anitha, K., Joseph, S., John, C.R., Ramasamy, E.V. and Prasad, S.N. 2010. Tree species diversity and community composition in a human-dominated tropical forest of Western Ghats biodiversity hotspot, India. *Ecological Complexity*,**7**: 217-224.

Anjum, R. 2007. Effect of application of soil and foliar K on nutrition and quality of apple. M.Sc Thesis Submitted to Sher-e-Kashmir University of

Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 28-41.

Anonymous, 1981.Working plan of Kandi forest range, J&K Forest Department, Srinagar.

Anonymous, 2001.Global Forest Resources Assessment 2000-Main Report.FAO Forestry Paper 140. Rome, Italy

Anonymous, 2007.Three Essential Strategies for Reducing Deforestation.Alianca da Terra, Amigos da Terra, Instituto Centro de Vida, IMAZON, Instituto de Pesquisa da Amazonia, Woods Hole Research Center and David and Lucile Packard Foundation.

Anonymous, 2008. Mexico: Mining causesecocide in Coahuayana, Michoacan. WRM's bulletin Nº 136, November 2008.

Anonymous, 2010.Annual administrative report, 2009-10, J&K Forest Department, Srinagar.

Anonymous, 2010. Global Forest Resources Assessment, 2010-Main Report. FAO Forestry Paper 163. Rome, Italy. 340p.

Anonymous, 2011a.State of the World's Forest. FAO, Rome. 163p.

Anonymous, 2011b.Mining, deforestation cause severe drought. March 5 The Asian Age, New Delhi.

Antoo, M.H. 2000. Studies on the soils of command area of Zangier canal sopore, district Baramulla. MSc. Thesis submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 1-78.

Arima, E.Y., Simmons, C.S., Walker, R.T. and Cochrane, M.A. 2007. Fire in the Brazilian Amazon: a spatially explicit model for policy impact analysis. *Journal of Regional Science* **47**(3) : 541-567.

Armenteras, D., Gast, F. and Villareal, H. 2003. Andean forest fragmentation and the representativeness of protected natural areas in the eastern Andes, Colombia. Biological Conservation **113** : 245-256.

Armesto, J. J. and Pickett, S. T. A. 1985. Experiments on disturbance in old – field plant communities: Impact on species richness and abundance. *Ecology*, **66**:230-240.

Arora, R.K. 1995. Himalayan Resources, Diversity and Conservation, In: U. Dhar (ed.),Himalayan Biodiversity. *GyanodayaPrakashan, Nainital***2** : 39-55.

Augusto, L., Ranger, J., Binkely, D. and Rothe, A. 2002.Impact of several common tree species of European temperate forests on soil fertility.*Ann. For. Sci.* **59**(3) : 233-253.

Austin, M.P. 1977. Use of ordination and other multivariate descriptive methods to study succession.*Vegetatio* **3 :** 165-175.

Awasthi A.,Uniyal, S. K., Rawat, G. S. and Rajvanshi, A. 2003. Forest resource availability and its use by the migratory villages of Uttarkashi, Garhwal Himalaya (India).*Forest Ecology and Management*, **174**: 13-24.

Ayappa, N. and Parthasarthy, N. 1999. Biodiversity inventories in a large scale permanent plots of tropical evergreen forest at Varagalair, Annamalais, WesternGhats, India. *Biodiversity and Conservation*, **8**: 1533-1544.

Baduni NP. 1996. Growing stock variation in different forest cover types of Pauri Garhwal. PhD thesis, HNB Garhwal University, Srinagar (Garhwal) Uttaranchal, India,.

Bali, S.K., Kumar, R., Xundal, H.S., Singh, K. and Singh, B. 2010. GIS aided mapping of DTPA extractable zinc and soil characteristics in the state of Punjab. *Journalof the Indian Society of Soil Science***58**(2): 189-199.

Bargali, K., Usman, S. and Joshi, M. 1998. Effect of forest covers on certain site and soil Characteristics in Kumaun Himalaya.*Indian Journal of Forestry***21**(3): 224-227.

Barnes, B. V., Zak, D. R., Denton, S. R. and Spurr, S. H. 1998.Forest Ecology.4th John Wiley and Sons, Inc New York.

Barreto, P., Arima, E. and Solomon, R. 2009. What is the effect of new policies against deforestation in the Amazon.Belim, PA, Brazil: Imazon.

Basumatary, A. and Bordoloi, P.K. 1992. Forms of potassium in some soils of Assam in relation to soil properties.*Journal of Indian Society of Soil Science* **40**(3) : 443-446.

Behera M. D, Kushwaha S. P. S, Roy P. S, Srivastava S, Singh T. P and Dubey R. C. 2002. Comparing structure and composition of coniferous forests in Subansiri district, Arunachal Pradesh. *Current Science*, **82**(1): 70–76.

Bekele, T. 1994. Phytosociology and ecology of humid Afromontane forest in the Central Plateaus of Ethiopia. *Journal of vegetation Science*, **5**: 87- 98.

Berg, W. P, Alessio, H. M., Mills, E. M and Tong C, 1997. Circumstances and consequences of falls in independent community-dwelling older adults. *Age and Ageing*, **26**: 261-268.

Berg M. P and Verhoef H. A, 1998. Ecological characteristics of a nitrogen saturated coniferous forest in the Netherlands. Biol. Fertil. Soils **26**: 258–267.

Bhandari B. S and Tiwari S. C. Dominance and diversity along an altitudinal gradient in a montane forest of Garhwal Himalaya. Proceedings of the Indian National Science Academy, Part B. *Biological sciences*, **63**(6): 639–646.

Bharali, S. and Mohamed, L. K. 2012.Rhododendrons in Arunachal Pradesh.The New Zealand Rhododendron Association.No.100.

Bhat, B.A. 2007. Ecological studies on Langate forest division in Kashmir valley. Ph.D thesisDeportment of Botany, University of Kashmir, pp. 35-37.

Bhat, M.I. 2010.Characterization, classification and nutrient indexing of saffron growing soils of district Pulwama. Thesis submitted Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 110-113.

Bhat, M.S. 2001. Nutritional status high density plantation of apple orchards soils of North Kashmir. M Sc. Thesis submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 13-75.

Bhatt, J. and Ram, J. 2007. Seed and seedling characteristics of the Himalayan hornbeam (Carpinusviminea Wall.), India.*Ecological Research*, **22** (1): 156-159.

Bhuyan, P., Khan, M.L. and Tripathi, R.S. 2003. Tree diversity and population structure in undisturbed and human impacted stands of tropical wet evergreen forest in Arunachal Pradesh, Eastern Himalayas, India. *Biodiversity Conservation***12 :**1753-1773.

Binkley, D., Valentine, D., Wells, C. and Valentine, U. 1989. An empirical analysis of factors contributing to 20 years decrease in soil pH in an old-field plantation of loblolly pine. *Biogeochem.*,**8**:39-54.

Binkley, D. and Giardina, C. 1998. Why do species affect soils? The warp and woof of tree-soil interaction.*Biogeochemistry***42**(1-2) : 89-106.

Bisht, A. S. and Bhatt, A. B. 2010. Physico-chemical Status of Forest Soils along Altitudinal Gradient in Western Uttarakhand Himalayas. *Indian J. Ecol.*, **37**(1): 65-69.

Bisht, S. and Lodhiyal, L.S. 2005. Various aspects of soil and tree layer vegetation analysis in reserve forests of Kumaon in central Himalaya. *India Journal of Forestry***28**(1) : 37-50.

Blake, L., Goulding, K.W.T., Mott, C.J.B. and Johnston, A.E. 1999. Changes in soil chemistry accompanying acidification over more than 100 years under woodland and grass at Rothamsted Experimental Station, UK. *Eurosian Journal of Soil Science* **50**: 401-412.

Boring, L. R., Monk, C. D. and Swank, W. T. 1981.Early regeneration of a clear-cut southern Appalachian forest.*Ecology*, **62**: 1244-1253.

Boruah H.C. and Nath, A.K. 1992. Potassium status in three major soil orders of Assam.*Journal of Indian Society of Soil Science***40**(3) : 559-561.

Brady N.C. 1996. The nature and properties of soil, 10thedn. Prentice Hall, New Delhi.

Brady, N. C. and Weil. R. R. 2002. The nature and properties of soil.Thirteenth ed. Pearson Education, Upper Saddle River, NJ.

Bruijnzeel, L.A. 1991. Hydrological Impacts of Tropical Forest Conversion.*Nature and Resources***27**(2) : 42-50.

Brune, D. E. and Doolittle, J. 1990. Locating lagoon with radar and electromagnetic survey. *Geology Water Science* **16** : 195-207.

Callaway, R. M. 1995. Positive interaction among plants.*Botanical Review*, **61**: 306 – 349.

Campbell, S. D. Inamdar, M. Rodrigues, V. Raghavan, V. Palazzolo, M. and Chovnick, A. 1992. The scalloped gene encodes a novel, evolutionarily conserved transcription factor required for sensory organ differentiation in Drosphila. *Genes & Development*, **6**:367–379.

Cauteaux, M.M., Bottner, P., Anderson, J.M., Berg, B., Bolger, T., Casals, P., Romanya, J., Thiery, J.M. and Vallejo, V.R. 2001. Decomposition of

13 C labelled standard plant material in a latitudinal transect of European coniferous forests: differential impact of climate on the decomposition of soil organic matter compartments. *Biogeochem*.**54**: 147-170.

Chakravarty, S., Shukla, G., Malla, S. and Suresh, C.P. 2008. Farmer's rights in conserving plant biodiversity with special reference to North-east India.*Journal of Intellectual Property Rights***13**: 225-233.

Chandran, M. D. S. and Gadgil, M. 1993.Sacred Groves and Sacred Trees of Uthara Kannada (A Pilot Study). Report submitted to the Indira Gandhi National Centre for Arts, New Delhi.Cited in: Ramakrishnan, P. S., Saxena, K. G &Chandrashekara, U. M (Ed.)., 1998. Conserving the Sacred for Biodiversity Management. Oxford & IBH Publ. Co. Pvt. Ltd., New Delhi. Pp. 230.

Chapin, I.I., Erika, F.S., Zavaleta, S., Eviner, V.T., Naylor, R.L., Vitousek, P.M., Reynolds, H.L., Hooper, D.U., Lavorel, S., Sala, O.E., Hobbie, S.E., Mack, M.C. and Diaz, S. 2000. Consequences of changing biodiversity.*Nature***405** : 234-242.

Charney, J.G. 1975. Dynamics of deserts and drought in the Sahel.*Quarterly Journal of Royal Meteorological Society***101** : 193-202.

Chen, C.R., Condron, L.M., Davis, M.R. and Sherlock, R.R. 2000. Effects of afforestation on phosphorus dynamics and biological properties in a New Zealand Grassland soils.*Plant and Soil* **220** : 151-163.

Chen C. R., Condron, L. M., Davis, M. R. and Sherlock, R. R. 2004. Effect of plant species on microbial biomass phosphorus and phosphatase activity in a range of grassland soils. *Biol. Fertil. Soils*, **40**: 313-322.

Chersetl, M.K. 1989. Geological concepts: the contribution of ecology to an understanding of the natural world. *British Ecological Society*/ Blackwell Scientific publications oxford.

Chomitz, K.M., Buys, P., Luca, G.D., Thomas, T.S. and Wertz-Kanounnik, S. 2007. At loggerheads?Agricultural expansion, poverty reduction and environment in the tropical forests.World Bank Policy Research Report.World Bank, Washington DC.

Clements, F. E. 1936. Nature and structure of climax.*Journal of Ecology*, **24**: 252-284.

Coates, K. D. 2002. Tree recruitment in gaps of various size, clearcuts and undisturbed mixed forest of interior British Columbia, Canada.*Forest Ecology and Management*, **155**: 387 – 398.

Colchester, M. and Lohmann, L. 1993.The Struggle for land and the fate of forest. Zed books, London.

Cole, D.W. Ford, E.D. and Turner, J. 1990. Nutrients, Moisture and productivity of established forests. *Forest Ecology Monage*.**30** : 283-299.

Collins, B. S., Dunne, K. P. and Pickett, S. T. A. 1985.Responses of forest herbs to canopy gaps, p. 218-234. In S.T.A. Pickett and White, P.S (eds.). The ecology of natural disturbance and patch dynamics, academic press, Inc., New York.

Currie D.J. 1991. Energy and large scale patterns of animal and plant species richness. *The American Naturalist***137**(1): 27-49.

Dale, V.H. and Pearson, S.M. 1997. Quantifying habitat fragmentation due to land use change in Amazonia.**In**: *Tropical Forest Remnants*. [Eds. W. Laurance and R. Bierregaard], The University of Chicago Press, Chicago, USA, pp. 400-414.

Dandroo, F.A. 2001. Characterization and classification of Lower Munda Watershed soil in south Kashmir. M.Sc Thesis submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 1-94.

Dangwal, L.R., Tajinder, S., Amandeep, S. and Antima, S. 2012. Plant diversity assessment in relation to disturbances in subtropical Chir pine forest of the western Himalaya of District Rajouri, J&K, India. *International Journal of Plant, Animal and Environmental Sciences***2**(2) : 206-213.

Dar, M.A. 1996. Nutrient status of cherry (*Prunus avium*L.) orchards of Srinagar district. M.Sc Thesis submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 1-140.

Deacon, R. T. 1999.Deforestation and Ownership: Evidence from Historical Accounts and Contemporary Data. *Land Economics*, **75** (3): 341-359.

DeLong, C., Skousen, J. and Yewtukhiw, E.P. 2011. Bulk Density of Rocky Mine Soils in Forestry Reclamation.*Soil Science Society of America*, doi:10.2136/sssaj2011.0380.

Devkumar, A.S., Kushalappa, C. G., and Prakash, N. A. 2007.Assessment of few natural capital components from three different land use systems for sustainable development. P. 159-165. In Challenges to sustainable agri-food systems: Biotechnology, environment, nutrition, trade and policy. (eds) P. G. Chengappa, N. Nagaraj, and I. K. Ramesh Kanwar. International Publishing house Pvt. Ltd. Banglore.

Devlal, R. and Sharma, N. 2008. Altitudinal changes in dominance- diversity and species richness of trees in a temperate forest of Garhwal Himalaya. *Life ScienceJournal***5**(2): 33-57.

Dhale, S.A. and Prasad, J. 2009. Characterization and classification of sweet orange growing soils of Jalna district, Maharashtra. *Journal of Indian Society of Soil Science***57**(1): 11-17.

Dhir, R.P. 1967. Pedological characteristics of some soils of North-Western Himalayas.*Journal of the Indian Society of Soil Science***15** : 61-69.

Dhir, R.P. 1973. A study on the composition of humus in some soil profiles of the North Western Himalayas. *Journal of Indian Society of Soil Science***21**(2) : 149-154.

Diaci J, R Pisek and A. Boncina. 2005. Regeneration in experimental gaps of subalpine Piceaabies forest in the Slovenian Alps. *European Journal of Forest Research*, **124**: 29-36.

Dickinson, R.E. 1981. Effects of tropical deforestation on climate.In blowing in the wind, deforestation and language implications.Studies in third world societies, Publ. No. 14.Dept of Anthropology, College of William and Mary, Williamsburg Virginia, pp. 411-441.

Dimiri, B.M., Jha, M.N. and Gupta, M.K. 2006. Soil potassium changes at different altitudes and seasons in upper Yamuna forest of Garhwal Himalayas. *Indian Forestry*, pp.609-614.

Dinesh, R., Ghoshal, C.S., Ganeshamurthy, A.N. and Dey, C. 2003. Changes in soil microbial indices and their relationships following deforestation and cultivation in wet tropical forests.*Applied Soil Ecology***24**: 17-26.

Docena, H. 2010. Philippines: Deforestation through mining subsidized by CDM project. WRM's bulletin Nº 161, December.

Drake, J.A. 1990. The mechanics of community assembly and succession.*Journal of Theoretical Biology***147**(2) : 213-233.

Dregne, H.E. 1983. Desertification of Arid lands.Harwood Academia Publishers, London.

Drohan, J.R. and Sharpe, W.E. 1997. Long term changes in forest soil acidity in Pennsylvania, USA. *Water Air and Soil Pollution* **95**: 299-311.

Duan, L.Tsang, I. Xu, D. and Chua, T. 2009. Domain adaptation from multiple sources via auxiliary classifiers.In Proceedings of the International Conference on Machine Learning (ICML), 103–112.

Duffy J. E, Cardinale, B. J. and France, K. E. 2007. The functional role of biodiversity in ecosystems: incorporating trophic complexity. *Ecological Letter*, **10**: 522–38.

Dwivedi, S.K., Sharma, V.D. and Bhardwaj, V. 2005.Status of available nutrients in soils of cold arid region of Ladakh.*Journal of the Indian Society of Soil Science***53**(3): 421-423.

Eden, M.J., Furley, P.A., McGregor, D.F.M., Milliken, W. and Ratter, J.A. 1991.Effect of forest clearance and burning on soil properties in northern Roraima, Brazil.*Forest Ecology and Management* **38**: 283-290.

Egli, M. 1998. Estimation of current and historical fluxes of N, Ca and K in the forest ecosystem. *Mohlin.Geo Journal***44**(1): 73-89.

Ellu, G. and Obua, J. 2005. Tree condition and natural regeneration in disturbed sites of Bwindi Impenetrable forest national park, southwestern Uganda. *Tropical Ecology***46**(1) : 99-111.

Elourard, C., Pascal, J.P., Pelissier, R., Ramesh, B.R., Houllier, F., Durand, M., Aravajy, S., Moravie, M.A. and Gimaret-Carpentier, C. 1997. Monitoring the structure and dynamics of a dense moist evergreen forest in the Western Ghats (Kodagu District, Karnataka, India). *Tropical Ecology***38**: 193-214.

FalkengrenGrerup, U. 1987. Long term changes in pH of forest soils in Southern Sweden. *Environmental Pollution***43**: 79-90.

FAO, 2001.State of the world's forests 2001. FAO, Rome, p. 166.

FAO. 2010. Global Forest Resources Assessment 2010, main report. FAO Forestry Paper No. 163. Rome. www.fao.org/docrep/013/i1757e/i1757e00.htm.

FAO/UNEP, 1982. Tropical Forest Resources Assessment Project4 Vols. Rome: FAO.

Farida, A. 1997.Evaluation of sulphur in some paddy growing soils of Kashmir. M.Sc Thesis submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 1-102.

Finzi, A.C., Canham, C.D. and Breemen, N.V. 1998. Canopy tree-soil interactions within temperate forests: species effects on pH and cations. *Ecology Applic*.**8**(2): 447-484.

Fu, B.J., Liu, S.L., Chen, L.D., Lu, Y.H. and Qiu, J. 2004. Soil quality regime in relation to land cover and slope position across a highly modified slope landscape.*Ecology Research***19** : 111-118.

Gadgil M and Meher-Homji V. M, 1990. Ecological diversity; in Conservation in developing countries: Problems and prospects (eds) J C Daniel and J S Serrao (Bombay: Bombay Natural History Society) pp 175–198.

Gain, P. 2003. Modhupur: A Stolen Forest, Robbed Adivasis. Dhaka Courier. 26 September. (Dhaka).

Gairola, S., Rawal, R. S. and Todaria, N.P. 2008. Forest Vegetation patterns along an altitudinal gradient in sub-alpine zone of west Himalaya, India. *African Journal of Plant Science***2**(6): 42-48.

Gairola, S., Sharma, C.M. and Ghildiyal, S.K. 2012.Chemical properties of soils in relation to forest composition in moist temperate valley slopes of Garhwal Himalaya.*Environmentalist*, DOI 10.1007/s10669-012-9420-7.

Gamfeldt, L. Hillebr, H. and Jonsson, P. R. 2008. Multiple functions increase the importance of biodiversity for overall ecosystem functioning. *Ecology*, **89**: 1223–31.

Ganai, M.R. 2001.Nutrient status of saffron soils and their management.**In**: *proceedings of a seminar-cum-workshop on the development of saffron*, held at Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar.

Ganesh, T., Ganesan, R., Soubadradevy, N., Davidar, P., and Bawa, K. S. 1996.Assessment of plant biodiversity at mid-elevation evergreen forests

of KalakadMundanthurai Tiger Reserve, Western Ghats, India.*Current Science*, **71**: 379-392.

Ganesh, T., R. Ganesan, S. D., Davidar, P. and Bawa, K. S. 1996. Assessment of plant biodiversity at a mid-elevation evergreen forest of KalakadMudanthurai Tiger Reserve, western ghats, India. *Current Science*, **71**: 379-392.

Gangopadhyay, S. K., Das, P. K., Mukhopadhyay, O. R., Nath, S. and Banerjee, S. K. 1990. Altitudinal pattern of soil characteristics under forest vegetation in eastern Himalayan region.Journal of Indian Society of Soil Science.**38**: 93-99.

Garcia, D., Zamora, R., Hodar, Jose A., Gomez, Jose M. and Castro, J. 2000. Yew (Taxus baccata L.) regeneration is facilitated by fleshy – fruited shrubs in Mediterranean environments. *Biological Conservation*, **95**: 31-38.

Gaston K.J. 2000. Global patterns in biodiversity. *Nature* **405**(6783) : 220-226.

Gaur, R. D. 1982.Dynamics of vegetation of Garhwal Himalayas. The Vegetational Wealth of the Himalayas (ed. G.S. Paliwal), Pp. 12-25.

Ghate, V., Joshi, N.V. and Gadgil, M. 1998.On the Patterns of tree diversity in Western Ghats of India.*Current Science*, 75: 594-603.

Ghildiyal S. K, Baduni N. P, Khanduri V. P and Sharma C. M. 1998.Community Structure and composition of oak forests along altitudinal gradient in Garhwal Himalaya.*Indian journal of Forestry*.**21**(3): 242–247.

Ghimire B. K, Lekhak H. D, Chaudhary R. P and Vetaas O. R. 2008. Vegetation analysis along an altitudinal gradient of Juniperus indica forest in Southern Manang Valley, Nepal. *International Journal of Ecology & Development*, **9**: 20–29.

Gigord, L., Picot, F. and Shykoff, J. 1999. Effects of habitat fragmentation on *Dombeyaacutangula* (Sterculiaceae), a native tree on La Reunion (Indian Ocean).*Biological Conservation***88** : 43-51.

Gilmore, A. R. and Mattis, D. S. 1981. Effect of past agricultural practices on the soil phosphorus system and growth of planted pine. *Soil Science*.,**131**(5): 313-319.

Global Forest Resources Assessment, 2005.FAO Forestry Paper 147, Rome, Italy, 2006. Hereafter cited as FAO 2005 FRA. The report and tables on forest area are at http://www.fao.org/forestry/fra2005/en/.

Gomez, K.A. and Gomez, A.A. 1984. Statistical Procedure for Agricultural Research.2nd edition. John Wiley and Sons, Inc., New York.

Gomez-Aparicio, L., Zamora, R. and Gomez, J. M. 2005. The regeneration status of the endangered Acer opalus sub sp. Granatense throughout its geographical distribution in the Iberian Peninsula. *Biological Conservation*, **121**: 195-206.

Good, N. F. and Good, R. E. 1972. Population dynamics of tree seedlings and saplings in mature eastern hardwood forests.*Bull. Torrey Bot. Club*., **99**: 172-178.

Grainger, A. 1980, The State of the World's Tropical Forests.*Ecologist***10** : 6-54.

Gregorich, E.G., Carter, M.R., Angers, D.A., Monreal, C.M. and Ellert, B.H. 1994.Towards a minimum data set to assess soil organic matter quality in agricultural soils.*Canadian Journal of Soil Science***74** : 367-385.

Greig-Smith, P. 1983.*Quantitative Plant Ecology*.3rd edn. Oxford: Blackwell Scientific.

Gressel, N., McColl, J.G., Preston, C.M., Newman, R.H. and Powers, R.F. 1996. Linkages between phosphorus transformation and carbon decomposition in a forest oil. *Biogeochem*.**33**: 97-123.

Griffiths, T. and Hirvela V.V. 2008. India: Illegal aluminum refinery in Tribal lands in Orissa. WRM's bulletin Nº 126, January 2008.

Grimble, R. and Laidlaw, M. 2002. Biodiversity Management and Local Livelihoods: Rio Plus 10 Natural Resources Perspective, 73, 2002 DFID. http://www.odi.org.uk/nrp073.pdf , Accessed on 5 September 24.

Grubb, P.J. 1997. The maintenance of species richness in plant communities.The importance of the regeneration niche.*Biological Review* **52 :**107-145.

Gupta, A., Thapliyal, P.K., Pal, P.K. and Joshi, P.C. 2005. Impact of deforestation on Indian monsoon- A GCM sensitivity study.*Journal of Indian Geophysical Union***9** : 97-104.

Gupta, M.K. and Sharma, S.D. 2008. Effect of tree plantation on soil properties, profile morphology and productivity index I. Poplar in Uttarakhand. *Ann. For.***16**(2) : 209-224.

Gupta, P. K. 2004. Soil, Plant, Water and Fertilizer Analysis.Agro Botanica, Vyas Nagar, Bikaner, India.

Gupta, R.D., Sanjay Arora, G.D., Gupta and Sumberia, N.M. 2010. Soil physical variability in relation to soil erodibility under different land uses in foothills of Siwaliks in N-W India, *Tropical Ecology***51**(2): 183-197.

Gupta, S. K. 1980. Effect of clipping on biomass and net productivity of underground parts in grassland ecosystem.*Indian Journal of Ecology*,**7**(2):215-223.

Gurtevik, N., Kelting, D.L. and Allen, H.L. 2004. Nitrogen mineralization following vegetation control and fertilization in a 14-year loblolly pine population. *Soil Science Society of American Journal***68** : 272-281.

Haghnia, G. H. and Pratt, P. F. 1988.Effect of exchangeable magnesium on the accumulation of sodium and potassium in soils.*Soil Science*. 145,432-436.

Hajabbasi, M.A., Jalalian, A. and Karimzadeh, H.R. 1997. Deforestation effects on soil physical and chemical properties, Lordegan, Iran. *Plant and Soil***190** : 301-308.

Haque, M.N. 1995. Raising Plantations on Barren Hills.The Bangladesh Observer.(Dhaka).

Harper, J. L. 1969.The role of predation in vegetational diversity. Brookhaven Symposia in Biology **22**: 48–62.

Hebel, A. 1995. Einfluss der organischensubstanz auf die raumliche and zeitlicheVariabilitat des Perlhirse-Watchstums auf LuvicArenosol des Sahel (Sadore/Niger). HohenheimerBodenkundlicheHefte 24, Stuttgart.

Hill, M. 0. 1973. Diversity and evenness: a unifying notation and its consequences. –Ecology, 54: 427-432.

Hillal Ahmad, N. A. Masoodi, T. H. Masoodi, K. N. Qaisar, S. A. Mir, Altamash Bashir and Mumtaz Majeed, 2012. Incremental growth of containerized *Pinus wallichiana* Jackson seedlings as affected by varying levels of nitrogen fertigation, *Applied Biological Research*, **14**(2):150-155.

Hodges, S.C. 1996. Soil fertility basics: N.C. certified crop advisor training. Soil Science Extension, North Carolina State University, p. 75.

Hole, R. S. 1914.Oecology of Sal (Shorea robusta) forests.A study on economy ecology.Ind. For. Rec. (Old series) Silviculture, B (2): Manager of Publications, Delhi.

Holland P. G, and Steyn D. G, 1975. Vegetational responses to latitudinal variations in slope angle and aspect.*Journal of Biogeography*.**2**:179-183.

Hooper, E, Legendre, P., and Richard, C. 2005.Barriers to forest regeneration of deforested and abandoned land in Panama.*Journal of Applied Ecology*, **42**: 1165-1174.

Howard, B. H. 1973. A measurement of the consistency of the response of cuttings to propagation treatments as guide to the value of experiments on nurseries.*Proc. Int. Plant. Prop. Soc*., **23**: 203-211.

Hubbell S. P, Foster R. B., Oobrien S. T, Harms K. E., Condit R., Wechsler B., Wright S. J. and Loo de Lao, S. 1999.Light-Gap Disturbances, Recruitment Limitation, and Tree Diversity in a Neotropical Forest. *Science,* 283: 554.

Hulme, P. E. 1996. Natural regeneration of Yew (Taxus baccata L.) micro sites, seed or herbivore limitation?*Journal of Ecology*, **84**: 853-861.

Hwang, J. and Son, Y. 2006. Short term effects of thinking and liming on forest soils of Pitch pine and Japanese larch plantations in central Korea. *Ecology Research***21**: 671-680.

Iftekhar, M.S. and Hoque, A.K.F. 2005. Causes of Forest Encroachment: An Analysis of Bangladesh. *Geo Journal***62**(1-2) : 105-110.

Iida, S. and Nakashizuka, T., 1995.Forest fragmentation and its effect on species diversity in sub-urban coppice forests in Japan.*Forest Ecology & Management* **73** : 197-210.

Ilorker, V.M. and Totey, N.G. 2001.Floristic diversity and soil studies in Navegaon National Park (Maharashtra).*Indian Journal of Forestry***24**(4): 442-447.

Itow, S. 1963. Grassland vegetation in uplands of western Honshu, Japan. Part II. Succession and grazing indicators.*Japan Journal of Botany*, **18**: 133–167.

Jacabson, S., Hogbam, L., Ring, E. and Nohrsted, H.O. 2004. Effect of wood ash dose and formulation on soil chemistry at two coniferous forest sites.*Water, Air and Soil Pollution* **158** : 113-125.

Jackson, M. L. 1967. Soil-Chemical analysis, 498 pp. Prentice-Hall of India- Pvt. Ltd., New Delhi.

Jacobson, S. 2003. Addition of stabilized wood ashes to Swedish coniferous stands on mineral soils - effects on stem growth and needle nutrient concentrations. *Silva Fenn*., 37: 437-450.

Jain, S. K. and Sastry, A. R. K. 1980.Threatened plants of India state- of- art Report.Botanic survey of India, Howrah.pp.1-48.

Jha, M.N., Gupta, M.K. and Dimri, B.M. 2002. Impact of changing natural forest cover and site conditions on the soil resources in western Himalayan region. **In**: *Natural Resources of Western Himalaya*. [Ed. Pandit Ashok K.], Valley Book House, Srinagar-190006, India. Department of Environmental Science, University of Kashmir, pp. 23-42.

Jiang Y, Kang M, Zhu Y and Xu G. 2007. Plant biodiversity patterns on Helan Mountain, China. *ActaOecologica*; **32**(2): 125–133.

Jiangming M. A, L Shirong, S. Zuomin, Z. Yuandong, K. Bing and C. Baoyu. 2008. Changes in species composition and diversity in the restoration process of subalpine dark brown coniferous forests in western Sichuan Province, China. *Frontiers of Biology in China*, **3**: 300-307.

Joshi, A., Joshi, K. and Shrestha, S.L. 2003. Environmental Management and Sustainable Development at the Cross Road.AnKuS, Kathmandu.

Joshil M. and Kumar, M. 2008. Effects of deforestation on species composition of ground vegetation in Kumaun Himalaya in India.*Ghana Journal of Forestry***23-24**: 35-41.

Jussy, J.H., Colin-Belgrand, M., Dambrine, E., Ranger, J., Zeller, B. and Bienaime, S. 2004. N deposition, N transformation and N leaching in acid forest soils. *Biogeochem*.**69**: 241-262.

Kala, C.P. and Mathur, V.B. 2002.Patterns of Plant Species Distribution in the Trans-Himalayan Region of Ladakh, India.*Journal of Vegetation Science* **13**(6): 751-754.

Karpagam, M. 1991. Environmental Economics. Sterling Publishers Private Limited. India.

Kaufmann, M. R. 1975. Leaf water stress in Engelmann spruce: Influence of the root and shoot environments. *Plant Physiology*.**56**:841-844.

Kaul, A.K. 1977. *Kashmir Physiography Inquiry***4**(7): 1-20.

Kaushal, R., Bhandari, A.R., Sharma, J.C. and Tripathi, D. 1997. Soil fertility status under natural deodar (*Cedrus deodara*) forest ecosystem of north-west Himalayas. *Indian Journal of Forestry***20**(2): 105-111.

Khademi, H. Mermut, A. R. 2003. Micromorphology and classification of Argids and associated gypsiferousAridisols from central Iran.*Catena,***54**: 439–455.

Khan, M. L., Rai, J. P. N. and Tripathi, R. S. 1986.Regeneration and survival of tree seedlings and sprouts in tropical deciduous and subtropical forests of Meghalaya, India.*Forest Ecology and Management*, **14**, 293-304.

Khan, M. S., Aamil, M and Zaidi, A. 1997.Associative effect of Bradyrhizobiumsp. (vigna) and phosphate solubilizing bacteria on moongbean [Vignaradiata (L.) wilczek], *Biojournal*. **10**: 101–106.

Khan, M., Rai, J.P.N. and Tripathi, R.S. 1987.Population structure of some tree species in disturbed and protected sub tropical forests of northeast India.*ActaEcology* **8 :** 247-255.

Khan, M.L. and Tripathi, R.S. 1989. Effect of soil moisture soil texture and light intensity on emergence, survival and growth of seedlings of a few sub-tropical trees. *Indian Journal of Forestry***12**(3): 196-204.

Khanduri V. P, Sharma C. M, Ghildiyal S. K and Puspwan K. S. 2002.Forest composition in relation to socioeconomic status of people at three high altitudinal villages of a part of Garhwal Himalayas.*Indian Forester*, **128**(12): 1335-1345.

Kharkwal G and Rawat YS. 2010. Structure and composition of vegetation in subtropical forest of Kumaun Himalaya. *African Journal of Plant Science*; **4**(4): 116–121.

Kharkwal, G. Poonam, M. and Rawat, Y. S. 2013.Taxonomic Diversity of Understorey Vegetation in Kumaun Himalayan Forests.*Cancer Biology*, **3**(3): 1-5.

Khoshoo, T. N. 1984. Environnlental concerns and strategies. New Delhi: Indian Environmental society.

Khumbongmayum, A. D., Khan, M. L., and Tripathi, R. S, 2005. Sacred groves of Manipur, northeast India: Biodiversity value, status and strategies for their conservation. *Biodiversity Conservation*, **14**: 1541–1582.

Kirby, K.R., Laurance, W.F., Albernaz, A.K., Schroth, G., Fearnside, P.M., Bergen, S., Venticinque, E.M. and Costa, C. 2006. The future ofdeforestation in the Brazilian Amazon.*Futures***38**: 432-453.

Kirmani, N.A. 2004. Characterization, classification and development of lacustrine soils of Kashmir valley. Ph.D Thesis submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp 1-96.

Kitayama K. 1992. An altitudinal transect study of the vegetation on Mount Kinabalu, Borneo. Plant Ecology; 102(2): 149–171.

Koch, J.A. and Makeschin, F. 2004. Carbon and nitrogen dynamics in top soils along forest conversion sequences in the Ore Mountains and the Saxonian lowland, Germany. *Eurasian Journal of Forest Research* **123**: 189-201.

Kohyama T . & Hara T . 1989. Frequency distribution of tree growth rate in natural forest stands. *Annals of Botany*, **64**(1): 47-57.

Koirala M. 2004. Vegetation composition and diversity of Piluwa micro–watershed in Tinjure–Milke region, East Nepal. *Himalayan Journal of Sciences*, **2**(3): 29–32.

Kolasa, J. and Rollo, C.D. 1991. Introduction: the heterogeneity, a glossary. **In**: *Ecological Heterogeneity*. [Eds. J. Kolasa and S.T.A. Pickett], Springer, New York, pp. 1-23.

Korner, C. 1999. Alpine Plant Life.Springer, Berlin.

Krauchi N, Brang, P., Schonerberger, W. 2000. Forests of mountainous regions: Gaps in knowledge and research needs. *Forest Ecology and Management*, **132**: 73-82.

Krebs, C. J. 1989. Ecological methodology.Harper & Row, NY, USA.

Kumar A and Ram J. 2005. Anthropogenic disturbances and plant biodiversity in forests of Uttaranchal, central Himalaya. *Biodiversity and Conservation*; **14**(2): 309–331.

Kumar M and Bhatt VP. 2006. Plant biodiversity and conservation of forests in foot hills of Garhwal Himalaya. *Journal of Ecology and Application*, **11**(2): 43–59.

Kumar M, Sharma C. M and Rajwar G. S. 2009. The effect of disturbance on forest structure and diversity at different altitude in Garhwal Himalaya. *Chinese Journal of Ecology*, **28**(3): 424–432.

Kumar, M., Sharma, C.M. and Rajwar, G.S. 2004. Physico-chemical properties of forest soil along altitudinal gradient in Garhwal Himalaya. *Journal of Hill Research* **17**(2) : 60-64.

Kumar, P., Verma, T.S. and Sharma, P.K. 2006.Effect of land uses on relation between organic carbon and available nutrients in dry temperature zone of Himachal Pradesh.*Journal of Indian Society of Soil Science* **54**(4): 485-488.

Kushalappa, C. G. and Kushalappa, K. A. 1998. Ecological changes in high altitude forests of Kodagu, South India. Proceedings of the Inter – Divisional Seoul conference, Seoul, Korea.Pp- 91-97.

Lal, R. 2005. Forest soils and carbon sequestration.*Forest Ecology Management* **220**: 242-258. Department of Environmental Science, University of Kashmir. 172.

Lan, S. 2003. Plant species diversity in Wuyishan national nature reserve. *ScientiaSilvaeSinicae***29**(1) : 36-43.

Lange, T. R., and Graham. R. C., 1983. Rabbits and the failure of regeneration in the Australian arid zones Acacia.*Australian Journal of Ecology*, **8**: 377-381.

Lavorel, S., McIntyre, S., Landsberg, J. and Forbes, T.D.A. 1997. Then Plant functional classifications: from general groups to specific groups based on response disturbance. *Tree***12** : 474-478.

Lawton, R.O., Nair, U.S., Pielke, Sr., R.A. and Welch, R.M. 2001.Climatic impact of tropical lowland deforestation on nearby Montane Cloud Forests.*Science***294** : 584-587.

Legarda, B. L., Mora, T.E. and Balco, L. M. 1973.Releation between some soil characteristis and altitude in Narino, Columbia.*Turrialba*, **23**(1): 97-103.

Li, Q., Yang, L. and Zhou, J. 2002. Comparative analysis on species diversity of hillcolsed afforested plant community in Beijing Jiulong Mountain. *Chinese Journal of Applied Ecology***13**(9): 1065-1068.

Likens, G. E., Bormann, F. H. Pierce, R. S. Eaton, J. S and Johnson, N. M. 1977.Biogeochemistry of a forested ecosystem. Springer-Verlag, N.Y.

Likens, G.E. and Bormann, F.H. 1999.Biogeochemistry of a forested ecosystem. Springer Verlag, New York, Inc.

Liski, J. and Westman, C.J. 1997. Carbon storage in forest soils of Finland. *Biogeochem*.**36**: 239-260.

Lister, T.W., Burger, J.A. and Patterson, S.C. 2004.Role of vegetation in mitigating soil quality impacted by forest harvesting.*Soil Science Society of American Journal* **68**: 263-271.

Lister, T.W., Burger, J.A. and Patterson, S.C. 2004.Role of vegetation in mitigating soil quality impacted by forest harvesting.*Soil Science Society of American Journal***68**: 263-271.

Liyun, M. W., Xiaoan and W. Zhigao. 2006. Studies on species diversity of Larix chinensis community ecotone. *Frontiers of Biology in China*, **2**: 163-167.

Lowry, G.L. 1975. Black Spruce site quality as related to soil and other site conditions.*Soil Science Society of American Proceedings* **39**: 125-131.

Lu, D., Mausel, P., Brondizio, E. and Moran, E. 2004.Relationship between forest stand parameters and Landsat TM spectral responses in the Brazilian Amazon Basin.*Forest Ecology Manual***198** : 149-167.

Lucas G. and Synge H. 1978. The IUCN plant Red Data Book. Morges, IUCN. Pp. 540.

MacArthur, R. H. and Wilson, E. O. 1967.The theory of island biogeography. Princeton University Press, New Jersey.

Magurran, A.E. 1988. Ecological diversity and measurment. Princeton University Press, Princeton, 354.

Majila B. S and Kala C. P. 2010. Forest Structure and Regeneration along the Altitudinal Gradient in the Binsar Wildlife Sanctuary, Uttarakhand Himalaya, India. *Russian Journal of Ecology*.**41**(1): 75–83.

Manabe T, Nishimura N, Miura M and Yamamoto S. 2000. Population structure and spatial patterns for trees in a temperate old–growth evergreen broad–leaved forest in Japan. *Plant Ecology*; **151**(2): 181–197.

Mandal, A.K. Nath, S., Gupta, S.K. and Banerjee, S.K. 1990. Characteristics and nutritional status of soil of middle hill and upper hill forest of the Eastern Himalayas. *Journal of Indian Society of Soil Science* **38**: 100-106.

Margulis, S. 2003. Causes of deforestation of the Brazilian Amazon.World Bank Working Paper Series, 22.

Masaki, T., Suzuki, W., Niiyama, K. Lida, S., Tanka, H. and Nakashizuka, T. 1992.Community structure of a species rich temperate forest, Ogawa Forest Reserve, Centrl Japan.*Vegetation*, **98**: 97-111.

Masoodi, T.H., Masood, N.A., Soni, P. and Zubair, A. 2003.Plant strategies for successful colonization on degraded land.*Annals of Forestry***11**(1) : 37-51.

Mather, A.S. 1991. Global Forest Resources.International Book Distributors, Dehra Dun.Sands, R. 2005.Forestry in a Global Context.CABI Publishing.

Matsuura, Y., Sanada, M., Takahashi, M., Sakai, Y. and Tanaka, N. 2001. Long-term monitoring study on rain throughfall and stream flow chemistry in evergreen coniferous forest in Hakkoida, northern Japan. *Water, Air, and Soil Pollution* **130**: 1661-1666.

Mehta J. P, Tewari S. C and Bhandari B. S. 1997. Phytosociology of woody vegetation under different management regimes in Garhwal Himalaya. *Journal of tropical Forest Science*; **10**(1): 24–34.

Metz, J. J. 1997. Vegetation dynamics of several little disturbed temperate forests in east central Neal. *Mountain Research and Development*, **17** (4): 333-351.

Minas, R. S. and Bora, N. C. 1982.Distribution of organic carbon and the forms of nitrogen in topographic sequences of soils.*Journal of Indian Society of Soil Science*, **30** (2): 135-139.

Mishra, A., Sharma, C.M., Sharma, S.D. and Baduni, N.P. 2000.Effect of aspect on the structure of vegetation community of moist Bhavar and Tarai Shorea robustaforest in Central Himalaya.*Indian Forester***126**(6) : 634-642.

Misra, R. 1968.Ecology Workshop. 244 pp. Calcutta: Oxford and IBH Publishing Co.

Moieza Ashraf, Bhat G.A. Idrees Yousuf Dar, Mudasir Ali, 2012. Physico-Chemical Characteristics of the Grassland Soils of Yusmarg Hill Resort (Kashmir, India).*Ecologia Balkanica***4**(1): 31-38.

Monica, H., Ann Mari and JanssonBengt-owe, 1993.Diversity change and sustainability.*Ambiology***22**(23): 97-105.

Mori, A. and Takeda, H. 2004. Effects of undisturbed canopy structure on population structure and species coexistence in an old growth subalpine forest in central Japan. *Forest Ecology and Management*, **200**: 89-100.

Mueller-Dombois, D. and Ellenberg, H. 1974.Aims and Methods of Vegetation Ecology. John-Wiley, New York.

Muller-Dombois, D. J., Jucobi, D., Cooray, R. G. and Balakrishan, N. 1980. Ohio rain fores study: ecological investigation of the Ohio dieback problem in Hawaii. Miscellaneous pub. 183: Hawaii Institute of Tropical Agriculture & Human Resource, Honolulu HI.

Mullick, B. and Griffiths, T. 2007. India: Indigenous movement in Jharkhand challenge plans for industrial development that threatens to destroy Adivasi forests, farmlands and way of life. WRM's bulletin Nº 116, March 2007.

Munshower, F.F. 1993. Practical hand book of disturbed land revegatation. Lewis Publishers, London, Tokyo.

Murali, K. S., Ganeshaiah, K. N., Uma Shankar, R. and Bawa, K. S. 1996.Extraction of non timber forest products in the forest of BilgiriRangan Hill, India. 2. Impact of NTFP extraction on regeneration, population structure and species composition. *Ecology*, **13**: 211-221.

Murthy, I.K., Murali, K.S., Hegde, G.T., Bhat, P.R. and Ravindranath, N.H.2002. A comparative analysis of regeneration in natural forest and joint forest management plantations in Uttara Kannada Dist., Western Ghats. *Current Science***83**: 1358-1364.

Mushki, G.M. 1994. Studies on apple (*Malusdomestica*Borkh) orchard soil of Kashmir. M.Sc Thesis submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 1-229.

Myers, N. 1980. Conversion of Tropical Moist Forests, National Academy of Sciences: Washington D.C.

Myers, N. 1993. Conversion of Tropical Moist Forests, National Academy of Sciences: Washington D. C.

Myers, N. 1994. Tropical deforestation: rates and patterns. **In**: *The Causes of Tropical of Tropical Deforestation*.

Myers, N. and Mittermeier, R.A. 2000. Biodiversity hotspots for conservation priorities.*Nature***403**: 853-854.

Myneni, R.B., Keeling, C.D., Tucker, C.J., Asrar, G. and Nemani, R.R. 1997.Increased plant growth in the northern latitudes from 1981-1991.*Nature***386**: 698-702.

Naiman, R.J., Pinay G., Johnston C.A. and Pastor, J. 1994. Beaver influences on the long-term biogeochemical characteristics of boreal forest drainage networks. *Ecology* **75**: 905-921.

Najar, G.R. 2002. Studies on pedogenesis and nutrient indexing of apple (Red Delicious) growing soils of Kashmir Thesis submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 1-204.

Najar, G.R., Akhtar, F., Singh, S.R. and Wani, J.A. 2009.Characterization and classification of some apple growing soil of Kashmir.*Journal of the Indian Society of Soil Science* **57**(1): 81-84.

Nautiyal, B. P. and Bhatt, A. B. 1999. Niche Width and Diversity Pattern in Different Landscapes of an Alpine Grazing land in Garhwal Himalaya, India. **125**(4): 375-380.

Nautiyal, B.P., Prakash, V. and Nautiyal, M.C. 1999. Structure and diversity pattern along analtitudinal gradient in an alpine meadow of Madhyamaheshwar, Garhwal Himalaya. *InternationalJournal of Environmental Science* **4:** 39-45.

Nautiyal, S. and Purohit, A.N.1980.High altitude acclimatization in plants.Stomatal frequency and anatomical changes in leaves of *Artemisia species*. *Biol. Plant*. **22**: 282-286.

Nayar, M. P. 1996. Hot spots of endemic plants of India, Nepal, and Bhutan.Tropical Botanic Garden and Research Institute, Palode, Thiruvananthapuram, India.

Nayar, M. P. and Sastry, A. R. K. (eds). 1987. Red Data Book of Indian Plants, International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.

Nazir, S. and Wani, M.A. 2009.Forms of potassium and potassium absorption behavior of soil under different cropping sequences.*SKUAST Journal of Research***11(**2): 133-137.

Neeraj, K., Arvind, K., Jeet, R. and Ashish, T. 2001.Plant diversity assessment in relation to disturbance in mid elevational forest of central Himalaya, India.*Tropical Ecology***42**(1): 83-95.

Negi, K. S. 1979. Species composition, biomass and nutrient relations of an oak forest.Ph. D. Thesis, Kumaon University, Nainital, India.

Negi, S. S. and Naithani, H. B. 1995.Oak regeneration problem. In: Oaks of India. Nepal and Bhutan.International Book Distributors, Dehradun.

Nepstad, D.C., Schwartzmann, S., Bamberger, B., Santilli, M., Ray, D., Schlesinger, P., Lefebvre, P., Alencar, A., Prinz, E., Fiske, G. and Rolla, A. 2006. Inhibition of Amazon deforestation and fire by parks and indigenous lands.*Conservation Biology***20** : 65-73.

Noss, R.F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology***4** : 355-364.

Nykvist, N. 1998. Logging can cause a serious lack of calcium in tropical rainforest ecosystems. An example from Sabah, Malaysia. In. *Soils of Tropical Forest Ecosystems: Characteristics, Ecology and Management* Schulte, A. and Ruhiyat, D. eds. *Springer-Verlag* Pp. 87–91.

Odland A and Birks H. J. B. 1999. The altitudinal gradient of vascular plant species richness in Aurland, western Norway. *Ecography*; **22**(5):548–566.

Odum, E.P. 1971. Fundamentals of Ecology.Saunders, Phildelphia, Pennsylvania.Pp. 574.

Olsen, S. R. Cole, C. V. Watanabe, F. S. and Dean, L. A. 1954.Estimation of available phosphorus in soils by extraction with sodium bicarbonate.United States Department of Agriculture Circ. Pp.939.

Osunkoya, O. O., Ash, J. E., Hopkins, M. S. and Graham, A. W. 1994. Influence of seed size and seedling ecological attributes on shade-tolerance of rain-

forest tree species in northern Queensland. *Journal of Ecology*, **82**: 149-163.

Ouimet, R., Tremblay, S., Perie, C. and Pregent, G. 2007. Ecosystem carbon accumulation fallow farmland afforestation with red pine in southern Quebec. *Canadian Journal of Forestry Research***37** : 1118-1133.

Page-Dumroese, D.S., Jurgensen, M.F., Brown, R.E. and Mroz, G.D. 1999.Comparison of methods for determining bulk density of rocky forest soils.*Soil Science Society of American Journal***63** : 379-383.

Pal, S., Panwar, P. and Bhardwaj, D.R. 2013. Soil quality under forest compared to other land-uses in acid soil of north western Himalaya, India. *Annual of Forest Research*, **56**(1): 187-198.

Panchal N. S and Pandey A. N. 2004. Analysis of vegetation of Rampara forest in Saurashtra region of Gujarat state of India. *Tropical Ecology*, **45**(2): 223–231.

Pande, P. K. 2000. Ecological floristic diversity and regeneration behavior of some tree species in Moist Temperate western Himalayan forests of Chakrata, Uttaranchal (India). *Van Vigyan*, **38** (1-4): 159-184.

Pande, P.K., Negi, J.D.S. and Sharma, S.C. 2002. Plant species diversity, composition, gradient analysis and regeneration behaviour of some tree species in a moist temperate western-Himalayan forest ecosystem. *Indian Forester***128**(8): 869-886.

Pande, P.K., Negi. J.D.S. and Sharma S.C. 1996.Plant species diversity and vegetation analysis in moist temperate Himalayan Forests.Abstract, First Indian Ecological Congress 27-31 December, New Delhi.

Pandey, A.N. and Singh, J.S. 1985. Mechanism of ecosystem recovery: A case study of Kumaun Himalaya. *Recreation and Revegetation Research*, **3**: 271-292.

Pandit, B.R. and Thampan, S. 1988. Total concentration of P, Ca, Mg, N & C in the soils of reserve forest near Bhavnagar (Gujarat State). *Indian Journal of Forestry* **11**(2) : 98-100.

Papke, H. and Papen, H. 1998. Influence of acid rain and liming on fluxes of NO and NO_2 from forest soil.*Plant and Soil***199**: 131-139.

Parsons, D.J. 1976. Vegetation structure in the Mediterranean scrub communities of California and Chile. *Journal of Ecology***64**(2): 435-447.

Parthasarathy, N. 1999. Tree diversity and distribution in undisturbed and human-impacted sites of tropical wet evergreen forest in southern Western Ghats, India. *Biodiversity Conservation*, **8**: 1365–1381.

Parthasarathy, N. 2001.Changes in forest composition and structure on three sites of tropical evergreen forests around Sengatheri, Western Ghats.*Current Science*, **80** (3): 389-393.

Pascal, J. P. 1988. Wet Evergreen Forests of the Western Ghats of India.Inst. fr.Pondichery, trav. sec. sci. tech. Tome 20.

Pascal, J. P. and Pelissier, R. 1996.Structure and floristic composition of a tropical evergreen forests in south west India.*Journal of Tropical Ecology*, **12** (2): 191 – 214.

Pascal, J.P. 1986. A Field Key to the Trees and Lianas of the Evergreen Forests of the Western Ghats (India). Inst. fr.Pondichéry, trav. sec. sci. Tech. Tome 23.

Patil, R.B. and Prasad, J. 2004. Characteristics and classification of some sal (*Shorea robusta*) supporting soils in Dindori district of Madhya Pradesh.*Journal of Indian Society of Soil Science***51**(2): 119-125.

Paul, J.W. and Beauchamp, E.G. 1996. Soil microbial biomass C, N mineralization, and N uptake by corn in dairy cattle slurry and urea amended soils. *Canadian Journal of Soil Science***6**: 469-472.

Pavon, N. P. Hernandez-Trejo, H and Rico-Gray, V. 2000. Distribution of plant life forms along an altitudinal gradient in the semi-arid valley of Zapotitlan, Mexico. *Journal of Vegetation Science*, **11**: 39–42.

Peet, D.C. and Veblen, T.T. 1974. Plant Succession: Theory and Prediction. Population and Community, (Eds) Biology Series. Chapman and Hall, London, pp. 352.

Peet, R.K. 1974. The Measurement of Species Diversity.*Annual Review Ecology.*

Pelissier, R. 1998.Tree spatial patterns in three contrasting plots of a southern Indian tropical moistevergreen forest.*Journal of Tropical Ecology*, **14**:1–16.

Pfaff, A.S.P. 1999. What Drives Deforestation in the Brazilian Amazon? – Evidence from Satellite and Socioeconomic Data. *Journal of Environmental Economics and Management***37** : 26-43.

Pielou, E.C. 1977. Mathematical Ecology.Wiley Interscience Publ.New York, pp. 383.

Pierce, C. and Munson, A.D. 2000. Ten-year responses of soil quality and conifer growth to silvicultural treatments.*Soil Science Society of American Journal* **64**: 1815-1826.

Pinker, R. 1980.The microclimate of a dry tropical forest.*Agricultural Meteorology***22**: 249-265.

Prates, R.C. 2008. Unequal deforestation in the Brazilian Amazon : Its evolution, its causes and consequences on welfare, School of Agriculture, Luiz de Queiroz. Universidade de Sao Paulo, Piracicaba.

Puri, A. N. 1930.A new method for estimating total carbonates in soils. Imp. Agr.Res. Pusa Bull. 206, Pp. 7.

Putz, F.E., Blate, G.M., Redford, K.H., Fimbel, R. and Robinson, J. 2001. Tropical forest management and conservation of biodiversity: An overview. *Conservation Biology***15** : 7-20.

Qazi, A.H. and Ashok, K.P. 2008.Impact of three different individual tree species on the chemistry of mineral top soil in Kashmir Himalaya.*Journal of Research & Development***8**: 41-47.

Raghu, D. 2003. Ecological studies on vegetation characteristics of Gersoppa forest range. M.Sc.thesis submitted to the University of Agricultural Sciences, Dharwad.

Rai, S. N. and J Proctor., 1986. Ecological studies on four rain forests in Karnataka, *India. Journal of Ecology*, **74**: 439 – 454 .

Rajbhandari, R. 2000. Biodiversity and conservation In: Environmental Education Source Book, Pande et al. (Eds.), TU/IUCN, Kathmandu.

Rajwar, G. S., Dhaulakhandi, M. and Kumar, P. 1999. Regeneration status of an oak forest of Garhwal Himalaya.**Indian Forester**, **125** (6): 623-630.

Ralhan, P. K., Khanna, R. K., Singh, S. P. and Singh, J. S. 1985. Certain phonological characters of the shrub layer of Kumaon Himalayan forests. *Vegetation*, **63**: 113-119.

Ralhan, P.K., Saxena A.K. and Singh, J.S. 1982. Analysis of forest vegetation at and around Nanital in Kumaon Himalaya. *Proceedings of Indian National Science Academy* **48**(1): 121-137.

Ram J, Kumar A and Bhatt J. 2004. Plant diversity in six forest types of Uttaranchal, Central Himalaya, India.*Current Science*.**86**(7): 975–978.

Ram, D., Ram, T. and Chand, S. 2010.Characterization and classification of flood-prone soils of eastern plains of Rajasthan for their corrective measures. *Journal of the Indian Society of Soil Science* **58**(2): 228-232.

Rao, A.P.V.P., Naidu, M.V.S., Ramavatharam, N. and Rao, G.R. 2008. Characterization, classification and evaluation of soils of different land forms in Ramachandrapuram Mandal of Chitpor district in Andhra Pradesh for sustainable land use planning. *Journal of the India Society of Soil Science***50**(1): 23-33.

Rawal, R. S., Bankoti, N. S., Samant, S. S. and Pangtey, Y. P. S. 1991.Phenology of tree layer species from the timber line around Kumaun in Central Himalaya, India.*Vegetation*,**93**: 109-118.

Reis, E.J. and Guzmán, R.M. 1992.An Econometric Model of Amazon Deforestation.Texto para discussão No. 265, IPEA-Instituto de Pesquisa Econômica Aplicada.

Repetto, R. 1988. The forest for the trees?Government policies and the misuse of forest resources. World Resource Institute, Washington DC.

Repetto, R. 1990. Deforestation in the Tropics. Scientific American April, p. 37.

Reynolds, P. J., Sharma, P., Jenneman, G. E., and Mclnerney, M. J.: 1989, Appl. Environ. *Microbiol*.**55**: 22-80.

Richards, P. W. 1952. The tropical rain forest.Cambridge University Press, Cambridge, England.

Richter, D.D., Comer, P.J., King, K.S., Sawin, H.A. and Wright, D.S. 1988. Effects of low ionic strength solutions on pH of acid forested soils. *Soil ScienceSociety of American Journal***52**: 261-264.

Romshoo, S.A., Shimada, M. and Igarshi, T. 2002.SAR Sensitivity for Vegetation Biomass and Ecosystem Dynamics from Tropical Forests of Southeast Asia.*AsianJournal of Geo-informatics***3**(1): 3-17.

Rowe, R., Sharma, N.P. and Bowder, J. 1992. Deforestation: problems, causes and concern. **In**: *Managing the world's forest: looking for balance*

between conservation and development. [Ed. N.P. Sharma]. Kendall/Hunt Publishing Company, Iowa, pp. 33-46.

Rowntree, P.R. 1988. Review of General Circulation Models as a basis for predicting the effects of vegetation change on climate. **In**: *Forests, climate and hydrology, regional impacts.* [Eds. E.R.C. Reynolds and F.B. Thompson]. The United Nations University, Tokyo Japan, pp. 162-196.

Running, S. W. and Reid, C. P. 1980. Soil temperature influences on root resistance of Pinus contort seedlings. *Plant Physiology*, **65**: 634-640.

Saetre, P. Brandtberg, P.O., Lundkuist, H. and Bengtsson, J. 1999. Soil organisms and carbon, nitrogen, and phosphorus mineralization in Norway spruce and mixed Norway spruce-birch stands. *Biol. Fertil. Soils***28** : 82-388.

Sagar, R., Raghubanshi, A.S. and Singh, J.S. 2003. Tree species composition, dispersion and diversity along a disturbance level in a dry tropical forest region of India. *For. Ecol. Manage.***186** : 61-71.

Saha, P. K., Saleque, M. A., Panaullah G. M. and Bhuiyan, N. J. 2000. Fertilizer management for rice based cropping systems productivity. *Bangladesh journal of Agriculture*, **25**(4): 555-560.

Sands, R. 2005.Forestry in a Global Context.CABI Publishing.

Santhosha, G. R. 2005. Vegetation analysis in different landscapes of Talakaveri, Kodagu, Central Western Ghats. M. Sc. Thesis submitted to the University of Agricultural Sciences, Banglore.

Sanchez, P. A. 1976. Properties and Management of Soils in the Tropics.Wiley and Sons, New York.

Sariyildiz, T., Anderson, J.M. and Kucku, M. 2005. Effects of tree species and topography on soil chemistry, litter quality and decomposition in northeast Turkey. *Soil Biol. Biochem.* **37**: 1695-1706.

Saxena, A. and Nautiyal, J.C. 1997. *Journal of Sustainable Forestry***5**(3/5). The Haworth Press, Inc.

Saxena, A. K. and Singh, J. S. 1984. Tree population structure of central Himalaya forests association and implications concerning their future composition. *Vegetation*, **85**: 61-69.

Saxena, A. K., Singh, S. P. and Singh, J. S. 1984. Population structure of forests of Kumaon Himalaya; Implication of management, *Journal of Environment Management*, **19**: 307-324.

Saxena, A.K. and Singh, J.S. 1982. A phytosociological analysis of forest communities of a part of Kumaun Himalaya. **In**: *Department of Environmental Science, University of Kashmir179 Glimpses of Ecology*. [Eds. J.S. Singh and B. Gopal]. International Scientific Publications, Jaipur, pp. 167-180.

Schall, J.J. and Pianka E.R. 1978. Geographical trends in numbers of species. *Science* **201**(4357): 679-686.

Scheiner, S.M. 1992. Measuring pattern of diversity.*Ecology***73**(5): 1860-1867.

Schlesinger, W.H., Reynolds, J.F., Cunningham, G.L., Huenneke, L.F., Jarrell, W.M., Virginia, R.A. and Whitford, W.G. 1990. Biological feedbacks in global desertification.*Science***247**: 1043-1048.

Schmidt, M.G., Macdonald, S.E. and Rothwell, R.L. 1996. Impacts of harvesting and mechanical site preparation on soil chemical properties of mixed wood boreal forest sites in Alberta. *Canadian Journal of Soil Science***76** : 531-540.

Schneider and Robert, R. 1995. Government and the Economy on the Amazon Frontier.World Bank Environment Paper, 11. Washington, D.C.

Schnitzer, M. 1986. Binding of humic substances by soil colloids. **In**: *Interactions of soil minerals with natural organics and microbes*. [Eds.

P.M. Huang and M. Schnitzer] Special Publication No.17, Soil Science Society of America, Madison, WI, pp. 77E 1.

Schnitzer, M. 1991. Soil organic matter-the next 75 years.*Soil Science***151**(1): 41-58.

Schreiber, J.D., Duffy, P.D. and McDowell, L.L. 1990. Nutrient leaching of a Loblolly pine forest floor by stimulated rainfall I. intensity effects. *Forest Science***36**(3): 765-776.

Schwartz, M.D. 1999. Advancing to full bloom: Planning phonological research for the 21st century.*International Journalof Biometeorology***42**: 113-118.

Schwendenmann, L. 2000. Soil properties of boreal riparian plant communities in relation to natural succession and clear cutting in Peace River lowlands, Wood Buffalo National Park, Canada. *Water, Air and Soil Pollution* **122**: 449-467.

Semwal D. P, Uniyal P. L and Bhatt A. B. 2010. Structure, Composition and Dominance–Diversity Relations in Three Forest Types of a Part of Kedarnath Wildlife Sanctuary, Central Himalaya, India. *NotulaeScientiaBiologicae*, **2**(3): 128–132.

Semwal J. K and Gaur R. D, 1981.Alpine flora of Tunganath in the Garhwal Himalaya; J. Bombay Nat. Hist. Soc. 78 498–512.

Semwal J. K, Gaur R. D and Purohit A. N. 1981. Floristic pattern of Tungnath alpine zone in Garhwal Himalaya. *Acto Botanica Indica*, **9**:110-114.

Sha, A. A., 1989. Natural regeneration in tropical rain forests.*My forest*, **28** (2): 103 – 112.

Shahid, F., Khan, A.Z., Yousaf, M. and Fazal, H. 2010. Phytosociological Study of Push Ziarat Area (Shawal) In The South Waziristan, Pakistan. *Pakistan Journal of Weed Science Research* **16**(1): 47-55.

Shank, R.E. and Noorie, E.N. 1950.Microclimate vegetation in a small valley in eastern Tennessee.*Ecology***11** : 531-539.

Sharma C. M and Baduni N. P. 2000. Effect of aspect on the structure of some natural stands of Abies pindrow in Himalayan moist temperate forests. The Environmentalist.**20**(4): 309–317.

Sharma, B.D., Arora, H., Kumar, R. and Nayyar, V.K. 2004.Relationship between soil characteristics and DTPA-extractable micronutrient in inceptisols of Punjab.*Communication in Soil Science and Plant Analysis***35**(5&6): 799-818.

Sharma, C.M., Suyal, S., Ghildiyal, S.K. and Gairola, S. 2009a. Role of Physiographic factors in distribution of *Abies pindrow* (Silver Fir) along an altitudinal gradient in Himalayan temperate Forests. *The Environmentalist.*

Sharma, C.M., Suyal, S., Gairola, S. and Ghildiyal, S.K. 2009b. Species richness and diversity along an altitudinal gradient in moist temperate forest of Garhwal Himalaya.*The Journal of American Science* **5**(5) : 119-128.

Sharma, P.K., Sood, A., Setea, R.K., Tur, N.S., Deepak, M. and Singh, H. 2008.Mapping of micronutrients in the soils of Amritsar district (Punjab)-A GIS approach.*Journal of the Indian Society of Soil Science* **56**(1): 34-41.

Sharma, U and Bhandari, A. R. 1992.Survey of nutrient status of apple orchards in Himachal Pradesh.*Indian Journal of Horticulture,***49**(3): 234-241.

Sheikh, A.M. 2006.Studies on micro-nutrient cation in paddy growing soils of district Kupwara. M.Sc. Thesis Submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 59-65.

Shimizu, Y. 1984. Regeneration of the subtropical evergreen broadleave forest at Shichijima in the Bonin (Ogasawara) islands with reference to an

environmental gradient and canopy gaps.*Japan Journal Ecology*, **34**: 87-100.

Shrestha, B. B., Ghimiro, B., Lekhar, H. D. and Jha, P. K. 2007.Regeneration of treeline Birch (Betula utilis D. Don) forest in a Trans- Himalayan Dry Valley in Central Nepal.*Mountain Research and Development*, **27**(3): 259-267.

Shukla, M.K., Lal, R. and Ebinger, M. 2006. Determining soil quality indicators by factor analysis.*Soil Tillage Research***2** : 194-204.

Simpson, B. B. 1974. Glacial migrations of plants: island bio-geographical evidence. *Science*, **185**: 698–700.

Singh, A.K., Parsad, A. and Singh, B. 1986.Availability of phosphorus and potassium and its relationship with physico-chemical properties of some forest soils of Pali-range (Shahodol, M.P.). *Indian Forestry*, **112**(12) : 1094-1104.

Singh, J.S. and Singh, S.P. 1987. Forest Vegetation of the Himalaya.*Botany Review***53**(1) : 81-192.

Singh, J.S. and Singh, S.P. 1992. Forests of Himalaya.GyanodayaPrakashan, Naini Tal, India.

Singh, K. and Bansal, S.K. 2009. Different fractions of soil potassium, olsen phosphorus and available sulphur status of intensively cultivated Berpureasoil series of India and nutrient indexing of rice crop. *Communication in Soil Science and Plant Analysis***40**: 1983-1984.

Singh, N., Ma, L. Q, Srivastava, M and Rathinasabapathi, B., 2006. Metabolic adaptations to arsenic-induced oxidative stress in Pterisvittata L. and Pterisensiformis L. *Plant Science*, **170**: 274–282.

Singh, R. 1976. Structure and net community production of the herbaceous vegetation in the sand dune regions around Pilani, Rajasthan, Ph. D. thesis, B.I.T.S. Pilani, India.

Singh, S. 1998. Assessment of floral and habitat diversity and collection of base line data to monitor vegetation of GHNP and WLs. WII, Report, Dehra Dun.

Singh, S. P., Rahlan, P. K., Upadhyay, V. P. and Negi, G. C. S. 1990. Seasonal changes in stem diameter and left development in a tropical montane forest. *Journal Vegetation Science*, **1**: 165-172.

Singh.R. and Joshi, M. C. 1979.Floristic composition and life forms of sand dune herbaceous vegetation near pilani, Rajasthan. *Intemational Journal of Ecology*, **6**:9-49.

Sitanggang, M., Rao, Y.S., Nayan, A. and Mahapatra, S.K. 2006.Characterization and classification of soils in watershed area of Shikohpur, Gurgaon district, Haryana.*Journal of Indian Society of Soil Science* **54**: 106-110.

Smal, H. and Olszewska, M. 2008. The effect of afforestation with Scot pines (Pinus Department of Environmental Science, University of Kashmir. 181 silverstris L.) of sandypsot-arable soils on selected properties. II. Reaction, carbon, nitrogen and phosphorus. *Plant and Soil***305**: 171-187.

Smeck, M.E. 1985. Phosphorus dynamics in soils and landscapes. *Geoderma* **35**: 185-199.

Smith, S. J., Andres, R., Conception, E., and Lurz, J. 2004. Sulfur Dioxide Emissions: 1850–2000 (JGCRI Report. PNNL-14537).

Sofi, J.A. 2001. Effect of phosphorus and potassium on nitrogen utilization in maize under rainified condition of Kashmir valley. M Sc. Thesis submitted

to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 7-10.

Soni, P. and Vasistha, H.B. 1986. Reclamation of mine spoils for environmental amelioration. *Indian Forester***112**(7) : 621-632.

Sood, R.D. and Kanwar, B.S. 1986. Distribution of organic and total phosphorous in some soil profiles of different agro-climatic zone of Himachal Paradesh. *Journal of Indian Society Soil Science***34** : 404-406.

Sponsel, L.E., Headland, T.N. and Bailey, R.C. 1996. Anthropological Perspectives on the Causes, Consequences and Solutions of Deforestation.**In**: *Tropical Deforestation: The Human Dimensions*. [Eds. E.S. Leslie, N.H. Thomas and R.C. Bailey], Columbia University Press, New York.

Staff, S. 2010. Mining deforestation nearly tripled between 2000-08. Archives, Wednesday October 13.

Stewart, J.W.B. and Tiessen, H. 1987. Dynamics of soil organic hosphorus. *Biogeochem*.**4** : 41-60.

Subbaiah, G. V. and Manickam, T. S. 1992. Ganesis and morphology of vertisols developed on different parent materials. *Journal of Indian Society of Soil Science*, **40**:150-155.

Sukumar, R., Suresh, H.S., Dattaraja, H.S. and Joshi, N.V. 1997. **In**: *Forest Diversity Research, Monitoring and Modeling: Conceptual Background and Old World Case Studies*. [Eds. F. Dallmeier and J.A. Comiskey].Vol. I. *Parthenon Publishing*, pp. 529-540.

Takahashi, M., Sakata, T. and Ishizuka, K. 2001. Chemical characteristics and acid buffering capacity of surface soils in Japanese forests. *Water, Air, and Soil Pollution***130**: 727-732.

Tang, Z., Fang, J. and Zhang, L. 2004. Patterns of woody plant species diversity along environmental gradients on Mt. Taibai, Qinling Mountains.*Biodiversity Science* **12**(1): 115-122.

Tappeiner, U. and Cernusca, A. 1996. Microclimate and fluxes of water vapor, sensible heat and carbon dioxide in structurally differing sub-alpine plant communities in the central Caucasus. *Plant Cell Environment***19** : 403-417.

Tate, K.W., Dudley, M.D., McDougald, N.K. and George, M.R. 2004.Effect of Canopy and Grazing on Soil Bulk Density.*Journal of Range Management***57**(4): 411-417.

TerBraak, C. J. F. 1987. Ordination. In: Jongman R.H.G., C.J.E ter Braak and O.ER. van Tongeren (eds.), Data analysis in communityy and landscape ecology, Pudoc, Wageningen (reprinted by Cambridge University Press, Cambridge, 1995), Pp. 91-173.

Thandani, R. and Ashton, P. M. S. 1995.Regeneration of banj oak (Quercus leucotrichophora A. Camus) in the central Himalaya.*Forest Ecology and Management*, **78**: 217-224.

Thangam, E. S. 1982. Regeneration methods of Dipterocarpus species in India.*Indian Forester*, **108**(10): 637-647.

Tilki, F. and Fisher, R.F. 1988. Tropical leguminous species for acid soils: Studies on plant form and growth in Costa Rica. *Forest Ecology and Management***108**: 175-192.

Tilman, D. 1994. Competition and biodiversity in spatially structured habitats. *Ecology***75**: 2-16.

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

Tittensor, R. M. 1980. Ecological history of Yew Taxus baccata L. in Southern England.*Biological Conservation*, **17**: 243-265.

Tiwari, S.D, Ritesh, J. andArjun, R. 2013. Physico-chemical properties of soils in cool-temperate forests of the "Nanda Devi Biosphere Reserve" in Uttarakhand (India), *Journal of Ecology and the Natural Environment***5**(6): 109-118.

Todaria, N. P. and Purohit, A.N.1979. Functional dynamics of plants at different altitudes. I. Growth pattern of *Artemisia vulgaris* . I*ndian J. Pl. Physiol*. **22**: 230-240.

Trasar-Cepeda, C., Leiros, C., Gil-Stories, F. and Seoane, S. 1998. Towards a biochemical quality index for soils: An expression relating several biological and biochemical propertied. *Biol. Fertil. Soils* **26**: 100-106.

Tremblay, S., Pierce, C. and Ouimet, R. 2006.Changes in organic C storage in a 50 year white spruce chrono sequence established on fallow land in Quebec.*CanadianJournal of Forest Research.***36**: 2713-2723.

Tripathi, D., Patial, K.S., Verma, J.R. and Singh, K. 2006. Soil Fertility status of Kiar-Nagali micro-watershed in Solar district of Himachal Pradesh. *Journal of the Indian Society of Soil Science***55**(2): 222-223.

Tripathi, R.S. and Khan, M.L. 2007.Regeneration dynamics of natural forests – A review.*Proc. Indian Natl. Sci. Acad*., **73 :**167-195.

Troug, E. 1947. Soil reaction influence on availability of plant nutrients. *Soil Science Society of American Proceedings* **11** : 305-308.

Turner, I. M. 2001. The Ecology of Trees in Tropical Rain forest. Cambridge University Press, the Edinburgh building, Cambridge UK.

Uma Shankar, 2001. A case of high tree diversity in a Sal (*Shorea robusta*) - dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. *Current Science* **81**: 776-786.

Uniyal P, Pokhriyal P, Dasgupta S, Bhatt D and Todaria NP. 2010. Plant diversity in two forest types along the disturbance gradient in Dewalgarh Watershed, Garhwal Himalaya. *Current Science*; **98**(7): 938–943.

Upreti N, Tewari J. C and Singh S. P. 1985. The oak forests of Kumaun Himalaya (India): Composition, Diversity, and regeneration. Mountain Research and Development; **5**(2): 163–174.

Veblen, T. T., and Ashton, D. H. and Schlsgel, F. J. 1979. Tree regeneration strategies in lowland Nothofagus dominated forest in south-central Chile. *Journalof Biogeography*, **6**: 329-340.

Verma, K.S., Shyampura, R.L. and Jain, S.P. 1990. Characterization of soils under forest of Kashmir valley. *Journal of Indian Society of Soil Science***38**: 107-115.

Verma, T.P., Singh, S.P. and Rathore, T.R. 2008.Effects of slope aspects and altitude on some soils characteristics in garhwal Himalayas.*Journal of the Indian Society of Soil Science* **50**(1): 42-48.

Vetaas, O. R. 2000. The effect of environmental factors on the regeneration of Quercus semecarpifolia Sm.In Central Himalaya, Nepal.*Plant Ecology*, **146**: 137-144.

Vitousek, P. 1982. Nutrient cycling and nutrient use efficiency. *The American Naturalist* **119**: 553-572.

Vogt, K.A., Grier, C.C. and Vogt, D.J. 1986. Production, turnover, and nutrient dynamics of above and below-ground detritus of world forests. *Advances in Ecological, Research,***15** : 303-366.

Waksman, S. A. Tenney, F. G. Stevens, K. R. 1928. The role of microorganisms in thetransformation of organic matter in forest soils.*Ecology*, **9**: 126-144.

Waksman, S.A., Tenney, F.G. and Stevens, K.R. 1928.The role of micro-organism in the transformation of organic matter in forest soils.*Ecology***9**(2): 126-144.

Walia, C. S. and Chamuah, G.S. 1992. Soil profile development in relation to land.

Walia, C. S., Rana, K.C.P., Sidhu, Mahapatra, S.K. and Terseem, L. 1999. Characterization and classification of some soils of ladakh region.

Wang Z, Tang Z and Fan J. 2007. Altitudinal patterns of seed plant richness in the Gaoligong Mountains, south–east Tibet, China. *Diversity and Distributions*, **13**(3): 845–854.

Wani, M. A. 1994. Distribution and forms of micronutrient cations (Zn, Cu, Fe and Mn) in some saffron (*Crocus sativus*L.) growing soil of Kashmir. Thesis submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 1-119.

Wani, M. A. 2005. Dynamics of potassium release in some soils of Kashmir. Ph.D. Thesis, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 209-210.

Wani, M. A., Wani, J. A., Kirmani, N. A. and Bhat, M. A. 2009. Potassium forms their interrelationship nd relationship with soil properties in rice soils of lesser Himalayas. *SKUAST Journal of Research***11**(1): 1-7.

Wani, M. A., Wani, J. A., Kirmani, N. A. and Chesti, M. H. 2007. Response of paddy to applied phosphorus under submerged condition. *SKUAST Journal of Research***9**(12): 127-132.

Watkinson A. R. 1997. Plant population dynamics. In: Plant Ecology (ed. M. J. Crawley) pp. 359–400. Blackwell Publishing Limited, Oxford.

Watmough, S. A. and Dillon, P.J. 2004. Major element Fluxes from a coniferous catchment in central Ontario, 1983-1999. *Biogeochemistry*, **67**: 369-398.

Weinhold, D. and Reis, E. 2008.Transportation costs and the spatial distribution of land use in the Brazilian Amazon.*Global Environmental Change***18**: 54-68.

West, D. C, Shugart, H. and Ranney, J. W. 1981.Population structure of forests over a large area.*Forest Science*, **27**:701–710.

Whittaker R. H. 1965. Dominance and diversity in land plant communities. *Science***147**: 250-260.

Whittaker R. H. 972. Evolution and measurement of species diversity.*Taxon***21**(2/3): 213-251.

Whittaker, R. H. 1975. Communities and Ecosystems. Macmillan Publisher, New York.

Wilkie, D. Shaw, E. Rotberg, F. Morelli, G. and Auzels, P. 2000. Roads, development and conservation in the Congo Basin.*Conservation Biology***14** : 1614-1622.

Wills, S. A, Burras, C. L and Sandor, J. A. 2007. Prediction of soil organic carbon content using field and laboratory measurements of soil color.*Soil Science Society of America Journal*, **71**: 380-388.

Zak, D. R., Grigal, D. F., Gleeson, S.and Tilman, D. 1990. Carbon and nitrogen cycling during old field succession constraints on plant and microbial biomass. *Biogeochem.***11**: 111-129.

Zarin, D. J., Johnson, A. H. and Thomas, S. M. 1998. Soil organic carbon and nutrient status in old growth mountane coniferous forest watersheds, Isiachiloe, Chile. *Plant and Soil***201**: 251-258.

Zhang, W. H., Wang, Y. P., Kang, Y. X. and Liu, X. J. 2004. Age structure and time sequence prediction of populations of an endangered plant, *Larix potaniniiv*ar. *Chinensis*. *Biodiversity Science***12**(3): 361-369.

Zhang, Y., Zheng, Zhi-hua, and Zhang, Zhi-xiang, 2007. Community structure and regeneration types of *Betula dahu-rica*forest in Badaling forest center of Beijing. *Forestry Studies in China***9**(2) : 152-156.

Zhong, L. and Qiguo, Z. 2001. Organic carbon content and distribution in soils under different land uses in tropical and subtropical china. *Plant and Soil***231**: 175-185.

Zhong, Z. and Makeschin, F. 2004. Comparison of soil nitrogen dynamics under beech, Norway Spruce and Scots pine in central Germany. *Eurasian Journal of Forest Research* **123**: 23-37.

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Forestry,
Shalimar Campus, Srinagar – 191 121
-::o::-

CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner **Prof. (Dr) Kulraj Singh Kapoor** Scientist-F and groupco-ordinator (Research), Himalayan Forest Research Institute Conifer Campus Panthaghati, SHIMLA (H.P), during Viva-Voce examination held on 06-12-2014 have been incorporated in the manuscript entitled **"Plant Diversity and Regeneration Status in Kandi Range of Kamraj Forest Division of Kashmir"** submitted by **Mr. Hillal Ahmad Rather** (Regd. No.2010-328-D).

(Prof. (Dr.) T. H. Masoodi)
Chairman
Advisory Committee