A STUDY ON EFFECT OF ANTHROPOGENIC DISTURBANCE ON DIVERSITY, DISTRIBUTION AND COMMUNITY CHARACTERISTICS OF PLANTS IN THE NOKREK BIOSPHERE RESERVE OF MEGHALAYA, INDIA

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SUBMITTED

IN PARTIAL FULFILLMENT OF THE REQUIREMENT OF THE DEGREE OF DOCTOR OF PHILOSOSPHY IN ENVIRONMENTAL SCIENCE OF MIZORAM UNIVERSITY, AIZAWL

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SUPERVISORS CERTIFICATE

This is to certify that the Ph.D thesis entitled ***''A STUDY ON EFFECT OF ANTHROPOGENIC DISTURBANCE ON DIVERSITY, DISTRIBUTION AND COMMUNITY CHARACTERISTICS OF PLANTS IN THE NOKREK BIOSPHERE RESERVE OF MEGHALAYA, INDIA''*** submitted by **Tremie M Sangma** for the award of Ph.D degree of Department of Environmental Science, Mizoram University embodies the original work carried out under my supervision. She is a bonafide research scholar and the work is worthy of being considered for the award of the Ph.D degree. The work has not been submitted for award of any degree or any other Institute or University of learning.

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DECLARATION

I, **Tremie M Sangma,** hereby declare that the subject matter of this thesis entitled **''A STUDY ON EFFECT OF ANTHROPOGENIC DISTURBANCE ON DIVERSITY, DISTRIBUTION AND COMMUNITY CHARACTERISTICS OF PLANTS IN THE NOKREK BIOSPHERE RESERVE OF MEGHALAYA, INDIA''** is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to do the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.

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

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CHAPTER- 1

INTRODUCTION

1.1 Biodiversity

Biodiversity is presently critical since we live in an era of Mass Holocene Extinction, a period of species loss caused by man, and unrivaled rate of species loss. Previously, the stress we put forth on the earth has almost increased and the naturally occurring resources upon which we rely on have reduced by one third or more. Biodiversity represents the variability in nature and relates to the differences within and between species and their surroundings. Broadly, the biodiversity is observed mainly at three levels- gene, species and ecosystem. Massive decline of biodiversity in all forms and levels has been a global concern. According to Global Forest Watch Report, 29.7-million-hectare forest was lost in 2016 which was 51 % higher than the record for the year 2015 (Global Forest Watch, 2016). Biodiversity has turn out to be the topic of worldwide attention because of increasing awareness of its significance and its swift depletion globally (Singh, 2002).

Currently, guarding the environment has developed as one of the main factor in the country as well as worldwide. In 1972 the first global conference under the banner “United Nations Conference on Human Environment” was organized in Stockholm. Again in 1992, “The Rio Earth Summit” was held which has led to the foundation of Convention on Biological Diversity (CBD) and United Nations Framework Convention on Climate Change (UNFCC). The biological diversity was stated by United Nations Earth Summit, 1992 as “the variability amongst living entities from all sources, terrestrial, marine, and aquatic ecosystems, and the environmental complexes including species diversity within and between the species and ecosystems” (CBD, 1992). The Convention also stated that the preservation of biodiversity is a major concern of humanity owing to its key values and significance.

With the exploitation of resources at the rise, sustainable living has been a centre of international debate. The ecosystem has been going through immense alteration impacting the climate, ocean, atmosphere and biodiversity as a whole. Involvement of the indigenous community is a must for proper management of the biodiversity. In 1971, the UNESCO'S Man and Biosphere Program (MAB) were initiated to maintain equilibrium between biodiversity conservation and sustainable management of the resources. It was further developed in 1974 and in 1983, first International Biosphere Reserve Congress was held in Belarus (UNESCO-MAB, 1974). The World Network of Biosphere Reserve's was formulated during the famous Seville Conference (1995) which focuses on `Conserving biodiversity, restoring and enhancing the ecosystem with a goal to sustainability (UNESCO, 1995). Biosphere reserve is an area where natural livelihood of indigenous people is supported. They extend over terrestrial areas and coastal ecosystems. The people in the buffer zone mostly they rely on natural resources. Economic activities like harvesting and selling of products from their home gardens and jhum fields are common in these areas.

There are 701 Biosphere Reserves in 124 countries [https://en.unesco.org/]. India has 18 Biosphere Reserves (MOEF Annual report, 2019). **(Table1.1)** According to 2019, World Network of Biosphere Reserve report, there are a total of 686 Biosphere Reserves in 122 countries under the umbrella of UNESCO's MAB programme. Out of which 11 are in India. Biosphere Reserve's are placed under Category V of Protected Areas as per IUCN classification (IUCN, 1979; Van Cuong *et al.*, 2017).

National Parks are areas protected under Wildlife Protection Act, 1972 mainly for conservation of wildlife and biodiversity. It falls under the Protected Area Network. In areas designated as National park, no human activity and private ownership are allowed. National parks are mainly set up to protect and preserve the wildlife in its natural form. The State government notifies the area as a National Park under the rules set up by the Wildlife Protection Act in those areas which has good ecological diversity along with flora and fauna solely for shielding the wildlife and environment. As per the guidelines given in Chapter IV of Wildlife Protection Act, 1972 a permit is required from the Chief Wildlife Warden to enter the National Park. Protected areas are those areas under the Wildlife Protection Act (1972) in which exploitation of resources are prohibited and human occupation is minimized. A protected area does not limit only to the forest and land resources but also include marine protected areas and trans boundary protected areas. India has 869 Protected Areas with an area of 165158.54 km^2 with a coverage percentage of 5.02 (Arora, 2003).

These protected areas cover National Parks, Wildlife Sanctuaries, Community Reserves, and Conservation Reserves. Out of the total of 5.02 %, National Parks cover 1.23 % of the area. As of January 2018, 104 National parks are present in India with an area of 40501.13 km^2. North East has 16 National Parks.Out of which two are in Meghalaya - Nokrek National Park and Balpakram National Park, and three Wildlife Sanctuaries -Nongkhyllem Wildlife Sanctuary, Siju Wildlife Sanctuary and Baghmara Sanctuary and 65 Community Reserves (National Wildlife Database, 2019).

The National parks are classified into core and buffer zone. No activities like hunting, human settlement are allowed inside the core zone. It is a protected area solely for the preservation of biological diversity. The buffer zone is the area for the local or the indigenous people to reside and agricultural activities for survival and livelihood are allowed. The entry into the area is permitted only with the permission from the Chief Wildlife Warden.

Table 1.1: List of Biosphere Reserves notified in India

Sl no	Name	Area (km^2)	Year of notification	States
1	Nilgiri	5520	1986	Tamil Nadu, Kerala, Karnataka
2	Nanda Devi	5860	1988	Uttarakhand
3	**Nokrek**	**820**	**1988**	**Meghalaya**
4	Manas	2837	1989	Assam
5	Sunderbans	9630	1989	Wesst Bengal
6	Gulf of Mannar	10500	1989	Tamil Nadu
7	Great Nicobar	885	1989	Andaman and Nicobar Islands
8	Similipal	4374	1994	Orissa
9	Dibru-Saikhova	765	1997	Assam
10	DehangDibang	5111	1998	Arunachal Pradesh
11	Pachmarhi	4981	1999	Madhya Pradesh
12	Kanchengjunga	2619	2000	Sikkim
13	Agasthyamalai	300	2001	Tamil Nadu and Kerala
14	Achanakmar-Amarkantak	3835	2005	Madhya Pradesh and Chattisgarh
15	Kachchh	12454	2008	Gujarat
16	Cold Desert	77770	2009	Himachal Pradesh
17	Seshachalam	4755	2010	Andra Pradesh
18	Panna	2998	2011	Madhya Pradesh

Article 2 of the Statutory Framework for the World Network of Biosphere Reserve proposes to accomplish three rudimentary tasks (Schaaf, 2002), which are complimentary and mutually reinforcing:

(i) **Conservation function -** to protect the whole of the ecosystem of the area pertaining to species and genetic variation.

(ii) **Development functions** - to nurture the social and economic needs of the people sustainably economic and human development which is socio-culturally and ecologically sustainable.

(iii) **Logistic function** - to deliver provision for exploration, monitoring, education and exchange of knowledge with the native people in regard to global conservation.

There are three distinct zones in a Biosphere reserve:

i. **Core zone:** It is a strictly protected area where human activities are not allowed. It provides opportunity for monitoring evolutionary changes and serves as totally protected area for natural regeneration of biodiversity.

ii. **Buffer zone:** It is the area that lies outside the core zone and face moderate disturbance as human activities are extended to this zone. These include environmentally sustainable use of natural resources and development, research, environmental education and regulated recreation. Human use is usually less intensive than what might be found in the transition zone.

iii. **Transition zone:** It is the area around the buffer zone where human activities and utilization of natural resources takes place. Most of the economic and social development activity occurs in this zone.

India has one of the richest biodiversity and heritage of the world covering tropical rain forest, alpine vegetation and coastlands. India is ranked 6th (covering 7% of the world biodiversity) among the 12 mega biodiversity countries of the world. These mega diversity countries support 35 hotspots of biodiversity (mega diversity centres), occupying 1.4% of the earth's surface. Unfortunately, 86% has been said to have ruined now (Mittermeier, 2011). The four biodiversity hotspots recognized in the country are The Himalayas, Western Ghats, Indo-Burma and Nicobar group of Islands (ENVIS, 2016).

According to the Global Forest Assessment (2015), only 4 billion hectares of forest has remained worldwide. The greatest biodiversity is found in the tropical rainforest world-wide (6% of the world's surface area), and it constitutes three quarters of earth's species of plants and animals. Southeast Asia falls under the area of the richest tropical diversity, whereas Africa has the lowest. Other than the tropical rainforest, areas which receive moderate rainfall like the lowland forests also have adequate number of flora and fauna. Approximately, 6 billion populations depend on biodiversity for goods and services. Sustainable agriculture needs to be implemented for the indigenous people, as 40 % of the world's economy and global food productions depend on the biological resources which acts as a genetic storehouse. On an international scale, timber trade is the foremost economic activity. Industries like the pharmaceutical and tourism industry also rely on biodiversity. With the recent rise in demand and profuse lifestyle, many of the forest wealth have been over exploited; the major one being the anthropogenic disturbance.

1.2 Loss of biodiversity

The threats to the biodiversity can be understood through various conservation measures including efforts made by various organizations most importantly IUCN. The World Conservation Union has classified species that have high possibility of extinction into- Critically endangered, Endangered and Vulnerable. Globally, many treaties and conventions have been set up to safeguard the environment (IUCN, 2018).

Unplanned land use, alien species, pollution and toxicity and climate change due to anthropogenic disturbance are the main causes of loss in biodiversity. This drastic change has not only impacted the flora and fauna but also human beings at a large. Global ecological and economic crises have also damaged the natural resources.Forest and soils have been depleted, water supplies have been scare and many land areas has been degraded. The increase in man-made disturbance has led to erosion of biodiversity and more extinction of species (Slingenberg, 2009).

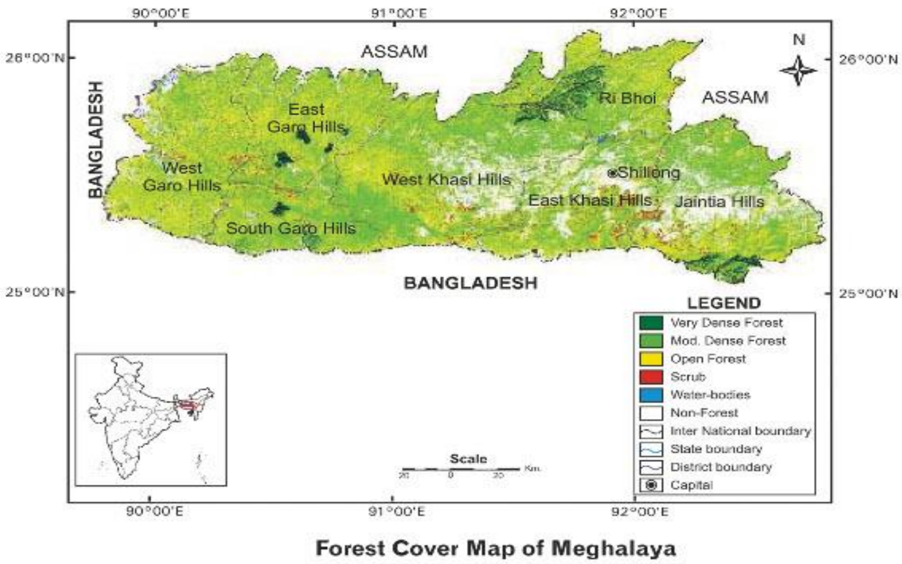
1.3 Conservation of Biodiversity

From the history of conservation movements around the world, we can see that- In the 19th century many conservation groups were set up by various International organisations. By the 20th century when most of the species have disappeared the real impact of anthropogenic disturbance on the biodiversity came to light. Until the industrial revolution, the impact on biodiversity was moderate (Allen, 2009). The conservation and environmental movements have also been practiced in various parts of India. The major one's like the Chipko movement, Appiko and Narmada Bachao Andolan (Karan, 1994). In Meghalaya, the sites for conservation of biodiversity are community reserves, sacred groves, national parks and biosphere reserve. Conservation of biodiversity conservation and sustainable management are of utmost importance for a balancing the ecosystem. The demands for biological resources are escalating more than the supply, as there is enormous growth in human population in last few decades, leading to continued struggle between human needs and resources availability, and resulting into great loss of biodiversity at desired pace. If we continue to use our resources in unsustainable manner, may run short of supplies in the future generation (Mishra *et al.*, 2004; Tripathi and Tripathi, 2010; Upadhaya *et al.*, 2008). Studies on forest disturbance has been done my many researchers (Marcot *et al.*, 2002; Lele *et al.*, 2008; Sharma and Roy, 2007; Roy *et al.*, 2013; Reddy *et al.*, 2013). The fragmentation has led to small patches (Kumar *et al.*, 2008). Balpakram National Park and Nokrek National Park are connected through an elephant corridor at Siju and Rewak in South Garo Hills of Meghalaya (Menon *et al.*, 2017).

Meghalaya has a total forest area of 17,217 km^2, of which 1,027.2 km2 is under the Forest Department constituting 4.58 % of the total geographical area of the State. According to the 6^{th} schedule of the Indian Constitution, the tribal areas of North East India own most of the forest in the form of community reserves for the benefit of the indigenous people living in the area (ISFR, 2019). The major forest types of Meghalaya and forest cover are given in **Table 1.2** and **Map 1**, respectively.

Table 1.2: Forest types of Meghalaya (Champion and Seth, 1968).

Serial No.	Forest types
1	Tropical evergreen forest
2	Tropical semi-evergreen forest
3	Sub-tropical broad leaved hill forest
4	Tropical moist deciduous forest
5	Grasslands and savannas
6	Temperate and tropical pine forest



Map 1: Forest cover map of Meghalaya

Source (http://www.megforest.gov.in/megfor_extent_forest.htm)

Recently, the number of settlement in vicinity of Nokrek Biosphere reserve has increased leading to intensified anthropogenic activities in the buffer zone, causing loss of biodiversity and depletion of dense forest cover. In view of the above, the present investigation is aimed to study the effects of anthropogenic disturbances on vegetation of Nokrek Biosphere reserve with the following

OBJECTIVES:

1. To determine plant community characteristics, diversity and distribution of plant species in core zone and buffer zone of the Nokrek Biosphere Reserve.
2. To assess the impact of anthropogenic activities on vegetation.
3. To formulate appropriate strategies for biodiversity conservation and management of Nokrek Biosphere Reserve.

CHAPTER- 2

REVIEW LITERATURE

For the existence of the human, biodiversity conservation and sustainable management are of paramount importance. The World Commission of Environment and Development (WCED) of the United Nations have stated importance on biodiversity conservation in the tropical forest of the world. Biological diversity constitutes species diversity, habitat diversity and genetic diversity. Tropical zones are said to have 70% of the world's species (Mittermeier *et al.,* 2011). Extensive research works are being carried out in biodiversity rich zones and reports represent that biological diversity is on the brink of elimination in some pockets (Maxwell, 2009; Manikandan and Lakshminarasimhan, 2012).

Approximately 6 billion populations depend on biodiversity for goods and services. The demands for biological resources are increasing more than the supply. Currently, it has not surpassed the carrying capacity but there may be shortage of supplies in the future generation. With the recent increase in demand and lifestyle, many of the forest resources have been over exploited; the major one being the anthropogenic disturbance. The sixth mass extinction taking place at the moment is said to be entirely anthropogenic.

The change in the environment due to various factors has not only led to global loss of biodiversity but has also impacted the climate a lot. Most of the tropical regions with high rainfall have the maximum species. Ozone layer has depleted due to various anthropogenic factors in the recent years in the Northern pole. Climate change has also caused heat and cold waves, the highest extinction of species are being recorded (Global Forest Assessment, 2015). This drastic change has not only impacted the flora and fauna but also human beings at a large. Toxic chemicals have found its way not only to animals and birds but human beings have been affected as well. (Brook *et al.,* 2008) has estimated that over 500 species of vertebrates- mostly mammals, birds, reptiles and amphibians have been extinct in the last 150 years. Presence of wildlife in the area represents the richness and diversity of the area. It also helps in the ecological balance and diversity of the area (Sergio *et al.*, 2006; Morell *et al.*, 2007; Pringle, 2008).

As a result of increase in natural habitat fragmentation and extinction of species; awareness in biodiversity along with the apprehension about conservation has grown-up rapidly in over the last few decades. Approximately 200 million hectare of forest has been lost largely through shifting cultivation in the developing countries. Many protected areas and reserves have been set up to preserve the lush green vegetation but with the population explosion the efforts have not been convincing in preserving the environment (Gadgil, 1991). People largely depend on the natural resources; but with the population growing at a fast trend it could barely meet their needs without rapid degradation. Biodiversity hotspots around the world contain high degree of endemism and are undergoing exceptional loss of habitat (Myers *et al.*, 2000).

Hotspots have been known to contain 20% of the flora species which are endemic and are in danger of extinction in the near future (Myers, 1988; Myers, 1990). Anthropogenic disturbance has been known to threaten the biodiversity hotspots of various regions around the world (Kacholi *et al.*, 2015). Tropical forests which are rich in species as well as diverse ecosystem have been utilized by humans in the past (Flenley, 1979). They are the richest areas where many taxonomically important plants exist. There has been alteration in the landscape, ecosystem and population structure through a common process known as disturbance (Williams *et al.*, 2016; D'Amato *et al.*, 2018; Kurth *et al.*, 2019). Fragmentation leads to small forest patches and in turn minimizes the areas of the core habitat. Anthropogenic activities are responsible for loss of biodiversity and destruction of species (Menon *et al.*, 2017).

Anthropogenic disturbance on plant diversity, distribution and community characteristics has been studied in various parts of the world (Linderman *et al.*, 2006; Chazdon, 2003; Ricker, 2010; Abdelall *et al.*, 2017). Scientist has been evaluating species diversity with the help of various ecological measurements (Misra, 1968; Muller-Dombois and Ellenberg, 1974; Simpson, 1949; Shannon and Weinner, 1963; Margalef, 1958; Pielou, 1969; Whitford, 1949). Ecological balance is changed by alterations in plant diversity patterns (Pedro *et al.,* 2015; Thompson *et al.,* 2009; Liu and Zhang, 2012).

Researches on diversity and distribution of plants have been carried out at desired pace at the global level (Morel *et al.,* 2015; Erenso *et al.,* 2014; Muhammed *et al.,* 2011; Rol *et al.,* 2013; Huang *et al.,* 2003; Rennolls and Laumonier, 2000), and national level (Puspwan *et al.,* 2019; Neelamegam *et al.,* 2016; Prathiphan *et al.,* 2016; Singh *et al.,* 2016; Brintha *et al.,* 2015). Work on protected areas like wildlife sanctuaries regarding plant diversity has been done (Xiongwen, 2001). Diversity and productivity of plant community has been impacted due to various anthropogenic disturbances (Gogoi and Sahoo 2018; Abdelaal *et al.,* 2017; Chaudhowry and Kunwar, 2002). In other parts of Asia, plant diversity in response to anthropogenic disturbance has been studied in the montane regions of China (Zhu *et al.,* 2007). Comparative study on diversity, composition and structure of the forest were studied in different sites in relation to various environmental factors (Gillespie *et al.,* 2000).

Some works suggested that moderate ecological disturbance makes the area favourable for the growth of the species (Sapkota *et al.,* 2010) contrary to the believe that the growth and diversity of the species get reduced in the degraded areas. Effects of disturbance on stand structure, diversity and dominance is still an important phenomenon.

The anthropogenic disturbance has not only impacted the plant diversity but it has impacted the faunal diversity as well (Nicholls *et al.,* 2010). Ecological processes can be understood by studying various forest structures (Parejiya *et al.,* 2013). Forests are important for providing food and shelter, stabilizing soil and climate, provides habitat for wild animals and pollinators, regulates water flow, nutrient cycling and carbon sequestration. The ecology of forest is a complex phenomenon (Sukumar *et al.,* 1992). Evaluation of forest communities is important to understand the species diversity (Hengeveld, 1996).

Forest dynamics and tree species richness are determined by different environmental factors (Al-Pavel *et al.,* 2016; Mukul and Herbohn, 2016; Uddin *et al.,* 2013). Understory communities like herbs, shrubs and epiphytes are the major component of forest ecosystem (Chen *et al.,* 2017).They constitute75% of vascular species (Gentry, 1992). Anthropogenic disturbance in forest canopy gaps has also been studied and has been said to have higher impact on the understory species (Zhu *et al*., 2007). Moderate light intensity areas with open canopies are more favourable for the plant species (Nesheim *et al*., 2010). High anthropogenic pressures decrease the vegetation cover of the area. The main causes of alteration are jhum cultivation, grazing, logging, collection of medicinal plants (Kala and Dubey, 2012).

India, the tenth among the twelve mega diversity countries of the world depends on biodiversity in many ways. 21.5% of the geographical area in the country is covered by forest.The richness in biodiversity is mainly due to vegetation of topography, climatic conditions and altitude coupled with varied ecological habitats (Agarwal, 2002). But increased human population leads to a survival pressure on the biodiversity which has in turn resulted into unsustainable use of forest resources, soil erosion, siltation as well as threats to indigenous people (Kumari *et al*., 2019). Plant wealth is decreasing at a fast rate and a number of economically and medicinally essential plant species are on the edge of elimination. Over the past few decades, excessive use of forest resources, led to immense loss of species. As a result, 20-25% of remaining plant species in India have become endangered (Laloo *et al.*, 2006).

Work on qualitative and quantitative analysis of plants has been done in various tropical forests of India (Pilania *et al.*, 2015; Raturi 2012; Tripathi and Singh, 2009). Work on plant diversity in Eastern Ghats has also been carried out extensively (Rao, 2014; Premavani *et al.*, 2014; Panda *et al.*, 2013; Chittibabu and Parthasathy, 2000). Quantitative work on diversity of trees has been studied in Western Ghats (Swamy *et al.*, 2000; Bhat *et al.*, 2000). Parthasarathy (1999), worked on the plant diversity in three stands- undisturbed, moderately and disturbed stands along with its role in conserving the biodiversity.In North India also works on vegetation parameters in relation to forest canopy was done (Arya *et al.*, 2012). In Southern India, many researches on anthropogenic effect forest ecology was done (Bharathi and Prasad, 2015; Sunil *et al.*, 2011). The presence of endemic species was observed (Bharathi and Prasad, 2017).

Number of trees is known to yield timber and medicinal purposes in various tropical regions and has economic importance (Saha and Sundriyal, 2013; Pilania *et al.,* 2015; Sati, 2014; Vidyarthi *et al.*, 2013).Various works on floristic diversity and population structure has been carried out in different Biosphere Reserves of India (Sahu *et al.*, 2008; Gairola *et al.*, 2015) and Wildlife sanctuaries (Majumdar and Datta, 2014; Roy, 2014).

Tree diversity is essential for the structural and functional attributes (Shulka *et al.,* 2014; Dash *et al.,* 2009). Increase in diversity of trees helps in mitigating climate change and reduces the disturbance on the ecosystem level (Pedro *et al.,* 2015; Vockenhuber *et al.,* 2011). Climate change along with human disturbances is known to alter the heterogeneity of trees (Xiongwen, 2001). Effect of tree species richness, disturbance and conservation of ecologically important species has been studied in Lawachara National Park (Al-Pavel *et al.*, 2016). Anthropogenic as well as natural factors influence the tree community structure and composition of the forest (Kolbe *et al.*, 2016) and woodlands (Omondi *et al.,* 2017).

Forest though an important resource for the livelihood of the people, has been affected by various activities like logging, extraction of NTFP, roadways. Shifting cultivation is one of the chief causes of disturbance. Forest fragmentation leads to depletion of flora and fauna (Uddin *et al.*, 2013b). Disturbance and forest fragmentations of undisturbed and disturbed stands in relation to tree species richness and diversity have been studied (Carvalho *et al.*, 2016). Impact of these mining activities has been known to cause changes in the tree diversity in the disturbed areas (Dubey and Dubey, 2011). Deforestation, encroachment are major causes of disturbance in the forest (Tole, 2002).

Population structure and composition of tree species has also been carried out by various workers (Kunwar and Sharma, 2004; Al-Pavel *et al.,* 2016).Regeneration of trees is disturbed by various micro environmental factors (Bharathi and Prasad, 2017; Vieira and Scariot, 2006; Singh, 2002; Tripathi *et al.*, 2010). Regeneration of seedling and sapling species are said to be higher in number in moderately disturbed areas (Omondi *et al.*, 2017; Nesheim *et al.*, 2010). Regeneration has been known to be affected by man-made disturbance (Williams, 2002). Contagious distribution is known to be the most common form of distribution pattern (Odum, 1971). Micro environmental components alter the biodiversity.

Population explosion has been a main cause of alteration in terms of landscape and biodiversity. Various environmental factors alter the composition of trees and are said to vary along the disturbance gradient. Natural as well as anthropogenic disturbance are the main factors (Kolbe *et al.,* 2016). Substantial alterations due to human activities have also been noted (Sagar *et al.,* 2003). Understanding the influence of disturbance on species structure is essential for management plan policies (Gillespie *et al.,* 2000). For safeguarding nature, proper formation of environmental awareness and partaking of the individual is important (Tole, 2002). Conservation can be achieved only when proper management strategies are set up (Omondi *et al.,* 2017). Effective conservation measures need to be adopted (Murthy *et al.,* 2003).

North East India is often referred to as the "cradle of ancient angiosperms" owing to occurrence of primitive species in the area (Takhtajan, 1969). About 50% of the Indian flora is confined to this region only (Hajra and Rao, 1986). The undisturbed forests in North East India are stable and more complex; however, species richness is highly supported by mild disturbance as moderate disturbance facilitates survival and growth of plants (Mishra *et al.,* 2004; Mishra *et al.,* 2005). Distribution of species abundance gives the idea of the degree of disturbance than richness of species. Studies have indicated that if existing disturbance prevails and rational protection methods are not adopted all primary forest would be lost.

Meghalaya with its favourable climate receiving the heaviest precipitaion and endowed with luxuriant vegetation is a part of biodiversity hot spot region of the world. Fertile soil and vegetation of the area favors the State to receive a good amount of precipitation making it into the biodiversity hot spot region. Greater than 3000 angiosperms are found in Meghalaya contributing to around one fourth of the country's flora. Record of high number of endemic species has also been reported (Khan *et al.,* 1997). According to the State's annual report, 436 (13.09 %) of rare, endangered and threatened plant species has been recorded .Endemic species are approximately around 281.The state is also a hub for varieties of orchid species. 27.08% representing 352 species and 98 genera with various medicinal properties are known to be found in Meghalaya (MBB Annual Report, 2015).

In low altitude areas community structure on vegetations of undisturbed forest has been studied in the state (Tripathi *et al.,* 2000; Singh and Ramakrishnan, 1982). Various work on flora of the forest of Meghalaya has been conducted (Shankar and Tripathi 2017; Laloo *et al.,* 2006; Jamir, 2000; Upadhaya, 2008; Kanjilal *et al.,* 1934) Many researchers have worked on the plant diversity in the State (Roy *et al.,* 2014; Tripathi and Shankar, 2014, Prabhu *et al.,* 2010; Mishra *et al.,* 2005).

Meghalaya is widely known for the presence of primitive families like Ranunculaceae, Annonaceae, Elaeocarpaceae, Elaeagnaceae and few primitive genera of *Myrica, Michelia, and Magnolia*. Rubiaceae, Lauraceae, Asteracea and Euphorbiaceae are said to be some of the dominant families in the state (Jamir and Pandey, 2003). Phytosociological analysis of plant vegetation and disturbance has been done by many workers (Upadhaya, 2015; Tripathi *et al.,* 2010). 90 % of the forest area of the state is mainly found in the form of community reserves, sacred groves and national parks (Tiwari *et al.,* 2010). Works on protected areas has been carried out widely in the Meghalaya (Khan *et al.,* 1997; Upadhaya *et al.,* 2015). Decrease of number of species is observed in secondary forest areas (Kumar *et al.,* 2006).

Eminent workers like Kanjilal *et al.,* (1934-40), Champion and Seth (1968), Balakrishnan (1981-83), Haridasan and Rao (1985), Hajra and Rao (1986) and (Singh *et al.,* 1992) had carried out their work in Meghalaya. The interior areas of the forest are comparatively undisturbed due to inaccessibility of modern roads (Upadhaya, 2015). Rest are either impacted by developmental activities or shifting cultivation. Geographical location makes the environment favorable for the survival of species. Many species listed in the IUCN category can be found in this region (Upadhya *et al.,* 2015; Prabhu, 2010; Pandey, 2003; Singh *et al.,* 2011). The natural forest resources in the form of wild edible and medicinal plants supports the tribal life of the people (Singh and Borthakur, 2011; Singh and Debnath, 2008; Kayang, 2007; Singh *et al.,* 2012). Traditional knowledge of the native people has been recorded extensively in the state (Singh *et al.*, 2014; Chetri, 2010; Laloo *et al.*, 2006).

Mishra *et al.,* (2005) has stated that most of the forests are highly disturbed. Shifting cultivation, timber extractions are the main anthropogenic factors. In addition, mining, developmental activities like an industry where land is cleared is responsible for the loss of forest cover. Timber removal for domestic purposes is one the major cause of anthropogenic disturbance. The work on the effect of anthropogenic disturbance on plant diversity and community structure of sacred grove in Meghalaya; concluded that alterations of habitat through human interference have led to disappearance of various species. Micro-environmental factors like vegetation, soil and rainfall are altered (Mishra *et al.*, 2004; Jeeva *et al.*, 2006).

Lack in management and conservation has been the main drawback in protecting the rich biodiversity of the state (Jamir and Pandey, 2003). Better ways of management is needed to enhance the diversity of the forest. Protected areas, Sanctuaries and National Parks act as a refuge for the conservation of species and the biological wealth of the state (Upadhaya *et al.*, 2013).

Jamir and Pandey (2003) have stated that Garo Hills is high in species diversity and some of them are confined only to this particular region of the hills. Luxuriant forms of vegetation as well as fauna are found in different parts of the forest of the area. Many endangered species of orchids and wild animals are known to exist (MBB Annual Report, 2015). Though the forest wealth in the state looks inexhaustible but with the current rate of disturbance the area may face deforestation. On a survey conducted on land use pattern for twenty years there has been a massive increase on jhum cultivation (Yadav *et al.*, 2012). Increase in population, lack of developmental activities planning, unsustainable use of resources has prompted people to depend on jhum activity (Ralte, 2004).

The people residing close to the forest rely heavily on the free resources available which in turn have impacted the vegetation of the area (Momin, 1995).The traditional activities of jhum cultivation practiced by the people living close to the reserves hampers the management of the biosphere reserve (Ashutosh, 1998). Many of the virgin and mature forest have been transformed into secondary forest in the buffer region (Tripathi, 2002; Tripathi *et al.,* 2008). Jhum activity has the highest possibility of endangering many animals and plants (Marcot *et al.,* 2002; Kumar *et al.,* 2008; Singh *et al.,* 2011).

Rapid destruction of forest has led not only to destruction of the habitat for wildlife but has led to man animal conflict and encroachment. Degradation in environment is caused by various factors like developmental activities and agricultural activities (Ralte, 2004; Yadav *et al.,* 2012). Mining activities have been reported in different parts of Garo Hills (Prabhu *et al.,* 2010; Sarma and Yadav, 2013).

Various phyto-sociological analyses of plants in the tropical forest of Garo hills has been done (Tripathi, 2002; Kumar *et al.,* 2006). Extensive work on floristic diversity of parts of Garo hills has been done (Singh, 2011; Roy *et al.,* 2014) and presence of many rare, endangered species has been recorded along with economically important species (Singh and Singh 2016; Singh *et al.,* 2011). Plants having ethno botanical importance was recorded in Garo hills (Singh and Debnath, 2008; Rao, 1981; Chhetri, 2010). 157 species is known for treatment various diseases (Singh *et al.,* 2014). Plants from the wild belonging to 71 species from 42 families has also been documented from Nokrek Biosphere Reserve (Singh and Borthakur, 2011; Singh *et al.,* 2012).Work on the different species of citrus has been carried by (Upadhya, 2016) and has recorded varieties of Citrus species in Garo hills.

Work on geoinformatics of landscape, conservation and forest management in the area has been done to analyse the threat and diversity of the biologically rich area (Yadav *et al.,* 2013; Kumar *et al.,* 2012 and Sarma *et al.,* 2012).According to the literatures, the core zone of Nokrek Biosphere Reserve is said to be rich in soil organic nutrients like phosphorous and organic carbon but the areas in the buffer region are deprived of these nutrients due to the practice of shifting cultivation (Ralte, 2004; Singh and Mudgal,2000).

Anthropogenic disturbance has been known to alter the diversity of plants in the Nokrek Biosphere Reserve (Prabhu *et al.,* 2010; Singh, 2011). Destruction of habitat has reduced the number of species (Tripathi *et al.,* 2008). Nokrek Biosphere Reserve and Balpakram National Park are the main areas where effective research and conservation management programmes needs to be strengthened in Garo hills (Pakrasi *et al.,* 2014).

CHAPTER- 3

STUDY AREA

The North-eastern part of India with its rich biological wealth and endemism is a part of the Indo-Burma hotspot (Mittermeier *et al.,* 2004). North-east with 7.76% of the geographical area of the country accounts for nearly 1/4th of its forest cover. Meghalaya, situated in the North Eastern part of India is one of the richest areas in terms of biological values. Meghalaya lies between 24°58' N to 26°07'N latitudes and 89°48'E to 92°51' E longitudes.The topography of Meghalaya is one of the exquisite areas of the region comprising of beautiful landscape, water bodies, climate, flora and fauna. The Khasi Hills has the highest altitude of 1961m whereas Garo Hills has the lowest altitude. High humidity can be felt in the regions of Garo Hills. Endowed with dense forests and rivers cascading down undulating terrain, this region is one of the most scenic of the North Eastern States. Meghalaya being situated in the North East India Bio-geographic zone represents an important part of the Indo-Burma biodiversity hotspot. The state of Meghalaya has been identified as a key area for biodiversity conservation due to its high species diversity and high level of endemism.

The vegetation of Meghalaya ranges from tropical rainforest in the foothills to Alpine meadows. It is considered as a high area of biodiversity conservation due to its high species diversity and high level of endemism (Meghalaya Biodiversity Board, 2017). In addition to the flora and fauna diversity, Meghalaya is also rich in aquatic diversity and is also a hub of mineral resources like limestone, coal, uranium, gypsum, clay and kaolin. With its rich biodiversity it is also an important tourist destination. People of the state earn most of its revenue and income from the tourism sector. With vast undulating hills and streams it is a hub for nature walkers and trekkers.

3.1 History, Culture of the State and Boundaries

Until 1970 Meghalaya was a part of Assam.Meghalaya got its separate state on 21st January, 1972. Meghalaya comprises of the three major tribes- the Garos, the Khasis and the Jaintias occupying the Western, Central and Eastern part of the state respectively. Being under the 6th schedule of the Indian constitution, the local people have power over the land. The District Councils and the State government coexist. Currently the state comprises of 11 districts (ISFR, 2019).

Meghalaya with an area of 22,429 km2 is bounded by Assam in the Northern and Eastern part. Towards the Southern region the state shares an international border with Bangladesh. The inter-state border with Assam is about 733 km in the Northern part. While the West and Southern part is shared by Bangladesh with a border area of 443 km. The altitude of Meghalaya varies from 50-1950 m the highest being the Shillong peak in Khasi hills with an altitude of 1961m and 1412m in Nokrek peak of Garo hills.

3.2 Physiography

The plateau of Meghalaya is believed to be of Pre-Cambrian age and is categorized into five different types geologically- the Archaean gneissic complex, Shillong group of rocks, Lower Gondwana rocks, Sylhet traps and Cretaceous-tertiary sediments. The central and the North bordering Assam state constitute the Archaean geneissic complex comprising of biotite gneiss, granulite, amphibolite, quartzite, schist etc. The central and Eastern part comprising of Khasi hills eastern is occupied by Shillong group of rocks constituting primarily of quartzite, phyllite, quarts-sericite schist, conglomerate etc.

The Garo Hills region mostly composed of the lower Gondwana rocks consisting of pebble bed, sandstones and carbonaceous shale. The Sylhet traps are found in the East-West direction parts of Shillong plateau overlying the Precambrian basement. The Cretaceous-Tertiary sediments lying in the lower elevations of the state is believed to be the continuation of the Cretaceous-Tertiary sediments of the Bengal basin (Directorate of Mineral Resources, 2018; Lamare and Singh, 2016;

Khonglah *et al.*, 2008). The Garo Hills has the oldest upper Tertiary sediments known as the Garo group represented by Simsang formation overlying the Kopili formation. The Eastern parts consist of Baghmara formation.The third is the Chengapara formation.

3.3 Population

The population density of Meghalaya is 132 per sq. km according to 2011 census.The total population is 29,66,889 spread over an area of 22429 sq. km (Meghalaya Statistics Report, 2019). In terms of religion majority of the population follows Christianity (70.01%) followed by Hinduism (13.27%), Muslims (4.49%), Buddhism (0.24%), Sikhs (0.13%) etc. The main languages used by the people of the state are Garo, Khasi, Hindi and Nepali but English is the most common language used in the communication of the three tribes.

3.4 Forest cover

The state has a forest area of about 15.657 km^2, out of which 1,027.20 km^2 (4.58% geographical area) is covered under the Meghalaya Forest Department constituting 6.57% of the state's forest area. Since the State falls under the Schedule 6 of the Indian Constitution it falls under the Autonomous District Councils (ADC) of the three tribes of the hills- the Khasi, Jaintia and Garo hills. The primary forest cover is around 9496 km^2 covering approximately 70% of the forest area. According to State Forest Report 2019, 76.32% of the total geographical area is covered by forest (ISFR, 2019).Tropical, subtropical and temperate forests dominate the hilly state of Meghalaya. Agro climatic conditions make the state of Meghalaya favourable for the growth of agriculture, horticulture and forestry.

3.5 Rainfall and Humidity

Meghalaya is known to receive one of the highest rainfalls in the world. This may be the factor enhancing the rich biodiversity of the State. The favourable climate of the region makes it a hub for various flora and fauna in the state. The rainfall not only escalates the growth of the biodiversity of the state but also supports the agriculture and cultivation of the people lying in the lower regions of the state.

The climatic conditions are also favorable beginning from April until October with the South west monsoons from neighboring Bay of Bengal and the far Arabian Sea. The state with profusely dense forest is unique and diverse with various flora and fauna. Being situated at a hilly region the areas are prone to soil erosion during the monsoons.

The State receives has longer durations of monsoon (April-September) and short dry winters (November-February).The autumn are normally in the month of October and spring are welcomed in March. April is said to be the hottest month of the year, while minimum temperature are normally recorded during January. Between November to April the region remains dry.

From May to October heavy rainfalls are received in the state. Winter is short lived in Meghalaya for only a couple of Months in December and January. The Summer’s last till May.The higher altitudes of the state like the capital Shillong are cooler than the lower altitudes of Garo Hills where the temperature is hot and humid in summers. The average annual rainfall in the state varies. The rainfall and relative humidity data was obtained for the study period of (2013-2016) from District and Local Research Station and Laboratories, Department of Agriculture, Sangsanggre, West Garo Hills, Tura, Meghalaya (**Figure 3.1 to 3.4**).

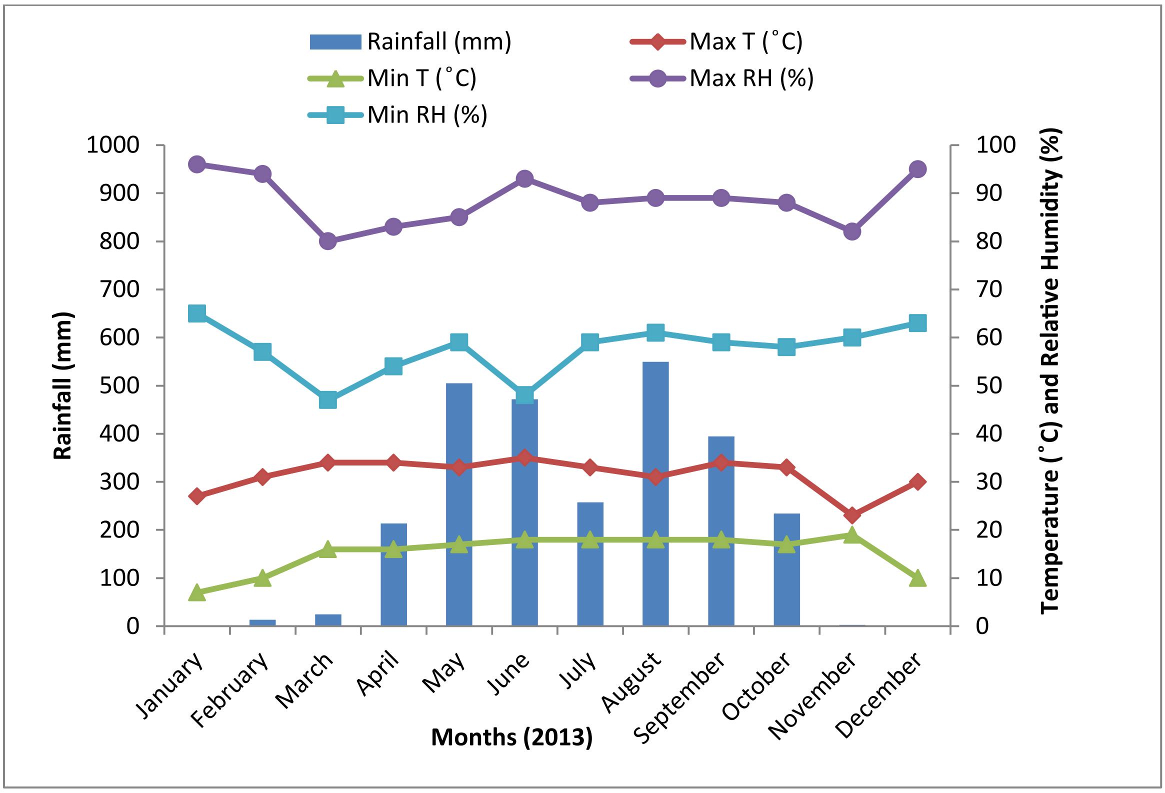


Fig 3.1: Rainfall, Humidity and Temperature data for the year 2013

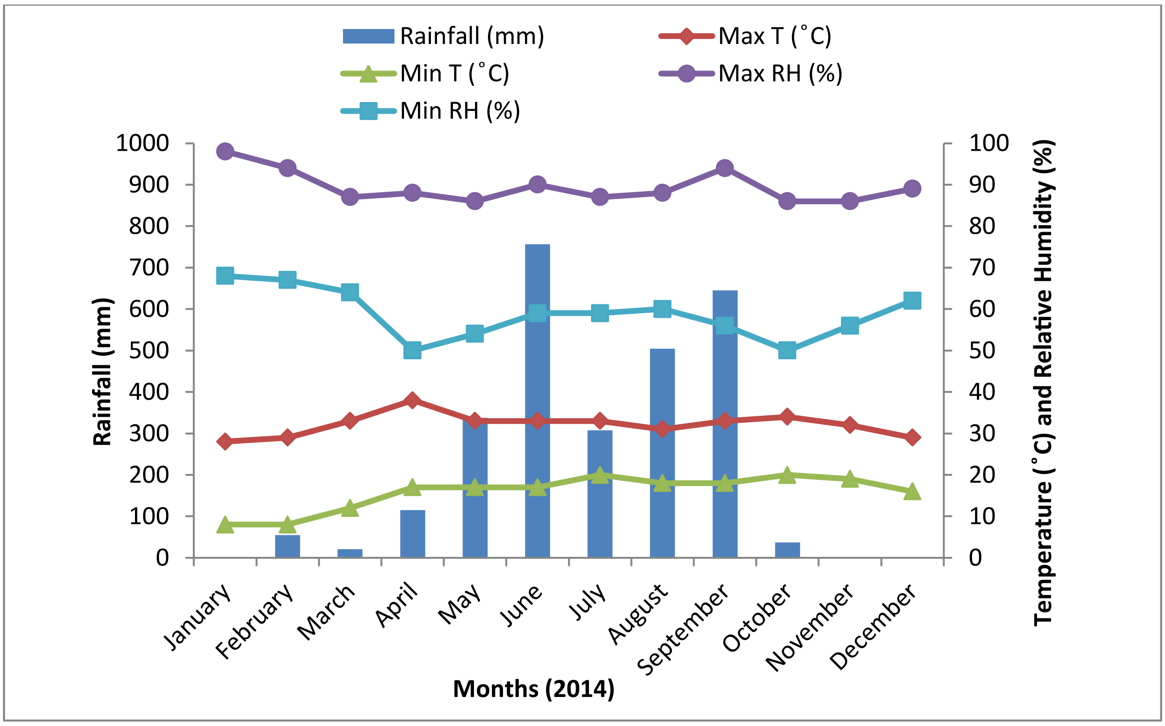


Fig 3.2: Rainfall, Humidity and Temperature data for the year 2014

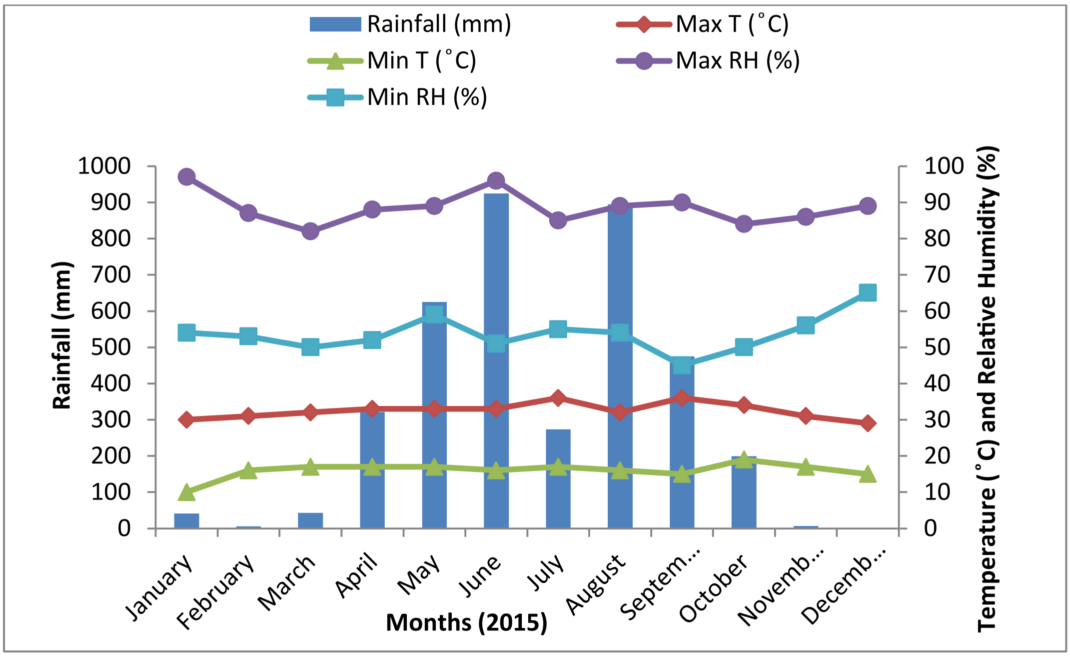


Fig 3.3: Rainfall, Humidity and Temperature data for the year 2015

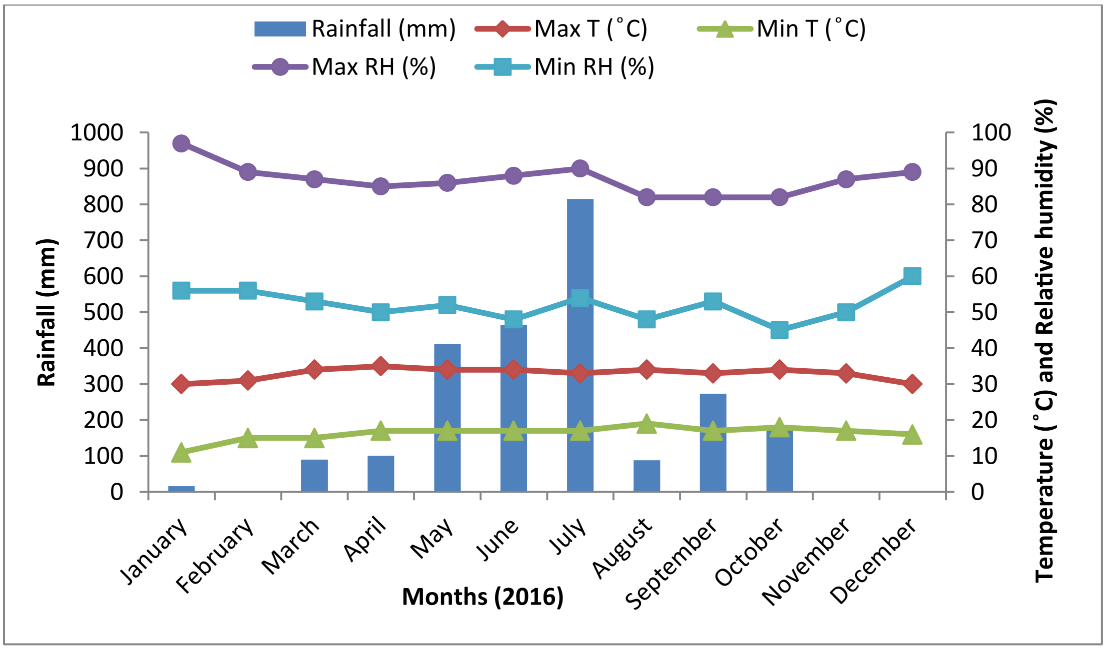


Fig 3.4: Rainfall, Humidity and Temperature data for the year 2016

Source: District and Local Research Station and Laboratories, Department of Agriculture, Sangsanggre, West Garo Hills, Tura, Meghalaya.

3.6 Soil

The soils of Meghalaya are mostly lateritic soil, sandy loam, red loam and clay loam. The lateritic soils are deficit in potash, phosphorous and lime.The red loamy soils are also deficient in nitrogen and phosphorous. In the hilly region the soil is rich in organic carbon and is acidic in nature.Areas in the higher altitude contain more moisture owing to low temperatures. The western part of soil is mostly lateritic. The lateritic soil makes the area fertile and the alluvial makes the area suitable for cultivation. But the plain belt of Garo Hills is mostly composed of loamy and silty soils.

3.7 Agriculture

Approximately 80% of the population depends on agricultural sources. Shifting cultivation is the main activity of the people of Garo Hills and many religious activities have attachment to various jhum activities. Agriculture, horticulture, livestock and forestry are the major source of livelihood in the state. In terms of livestock, people mostly rear cattle, goats, pigs and poultry for meat, milk and agricultural usage.More than 30 (%) of the area are believed to be covered by dense forests along with various flora and fauna.With uneven rainfall it has diverse vegetation. Rice being the staple food is the major food crop followed by maize, banana, pineapple, pear, lemon. The cash crops found abundantly in the state are cashew nuts, tea, areca nut, ginger, cotton, black pepper and bay leaves.

Over the years many researchers have worked on the plant diversity of Meghalaya. Recently, changes due to anthropogenic disturbances has led to loss of many native, endangered and threatened species. The species are now confined only to the protected zones. These protected areas occupy only 5.06 % of the geographical area and act as a refuge to the flora and fauna of the state. The State has 2 National Parks, 4 Wildlife Sanctuaries and 1 Biosphere Reserves. The local people who are living within the Biosphere Reserve are both economically and educationally backward and they still practice shifting cultivation in their settlements.

3.8 Biodiversity

According to Kanjilal, the types of forest found in Meghalaya are- Tropical Evergreen Forests, Tropical Semi-Evergreen Forests, Tropical Moist and Dry Deciduous Forests, Grasslands and Savannas, Temperate Forests and Sub-tropical Pine Forests. The State has many endangered and rare species of flora and fauna.

It is a centre for varieties of medicinal plants like *Taxus baccata*, *Citrus indica*, *Nephenthes khasiana* and many timber *viz*., teak, sal and non-timber forest products like honey, rattans, and orchids. Not only is it endowed with diverse plants, many variety of mammals, birds, reptiles and it is also a habitat to some primates, reptiles, carnivores, ungulates such as elephants, sambar, barking deer, red panda, pangolins.

The balance of ecosystem can be still found in the State with the presence of these various types of flora and fauna. Because of its rich flora it has also attracted tourist from many parts of the world and the country. The floristic diversity of the state has been recorded by many eminent scientists in the past. The topography of the state with high rainfall makes it favourable for the species to flourish. The State is also a hub for varieties of orchid species. 27.08% representing 352 species and 98 genera of orchids with various medicinal properties are known to be found in Meghalaya. 25.04% is utilized for various medicinal purposes. The State is said to export orchids to its neighbouring states and countries as well like Sikkim, Bhutan, Nepal, China, Thailand, Burma, and Malaysia.

3.9 Conservation Programmes in the State

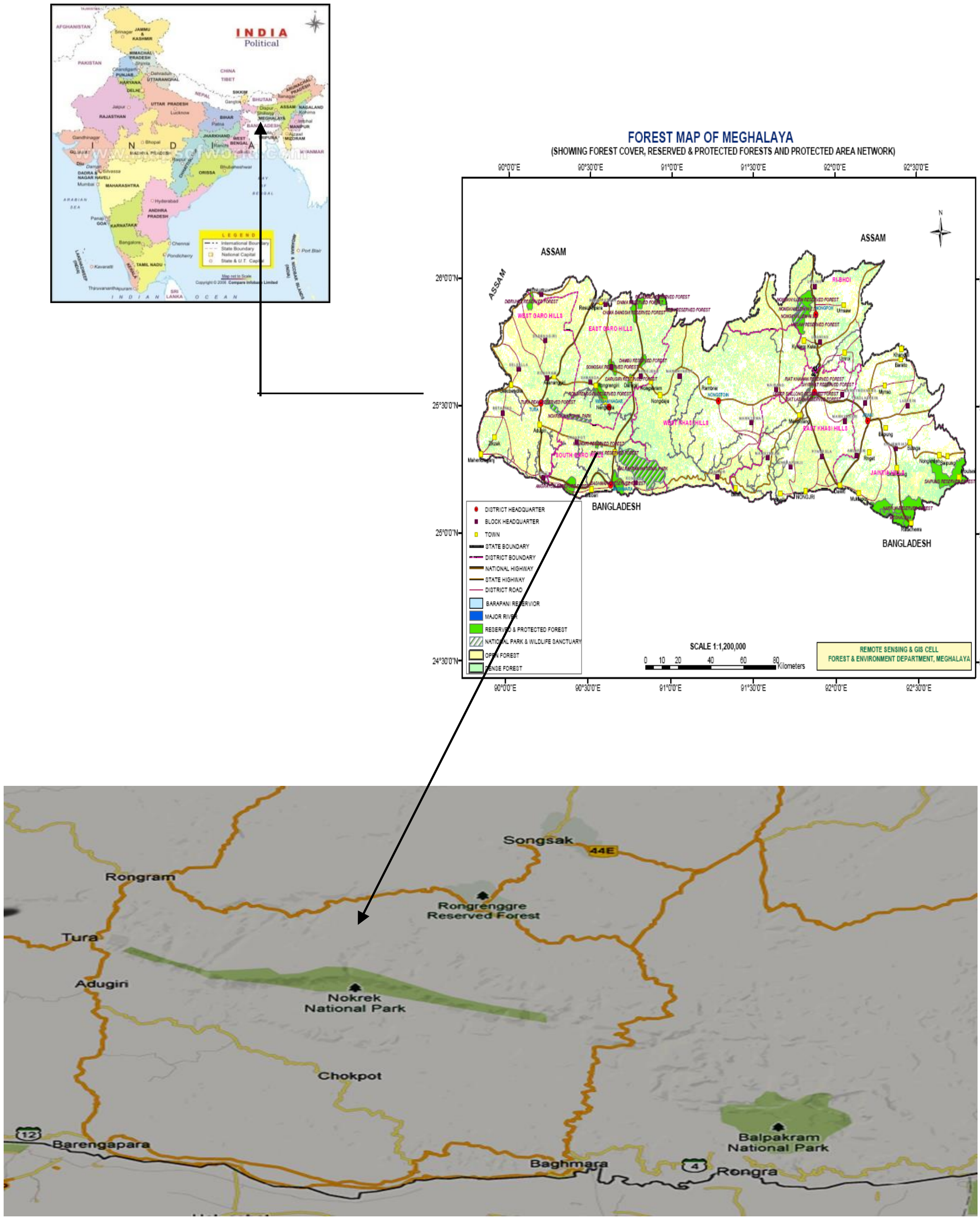
Under Section 63(i) of the Biological Diversity Act, 2002; the Government of Meghalaya has enacted the Meghalaya Biological Diversity Rules 2010 for exercising its power in the State in relation to biological diversity. Biodiversity Management Committees (BMCs) have been formed with the help of the State government at the local bodies for promoting conservation, sustainable use of resources, preservation of habitat and conservation. From 2012 to 2013 101 BMCs have been formed in the State (MBB Annual Report, 2017).

The rituals and beliefs of the indigenous people have left most of the forest untouched in different parts of the State. Many sacred groves have also been studied from Meghalaya (Tiwari *et al.*, 2010; Jeeva *et al*, 2006; Upadhaya *et al*, 2008; Mishra *et al.*, 2004; Jamir and Pandey, 2003, Ormsby, 2013). Not only does the tribal people of Meghalaya belief in preserving the forest on account of their beliefs in mythologies but they also belief in not harming the animals *viz*., elephants, hoolock gibbons. With the rise in population, the fallow period of the jhum activity has also reduced. Destruction of elephant corridors the cases of human wildlife conflict has been reported in the past years (Menon *et al.*, 2017). Jhum cultivation is one of the major causes of forest fragmentation.

3.10 Nokrek Biosphere Reserve

Nokrek Biosphere Reserve (NBR) is located on Tura Range of mountain system which is a part of Meghalaya Plateau overlapping with parts of three districts, i.e. East, West and South Garo Hills. It lies between 25° 20' to 25° 29' N Latitude and 90° 13' to 90° 35' E Longitude **(Map 3.1).** The area was declared as the Nokrek Biosphere Reserve (NBR) on September 1st, 1988 and the core area as the National Park on 23rd December, 1997. It has an average altitude of 600m; the highest point being the Nokrek peak 1412m (Momin, 2002).

The temperature ranges from 3°C to 30°C with rainfall > 3,000mm. The bio-geographical province of the area is 4.09.04 (Panwar and Rodgers, 1988). The Reserve spreads over an area of approximately 820 sq. km of which 47.48 sq. km is the Nokrek National Park (NNP) which constitutes the core area of the Nokrek Biosphere Reserve. The Nokrek National Park area remains comparatively undisturbed, consisting of primary evergreen forests and is accessible only on foot.



Map 3.1: Map showing the location of Nokrek Biosphere Reserve Meghalaya, India.

The Nokrek Peak is approximately 26km from the headquater of West Garo Hills, Tura. Nokrek is believed to be the progenitor of the genus *Citrus*. *Citrus indica* an endemic species is found in surrounding areas. According to the folklore, after the dead of Maopa Chong·dopa, the first mortal to die in Nokrek had to go to Balpakram, the land of the spirits. In the land of the Spirits he knew none and requested the chief of the guardian to send him back to the village. On his way back he carried a basket of oranges for his daughter. Legend says the father could not delay and left the basket full of oranges at the doorstep and returned to Balpakram, which the Garos believe as the eternal home where the dead resides. With this folklore, the name has been passed down by the locals with the name Memangnarang (Memang- ghost; Narang- orange) for the endemic *Cirtus indica.* A gene sanctuary for *Citrus indica* has also been set up by the Wildlife department in the buffer zone to preserve the rare species.

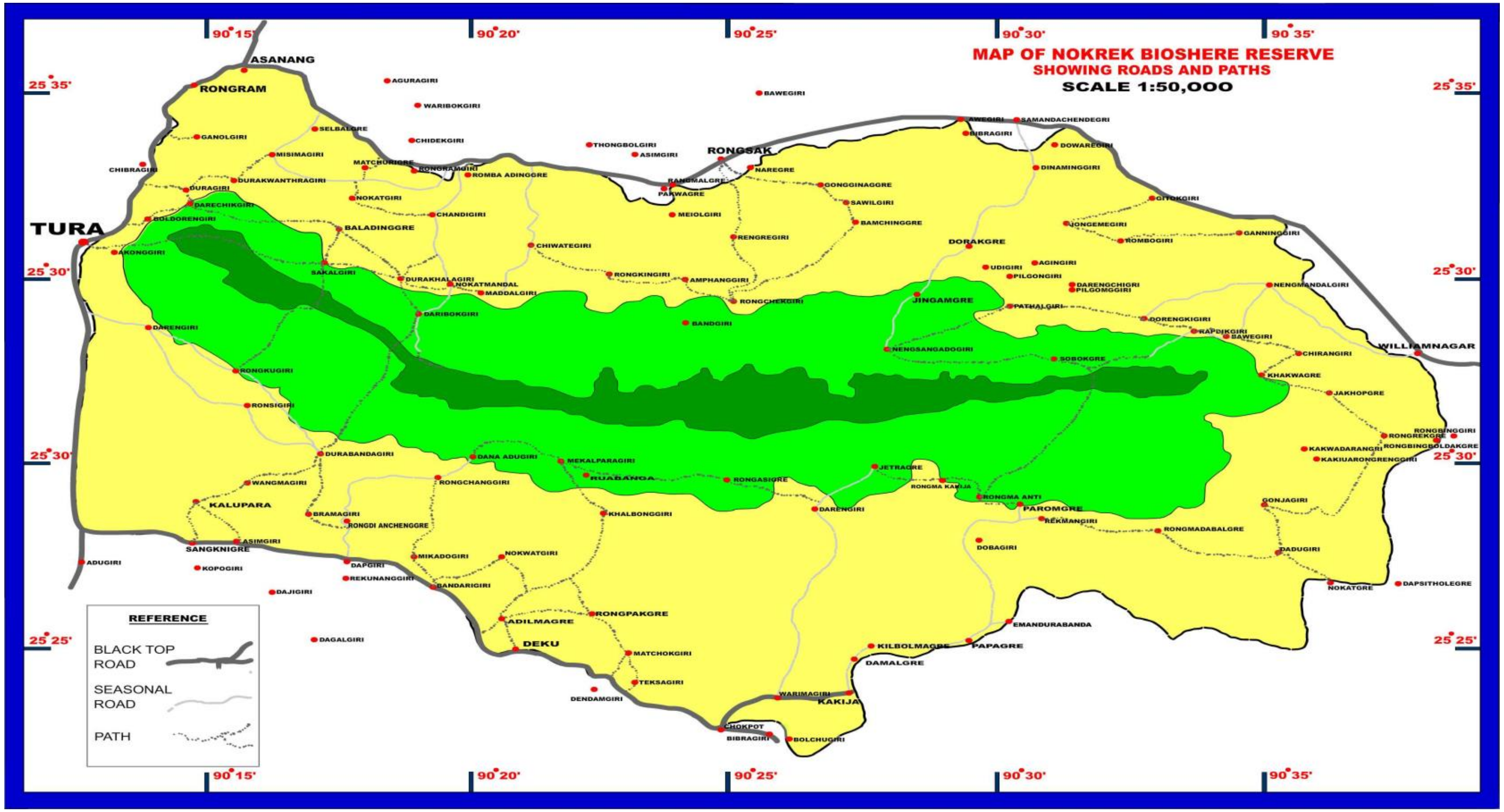
The Nokrek Biosphere Reserve of Meghalaya covering an area of 820 km^2 was recognized by the UNESCO's World Network of Biosphere Reserve on 26^{th} May, 2009.The core zone is the Nokrek National Park covering an area of 47.48 Sq Km and the buffer zone has an area of 227.92 sq. km. TheNokrek Biosphere Reserve acts as a principal watershed for all the rivers of Garo Hills.

It lies between $25^o20'$ to $25^o29'$ N Latitude and $90^o13'$ to $90^o35'$ E Longitude. The highest point of Garo Hills is the Nokrek Peak with an altitude of above (1415 m above sea level). These forests have been free from human interference over the centuries. This has been mainly due to the less human population in the area and the location of the villages on the inaccessible hill top. So far, there is no record of any commercial exploitation of these forests. The geographical information on Nokrek Biosphere Reserve is given in **Table 3.1**.

Table 3.1: Geographical information on Nokrek Biosphere Reserve

Area	820 km^2
Core zone	47 .48 km^2
Buffer zone	227.92 km^2
Transition zone	544.60 km^2
Latitude	25°20' to 25°29'N
Longitude	90°13' to 90°35'E
Altitude	> 600 msl

The Nokrek Biosphere Reserve area is important from conservation point of view because of its rich diverse flora and fauna and varied human cultures. All the major rivers like Simsang, the biggest and the longest river, Ganol and numerous streams of the three districts of Garo Hills originate from this area (Lahkar *et al*., 2002). It acts as a principle watershed for the district. In the sub-Himalayan ranges, Nokrek Biosphere Reserve is considered to be one of the least disturbed forests with natural protective barriers.



Map 3.2: Map of Nokrek Biosphere Reserve showing roads and paths along with the boundary

(Source: Divisional Forest Office, East and West Garo hills Division, Tura, Meghalaya)

The last remaining primary forests are also believed to be found in this area. It is the first Biosphere Reserve of its kind in the North-East region of India. Nokrek Biosphere Reserve was recognized by the UNESCO's World Network of Biosphere Reserve on 26th May, 2009 (Sen, 2013; Singh, and Borthakur, 2015).

The longest river of Garo Hills, the Simsang which sustains most of the livelihood of the people with its natural resources originate from the Nokrek Biosphere Reserve of Meghalaya. From the Nokrekmountains it moves towards the Eastern town of Garo Hills then flows towards various district of South Garo Hills finally joining the tributaries of Bangladesh. Another river that originates from Nokrek National Park is the Ganolriver which flows through major towns of West Garo Hills and joins itself with the rivers of Assam. The rest of the small rivers in the state are seasonal rivers.

Nokrek Biosphere Reserve is located on Tura range of mountain system in the western part of the State, Meghalaya. The northern part of the Biosphere Reserve is bound by Tura-Williamnagar PWD road; southern part by Tura-Kakija (Chokpot) PWD road; eastern side by A·king (clan) land of Tolegre and Rongbinggre; western part by Tura-Dalu road **(MAP 3.2).**

The total area of Nokrek Biosphere Reserve is 820 km^2. Of this, the contributions of distinct zones are as follows:

i) Core Zone has an area of 47.48 km^2 and is highly protected. It also forms the Nokrek National Park.
ii) Buffer Zone has an area of 227.92 km^2.The area belongs to the private owners. According to the Socio-Economic survey, the buffer zone has a population of 3885 in 23 villages.
iii) Transition zone, being the outermost part with an area of 544.60 km^2 has the highest human density. The transition zone has around 143 villages with a population of about 18,199 (Sen, 2013; Singh, and Borthakur, 2015).

The forest of Nokrek is mostly evergreen and semi-evergreen with a few bamboo brakes at lower elevations. 90% is evergreen in the National Park of the reserve. The Southern slopes are mostly of moist deciduous forest.The density of the forest is very high along the ridges making the entire area dark even during the day time. The entire region is highly humid and dense. The area is rich in wild varieties of citrus species mainly *Citrus indica* (memang narang), an endemic species believe to be the progenitor of the *Citrus spp.* Many indigenous species like *Nepenthus khasisana* (pitcher plant; memangkoksi) and various other medicinal plants and orchids are also found in the area. In addition to the floral diversity, many faunal species like Hoolock gibbon, elephant, clouded leopard, tiger are present there (Gogoi, 1981). Rich flora, mainly angiopserms are found in abundance in the forest of Garo hills. The Nokrek Biosphere Reserve covers East, West and South Garo hills and the Balpakram National Park in the South are the areas endowed with natural wealth.

CHAPTER- 4

METHODOLOGY

4.1 Selection of sampling sites

The study was conducted in the core zone (representing undisturbed stand) and buffer zone (representing disturbed stand) of the Nokrek Biosphere Reserve in Meghalaya (India), during the year 2014 to 2016. One hectare area each of the aforesaid stands was sampled for detailed ecological investigation.The area for sampling was carried out in the Eastern and Western zone for both the stands of the reserve.

4.2 Phyto-sociological analyses

Vegetation analysis was carried out following the methods outlined in Misra (1968), Mueller-Dombois and Ellenberg (1974). The size of quadrat was 10m x 10m for trees, 5m x 5m for shrubs and 1m x 1m for herbs. For shrubs and herbs quadrats were laid within 10m x 10m quadrats as demarcated for trees. A total of 100 quadrats each for trees (cbh≥30 cm), shrubs (cbh<30cm) and herbs were laid following the belt in each the Core (Undisturbed) and Buffer zone (Disturbed) of the reserve. The gbh (girth at breast height) of trees was measured at the height of 1.37 m, and the girth class distribution of trees was determined accordingly. The field data was utilized for computing various phyto-sociological attributes namely Frequency, Density, Abundance, Basal area and IVI. Subsequently, species richness index, diversity and dominance indices were calculated. The distribution pattern of species was determined by computing Whitford index.

The plant specimens were collected and mounted on herbarium sheets following the works of Jain and Rao (1977). The species were recorded and identified with the help of floras and herbarium from the BSI, Shillong, Flora of Meghalaya (Haridasan and Rao, 1985), Flora of Assam (Kanjilal *et al*., 1934- 1940), Flora of Jowai (Balakrishnan, 1981-1983). The updated version of classification of the plants was followed from the online websites of the Plant List (Version 1.1), and the International Plant Names Index (IPNI). Specimen identification was done with the support of pictures, photographs and old records.

The methods for various phyto-sociological attributes and diversity-distribution indices are as follows.

4.2.1 Frequency

Frequency refers to the number of individual species occurring in an area expressed in terms of percentage. It was calculated as follows:

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

4.2.2 Density

Density provides numerical strength, and is the total number of individuals of a species in defined area. It was calculated by the following equation:

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

4.2.3 Abundance

Abundance provides dominance of a species. It was calculated as follows:

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

4.2.4 Basal area

The basal area provides coverage, for trees, that it was calculated with the following formula:

$$\boldsymbol{Basal\ area} = \frac{\mathrm{gbh}^2}{4\pi}$$

Where,

‘gbh’ is girth at breast height.

4.2.5 Importance Value Index

Importance Value Index determines the ecological success of the species within the community. It is measured by taking into consideration the Relative Frequency, Relative Density and Relative Dominance (Phillips, 1959). It was calculated by the following formula:

IVI = Relative Density + Relative Frequency + Relative Dominance

4.2.6 Relative Frequency

Relative frequency is the dispersion of individual species in an area, and calculated as follows:

$$Relative\ Frequency\ (\%) = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} \times 100$$

4.2.7 Relative Density

It is defined as the number of individuals of a species in relation to the total number of individuals of all the species. It was calculated as follows:

$$Relative\ Density\ (\%) = \frac{\text{Density of a species}}{\text{Density of all species}} \times 100$$

4.2.8 Relative dominance

Basal cover of the species is defined as the dominance of the species. Relative dominance was calculated as follows:

$$Relative\ Dominance\ (\%) = \frac{\text{Dominance (cover) of a species}}{\text{Dominance (cover) of all species}} \times 100$$

4.2.9 Simpson Index of Dominance, (Simpson, 1949)

$$\text{Cd} = \sum_{i=0}^{n} \text{p}i^2$$

Where, p_i = proportion of individual in the $\underline{i}^{th}$ species.

As the Simpson's index values increases, diversity decreases. Simpson index is therefore usually expressed as "1 – Cd.

4.2.10 Shannon–Weiner Diversity Index, (Shannon and Weinner, 1963)

$$H' = -\sum_{5=1}^{s} pilnpi$$

Where,

H' = the Shannon–Weiner diversity index

pi = the proportion of individuals in the *i*th species i.e. (ni/N).

4.2.11 Margalef's Species Richness Index, (Margalef, 1958)

$$\mathbf{D_{Mg}=(S\text{-}}1)/\ln N$$

Where,

S= number of species recorded

N= total number of individuals

ln= Natural logarithm

4.2.12 Evenness Index, (Pielou, 1969)

$$\text{E} = \frac{\text{H}'}{ln\,\text{S}}$$

where ,

H' = Shannon–Weiner diversity index

S = total number of species.

4.2.13 Whitford Index, (Whitford, 1949)

Whitford Index = $\frac{A}{F}$

Where A = abundance of a species, and

F = frequency of a species.

(A/F ratio < 0.025 considered as regular distribution; 0.025 to 0.05 as random distribution; > 0.05 as contagious distribution).

Analysis of data was done in Microsoft excel and correlation between various parameters was done to determine interrelationship between ecological attributes using IBM SPSS 23.

4.3 Questionnaire survey

Socio-economic survey was conducted in the village by consulting community leaders and local people, to know the history and livelihood of the people. Information regarding the area and historical background was collected from the headman and forest department. The information on use of plants for herbal medicines and was procured from elderly aged indigenous people having ethno-medicinal knowledge. The important timber species were also recorded for both the core and the buffer zone of reserve with the help of questionnaire survey. Systematic appraisal for the impacts on the life of the local people affected by the developmental activities or a change in policy was also recorded (Mukherjee, 2003). A set of questionnaire was prepared and interviewed, and data obtained helped to reveal the reality of chain of socio-economic to the biophysical impacts.

4.4 Soil analysis

Soil samples were collected in triplicate from the core and buffer zone of the reserve from two locations *i.e.*, East and West parts. Soil samples were taken from two depths *i.e.*, 0-15cm (top-soil) and 15-30cm (sub-soil) on seasonal basis Pre-Monsoon Season from February to March; Monsoon Season from July to August; Post- Monsoon Season from November to December.

The soil samples were packed, sealed and labeled with care and brought to the laboratory at District and Local Research Station and Laboratories, Department of Agriculture, Sangsanggre, West Garo Hills, Tura, Meghalaya. Most of the physical characteristics like soil moisture, pH, bulk density were analysed immediately in the laboratory. For the chemical characteristics, the soil samples were air dried and then powdered with the help of mortar and pestle. The powdered samples were passed through 2mm sieve and used for further analysis of organic carbon, available phosphorous and exchangeable potassium. Soil characteristics were analyzed following the methods as outlined by Allen *et al*. (1974) and Anderson and Ingram (1963). Nitrogen was analysed in the Central Instrumentation laboratory of Mizoram University.

4.4.1 Soil moisture

Soil moisture was determined by Gravimetric method. 10 gm of freshly collected sample was taken. The difference between the fresh and dried samples was calculated after oven drying them for 24 hours in 105 °C. The air dry sample was weighed and recorded. It was then calculated with the help of the following formula

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

Where, W_1 = Initial weight of the soil

W_2= Final weight of the oven dried soil

4.4.2 Bulk density

Bulk density was estimated with the help of the corer. Soil samples were collected from the field with the help of corer. The sample from the corer was oven dried for 12 hours at 105 °C and weight was taken. The following formula was used for calculation

$$\text{Bulk density (D)} = \frac{\text{Weight of oven dried – dried soil}}{\text{Volume of soil core}} \ g/cm^3$$

Where,

Volume of soil corer = 3.14. x r^2 x h

r=inside radius of the cylinder (cm)

h=height of cylinder (cm)

4.4.3 Soil pH

10 gram of fresh soil sample was taken in a 100ml beaker. 50 ml of distilled water was added and kept in a magnetic stirrer for 20 minutes. The mixture was allowed to settle. The reading was taken with the help of digital pH meter.

4.4.4 Organic carbon

Walkey and Black's titration method was used for determining organic carbon.1 gram of soil was oxidized by 1N solution of $K_2Cr_2O_7$ and H_2SO_4. After half an hour, 10 ml of ortho-phosporic was added. Finally, 1ml of diphenylamine indicator is added.

The titration was then carried out by ferrous ammonium sulphate. Simultaneously a blank was run without the soil. The organic carbon content in the soil was calculated by the following formula-

$$\text{Organic carbon (\%)} = \frac{0.003 \times 10\ (B-T) \times 100}{B \times S}$$

Where, B= Volume of ferrous ammonium sulphate solution required for blank titration in ml

T= Volume of ferrous ammonium sulphate solution required for soil sample in ml and S= Weight of soil in gram

4.4.5 Nitrogen

CHN analyser (Perkin Elmer, 2400 Series II) was used for estimating the content of Nitrogen in the Central Instrumentation laboratory of Mizoram.

4.4.6 Available phosphorous

Available phosphorous was determined by Olsen's method. Available phosphorous was determined by extracting soil phosphorous with 0.5M $NaHCO_3$ solution by Olsen's method. 2.5g of soil sample was added into the conical flask. 50ml of sodium bicarbonate solution was added. The mixture was shaken for 30 minutes in the shaker and the suspension was filtered through Whatman No 40. Activated carbon was added to obtain a clear filtrate.

Olsen's Phosphorous (kg/ha) = $R \times V/v \times 1/S \times (2.24 \times 10^{6})/10^{6}$

$= R \times (50/5) \times (1/2.5) \times 2.24$

$= R \times 8.96$

Where,

V= Total volume of extractant

v= Volume of aliquot taken for analysis (5ml)

S= Weight of soil

R= Weight of the aliquot in ug (from standard curve)

4.4.7 Exchangeable potassium

Exchangeable potassium was determined with the help of flame photometer. 5gm of dry soil sample was taken in a 250ml conical flask. 25ml of normal ammonium acetate solution was added and was shaken for 5 minutes and filtered immediately with Whatman No.1 filter paper. The potassium concentration in the extract was then determined with the help of flame photometer at K- filter (Ghosh *et al*., 1983 and Maiti, 2003).The following formula was used:

$$\text{Exchangeable Potassium (Kg/ha)} = \frac{R \times V \times 224 \times 10^{6}}{W \times 10^{6}}$$

CHAPTER- 5

VEGETATION ANALYSIS FOR TREE SPECIES

5.1 Species and Family richness

Altogether, a total of 124 tree species belonging to 92 genera and 52 families were recorded from both sites of study area i.e., core and buffer zone of Nokrek biosphere reserve. The girth of the tree species was measured at 1.37 m height for all the trees having circumference ≥ 30cm gbh were considered as trees. The total number of trees recorded in the core zone was 91 species and buffer zone was 82 species. The number of families in the core zone was 40 and 42 in the buffer with the genera of 67 and 66, respectively for both the core and the buffer zone.The tree density in the core zone was 733 individuals ha^{-1} and the basal area was 68.99 m^2ha^{-1} whereas the tree density in the buffer zone was 1272 individuals' ha^{-1} and the basal area was 34.16 m^2 ha^{-1}.

The phytosociological data of the tree species in the core and buffer zones has been presented in **Table 5.1**. The correlation between different variables such as density, basal area and diversity indices which was carried out in SPSS 23.0 showed a significant positive correlation at 0.01 level (**Table 5.2**).

Table 5.1: Phytosociological attributes in the Core and Buffer zones of the Nokrek Biosphere Reserve

Parameter	Core zone	Buffer zone
Number of Family	40	42
Number of Genera	67	66
Number of Species	91	82
Tree density (individuals ha^{-1})	733	1272
Tree basal area (m^2 ha^{-1})	68.99	34.16
Shannon Diversity Index	3.81	3.50
Simpson Dominance Index	0.03	0.05
Evenness Index	0.85	0.79
Margalef Index of Species	13.64	11.33

Table5.2: Correlation between density, basal area and diversity indices

Parameters	Core zone	Buffer zone
Density and basal area	0.875**	0.790**
Density and Shannon H'	0.910**	0.932**
Density and Simpson Cd	0.909**	0.975**
Basal area and Shannon H'	0.820**	0.653**
Basal area and Simpson Cd	0.912**	0.826**

**. Correlation is significant at 0.01 level (2-tailed).

5.2 Phytosociological attributes

The tree density (≥ 30cm dbh) was lower in the core zone 733 individuals ha^{-1}. The dominant species in the core zone was *Syzygium claviflorum* (IVI 27.87). The co- dominant species were *Macropanax dispermus* (IVI 19.57) and *Castanopsis indica* (IVI 16.11) with a density of 57, 25 and 40 individuals ha^{-1} respectively. *Eurya accuminata* and *Terminalia citrina* were the most abundant species. Although the tree density was lower in the core zone but having the more basal area of 68.99 m^2 ha^{-1} could be due to presence of large number of individuals having more girth.

Syzygium claviflorum had the highest basal area of 8.40 m^2 ha^{-1} followed by *Macropanax dispermus* 4.89 m^2 ha^{-1} and *Castanopsis indica* 4.07 m^2 ha^{-1}.

The density of tree species was greater in the buffer zone (1272 trees ha^{-1}) than the core zone (733 trees ha^{-1}). The dominant species in the buffer zone were *Saurauia punduana* (IVI 29.25), *Saurauia napaulensis* (IVI 22.09), *Eurya accuminata* (IVI 19.40). Based on density, *Saurauia punduana*, *Saurauia napaulensis* and *Eurya accuminata* with 153 trees ha^{1}, 127 trees ha^{-1} and 97 trees ha^{-1} respectively were found to be dominant species.

About 98% species exhibited contiguous distribution pattern in the core zone and 95% in the buffer zone. Only 2% and 5% species in the core and buffer zone were randomly distributed. *Macropanax dispermus* and *Ocotea lancifolia* showed random distribution in the core zone. In the buffer zone, 4 species were randomly distributed - *Callicarpa arborea*, *Eurya accuminata*, *Glochidion daltonii* and *Schefflera elliptica*. None of the species showed regular distribution. The findings on the phytosociological analyses reveal that, *Syzygium claviflorum, Macropanax undulatus* and *Castanopsis indica,* the dominant species of the core zone was replaced by *Saurauia punduana, Saurauia napaulensis* and *Eurya accuminata* in the buffer zone.

5.3 Diversity Indices

The diversity indices were analysed and Shannon diversity index was higher in the core zone with the values of 3.81 than the buffer zone (3.50). Similarly, Evenness index and Margalef index of species were also higher in the core zone 81 than the buffer zone. Simpson dominance index followed a reverse trend with the values being higher (0.05) in the buffer zone than the core zone (0.03). The plant community structure in the core and buffer zone are given in **Table 5.3 and 5.4.**

Table 5.3: Plant community structure in the Core zone

Sl.	Scientific name	Family	Density	Frequency	Abundance	A:F	Distribution pattern
1	*Aesculus assamica* Griff.	Sapindaceae	5	5	1	0.2	Contagious
2	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	1	1	1	1	Contagious
3	*Aphanamixis wallichii* (King) Harid. & R.R.Rao	Meliaceae	6	6	1	0.17	Contagious
4	*Ardisia macrocarpa* Wall.	Myrsinaceae	3	3	1	0.33	Contagious
5	*Arenga pinnata* (Wurmb) Merr.	Arecaceae	1	1	1	1	Contagious
6	*Baliospermum sp*	Euphorbiaceae	10	5	2	0.4	Contagious
7	*Betula alnoides* Buch.-Ham. ex D.Don	Betulaceae	5	4	1.25	0.31	Contagious
8	*Bridelia retusa* (L.) A. Juss.	Euphorbiaceae	1	1	1	1	Contagious
9	*Calophyllum polyanthum* Wall. ex Choisy	Clusiaceae	16	13	1.231	0.10	Contagious
10	*Carallia brachiata* (Lour.) Merr.	Rhizophoraceae	1	1	1	1	Contagious
11	*Cassia fistula L.*	Caesalpiniacea	1	1	1	1	Contagious
12	*Castanopsis hystrix* Hook. f. & Thomson ex A. DC.	Fagaceae	2	2	1	0.5	Contagious
13	*Castanopsis indica* (Roxb. ex Lindl.) A.DC.	Fagaceae	40	24	1.667	0.07	Contagious
14	*Castanopsis sp.*	Fagaceae	3	3	1	0.33	Contagious
15	*Castanopsis lanceifolia* (Oerst.) Hickel & A.Camus	Fagaceae	1	1	1	1	Contagious
16	*Castanopsis tribuloides* (Sm.) A.DC	Fagaceae	8	5	1.6	0.32	Contagious
17	*Toona ciliata* M.Roem.	Meliaceae	3	2	1.5	0.75	Contagious
18	*Ceiba sp.*	Malvaceae	1	1	1	1	Contagious

19	*Cinnamonum camphora* (L.)J.Presl.	Lauraceae	8	8	1	0.13	Contagious
20	*Cinnamomum glaucescens* Nees.	Lauraceae	1	1	1	1	Contagious
21	*Cinnamomum bejolghota* Nees	Lauraceae	1	1	1	1	Contagious
22	*Cinnamomum curvifolium* (Lam.) Nees	Lauraceae	1	1	1	1	Contagious
23	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	Lauraceae	3	3	1	0.33	Contagious
24	*Cordia dichotoma* Forst	Boraginaceae	34	15	2.267	0.15	Contagious
25	*Crypteronia paniculata* Blume	Crypteroniaceae	2	2	1	0.5	Contagious
26	*Cryptocarya amygdalina* Nees	Lauraceae	24	19	1.263	0.07	Contagious
27	*Cyathocalyx zeylanicus* Champ. ex Hook.f. & Thomson	Annonaceae	4	2	2	1	Contagious
28	*Dasymaschalon longiflorum* (Roxb.) Finet & Gagnep.	Annonaceae	2	2	1	0.5	Contagious
29	*Dimocarpus longan* Lour.	Sapindaceae	16	11	1.455	0.13	Contagious
30	*Diospyros lanceifolia* Roxb.	Symplocaceae	17	15	1.133	0.08	Contagious
31	*Drimycarpus racemosus* (Roxb.) Hook.f. ex Marchand.	Anacardiaceae	7	6	1.167	0.19	Contagious
32	*Dysoxylum excelsum* Blume	Meliaceae	1	1	1	1	Contagious
33	*Dysoxylum procerum* Hiern	Meliaceae	7	5	1.4	0.28	Contagious
34	*Engelhardia spicata* Lenchen ex Blume	Juglandaceae	6	4	1.5	0.38	Contagious
35	*Eurya accuminata* DC	Theaceae	22	7	3.143	0.449	Contagious
36	*Garcinia cowa* Roxb. Ex. Dc	Clusiaceae	2	2	1	0.5	Contagious
37	*Garcinia kydia* Roxb.	Clusiaceae	16	14	1.143	0.08	Contagious
38	*Gleditsia assamica Bor*	Fabaceae	1	1	1	1	Contagious
39	*Glochidion daltonii* (Müll.Arg.) Kurz	Euphorbiaceae	16	9	1.778	0.20	Contagious
40	*Helicia robusta* (Roxb.) R.Br. ex Blume	Proteaceae	6	5	1.2	0.24	Contagious
41	*Homalium bhamoense* Cubitt & W.W.Sm.	Flacortiaceae	1	1	1	1	Contagious

42	*Gynocardia odorata R.Br*	Achariaceae	1	1	1	1	Contagious
43	*Knema linifolia* (Roxb.) Warb	Myrstiaceae	1	1	1	1	Contagious
44	*Kydia calycina* Roxb.	Malvaceae	1	1	1	1	Contagious
45	*Lepisanthes rubiginosa* (Roxb.) Leenh.	Sapindaceae	8	6	1.333	0.22	Contagious
46	*Ligustrum robustum* (Roxb.) Blume	Oleaceae	35	21	1.667	0.08	Contagious
47	*Lindera heterophylla* Benth	Lauraceae	2	1	2	2	Contagious
48	*Lithocarpus elegans* (Blume) Hatus. ex Soepadmo	Fagaceae	2	1	2	2	Contagious
49	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	7	4	1.75	0.44	Contagious
50	*Macaranga indica* Wight	Euphorbiaceae	3	2	1.5	0.75	Contagious
51	*Macropanax dispermus* (Blume) Kuntze	Araliaceae	48	30	1.6	0.04	**Random**
52	*Macropanax sp.*	Araliaceae	3	2	1.5	0.75	Contagious
53	*Macropanax undulata* Seem.	Araliaceae	25	18	1.389	0.08	Contagious
54	*Mallotus paniculatus (Lam.)* Müll.Arg.	Euphorbiaceae	1	1	1	1	Contagious
55	*Mallotus repandus* Wall	Euphorbiaceae	1	1	1	1	Contagious
56	*Mangifera sylvatica* Roxb.	Annacardiaceae	1	1	1	1	Contagious
57	*Mesua ferrea* Linn.	Calophyllaceae	6	5	1.2	0.24	Contagious
58	*Micromelum integerrimum* (Buch.-Ham. ex DC.) Wight & Arn. ex M. Roem.	Rutaceae	2	2	1	0.5	Contagious
59	*Myrica esculenta* Buch.-Ham. ex D.Don	Myricaceae	1	1	1	1	Contagious
60	*Oreocnide integrifolia* (Gaud.) Miq	Urticaceae	2	2	1	0.5	Contagious
61	*Ostodes pannniculata* Blume	Euprorbiaceae	12	12	1	0.08	Contagious
62	*Magnolia baillonii* Pierre	Magnoliaceae	1	1	1	1	Contagious
63	*Parkia timoriana (DC.)* Merr.	Fabaceae	3	3	1	0.33	Contagious
64	*Persea odoratissima* (Nees) Kosterm.	Lauraceae	38	22	1.727	0.08	Contagious
65	*Phoebe attenuata* (Nees) Nees	Lauraceae	2	1	2	2	Contagious

66	*Phoebe goalparensis* Bull. Misc. Inform. Kew	Lauraceae	4	4	1	0.25	Contagious
67	*Ocotea lancifolia* (Schott) Mez	Lauraceae	40	26	1.538	0.04	**Random**
68	*Phoebe macrocarpa* C.Y. Wu	Lauraceae	21	14	1.5	0.107	Contagious
69	*Phoebe paniculata* Nees	Lauraceae	4	2	2	1	Contagious
70	*Premna cordifolia* Roxb.	Lamiaceae	1	1	1	1	Contagious
71	*Premna mollissima* Roth	Lamiaceae	10	7	1.429	0.20	Contagious
72	*Quercus glauca* Thunb.	Fagaceae	5	4	1.25	0.31	Contagious
73	*Quercus lancifolia* Schltdl. & Cham..	Fagaceae	15	12	1.25	0.10	Contagious
74	*Quercus spicata* Sm	Fagaceae	5	3	1.667	0.56	Contagious
75	*Randia sp.*	Rubiaceae	1	1	1	1	Contagious
76	*Reevesia pubescens* Mast.	Malvaceae	6	4	1.5	0.38	Contagious
77	*Rhus javanica* L.	Anacardiaceae	1	1	1	1	Contagious
78	*Sapindus alternatus* Wall	Sapindaceae	1	1	1	1	Contagious
79	*Sapium baccatum* Roxb.	Euphorbiaceae	3	2	1.5	0.75	Contagious
80	*Saurauia napaulensis* DC.	Actinidiaceae	1	1	1	1	Contagious
81	*Saurauia punduana* Wall.	Actinidiaceae	13	5	2.6	0.52	Contagious
82	*Sterculia coccinea* Roxb	Sterculiaceae	3	3	1	0.33	Contagious
83	*Stereospermum chelonoides* (L.f.) DC.	Bignoniaceae	1	1	1	1	Contagious
84	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	Myrtaceae	57	40	1.425	0.04	Contagious
85	*Syzygium cumini* (L.) Skeels	Myrtaceae	2	1	2	2	Contagious
86	*Terminalia citrina* Roxb.	Combretaceae	3	1	3	3	Contagious
87	*Terminalia myriocarpa* Van Heurck & Müll. Arg	Combretaceae	7	5	1.4	0.28	Contagious
88	*Terminalia sp.*	Combretaceae	5	5	1	0.2	Contagious
89	*Toona sureni* (Blume) Merr.	Meliaceae	1	1	1	1	Contagious

90	*Turpinia pomifera* (Roxb.) DC.	Staphylaceae	8	5	1.6	0.32	Contagious
91	*Walsura robusta* Roxb.	Meliaceae	3	1	3	3	Contagious

Table 5.4: Plant community structure in the buffer zone

Sl	Scientific name	Family	Density	Frequency	Abundance	A:F	Distribution pattern
1	*Albizzia chinensis* (Osbeck) Merr.	Mimosaceae	12	7	1.714	0.245	Contagious
2	*Archidendron cyperinum* (Roxb.)	Mimosaceae	5	3	1.667	0.556	Contagious
3	*Ardisia macrocarpa* Wall.	Myrsinaceae	8	5	1.6	0.32	Contagious
4	*Arenga pinnata* (Wurmb) Merr.	Arecaceae	3	3	1	0.333	Contagious
5	*Baccaurea ramiflora* Lour.	Phyllanthaceae	2	1	2	2	Contagious
6	*Betula alnoides* Buch.-Ham. ex D.Don	Betulaceae	12	9	1.333	0.148	Contagious
7	*Bischofia javanica* Blume	Euphorbiaceae	1	1	1	1	Contagious
8	*Bombax ceiba* L.	Bombacaceae	2	2	1	0.5	Contagious
9	*Bridelia monoica* (Lour.) Merr.	Euphorbiaceae	1	1	1	1	Contagious
10	*Bridelia retusa* (L.) A. Juss.	Phyllantaceae	2	1	2	2	Contagious
11	*Callicarpa arborea* Roxb.	Verbanaceae	65	34	1.912	0.046	**Random**
12	*Calophyllum polyanthum* Wall. ex Choisy	Clusiaceae	2	2	1	0.5	Contagious
13	*Cassia fistula* L.	Caesalpiniacea	1	1	1	1	Contagious
14	*Castanopsis hystrix* Hook. f. & Thomson ex A. DC.	Fagaceae	16	6	2.667	0.444	Contagious
15	*Castanopsis indica* (Roxb. ex Lindl.) A.DC.	Fagaceae	34	19	1.789	0.094	Contagious
16	*Castanopsis tribuloides* (Sm.) A.DC	Fagaceae	39	10	3.9	0.39	Contagious

17	*Cinnamonum camphora* Nees	Lauraceae	3	3	1	0.333	Contagious
18	*Cinnamomum glaucescens* Nees.	Lauraceae	2	2	1	0.5	Contagious
19	*Cinnamomum bejolghota* Nees	Lauraceae	1	1	1	1	Contagious
20	*Cordia dichotoma* Forst	Boraginaceae	29	14	2.071	0.148	Contagious
21	*Croton persimilis* Müll.Arg.	Euphorbiaceae	3	1	3	3	Contagious
22	*Crypteronia paniculata* Blume	Crypteroniaceae	2	1	2	2	Contagious
23	*Cryptocarya amygdalina* Nees	Lauraceae	26	11	2.364	0.215	Contagious
24	*Dimocarpus longan* Lour.	Sapindaceae	5	4	1.25	0.313	Contagious
25	*Diospyros lanceifolia* Roxb.	Symplocaceae	18	10	1.8	0.18	Contagious
26	*Diospyros sp.*	Ebenaceae	3	1	3	3	Contagious
27	*Duabanga grandiflora* (DC.) Walp.	Lythraceae	1	1	1	1	Contagious
28	*Dysoxylum excelsum* Blume	Meliaceae	1	1	1	1	Contagious
29	*Ehretia accuminata* R.Br.	Boraginaceae	6	5	1.2	0.24	Contagious
30	*Elaeocarpus rugosus* Roxb. ex G.Don	Elaeocarpaceae	2	1	2	2	Contagious
31	*Engelhardia spicata* Lenchen ex Blume	Juglandaceae	14	11	1.273	0.116	Contagious
32	*Eurya accuminata* DC	Theaceae	97	42	2.310	0.045	**Random**
33	*Ficus auriculata* Lour.	Moraceae	2	1	2	2	Contagious
34	*Ficus hirta* Vahl	Moraceae	7	7	1	0.1429	Contagious
35	*Ficus neriifolia* Sm.	Moraceae	2	1	2	2	Contagious
36	*Ficus semicordata* Buch. -Ham. ex Sm.	Moraceae	17	13	1.308	0.101	Contagious
37	*Gleditsia assamica* Bor	Fabaceae	9	3	3	1	Contagious
38	*Glochidion daltonii* (Müll.Arg.) Kurz	Phyllantaceae	51	30	1.7	0.047	**Random**
39	*Microcos tomentosa* Sm.	Malvaceae	1	1	1	1	Contagious
40	*Helicea robusta* Wall	Proteaceae	38	21	1.810	0.086	Contagious
41	*Helicia nilagirica* Bedd.	Proteaceae	5	1	5	5	Contagious
42	*Gynocardia odorata* R.Br	Achariaceae	3	3	1	0.333	Contagious

43	*Lagerstroemia parviflora* Roxb.	Lythraceae	6	4	1.5	0.375	Contagious
44	*Ligustrum robustum* (Roxb.) Blume	Oleaceae	8	6	1.333	0.222	Contagious
45	*Lindera heterophylla* Benth	Lauraceae	5	4	1.25	0.313	Contagious
46	*Litsea cubeba* (Lour.) Pers.	Lauraceae	2	1	2	2	Contagious
47	*Macaranga denticulata* (Blume) Müll.Arg	Euphorbiaceae	90	33	2.727	0.083	Contagious
48	*Macaranga indica* Wight	Euphorbiaceae	20	16	1.25	0.078	Contagious
49	*Macropanax dispermus* (Blume) Kuntze	Araliaceae	27	15	1.8	0.12	Contagious
50	*Maesa indica* Wall.	Myrsinaceae	2	1	2	2	Contagious
51	*Mallotus paniculatus* (Lam.) Müll.Arg.	Euphorbiaceae	55	28	1.964	0.070	Contagious
52	*Mallotus philippinensis* Muell. Arg	Euphorbiaceae	2	1	2	2	Contagious
53	*Mallotus roxburghianus* Muell.-Arg.	Euphorbiaceae	2	1	2	2	Contagious
54	*Melia birmanica* Kurz	Meliaceae	1	1	1	1	Contagious
55	*Meliosma pinnata* (Roxb.)	Sabiaceae	21	13	1.615	0.124	Contagious
56	*Mesua ferrea* Linn.	Callophyllaceae	1	1	1	1	Contagious
57	*Myrica esculenta* Buch. -Ham. ex D.Don	Myricaceae	1	1	1	1	Contagious
58	*Oreocnide integrifolia* (Gaud.) Miq	Urticaceae	23	9	2.556	0.284	Contagious
59	*Ostodes pannniculata* Blume	Euprorbiaceae	16	7	2.286	0.327	Contagious
60	*Persea odoratissima* (Nees) Kosterm.	Lauraceae	19	8	2.375	0.297	Contagious
61	*Phoebe attenuata* (Nees) Nees	Lauraceae	22	16	1.375	0.086	Contagious
62	*Ocotea lancifolia* (Schott) Mez	Lauraceae	2	2	1	0.5	Contagious
63	*Premna cordifolia* Roxb.	Lamiaceae	1	1	1	1	Contagious
64	*Pterospermum lanceifolium* Roxb.	Malvaceae	2	1	2	2	Contagious
65	*Quercus glauca* Thumb.	Fagaceae	1	1	1	1	Contagious
66	*Quercus lancaefolia* Roxb.	Fagaceae	28	10	2.8	0.28	Contagious
67	*Quercus spicata* Sm	Fagaceae	20	11	1.818	0.165	Contagious
68	*Randia sp.*	Rubiaceae	1	1	1	1	Contagious

69	*Reevesia pubescens* Mast.	Malvaceae	1	1	1	1	Contagious
70	*Rhus javanica L.*	Anacardiaceae	2	2	1	0.5	Contagious
71	*Sapium baccatum* Roxb.	Euphorbiaceae	2	2	1	0.5	Contagious
72	*Saurauia napaulensis* DC.	Actinidiaceae	127	27	4.704	0.174	Contagious
73	*Saurauia punduana* Wall.	Actinidiaceae	153	61	2.508	0.041	**Random**
74	*Schefflera elliptica* (Blume) Harms	Araliaceae	2	2	1	0.5	Contagious
75	*Schima wallichii* (DC.) Korth	Theaceae	16	8	2	0.25	Contagious
76	*Flueggea virosa* (Roxb. ex Willd.) Royle.	Phyllantaceae	2	2	1	0.5	Contagious
77	*Sterculia coccinea* Roxb	Sterculiaceae	8	6	1.333	0.222	Contagious
78	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	Myrtaceae	3	2	1.5	0.75	Contagious
79	*Terminalia citrina* Roxb.	Combretaceae	16	9	1.778	0.198	Contagious
80	*Trema orientalis* (L.) Bl.	Cannabaceae	1	1	1	1	Contagious
81	*Trevesia palmata* (Roxb. ex Lindl.) Vis.	Araliaceae	5	2	2.5	1.25	Contagious
82	*Turpinia pomifera* (Roxb.)DC.	Staphylaceae	3	2	1.5	0.75	Contagious

Table 5.5: Species ranking (based on Importance Value Index) in the Core and Buffer zone of Nokrek biosphere reserve

Species rank	Core zone	IVI	Buffer zone	IVI
1	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	27.87	*Saurauia punduana* Wall.	29.25
2	*Macropanax undulata* Seem.	19.57	*Saurauia napaulensis* DC.	22.09
3	*Castanopsis indica* (Roxb. ex Lindl.) A.DC..	16.11	*Eurya accuminata* DC	19.40
4	*Ocotea lancifolia* (Schott) Mez	15.30	*Castanopsis indica* (Roxb. ex Lindl.) A.DC.	16.68
5	*Cordia dichotoma* Forst	13.48	*Macaranga denticulata* (Blume) Müll.Arg	15.63
6	*Ligustrum robustum* (Roxb.) Blume	12.91	*Callicarpa arborea* Roxb.	14.29
7	*Persea odoratissima* (Nees) Kosterm.	12.57	*Mallotus paniculatus* (Lam.) Müll.Arg.	14.19
8	*Aphanamixis wallichii* (King) Harid. & R.R.Rao	9.89	*Glochidion daltonii* (Müll.Arg.) Kurz	11.95
9	*Cryptocarya amygdalina* Nees	9.25	*Castanopsis tribuloides* (Sm.) A.DC	9.21
10	*Quercus lancaefolia* Roxb.	7.49	*Helicea robusta* Wall	8.53
11	*Phoebe macrocarpa* C.Y. Wu	7.04	*Cordia dichotoma* Forst	7.71
12	*Diospyros lanceifolia* Roxb.	6.53	*Macropanax undulata* Seem.	6.97
13	*Calophyllum polyanthum* Wall. ex Choisy	6.49	*Quercus spicata* Sm	6.30
14	*Glochidion daltonii* (Müll.Arg.) Kurz	6.02	*Quercus lancaefolia* Roxb.	6.20
15	*Drimycarpus racemosus* (Roxb.) Hook.f. ex Marchand.	5.71	*Betula alnoides* Buch.-Ham. ex D.Don	6.16
16	*Aphanamixis polystachya* (Wall.)	5.65	*Phoebe alternata* Nees.	5.86
17	*Eurya accuminata* DC	5.57	*Macaranga indica* Wight	5.60
18	*Garcinia kydia* Roxb.	5.41	*Cryptocarya amygdalina* Nees	5.42
19	*Ostodes pannniculata* Blume	5.27	*Englrhertia spicata* Lenchen ex Blume	5.30
20	*Terminalia myriocarpa* Van Heurck & Müll. Arg	4.37	*Meliosma pinnata* (Roxb.)	5.16
21	*Baliospermum* sp	3.62	*Castanopsis hystrix* Hook. f. & Thomson ex A. DC.	4.92
22	*Randia sp.*	3.49	*Schima wallichii* (DC.) Korth	4.88
23	*Cinnamonum camphora* (L.)J.Presl.	3.31	*Ficus semicordata* Buch.-Ham. ex Sm.	4.85
24	*Betula alnoides* Buch.-Ham. ex	3.21	*Oreocnide integrifolia* (Gaud.)	4.50

	D.Don		Miq	
25	*Dysoxylum procerum* Hiern	3.10	*Terminalia citrina* Roxb.	3.91
26	*Premna latifolia* Roxb.	3.07	*Diospyros lanceifolia* Roxb.	3.82
27	*Saurauia punduana* Wall.	3.02	*Persea odoratissima* (Nees) Kosterm.	3.62
28	*Terminalia sp.*	2.94	*Albizzia chinensis (*Osbeck) Merr.	3.29
29	*Englrhertia spicata* Lenchen ex Blume	2.90	*Ostodes pannniculata* Blume	3.23
30	*Dysoxylum excelsum* (Buch.-Ham.) Merr.	2.85	*Gleditsia assamica* Bor	2.19
31	*Quercus glauca* Thumb.	2.79	*Ligustrum robustum* (Roxb.) Blume	2.02
32	*Turpinia pomifera* (Roxb.) DC.	2.71	*Ficus hirta* Vahl	1.95
33	*Lepisanthes rubiginosa* (Roxb.) Leenh.	2.63	*Ehretia accuminata* R.Br.	1.92
34	*Toona ciliata* M.Roem.	2.63	*Sterculia coccinea* Roxb	1.87
35	*Castanopsis tribuloides* (Sm.) A.DC	2.59	*Aphanamixis polystachya* (Wall.)	1.77
36	*Litsea polyantha* Juss.	2.50	*Arenga pinnata* (Wurmb) Merr.	1.76
37	*Phoebe paniculata* Nees	2.33	*Ardisia macrocarpa* Wall.	1.68
38	*Aesculus assamica* Griff.	2.19	*Lagerstroemia parviflora* Roxb.	1.51
39	*Castanopsis sp.*	2.17	*Lindera heterophylla* Benth	1.37
40	*Helicea robusta* wall	2.16	*Archidendron cyperinum* (Roxb.)	1.37
41	*Sterculia coccinea* Roxb	2.05	*Sapium baccatum* Roxb.	1.32
42	*Mesua ferrea* Linn.	1.99	*Bombax ceiba* L.	1.20
43	*Reevesia pubescens* Mast.	1.97	*Cinnamomum glaucescens* Nees.	0.88
44	*Phoebe goalparensis* Bull. Misc. Inform. Kew	1.75	*Cinnamonum camphora* Nees	0.86
45	*Quercus spicata* Sm	1.73	*Trevesia palmata* (Roxb. ex Lindl.) Vis.	0.85
46	*Castanopsis hystrix* Hook. f. & Thomson ex A. DC.	1.57	*Gynocardia odorata R.Br*	0.83
47	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	1.42	*Diospyros sp.*	0.77
48	*Castanopsis lanceifolia* (Oerst.) Hickel & A.Camus	1.38	*Turpinia pomifera* (Roxb.)DC.	0.72
49	*Parkia timoriana* (DC.) Merr.	1.28	*Helicia nilagirica* Bedd.	0.69
50	*Ardisia macrocarpa* Wall.	1.22	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	0.69
51	*Sapium baccatum* Roxb.	1.18	*Calophyllum polyanthum* Wall. ex Choisy	0.68

52	*Walsura robusta* Roxb.	1.11	*Ocotea lancifolia* (Schott) Mez	0.63
53	*Gleditsia assamica* Bor	1.10	*Croton persimilis* Müll.Arg.	0.62
54	*Cyathocalyx zeylanicus* Champ. ex J. Hk	1.09	*Rhus javanica* L.	0.59
55	*Crypteronia paniculata* Blume	1.03	*Quercus glauca* Thumb.	0.57
56	*Macropanax sp.*	0.92	*Schefflera elliptica* (Blume) Harms	0.55
57	*Dasymaschalon longiflorum* (Roxb.) Finet & Gagnep.	0.92	*Flueggea virosa* (Roxb. ex Willd.) Royle	0.54
58	*Syzygium cumini* (L.) Skeels	0.90	*Bischofia javanica* Blume	0.47
59	*Toona sureni* (Blume) Merr.	0.88	*Litsea cubeba* (Lour.) Pers.	0.47
60	*Macaranga indica* Wight	0.87	*Ficus neriifolia* Sm.	0.43
61	*Micromelum integerrimum* (Buch.-Ham. ex DC.) Wight & Arn. ex M. Roem.	0.84	*Pterospermum lanceifolium* Roxb.	0.43
62	*Terminalia citrina* Roxb.	0.76	*Mallotus roxburghianus* Muell.-Arg.	0.41
63	*Oreocnide integrifolia* (Gaud.) Miq	0.74	*Baccaurea ramiflora* Lour.	0.41
64	*Garcinia cowa* Roxb. Ex. Dc	0.71	*Myrica esculenta* Buch.-Ham. ex D.Don	0.40
65	*Mallotus paniculatus* (Lam.) Müll.Arg.	0.70	*Maesa indica* Wall.	0.40
66	*Phoebe attenuata* (Nees) Nees	0.69	*Mallotus philippinensis* Muell. Arg	0.38
67	*Lithocarpus elegans* (Blume) Hatus. ex Soepadmo	0.58	*Bridelia retusa* (L.) A. Juss.	0.37
68	*Carallia brachiata* (Lour.) Merr.	0.52	*Crypteronia paniculata* Blume	0.37
69	*Alstonia scholaris* (L.) R. Br.	0.52	*Elaeocarpus rugosus* Roxb. ex G.Don	0.37
70	*Lindera heterophylla* Benth	0.51	*Ficus auriculata* Lour.	0.36
71	*Magnolia baillonii* Pierre	0.51	*Melia birmanica* Kurz	0.33
72	*Gynocardia odorata* R.Br	0.46	*Cinnamomum bejolghota* Nees	0.31
73	*Macropanax sp.*	0.46	*Duabanga grandiflora* (DC.) Walp.	0.30
74	*Mangifera sylvatica* Roxb.	0.45	*Premna cordifolia* Roxb.	0.29
75	*Saurauia napaulensis* DC.	0.44	*Trema orientalis* (L.) Bl.	0.28
76	*Stereospermum chelonoides* (L.f.) DC.	0.43	*Randia sp.*	0.28
77	*Ceiba sp.*	0.42	*Dysoxylum excelsum* Blume	0.28
78	*Knema linifolia* (Roxb.) Warb	0.42	*Cassia fistula* L.	0.27
79	*Bridelia retusa* (L.) A. Juss.	0.40	*Microcos tomentosa* Sm.	0.27
80	*Randia sp.*	0.40	*Bridelia monoica* (Lour.) Merr.	0.27
81	*Arenga pinnata* (Wurmb) Merr.	0.39	*Reevesia pubescens* Mast.	0.26
82	*Cinnamomum glaucescens* Nees.	0.38	*Mesua ferrea* Linn.	0.26

83	*Mallotus repandus* Wall	0.37		
84	*Kydia calycina* Roxb.	0.37		
85	*Rhus javanica* L.	0.36		
86	*Myrica esculenta* Buch.-Ham. ex D.Don	0.36		
87	*Homalium bhamoense* Cubitt & W.W.Sm.	0.35		
88	*Premna cordifolia* Roxb.	0.35		
89	*Cinnamomum bejolghota* Nees	0.35		
90	*Cinnamomum curvifolium* (Lam.) Nees	0.35		
91	*Cassia fistula* L.	0.34		

5.4 Dominance diversity pattern

The dominance diversity curve based on IVI was found to be short for the tree species in the buffer zone showing mild disturbance and instability than the core zone (**Table 5.5** and **Fig.5.1**).

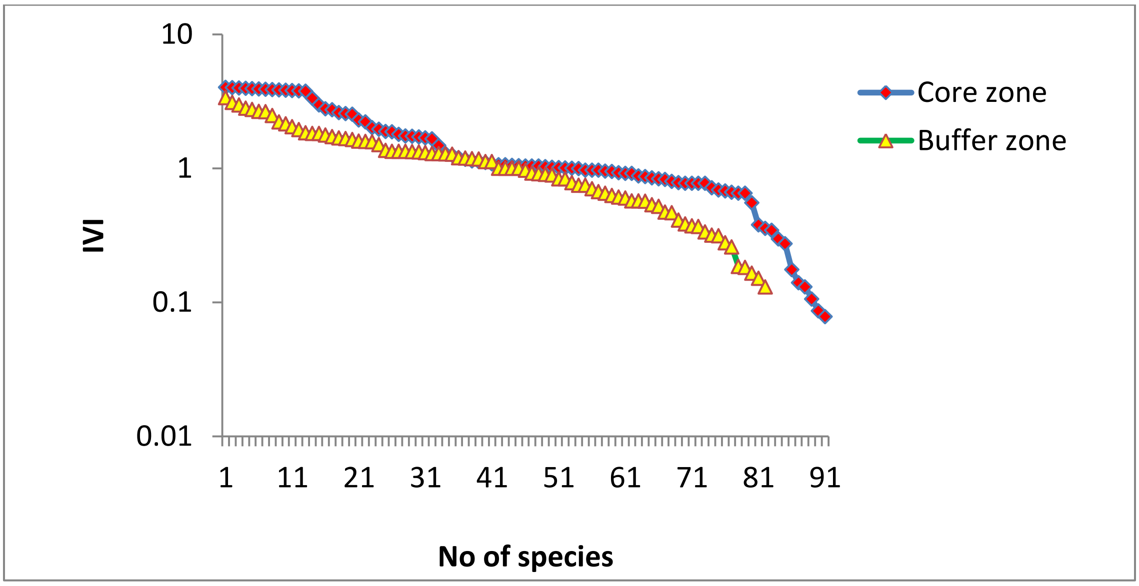


Fig 5.1: Dominance-diversity curve of tree species in the core and buffer zone

5.5 Family composition

In the core zone, Lauraceae with 14 species constitute 15% of the total family richness, Fagaceae 9 species followed by Euphorbiaceae and Meliaceae constitute 10 %, 9 % and 7 % respectively.Sapindaceae contributed 4%. Anacardiaceae, Araliaceae, Clusiaceae, Combretaceae and Malvaceae constitute 3% each. Actinidiaceae, Annonaceae, Fabaceae, Lamiaceae and Myrtaceae constitute 10 % of the species. The rest families are monospecific. The genus Castanopsis contributed the maximum number of species- *Castanopsis hystrix*, *Castanopsis indica*, *Castanopsis lancaefolia* and *Castanopsis tribuloides* followed by the genus *Persea* and *Cinnamomum* with 4 species each.

In the buffer zone, Euphorbiaceae with 10 species constitute 12 %, Lauraceae 9 species 11 %, Fagaceae 6 species 7 %, Moraceae and Phyllantaceae 5 %, Araliaceae and Malvaceae with 3 species each constituted 4 %. Actinidiaceae, Boraginaceae, Lythraceae, Meliaceae, Mimosaceae, Myrsinaceae, Proteaceae and Theaceae together constitute a total of 16% and the rest are monospecific. The genus *Ficus* contributed the maximum number of species-*Ficus auriculata*, *Ficus hirta*, *Ficus neriifolia* and *Ficus semicordata*. The family distribution of species is given in **Fig. 5.2** , dominance and ranking are given in **Fig.5.3** and **Table 5.6**.

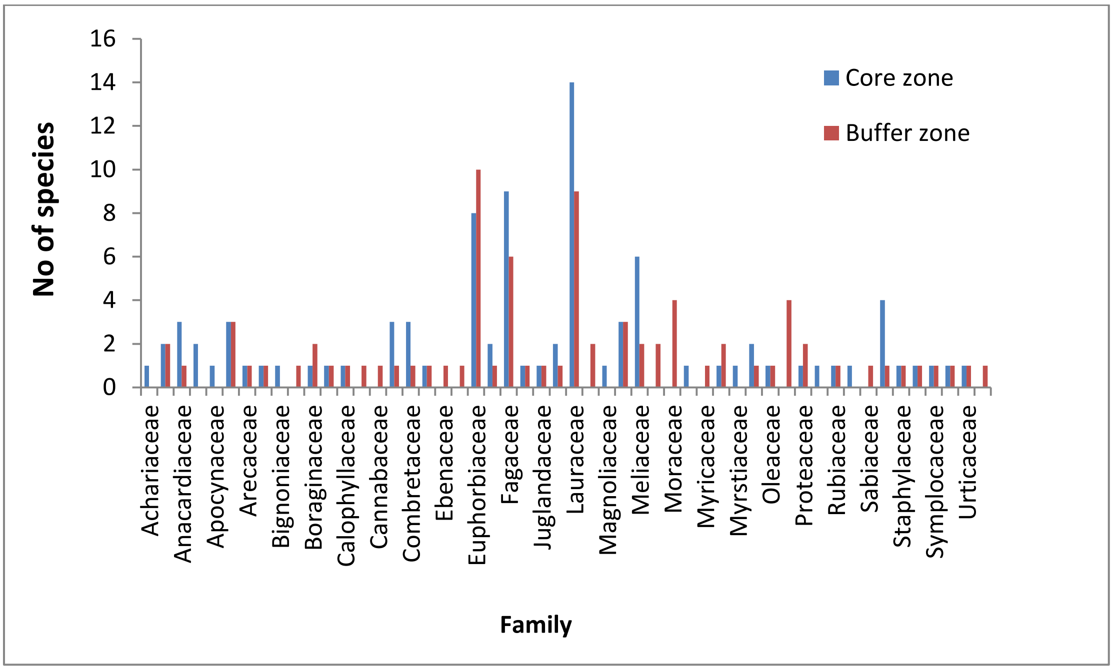


Fig 5.2: Family-wise distribution of species in core zone and buffer zone

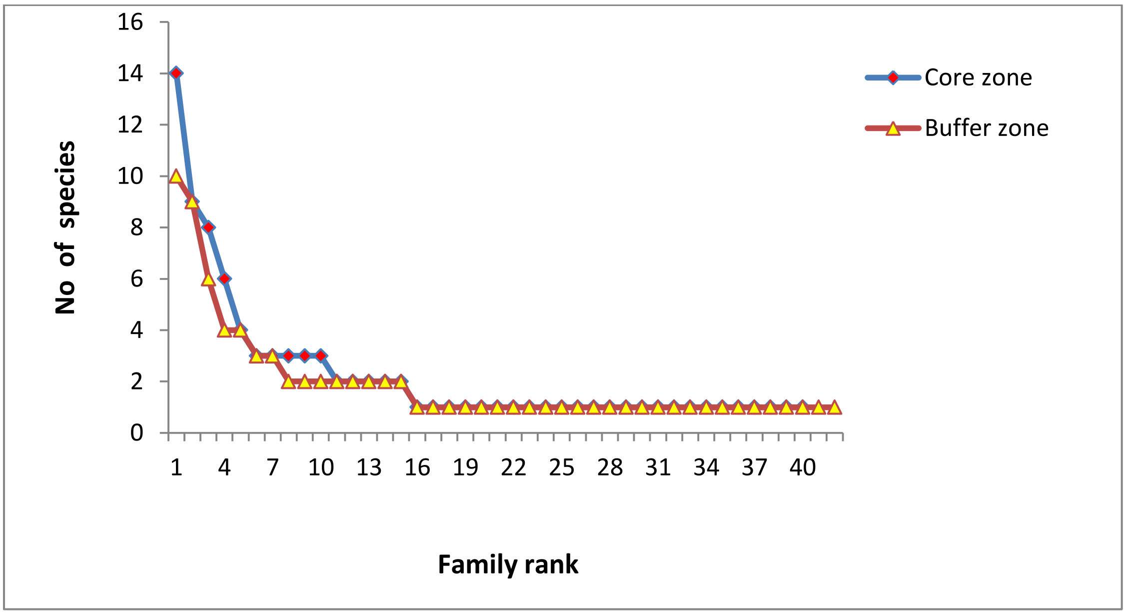


Fig 5.3: Family dominance (based on richness) distribution of species in the core and the buffer zone

Table 5.6: Family ranking in the core zone and buffer zone of the Nokrek Biosphere Reserve

Rank	Core zone		Buffer zone	
	Family	No. of species	Family	No. of species
1	Lauraceae	14	Euphorbiaceae	10
2	Fagaceae	9	Lauraceae	9
3	Euphorbiaceae	8	Fagaceae	6
4	Meliaceae	6	Moraceae	4
5	Sapindaceae	4	Phyllanthaceae	4
6	Anacardiaceae	3	Araliaceae	3
7	Araliaceae	3	Malvaceae	3
8	Clusiaceae	3	Actinidiaceae	2
9	Combretaceae	3	Boraginaceae	2
10	Malvaceae	3	Lythraceae	2
11	Actinidiaceae	2	Meliaceae	2
12	Annonaceae	2	Mimosaceae	2
13	Fabaceae	2	Myrsinaceae	2
14	Lamiaceae	2	Proteaceae	2
15	Myrtaceae	2	Theaceae	2
16	Achariaceae	1	Anacardiaceae	1
17	Apocynaceae	1	Arecaceae	1
18	Arecaceae	1	Betulaceae	1
19	Betulaceae	1	Bombacaceae	1
20	Bignoniaceae	1	Caesalpiniacea	1
21	Boraginaceae	1	Calophyllaceae	1
22	Caesalpiniacea	1	Cannabaceae	1
23	Calophyllaceae	1	Clusiaceae	1
24	Crypteroniaceae	1	Combretaceae	1

25	Flacourtiaceae	1	Crypteroniaceae	1
26	Juglandaceae	1	Ebenaceae	1
27	Magnoliaceae	1	Elaeocarpaceae	1
28	Myricaceae	1	Fabaceae	1
29	Myrsinaceae	1	Flacourtiaceae	1
30	Myrstiaceae	1	Juglandaceae	1
31	Oleaceae	1	Lamiaceae	1
32	Proteaceae	1	Myricaceae	1
33	Rhizophoraceae	1	Myrtaceae	1
34	Rubiaceae	1	Oleaceae	1
35	Rutaceae	1	Rubiaceae	1
36	Staphylaceae	1	Sabiaceae	1
37	Sterculiaceae	1	Sapindaceae	1
38	Symplocaceae	1	Staphylaceae	1
39	Theaceae	1	Sterculiaceae	1
40	Urticaceae	1	Symplocaceae	1
41			Urticaceae	1
42			Verbanaceae	1

5.6 Girth class distribution

The tree density in the core zone irrespective of their girth class was lower than the buffer zone. The densities of young trees were higher than the older trees. The highest tree stand density and species richness were recorded in the lower girth class 30-60 cm. The trees of medium girth class (121-150) cm were more dominant in the core zone in terms of basal area. In the buffer zone no tree was recorded having girth of more than 300 cm girth. Tree density and species richness decreased with the increasing girth class of tree species. It follows a reverse J-shaped curve. In the buffer zone, the highest tree density was observed in (30-60) cm dbh class followed by (61-90) cm dbh class. The lowest was (181-210) cm.

In the core zone, the highest tree density was observed in (121-150) cm dbh class followed by (151-180) cm girth class. The lowest was in girth 30-60 cm. Few species of trees like *Dysoxylum excelsum* , *Drimycarpus racemosus* and *Terminalia myriocarpa* has girth greater ≥ 300 cm supporting the voluminous basal area (**Fig. 5.4 and 5.5**).

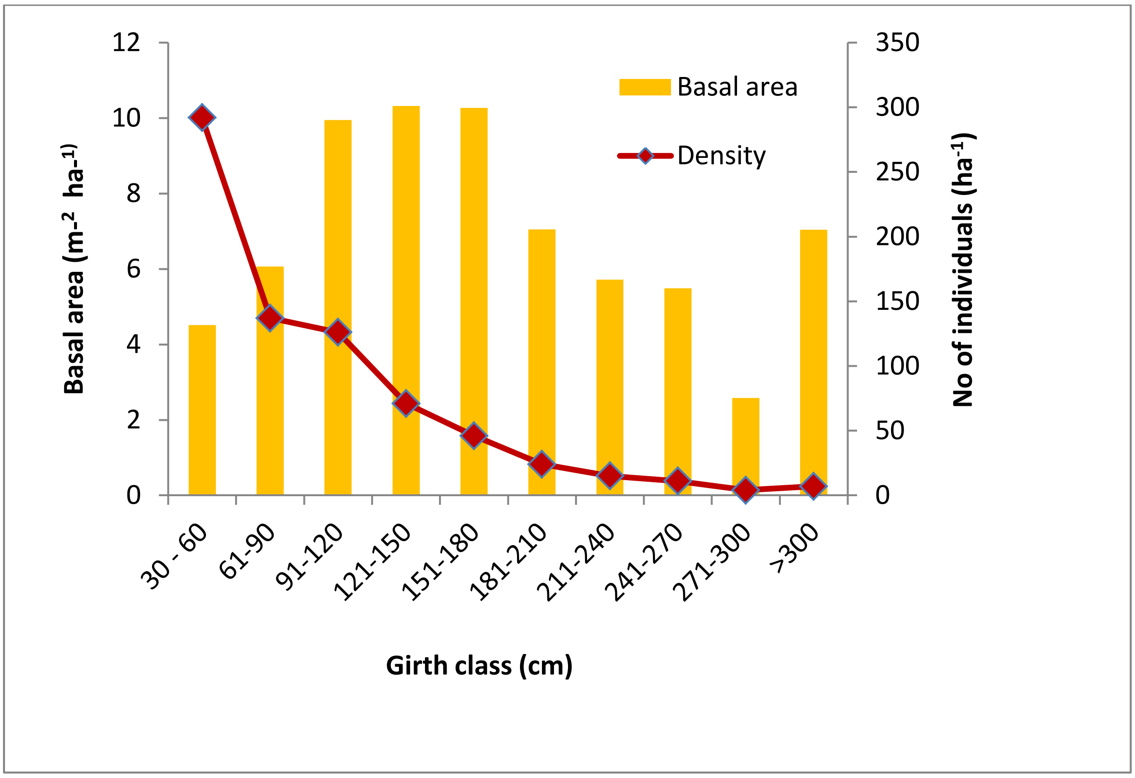


Fig 5.4: Density and basal area distribution in different girth classes under the core zone

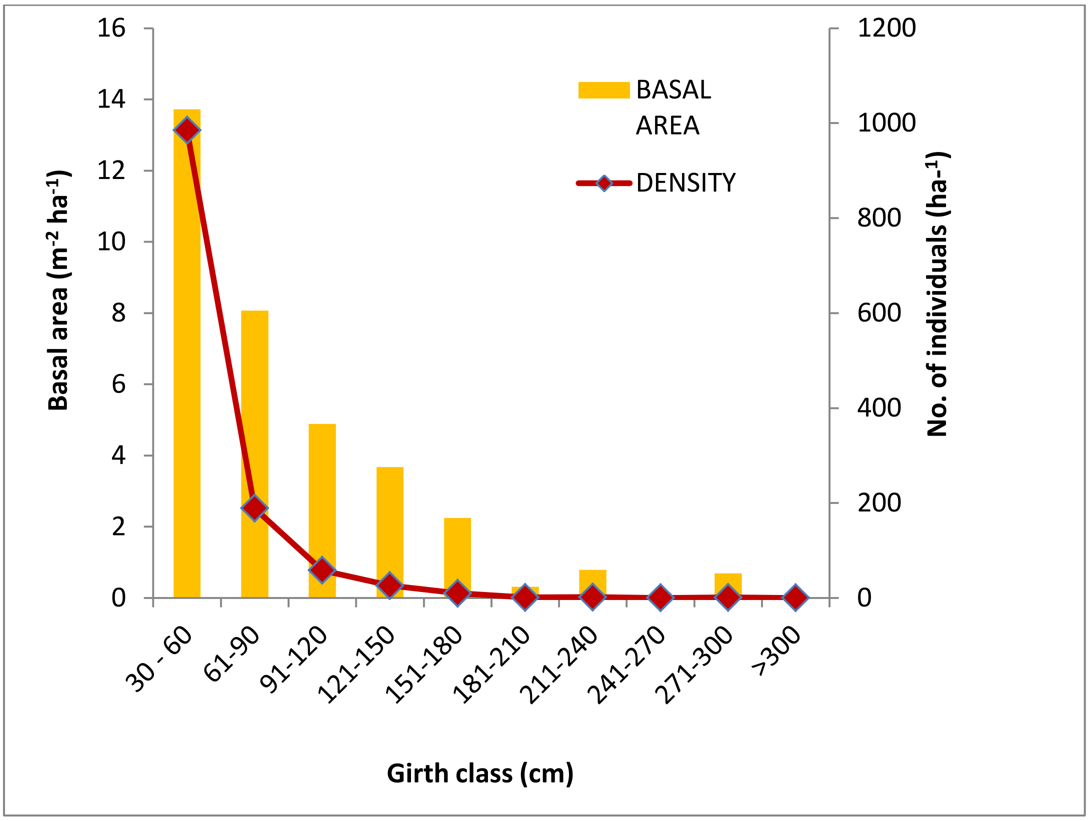


Fig 5.5: Density and basal area distribution in different girth classes under the buffer zone

The species restricted to core zone and buffer zones are represented in **Table 5.7** and **Table 5.8.** 49 species are found to be common in both the core and buffer zone.Some of the common species found from the two sites were *Betula alnoides, Diospyros lanceifolia, Myrica esculenta, Cinnamomum bejolghota* **(Table 5.9).**

Table 5.7: Tree species restricted to core zone of Nokrek biosphere reserve

Sl no	Species	Family
1	*Aesculus assamica* Griff.	Sapindaceae
2	*Alstonia scholaris* (L.) R. Br.	Apocynaceae
3	*Aphanamixis polystachya* (Wall.) R.Parker	Meliaceae
4	*Baliospermum calycinum* Müll.Arg.	Euphorbiaceae

5	*Carallia brachiata* (Lour.) Merr.	Rhizophoraceae
6	*Castanopsis lanceifolia* (Oerst.) Hickel & A.Camus	Fagaceae
7	*Castanopsis sp.*	Fagaceae
8	*Ceiba sp.*	Malvaceae
9	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	Lauraceae
10	*Cinnamomum curvifolium* (Lam.) Nees	Lauraceae
11	*Cyathocalyx zeylanicus* Champ. ex Hook.f. & Thomson	Annonaceae
12	*Dasymaschalon longiflorum* (Roxb.) Finet & Gagnep.	Annonaceae
13	*Drimycarpus racemosus* (Roxb.) Hook.f. ex Marchand.	Anacardiaceae
14	*Dysoxylum procerum Hiern*	Meliaceae
15	*Garcinia kydia* Roxb.	Clusiaceae
16	*Garcinia cowa* Roxb. ex Choisy	Clusiaceae
17	*Homalium bhamoense* Cubitt & W.W.Sm.	Flacourtiaceae
18	*Gynocardia odorata R.Br*	Achariaceae
19	*Knema linifolia* (Roxb.) Warb	Myrstiaceae
20	*Kydia calycina* Roxb.	Malvaceae
21	*Lepisanthes rubiginosa* (Roxb.) Leenh.	Sapindaceae
22	*Lithocarpus elegans* (Blume) Hatus. ex Soepadmo	Fagaceae
23	*Litsea monopetala* (Roxb.) Pers.	Lauraceae
24	*Macropanax sp.*	Araliaceae
25	*Macropanax undulatus* (Wall. ex G.Don) Seem.	Araliaceae
26	*Magnolia baillonii* Pierre	Magnoliaceae
27	*Mallotus repandus* (Willd.) Müll.Arg.	Euphorbiaceae
28	*Mangifera sylvatica* Roxb.	Annacardiaceae
29	*Micromelum integerrimum* (Buch.-Ham. ex DC.) Wight & Arn. ex M. Roem.	Rutaceae
30	*Parkia timoriana* (DC.) Merr.	Fabaceae
31	*Phoebe goalparensis* Bull. Misc. Inform. Kew	Lauraceae
32	*Phoebe macrocarpa* C.Y. Wu	Lauraceae
33	*Phoebe paniculata* (Nees) Nees	Lauraceae
34	*Premna mollissima* Roth	Lamiaceae

35	*Sapindus alternatus* Wall	Sapindaceae
36	*Stereospermum chelonoides* (L.f.) DC.	Bignoniaceae
37	*Syzygium cumini* (L.) Skeels	Myrtaceae
38	*Terminalia myriocarpa* Van Heurck & Müll. Arg	Combretaceae
39	*Terminalia sp.*	Combretaceae
40	*Toona sureni* (Blume) Merr.	Meliaceae
41	*Toona ciliata* M.Roem.	Meliaceae
42	*Walsura robusta* Roxb.	Meliaceae

Table 5.8. Tree species restricted in the buffer zone of Nokrek biosphere reserve

Sl no	Species	Family
1	*Albizzia chinensis* (Osbeck) Merr.	Mimosaceae
2	*Archidendron clypearia* (Jack) I.C.Nielsen	Leguminosae
3	*Baccaurea ramiflora* Lour.	Phyllanthaceae
4	*Bischofia javanica* Blume	Euphorbiaceae
5	*Bombax ceiba* L.	Bombacaceae
6	*Bridelia monoica* (Lour.) Merr.	Euphorbiaceae
7	*Callicarpa arborea* Roxb.	Verbanaceae
8	*Croton persimilis* Müll.Arg.	Euphorbiaceae
9	*Diospyros sp.*	Ebenaceae
10	*Duabanga grandiflora* (DC.) Walp.	Lythraceae
11	*Ehretia acuminata* R.Br.	Boraginaceae
12	*Elaeocarpus rugosus* Roxb. ex G.Don	Elaeocarpaceae
13	*Ficus auriculata* Lour.	Moraceae
14	*Ficus hirta* Vahl	Moraceae
15	*Ficus neriifolia* Sm.	Moraceae
16	*Ficus semicordata* Buch.-Ham. ex Sm.	Moraceae
17	*Flueggea virosa* (Roxb. ex Willd.) Royle	Phyllanthaceae
18	*Helicia nilagirica* Bedd.	Proteaceae

19	*Hydnocarpus pentandrus* (Buch.-Ham.) Oken	Flacourtiaceae
20	*Lagerstroemia parviflora* Roxb.	Lythraceae
21	*Litsea cubeba* (Lour.) Pers.	Lauraceae
22	*Macaranga denticulata* (Blume) Müll.Arg	Euphorbiaceae
23	*Maesa indica* (Roxb.) A. DC.	Primulaceae
24	*Mallotus roxburghianus* Muell.-Arg.	Euphorbiaceae
25	*Mallotus philippensis* (Lam.) Müll.Arg.	Euphorbiaceae
26	*Melia azedarach* L.	Meliaceae
27	*Meliosma pinnata* (Roxb.) Maxim.	Sabiaceae
28	*Microcos tomentosa* Sm.	Malvaceae
29	*Pterospermum lanceifolium* Roxb.	Malvaceae
30	*Schefflera elliptica* (Blume) Harms	Araliaceae
31	*Schima wallichii* Choisy	Theaceae
32	*Trema orientalis* (L.) Blume	Cannabaceae
33	*Trevesia palmata* (Roxb. ex Lindl.) Vis.	Araliaceae

Table 5.9: Species common both in the core and buffer zone

Sl no	Species	Family
1	*Ardisia macrocarpa* Wall.	Myrsinaceae
2	*Arenga pinnata* (Wurmb) Merr.	Arecaceae
3	*Betula alnoides* Buch.-Ham. ex D.Don	Betulaceae
4	*Bridelia retusa* (L.) A. Juss.	Phyllanthaceae
5	*Calophyllum polyanthum* Wall. ex Planch. & Triana	Clusiaceae
6	*Cassia fistula* L.	Caesalpiniacea
7	*Castanopsis hystrix* Hook. f. & Thomson ex A. DC.	Fagaceae
8	*Castanopsis indica* (Roxb. ex Lindl.) A.DC.	Fagaceae
9	*Castanopsis tribuloides* (Sm.) A.DC	Fagaceae
10	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet	Lauraceae
11	*Cinnamomum camphora* (L.) J.Presl	Lauraceae

12	*Cinnamomum glaucescens* (Nees) Hand.-Mazz.	Lauraceae
13	*Cordia dichotoma* G.Forst.	Boraginaceae
14	*Cryptocarya amygdalina* Nees	Lauraceae
15	*Crypteronia paniculata* Blume	Crypteroniaceae
16	*Dimocarpus longan* Lour.	Sapindaceae
17	*Diospyros lanceifolia* Roxb.	Symplocaceae
18	*Dysoxylum excelsum* Blume	Meliaceae
19	*Engelhardtia spicata* Lechen ex Blume	Juglandaceae
20	*Eurya accuminata* DC	Theaceae
21	*Gleditsia assamica* Bor	Fabaceae
22	*Glochidion daltonii* (Müll.Arg.) Kurz	Phyllanthaceae
23	*Helicia robusta* (Roxb.) R.Br. ex Blume	Proteaceae
24	*Ligustrum robustum* (Roxb.) Blume	Oleaceae
25	*Lindera heterophylla* Benth	Lauraceae
26	*Macaranga indica* Wight	Euphorbiaceae
27	*Macropanax dispermus* (Blume) Kuntze	Araliaceae
28	*Mallotus paniculatus* (Lam.) Müll.Arg.	Euphorbiaceae
29	*Mesua ferrea* L.	Calophyllaceae
30	*Myrica esculenta* Buch.-Ham. ex D.Don	Myricaceae
31	*Ocotea lancifolia* (Schott) Mez	Lauraceae
32	*Oreocnide integrifolia* (Gaud.) Miq	Urticaceae
33	*Ostodes pannniculata* Blume	Euprorbiaceae
34	*Persea odoratissima* (Nees) Kosterm.	Lauraceae
35	*Phoebe attenuata* (Nees) Nees	Lauraceae
36	*Premna cordifolia* Roxb.	Lamiaceae
37	*Quercus glauca* Thunb.	Fagaceae
38	*Quercus lancifolia* Schltdl. & Cham.	Fagaceae
39	*Quercus spicata* Sm	Fagaceae
40	*Randia sp.*	Rubiaceae
41	*Reevesia pubescens* Mast.	Malvaceae

42	*Rhus javanica* L.	Anacardiaceae
43	*Sapium baccatum* Roxb.	Euphorbiaceae
44	*Saurauia napaulensis* DC.	Actinidiaceae
45	*Saurauia punduana* Wall.	Actinidiaceae
46	*Sterculia coccinea* Roxb	Sterculiaceae
47	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	Myrtaceae
48	*Terminalia citrina* Roxb.	Combretaceae
49	*Turpinia pomifera* (Roxb.)DC.	Staphylaceae

__CHAPTER- 6__

VEGETATION ANALYSIS FOR SHRUB SPECIES

6.1 Phytosociological attributes

The findings of present investigation reveal that altogether a total of 66 shrub species belonging to 63 genera and 30 families of angiosperm were recorded. Of this, the core zone harbours 34 species from 28 genera and 18 families, and buffer zone had 51 species belonging to 35 genera and 28 families. Moreover, buffer zone also possessed high density (3756 individuals ha^{-1}) than the core zone (1428 individuals ha^{-1}).

The Shannon diversity index was found higher in the buffer zone (3.25) than the core zone (3.24). On the contrary, Simpson dominance index showed a reverse trend in result and value was high in core zone (0.05) than the buffer zone (0.07). The Margalef's index of species richness was also found to be higher in the buffer zone (7.30) than in the core zone (5.04). However, core zone has higher evenness index value of 0.92 and 0.83 in buffer zone **(Table 6.1).**

Table 6.1: Phytosociological attributes of shrubs in core and buffer zone

Parameter	Core zone	Buffer zone
Number of Family	18	28
Number of Genera	28	35
Number of Species	34	51
Shrub density (individuals ha^{-1})	1428	3756
Shannon Diversity Index	3.24	3.25
Simpson Dominance Index	0.05	0.07
Evenness Index	0.92	0.83
Margalef Index of Species	5.04	7.30

In core zone, the most dominant species was *Phlogacanthus curviflorus* (IVI- 25.06 and density- 192 individual's ha^{-1}) and was followed by *Rauvolfia serpentina* (IVI- 16.34 and density- 132 individual's ha^{-1}). On other hand, in buffer zone, the dominant species was *Rhynchotechum ellipticum* (IVI- 33.14 and density- 812 individual's ha^{-1}), and it was followed by *Phlogacanthus curviflorus* (IVI- 11.57 and density- 180 individual's ha^{-1}) and *Mussaenda roxburghii* (IVI- 10.30 and density- 196 individual's ha^{-1}) **Table 6.2 to 6.4.**

Table 6.2 Community structure of shrubs in the core zone

Sl. No.	Scientific name	Family	Density (ha^{-1})	Frequency (%)	Abundance	IVI	A/F ratio
1	*Ardisia solanacea* Roxb.	Myrsinaceae	20	2	2.50	2.69	1.25
2	*Ardisia virens* Roxb	Myrsinaceae	20	4	1.25	3.98	0.31
3	*Artemisia nilagirica* (C. B. Clarke)	Asteraceae	44	4	2.75	5.66	0.69
4	*Baliospermum calycinum* Mull.Arg.	Euphorbiaceae	24	4	1.50	4.26	0.38
5	*Boehmeria platyphylla* Roxb.	Urticaceae	16	1	4.00	1.77	4.00
6	*Bridelia retusa* (L.) A.Juss.	Euphorbiaceae	20	2	2.50	2.69	1.25
7	*Capparis acutifolia* Sw.	Capparidaceae	44	3	3.67	5.02	1.22
8	*Capparis olacifolia* Hook.f. & Thomson	Capparidaceae	24	2	3.00	2.97	1.50
9	*Capparis multiflora* Hook.f. & Thomson	Capparadaceae	24	4	1.50	4.26	0.38
10	*Chassalia curviflora* (Wall.) Thwaites	Rubiaceae	40	5	2.00	6.03	0.40
11	*Citrus indica* Tanaka	Rutaceae	44	8	1.38	8.24	0.17
12	*Citrus medica* L.	Rutaceae	24	3	2.00	3.62	0.67
13	*Clerodendrum infortunatum* L.	Lamiaceae	20	5	1.00	4.63	0.20
14	*Clerodendrum wallichii* Merr.	Lamiaceae	24	3	2.00	3.62	0.67
15	*Corchorus capsularis* L.	Tiliaceae	72	7	2.57	9.56	0.37
16	*Dalbergia stipulacea* Roxb.	Fabaceae	52	4	3.25	6.22	0.81
17	*Dendrocnide sinuata* (Blume)	Urticaceae	64	8	2.00	9.64	0.25
18	*Elaeagnus conferta* Roxb.	Elaeagnaceae	48	7	1.71	7.88	0.24
19	*Eranthemum suffruticosum* Roxb.	Acanthaceae	40	4	2.50	5.38	0.63
20	*Garcinia acuminata* Planch.	Clusiaceae	24	3	2.00	3.62	0.67
21	*Grewia nervosa* L.	Sterculiaceae	4	1	1.00	0.93	1.00
22	*Justicia gendarussa* Burm.f.	Acanthaceae	36	5	1.80	5.75	0.36

23	*Leea umbraculifera* C.B.Clarke	Leeaceae	16	2	2.00	2.41	1.00
24	*Melastoma malabathricum* L.	Melastomataceae	60	5	3.00	7.43	0.60
25	*Millettia caudata* (Benth.) Baker	Fabaceae	24	4	1.50	4.26	0.38
26	*Mussaenda roxburghii* Hook.f.	Rubiaceae	48	4	3.00	5.94	0.75
27	*Osbeckia nepalensis* Hook. f.	Melastomeaceae	12	2	1.50	2.13	0.75
28	*Phlogacanthus curviflorus* (Wall.) Nees	Acanthaceae	192	18	2.67	25.06	0.15
29	*Rauvolfia serpentina* (L.) Benth. ex Kurz	Apocynaceae	132	11	3.00	16.34	0.27
30	*Rhynchotechum ellipticum* (Wall. ex D. Dietr.) A. DC.	Gesneriaceae	92	7	3.29	10.96	0.47
31	*Strobilanthes coloratus* T. Anders	Acanthaceae	20	2	2.50	2.69	1.25
32	*Strobilanthes capitata* (Nees) T. Anderson	Acanthaceae	60	3	5.00	6.14	1.67
33	*Trigonostemon semperflorens* Müll.Arg.	Euphorbiaceae	12	3	1.00	2.78	0.33
34	*Zanthozylum khasianum* Hook.f.	Rutaceae	32	5	1.60	5.47	0.32

*IVI=Importance Value Index, A/F ratio=Abundance by Frequency ratio.

Table 6.3 Community structure of shrubs in the buffer zone

Sl. No.	**Scientific name**	**Family**	**Density (ha^{-1})**	**Frequency (%)**	**Abundance**	**IVI**	**A/F ratio**
1	*Ardisia solanacea* Roxb.	Myrsinaceae	184	13	3.54	9.31	0.27
2	*Breynia sp*	Phyllantaceae	36	3	3.00	1.98	1.00
3	*Bridelia retusa* (L.) A.Juss.	Euphorbiaceae	8	2	1.00	0.89	0.50
4	*Callicarpa americana* L.	Verbanaceae	24	4	1.50	1.99	0.38
5	*Citrus hystrix* D.C	Rutaceae	20	3	1.67	1.55	0.56

6	*Citrus indica* Tanaka	Rutaceae	20	5	1.00	2.23	0.20
7	*Citrus macroptera* Montrouz.	Rutaceae	4	1	1.00	0.45	1.00
8	*Citrus maxima* (Burm.) Merr.	Rutaceae	4	1	1.00	0.45	1.00
9	*Citrus medica* L.	Rutaceae	28	2	3.50	1.42	1.75
10	*Clerodendrum bracteatum* Wall. ex Walp.	Lamiaceae	60	5	3.00	3.29	0.60
11	*Clerodendrum glandulosum* Lindl.	Lamiaceae	40	4	2.50	2.42	0.63
12	*Clerodendrum infortunatum* L.	Lamiaceae	32	5	1.60	2.55	0.32
13	*Clerodendrum wallichii* Merr.	Lamiaceae	40	4	2.50	2.42	0.63
14	*Codariocalyx gyroides* (Link) Hassk..	Fabaceae	16	2	2.00	1.10	1.00
15	*Codariocalyx motorius* (Houtt.) H.Ohashi	Fabaceae	52	3	4.33	2.40	1.44
16	*Conyza cappa* Buch.-Ham. ex D.Don	Asteraceae	44	7	1.57	3.54	0.22
17	*Dendrocnide sinuata* (Blume)	Urticaceae	140	7	5.00	6.10	0.71
18	*Elaeagnus conferta* Roxb.	Elaeagnaceae	16	4	1.00	1.78	0.25
19	*Flueggea virosa* (Roxb. ex Willd.) Royle	Euphorbiaceae	40	4	2.50	2.42	0.63
20	*Garcinia acuminata* Planch.	Clusiaceae	20	3	1.67	1.55	0.56
21	*Hedyotis scandens* Roxb.	Rubiaceae	76	6	3.17	4.06	0.53
22	*Hiptage benghalensis* (L.) Kurz	Combretaceae	144	17	2.12	9.60	0.12
23	*Jasminum laurifolium* Roxb. ex Hornem.	Oleaceae	8	1	2.00	0.55	2.00
24	*Jasminum nervosum* Lour.	Oleaceae	12	3	1.00	1.34	0.33
25	*Justicia gendarussa* Burm.f.	Acanthaceae	52	6	2.17	3.42	0.36
26	*Lantana camara* L.	Verbenaceae	68	8	2.13	4.52	0.27
27	*Leea umbraculifera* C.B.Clarke	Leeaceae	16	3	1.33	1.44	0.44
28	*Maesa chisia* Buch.-Ham. ex D. Don	Myrsinaceae	32	3	2.67	1.87	0.89
29	*Maesa indica* (Roxb.) A. DC.	Myrsinaceae	12	3	1.00	1.34	0.33
30	*Melastoma malabathricum* L.	Melastomataceae	52	4	3.25	2.74	0.81

31	*Millettia caudata* (Benth.) Baker	Leguminosae	8	2	1.00	0.89	0.50
32	*Millettia pachycarpa* Benth.	Leguminosae	36	6	1.50	2.99	0.25
33	*Mimosa pudica* L.	Mimosaceae	52	5	2.60	3.08	0.52
34	*Mussaenda frondosa* L.	Rubiaceae	40	4	2.50	2.42	0.63
35	*Mussaenda roxburghii* Hook.f.	Rubiaceae	196	15	3.27	10.30	0.22
36	*Osbeckia nepalensis* Hook. f.	Melastomeaceae	24	3	2.00	1.66	0.67
37	*Passiflora edulis* Sims	Passifloraceae	24	3	2.00	1.66	0.67
38	*Phlogacanthus curviflorus* (Wall.) Nees	Acanthaceae	180	20	2.25	11.57	0.11
39	*Phrynium capitatum* Willd.	Marantaceae	220	7	7.86	8.23	1.12
40	*Rhynchotechum ellipticum* (Wall. ex D. Dietr.) A. DC.	Gesneriaceae	812	34	5.97	33.14	0.18
41	*Rotheca serrata* (L.) Steane & Mabb.	Lamiaceae	56	6	2.33	3.52	0.39
42	*Rubus alceifolius* Poir.	Rosaceae	216	11	4.91	9.48	0.45
43	*Rubus ellipticus.* Sm.	Rosaceae	68	5	3.40	3.51	0.68
44	*Rubus moluccanus* L.	Rosaceae	12	3	1.00	1.34	0.33
45	*Scurrula parasitica* L.	Loranthaceae	28	2	3.50	1.42	1.75
46	*Solanum aethiopicum* L.	Solanaceae	24	3	2.00	1.66	0.67
47	*Solanum anguivi* Lam.	Solanaceae	20	3	1.67	1.55	0.56
48	*Solanum torvum* Sw.	Solanaceae	156	7	5.57	6.53	0.80
49	*Tabernaemontana divaricata* (L.) R.Br. ex Roem. & Schult	Apocynaceae	104	7	3.71	5.14	0.53
50	*Trevesia palmata* (Roxb. ex Lindl.) Vis.	Araliaceae	20	4	1.25	1.89	0.31
51	*Triumfetta rhomboidea* Jacq	Malvaceae	160	9	4.44	7.31	0.49

*IVI=Importance Value Index, A/F ratio=Abundance by Frequency ratio

Table 6. 4: Species ranking (based on IVI) in core and buffer zone

Species rank	Core zone	IVI	Buffer zone	IVI
1	*Phlogacanthus curviflorus* (Wall.) Nees	25.06	*Rhynchotechum ellipticum* (Wall. ex D. Dietr.) A. DC.	33.14
2	*Rauvolfia serpentina* (L.) Benth. ex Kurz	16.34	*Phlogacanthus curviflorus* (Wall.) Nees	11.57
3	*Rhynchotechum ellipticum* (Wall. ex D. Dietr.) A. DC.	10.96	*Mussaenda roxburghii* Hook.f.	10.30
4	*Dendrocnide sinuata* (Blume)	9.64	*Hiptage benghalensis* (L.) Kurz	9.60
5	*Corchorus capsularis* L.	9.56	*Rubus alceifolius* Poir.	9.48
6	*Citrus indica* Tanaka	8.24	*Ardisia solanacea* Roxb.	9.31
7	*Elaeagnus conferta* Roxb.	7.88	*Phrynium capitatum* Willd.	8.23
8	*Melastoma malabathricum* L.	7.43	*Triumfetta rhomboidea* Jacq	7.31
9	*Dalbergia stipulacea* Roxb.	6.22	*Solanum torvum* Sw.	6.53
10	*Strobilanthes capitata* (Nees) T. Anderson	6.14	*Dendrocnide sinuata* (Blume)	6.10
11	*Chassalia curviflora* (Wall.) Thwaites	6.03	*Tabernaemontana divaricata* (L.) R.Br. ex Roem. & Schult	5.14
12	*Mussaenda roxburghii* Hook.f.	5.94	*Lantana camara* L.	4.52
13	*Justicia gendarussa Burm.f.*	5.75	*Hedyotis scandens* Roxb.	4.06
14	*Artemisia nilagirica* (C. B. Clarke)	5.66	*Conyza cappa* Buch.-Ham. ex D.Don	3.54
15	*Zanthozylum khasianum* Hook.f.	5.47	*Rotheca serrata* (L.) Steane & Mabb.	3.52
16	*Eranthemum suffruticosum* Roxb.	5.38	*Rubus ellipticus.* Sm.	3.51
17	*Capparis acutifolia* Sw.	5.02	*Justicia gendarussa* Burm.f.	3.42
18	Clerodendrum infortunatum L.	4.63	*Clerodendrum bracteatum* Wall. ex Walp.	3.29
19	*Millettia caudata* (Benth.) Baker	4.26	*Mimosa pudica* L.	3.08
20	*Capparis multiflora* Hook.f. & Thomson	4.26	*Millettia pachycarpa* Benth.	2.99
21	*Baliospermum calycinum* Mull.Arg.	4.26	*Melastoma malabathricum* L.	2.74
22	*Ardisia virens* Roxb	3.98	*Clerodendrum infortunatum* L.	2.55
23	*Clerodendrum wallichii* Merr.	3.62	*Mussaenda frondosa* L.	2.42
24	*Citrus medica* L.	3.62	*Flueggea virosa* (Roxb. ex Willd.) Royle	2.42
25	*Garcinia acuminata* Planch.	3.62	*Clerodendrum glandulosum*	2.42

			Lindl.	
26	*Capparis olacifolia* Hook.f. & Thomson	2.97	*Clerodendrum wallichii* Merr.	2.42
27	*Trigonostemon semperflorens* Müll.Arg.	2.78	*Codariocalyx motorius* (Houtt.) H.Ohashi	2.40
28	*Bridelia retusa* (L.) A.Juss.	2.69	*Citrus indica* Tanaka	2.23
29	*Ardisia solanacea* Roxb.	2.69	*Callicarpa americana* L.	1.99
30	*Strobilanthes coloratus* T. Anders	2.69	*Breynia sp*	1.98
31	*Leea umbraculifera* C.B.Clarke	2.41	*Trevesia palmata* (Roxb. ex Lindl.) Vis.	1.89
32	*Osbeckia nepalensis* Hook. f.	2.13	*Maesa chisia* Buch.-Ham. ex D. Don	1.87
33	*Boehmeria platyphylla* Roxb.	1.77	*Elaeagnus conferta* Roxb.	1.78
34	*Grewia nervosa* L.	0.93	*Solanum aethiopicum* L.	1.66
35			*Osbeckia nepalensis* Hook. f.	1.66
36			*Passiflora edulis* Sims	1.66
37			*Solanum anguivi* Lam.	1.55
38			*Garcinia acuminata* Planch.	1.55
39			Citrus hystrix D.C	1.55
40			*Leea umbraculifera* C.B.Clarke	1.44
41			*Citrus medica* L.	1.42
42			*Scurrula parasitica* L.	1.42
43			*Rubus moluccanus* L.	1.34
44			*Jasminum nervosum* Lour.	1.34
45			*Maesa indica* (Roxb.) A. DC.	1.34
46			*Codariocalyx gyroides* (Link) Hassk.	1.10
47			*Millettia caudata* (Benth.) Baker	0.89
48			*Bridelia retusa* (L.) A.Juss.	0.89
49			*Jasminum laurifolium* Roxb. ex Hornem.	0.55
50			*Citrus macroptera* Montrouz.	0.45
51			*Citrus maxima* (Burm.) Merr.	0.45

6.2 Dominance-diversity of Family

The dominant family in the core zone was Acanthaceae with 5 species (15 % species), and followed by Capparidaceae, Euphorbiaceae and Rutaceae respresenting 3 species (9 % species) each. Fabaceae, Lamiaceae, Melastomataceae, Rubiaceae and Urticaceae have 2 spcecies each covering 6% species. The number of monospecific families amounting to 10 (30 % species). In the buffer zone, Lamiaceae and Rutaceae was the most dominant family with 5 species (10 % species), and it was followed by Myrsinaceae, Rosaceae, Rubiaceae and Solanaceae with 3 species each (6 % species). 7 families have 2 species each representing a total of 28 % of species. 15 families were monospecific contributing to 30% species **(Table 6.5 and Fig.6.1).** The diversity-distribution curve showed stability in terms of families in both zones **(Fig. 6.2, 6. 3).**

Table 6.5 Family ranking in core and buffer zone

Family rank	Core zone		Buffer zone	
	Family	No of species	Family	No of species
1	Acanthaceae	5	Lamiaceae	5
2	Capparidaceae	3	Rutaceae	5
3	Euphorbiaceae	3	Myrsinaceae	3
4	Rutaceae	3	Rosaceae	3
5	Fabaceae	2	Rubiaceae	3
6	Lamiaceae	2	Solanaceae	3
7	Melastomataceae	2	Acanthaceae	2
8	Myrsinaceae	2	Euphorbiaceae	2
9	Rubiaceae	2	Fabaceae	2
10	Urticaceae	2	Leguminosae	2
11	Apocynaceae	1	Melastomataceae	2
12	Asteraceae	1	Oleaceae	2
13	Clusiaceae	1	Verbanaceae	2
14	Elaeagnaceae	1	Apocynaceae	1
15	Gesneriaceae	1	Araliaceae	1
16	Leeaceae	1	Asteraceae	1
17	Sterculiaceae	1	Clusiaceae	1
18	Tiliaceae	1	Combretaceae	1
19			Elaeagnaceae	1
20			Gesneriaceae	1

21			Leeaceae	1
22			Loranthaceae	1
23			Malvaceae	1
24			Marantaceae	1
25			Mimosaceae	1
26			Passifloraceae	1
27			Phyllantaceae	1
28			Urticaceae	1

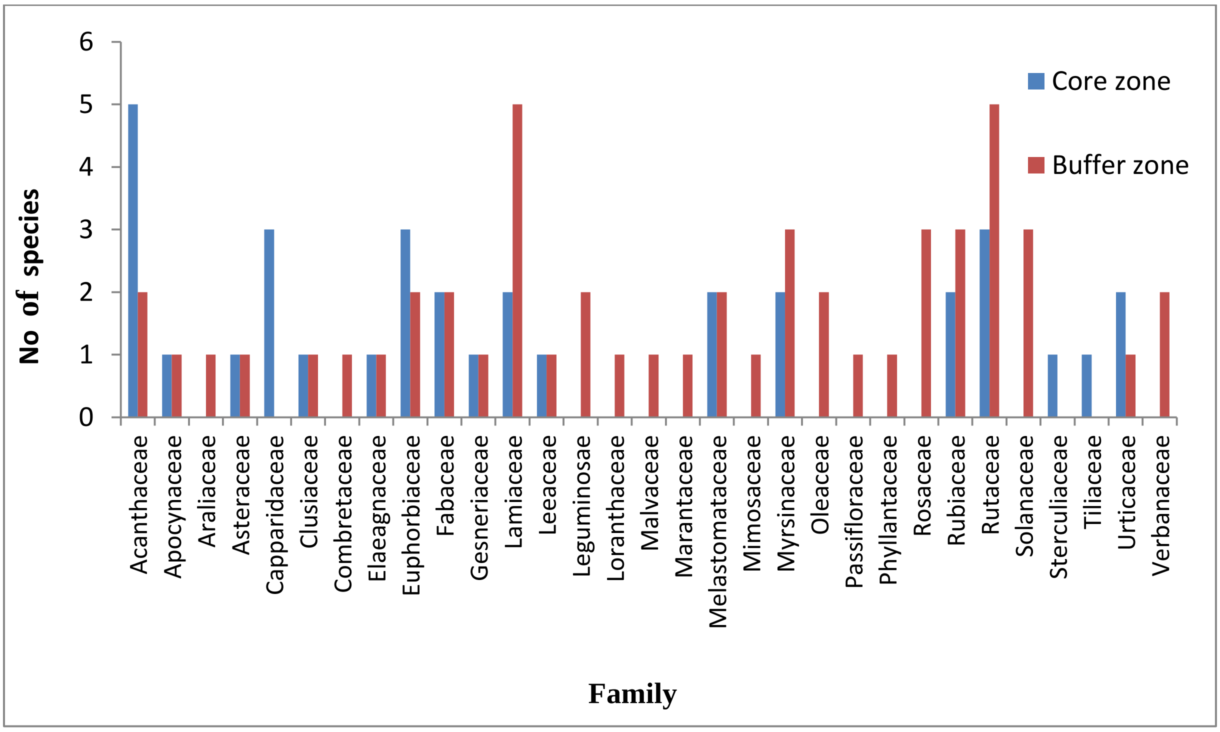


Fig 6.1: Family-wise distribution of species in core zone and buffer zone

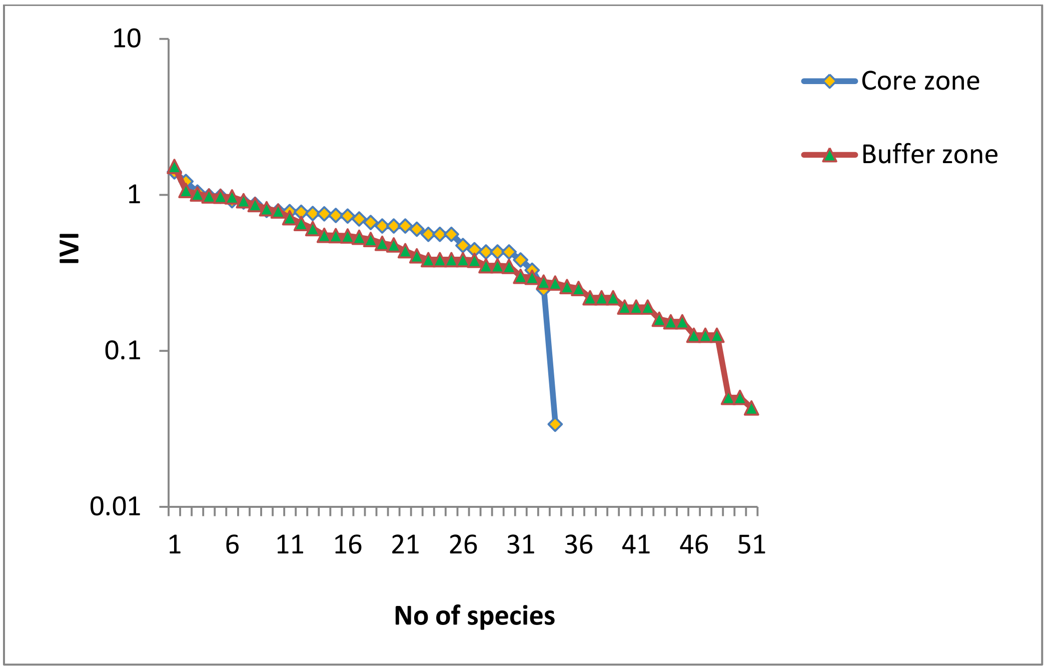


Fig 6.2: Species dominance-distribution curve in core zone and buffer zone

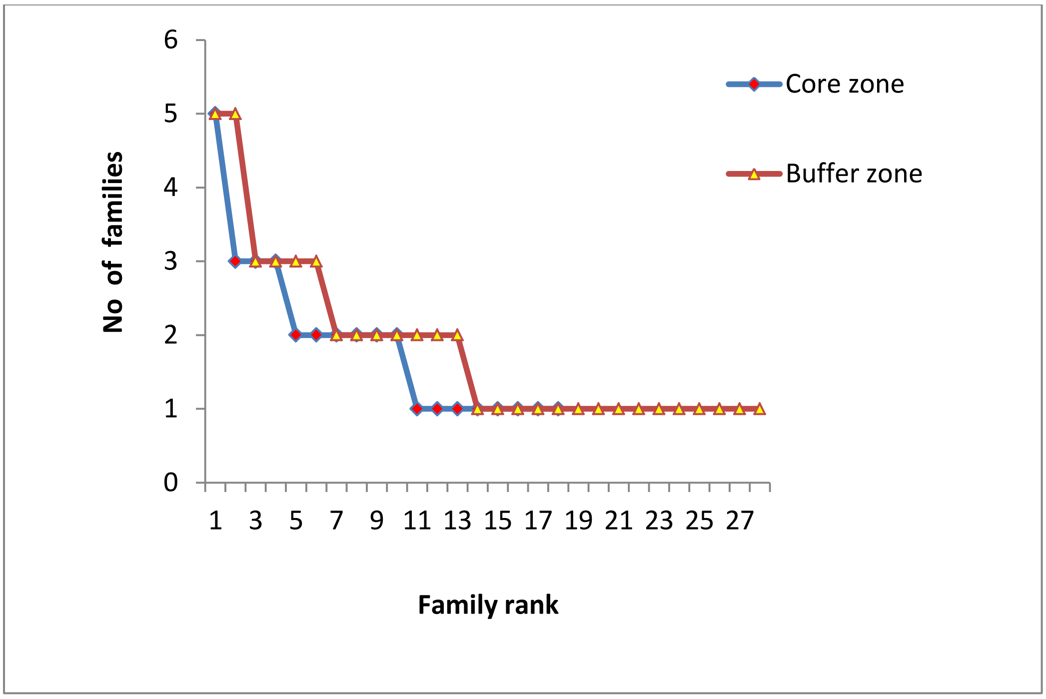


Fig 6.3: Family dominance-distribution curve in core zone and buffer zone

The high species richness with more number of genera and families in the buffer zone could be linked with disturbance, as disturbance might have supported herbs and shrubs due to open canopy that may also lead to high density. The Simpson dominance index exhibited reverse trend in results with that of Shannon index of diversity, as it is always found in natural vegetation. The high value of evenness index in both the zones argued uniform distribution of species. *Phlogacanthus curviflorus*, the dominant species in core zone was replaced by *Rhynchotechum ellipticum* in buffer zone. Similarly, Acanthaceae, the dominant family in the core zone was replaced by Lamiaceae in buffer zone.

Moreover, the number of monospecific families was high in buffer zone. The shift in position of species and families and more number of monospecific families in buffer zone could be attributed due to disturbance, as certain species and families are sensitive to the disturbance and eliminated from the habitat. In fact, gaps created due to disturbance and exposed canopy have favored the survival and growth of certain species, and facilitate introduction of some families and species.

The species common in both zones showed tolerance towards disturbance, and play significant role in functioning of the ecosystem. The species present in core zone appeared to have greater ecological amplitude with respect to disturbance. On the other hand, the species absent in buffer zone appeared to be more vulnerable to disturbance. The normal diversity-distribution curves for species and family indicate stability and complexity of community.

Table 6.6 Shrub species found only in the core zone

Sl no	Species	Family
1	*Ardisia virens* Kurz	Myrsinaceae
2	*Artemisia nilagirica* (C. B. Clarke)	Asteraceae
3	*Baliospermum calycinum* Mull.Arg.	Euphorbiaceae
4	*Boehmeria platyphylla* Roxb.	Urticaceae
5	*Capparis acutifolia* Sw.	Capparidaceae
6	*Capparis olacifolia* Hook.f. & Thomson	Capparidaceae
7	*Chassalia curviflora* (Wall.) Thwaites	Rubiaceae
8	*Clerodendrum wallichii* Merr.	Lamiaceae
9	*Corchorus capsularis* L.	Tiliaceae
10	*Crataeva religiosa* Ham	Capparaceae
11	*Dalbergia stipulacea* Roxb.	Fabaceae
12	*Eranthemum suffruticosum* Roxb.	Acanthaceae
13	*Grewia microcos* L.	Malvaceae
14	*Mussaenda* sp.	Rubiaceae
15	*Rauvolfia serpentina* (L.) Benth. ex Kurz	Apocynaceae
16	*Trigonostemon semperflorens* Müll.Arg.	Euphorbiaceae
17	*Zanthoxylum rhetsa* DC	Rutaceae

Table 6.7 Shrub species found only in the buffer zone

Sl no	Species	Family
1	*Breynia sp*	Phyllantaceae
2	*Callicarpa americana* L.	Verbanaceae
3	*Citrus hystrix* DC.	Rutaceae
4	*Citrus macroptera* Montrouz.	Rutaceae
5	*Citrus maxima* (Burm.) Merr.	Rutaceae
6	*Citrus reticulata* Blanco	Rutaceae
7	*Clerodendrum bracteatum* Wall. ex Walp.	Lamiaceae

8	*Clerodendrum glandulosum* Lindl.	Lamiaceae
9	*Codariocalyx gyroides* (Link) Hassk..	Fabaceae
10	*Codariocalyx motorius* (Houtt.) H.Ohashi	Fabaceae
11	*Conyza cappa* Buch.-Ham. ex D.Don	Asteraceae
12	*Flueggea virosa* (Roxb. ex Willd.) Royle	Euphorbiaceae
13	*Hedyotis scandens* Roxb.	Rubiaceae
14	*Hiptage benghalensis* (L.) Kurz	Combretaceae
15	*Jasminum laurifolium* Roxb. ex Hornem.	Oleaceae
16	*Jasminum nervosum* Lour.	Oleaceae
17	*Lantana camara* L.	Verbenaceae
18	*Maesa chisia* Buch.-Ham. ex D. Don	Myrsinaceae
19	*Maesa indica* (Roxb.) A. DC.	Myrsinaceae
20	*Millettia pachycarpa* Benth	Leguminosae
21	*Mussaenda frondosa* L.	Rubiaceae
22	*Rotheca serrata* (L.) Steane & Mabb.	Lamiaceae
23	*Rubus alceifolius* Poir.	Rosaceae
24	*Rubus ellipticus.* Sm.	Rosaceae
25	*Rubus moluccanus* L.	Rosaceae
26	*Scurrula parasitica* L.	Loranthaceae
27	*Solanum aethiopicum* L.	Solanaceae
28	*Solanum anguivi* Lam.	Solanaceae
29	*Solanum torvum* Sw.	Solanaceae
30	*Tabernaemontana divaricata* (L.) R.Br. ex Roem. & Schult	Apocynaceae
31	*Trevesia palmata* (Roxb. ex Lindl.) Vis.	Araliaceae
32	*Triumfetta rhomboidea* Jacq	Malvaceae

Table 6.8 Shrub species common in both the study sites

Sl no	Species	Family
1	*Ardisia solanacea* Roxb.	Myrsinaceae
2	*Bridelia retusa* (L.) A.Juss.	Phyllantaceae
3	*Citrus indica* Tanaka	Rutaceae
4	*Citrus medica* L.	Rutaceae
5	*Clerodendrum infortunatum L.*	Lamiaceae
6	*Dendrocnide sinuata* (Blume)	Urticaceae
7	*Elaeagnus conferta* Roxb.	Elaeagnaceae
8	*Garcinia acuminata* Planch.	Clusiaceae
9	*Justicia gendarussa* Burm.f.	Acanthaceae
10	*Leea umbraculifera* C.B.Clarke	Leeaceae
11	*Melastoma malabathricum* L.	Melastomataceae
12	*Millettia caudata* (Benth.) Baker	Leguminosae
13	*Mussaenda roxburghii* Hook.f.	Rubiaceae
14	*Osbeckia nepalensis* Hook. f.	Melastomeaceae
15	*Phlogacanthus curviflorus* (Wall.) Nees	Acanthaceae
16	*Phrynium capitatum* Willd.	Marantaceae

CHAPTER- 7

VEGETATION ANALYSIS FOR HERBACEOUS SPECIES

7.1 Phytosociological attributes

The findings of present investigation reveal that altogether a total of 77 herbaceous species belonging to 63 genera and 38 families of angiosperm were recorded. Of this, the core zone harbours 44 species from 34 genera and 23 families, and buffer zone had 52 species belonging to 44 genera and 29 families. Moreover, buffer zone also possessed high density (914 individuals per 100 m^2) than core zone (889 individuals per 100 m^2). The Shannon diversity index was found higher in the buffer zone (3.21) than core zone (3.10). On the contrary, Simpson dominance index showed a reverse trend in result and value was high in core zone (0.10) than the buffer zone (0.08). The Margalef's index of species richness was also found to be higher in the buffer zone (7.48) than in the core zone (6.33). However, both zones possessed same value of 0.82 for evenness index **(Table 7.1)**

Table 7.1: Phytosociological attributes of herbs in core and buffer zone

Parameter	Core zone	Buffer zone
Number of Family	23	29
Number of Genera	34	44
Number of Species	44	52
Herb density (individuals per 100 m^2)	889	914
Shannon Diversity Index	3.10	3.21
Simpson Dominance Index	0.10	0.08
Margalef Index of Species	6.33	7.48
Evenness Index	0.82	0.82

In core zone, the most dominant (IVI- 40.48 and density- 247 individuals per 100 m^2) species was *Elatostema sessile*, and was followed by *Urtica dioica* (IVI- 12.58) and density- 66 individuals per 100 m^2). On other hand, in buffer zone, the dominant species was *Pteris quadriaurita* (IVI- 35.47 and density- 212 individuals per 100 m^2), and it was followed by *Selaginella* sp. (IVI- 15.03 and density- 45 individuals per 100 m^2) and *Molineria latifolia* (IVI- 13.93 and density- 58 individuals per 100 m^2) **Table 7.2 to 7.4.** All herbaceous species in both zones followed contagious distribution pattern. The normal dominance-distribution curve in both zones indicates stability of the community.

Table 7.2: Community structure of herbs in the core zone

Sl. No	Scientific name	Family	Density (per 100m^2)	Frequency (%)	Abundance	IVI	A/F ratio
1	*Aletris gracilis* Lendle	Liliaceae	9	4	2.25	2.60	0.56
2	*Alpinia galanga* (L.) Sw.	Zingiberaceae	8	3	2.67	2.09	0.89
3	*Amorphophallus paeoniifolius* (Dennst.) Nicolson	Araceae	7	2	3.50	1.58	1.75
4	*Arisaema album* N.E. Br	Araceae	2	1	2.00	0.62	2.00
5	*Asplenium nidus* L.	Aspleniaceae	15	3	5.00	2.88	1.67
6	*Blumea myriocephala* D.C	Asteraceae	9	4	2.25	2.60	0.56
7	*Boehmeria macrophylla* Hornem.	Urticaceae	14	6	2.33	3.96	0.39
8	*Boehmeria platyphylla D*. Don	Urticaceae	21	7	3.00	5.14	0.43
9	*Cardamine indica* L.	Brassicaceae	10	3	3.33	2.32	1.11
10	*Caulokaempferia scunda* (Wall) Carsen	Zingiberaceae	5	2	2.50	1.36	1.25
11	*Colocasia antiquorum* Schott	Araceae	8	3	2.67	2.09	0.89
12	*Colocasia esculenta* (L.) Schott	Araceae	10	6	1.67	3.51	0.28
13	*Costus speciosus* Koen ex. Retz.	Costaceae	36	9	4.00	7.62	0.44
14	*Curcuma sp.*	Zingiberaceae	8	3	2.67	2.09	0.89

15	*Davallia trichomanoides* Blume	Davalliaceae	5	2	2.50	1.36	1.25
16	*Dioscorea sp.*	Dioscoreaceae	9	2	4.50	1.81	2.25
17	*Disporum cantoniense* (Lour.) Merr.	Convallariaceae	9	3	3.00	2.20	1.00
18	*Elatostema sessile* J.R.Forst. & G.Forst.	Urticaceae	247	32	7.72	40.48	0.24
19	*Elephantopus scaber L.*	Asteraceae	23	8	2.88	5.76	0.36
20	*Girardinia diversifolia* (Link) Friis	Urticaceae	4	3	1.33	1.64	0.44
21	*Impatiens chinensis* L.	Balsaminaceae	38	17	2.24	11.02	0.13
22	*Impatiens porrecta* Hook.f. & Th.	Balsaminaceae	19	4	4.75	3.72	1.19
23	*Impatiens trilobata* Colebr.	Balsaminaceae	39	15	2.60	10.34	0.17
24	*Laportea crenulata* Gaud	Urticaceae	14	6	2.33	3.96	0.39
25	*Molineria capitulata* (Lour.) Herb	Hypoxdaceae	30	7	4.29	6.15	0.61
26	*Molineria latifolia (*Dryand. ex W.T.Aiton) Herb. ex Kurz	Hypoxdaceae	24	5	4.80	4.68	0.96
27	*Oxalis corniculata* L.	Oxalidaceae	13	5	2.60	3.45	0.52
28	*Paederia foetida* L.	Poaceae	2	1	2.00	0.62	2.00
29	*Panax sp*	Araliaceae	5	4	1.25	2.15	0.31
30	*Peliosanthes teta* Andrews	Convallariaceae	10	4	2.50	2.71	0.63
31	*Persicaria capitata* (Buch.-Ham. ex D.Don)	Polygonaceae	5	4	1.25	2.15	0.31

	H.Gross						
32	*Phrynium capitatum* Willd.	Marantaceae	16	6	2.67	4.18	0.44
33	*Polygonum chinensis* L.	Polygonaceae	10	3	3.33	2.32	1.11
34	*Pouzolzia hirta* (Blume) Blume ex Hassk.	Urticaceae	9	2	4.50	1.81	2.25
35	*Pouzolzia viminea* (Blume) Wedd	Urticaceae	30	9	3.33	6.95	0.37
36	*Pteris grandifolia* L.	Pteridaceae	14	8	1.75	4.75	0.22
37	*Pteris sp*	Pteridaceae	40	12	3.33	9.26	0.28
38	*Ruellia prostrata* Poir.	Acanthaceae	9	3	3.00	2.20	1.00
39	*Scoparia dulcis* L.	Scrophulariaceae	10	4	2.50	2.71	0.63
40	*Selaginella decipiens* Warb	Selaginellaceae	10	6	1.67	3.51	0.28
41	*Solanum sp.*	Solanaceae	4	3	1.33	1.64	0.44
42	*Urtica dioica* L.	Urticaceae	66	13	5.08	12.58	0.39
43	*Urtica incisa* Poir.	Urticaceae	8	2	4.00	1.69	2.00
44	*Urtica urens L.*	Urticaceae	5	3	1.67	1.75	0.56

* IVI=Importance Value Index, A/F ratio=Abundance by Frequency ratio

Table 7.3: Community structure of herbs in the buffer zone

Sl no	Scientific name	Family	Density (per100m^2)	Frequency	Abundance	IVI	A/F ratio
1	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	Asteraceae	18	11	1.64	5.94	0.15
2	*Amomum maximum* Roxb.	Zingiberaceae	8	2	4.00	1.60	2.00
3	*Ageratina sp.*	Asteraceae	39	8	4.88	7.16	0.61
4	*Ageratum conyzoides* (L.)	Asteraceae	40	17	2.35	10.51	0.14
5	*Aletris gracilis* Rendle	Nartheciaceae	5	3	1.67	1.63	0.56
6	*Allium tuberosum* Rottler ex Spreng.	Amaryllidaceae	3	1	3.00	0.69	3.00
7	*Alpinia galanga* (L.) Willd.	Zingiberaceae	3	2	1.50	1.05	0.75
8	*Amomum subulatum* Roxb.	Zingiberaceae	6	3	2.00	1.74	0.67
9	*Anisomeles malabarica* (L.) R.Br. ex Sims	Lamiaceae	4	3	1.33	1.52	0.44
10	*Arisaema album* N.E. Br	Araceae	7	3	2.33	1.85	0.78
11	*Bidens pilosa* L.	Asteraceae	18	4	4.50	3.41	1.13
12	*Carex crinita* Lam.	Cypernum	13	3	4.33	2.51	1.44
13	*Colocasia antiquorum* Schott	Araceae	3	1	3.00	0.69	3.00
14	*Colocasia esculenta* (L.) Schott	Araceae	7	2	3.50	1.49	1.75
15	*Commelina paludosa* Blume	Commelinaceae	10	3	3.33	2.18	1.11
16	*Crassocephalum crepidioides* (Benth.) S.Moore	Asteraceae	14	5	2.80	3.34	0.56
17	*Curcuma amada* Roxb	Zingiberaceae	12	3	4.00	2.40	1.33
18	*Dioscorea bulbifera* L.	Dioscoreaceae	16	12	1.33	6.08	0.11
19	*Dryopteris affinis* Fraser-Jenk.	Dryopteridaceae	11	3	3.67	2.29	1.22

20	*Elatostema sessile* J.R.Forst. & G.Forst.	Urticaceae	63	10	6.30	10.50	0.63
21	*Elephantopus scaber* Linn.	Asteraceae	3	1	3.00	0.69	3.00
22	*Eleutheranthera ruderalis* (Sw.) Sch.Bip.	Asteraceae	9	2	4.50	1.71	2.25
23	*Eryngium foetidum L.*	Apiaceae	3	1	3.00	0.69	3.00
24	*Hautounia cordata* Thunb	Piperaceae	5	2	2.50	1.27	1.25
25	*Hedychium coccinum* Smith	Zingiberaceae	9	2	4.50	1.71	2.25
26	Paederia *foetida L.*	Apiaceae	2	1	2.00	0.58	2.00
27	*Hydrocotyle javanica* Thunb.	Apiaceae	34	3	11.33	4.80	3.78
28	*Impatiens chinensis* L.	Balsaminaceae	10	5	2.00	2.90	0.40
29	*Impatiens porrecta* Hook.f. & Th.	Balsaminaceae	5	2	2.50	1.27	1.25
30	*Impatiens trilobata* Colebr.	Balsaminaceae	22	6	3.67	4.57	0.61
31	*Jasminum nervosum* Lour.	Oleaceae	3	1	3.00	0.69	3.00
32	*Ludwigia octovalvis subsp. sessiliflora (*Micheli) P.H.*Raven*	Onargaceae	3	1	3.00	0.69	3.00
33	*Molineria capitulata* (Lour.) Herb	Hypoxidaceae	30	11	2.73	7.25	0.25
34	*Molineria latifolia* (Dryand. *ex W.T.Aiton) Herb. ex Kurz*	Hypoxidaceae	58	21	2.76	13.93	0.13
35	*Oxalis corniculata* L.	Oxalidaceae	12	3	4.00	2.40	1.33
36	*Peliosanthes teta* Andrews	Convallariaceae	4	3	1.33	1.52	0.44
37	*Phrynium capitatum* Willd.	Marantaceae	19	7	2.71	4.61	0.39
38	*Phyllanthus urinaria* L	Phyllanthaceae	2	1	2.00	0.58	2.00
39	*Pilea umbrosa* Blume	Urticaceae	12	5	2.40	3.12	0.48
40	*Plantago major L.*	Plantaginaceae	3	1	3.00	0.69	3.00
41	*Prismatomeris albidiflora* Thwaites	Rubiaceae	6	4	1.50	2.10	0.38
42	*Pteris quadriaurita* Retz	Pteridaceae	212	34	6.24	35.47	0.18

43	*Pteris sp*	Pteridaceae	49	15	3.27	10.78	0.22
44	*Saccharum spontaneum* Linn.	Poaceae	8	3	2.67	1.96	0.89
45	*Scoparia dulcis L.*	Scrophulariaceae	8	2	4.00	1.60	2.00
46	*Selaginella sp*	Selaginellaceae	45	28	1.61	15.03	0.06
47	*Sida rhombifolia L.*	Malvaceae	3	2	1.50	1.05	0.75
48	*Thysanolaena maxima* (Roxb.) Kuntze.	Poaceae	17	4	4.25	3.30	1.06
49	*Vernonia silhetensis* (DC.) Craib	Asteraceae	7	3	2.33	1.85	0.78
50	*Vernonia volkameriifolia DC.*	Asteraceae	4	2	2.00	1.16	1.00
51	*Viola betonicifolia* Sm.	Violaceae	3	1	3.00	0.69	3.00
52	*Zingiber zerumbet* Sm	Zingiberaceae	4	1	4.00	0.80	4.00

Table7.4. Species ranking (based on IVI) in core and buffer zone

Species rank	Species (core zone)	IVI	Species (buffer zone)	IVI
1	*Elatostema sessile* J.R.Forst. & G.Forst.	40.48	*Pteris quadriaurita* Retz	35.47
2	*Urtica dioica* L.	12.58	*Selaginella sp*	15.03
3	*Impatiens chinensis* L.	11.02	*Molineria latifolia* (Dryand. ex W.T.Aiton) Herb. ex Kurz	13.93
4	*Impatiens trilobata* Colebr.	10.34	*Pteris sp*	10.78
5	*Pteris sp*	9.26	*Ageratum conyzoides* (L.)	10.51
6	*Costus speciosus* Koen ex. Retz.	7.62	*Elatostema sessile* J.R. Forst. & G.Forst.	10.50
7	*Pouzolzia viminea* (Blume) Wedd	6.95	*Molineria capitulata* (Lour.) Herb	7.25
8	*Molineria capitulata* (Lour.) Herb	6.15	*Ageratina sp.*	7.16
9	*Elephantopus scaber* L.	5.76	*Dioscorea bulbifera* L.	6.08
10	*Boehmeria platyphylla* D. Don	5.14	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	5.94
11	*Pteris grandifolia* L.	4.75	*Hydrocotyle javanica* Thunb.	4.80
12	*Molineria latifolia* (Dryand. ex W.T. Aiton) Herb. ex Kurz	4.68	*Phrynium capitatum* Willd.	4.61
13	*Phrynium capitatum* Willd.	4.18	*Impatiens trilobata* Colebr.	4.57
14	*Boehmeria macrophylla* Hornem.	3.96	*Bidens pilosa* L.	3.41
15	*Laportea crenulata* Gaud	3.96	*Crassocephalum crepidioides* (Benth.) S.Moore	3.34
16	*Impatiens porrecta* Hook.f. & Th.	3.72	*Thysanolaena maxima* (Roxb.) Kuntze.	3.30

17	*Colocasia esculenta* (L.) Schott	3.51	*Pilea umbrosa* Blume	3.12
18	*Selaginella decipiens* Warb	3.51	*Impatiens chinensis* L.	2.90
19	*Oxalis corniculata L.*	3.45	*Carex crinita* Lam.	2.51
20	*Asplenium nidus L.*	2.88	*Curcuma amada* Roxb	2.40
21	*Scoparia dulcis L.*	2.71	*Oxalis corniculata L.*	2.40
22	*Peliosanthes teta* Andrews	2.71	*Dryopteris affinis* Fraser-Jenk.	2.29
23	*Aletris gracilis* Lendle	2.60	*Commelina paludosa* Blume	2.18
24	*Blumea myriocephala* D.C	2.60	*Prismatomeris albidiflora* Thwaites	2.10
25	*Polygonum chinensis L.*	2.32	*Saccharum spontaneum* Linn.	1.96
26	*Cardamine indica L.*	2.32	*Arisaema album* N.E. Br	1.85
27	*Disporum cantoniense* (Lour.) Merr.	2.20	*Vernonia silhetensis* (DC.) Craib	1.85
28	*Ruellia prostrata* Poir.	2.20	*Amomum subulatum* Roxb.	1.74
29	*Panax sp*	2.15	*Eleutheranthera ruderalis* (Sw.) Sch.Bip.	1.71
30	*Persicaria capitata (*Buch. -Ham. ex D.Don) H.Gross	2.15	*Hedychium coccinum* Smith	1.71
31	*Colocasia antiquorum* Schott	2.09	*Aletris gracilis* Rendle	1.63
32	*Alpinia galanga* (L.) Sw.	2.09	*Scoparia dulcis L.*	1.60
33	*Curcuma sp.*	2.09	*Amomum maximum* Roxb.	1.60
34	*Dioscorea sp.*	1.81	*Peliosanthes teta* Andrews	1.52
35	*Pouzolzia hirta* (Blume) Blume ex Hassk.	1.81	*Anisomeles malabarica* (L.) R.Br. ex Sims	1.52
36	*Urtica urens L.*	1.75	*Colocasia esculenta* (L.) Schott	1.49
37	*Urtica incisa* Poir.	1.69	*Impatiens porrecta* Hook.f. & Th.	1.27
38	*Girardinia diversifolia* (Link) Friis	1.64	*Houttuynia cordata* Thunb	1.27
39	*Solanum sp.*	1.64	*Vernonia volkameriifolia DC.*	1.16

40	*Amorphophallus paeoniifolius (*Dennst.) Nicolson	1.58	*Alpinia galanga* (L.) Willd.	1.05
41	*Caulokaempferia scunda* (Wall) Carsen	1.36	*Sida rhombifolia L.*	1.05
42	*Davallia trichomanoides* Blume	1.36	*Zingiber zerumbet* Sm	0.80
43	*Paederia foetida L.*	0.62	*Eryngium foetidum L.*	0.69
44	*Arisaema album* N.E. Br	0.62	*Allium tuberosum* Rottler ex Spreng.	0.69
45			*Colocasia antiquorum* Schott	0.69
46			*Elephantopus scaber* Linn.	0.69
47			*Plantago major L.*	0.69
48			*Jasminum nervosum* Lour.	0.69
49			*Ludwigia octovalvis* subsp. sessiliflo ra (Micheli) P.H.Raven	0.69
50			*Viola betonicifolia* Sm.	0.69
51			*Phyllanthus urinaria* L.	0.58
52			*Paederia foetida L.*	0.58

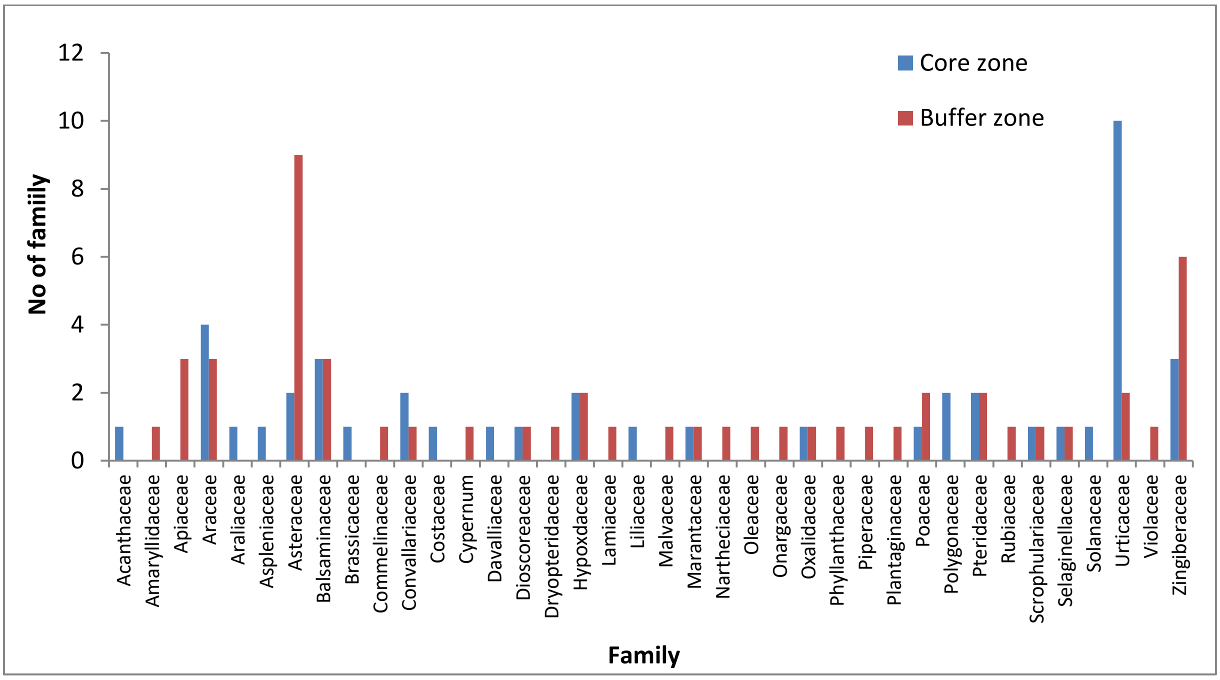


Fig 7.1: Family-wise distribution of species in core zone and buffer zone

7.2 Dominance-diversity of Family

The dominant family in the core zone was Urticaceae with 10 species (23 % species), and followed by Araceae with 4 species (9 % species). The number of monospecific families amounting to 14 (28 % species). In the buffer zone, Asteraceae was the most dominant family with 9 species (17 % species), and it was followed by and Zingiberaceae with 6 species (12 %) species (**Fig 7.1)** The 20 families were monospecific and contributing 40 % species **(Table 7.5 and Fig. 7. 2).** The diversity-distribution curve showed stability in terms of families in both zones **(Fig. 7. 3).**

The high species richness with more number of genera and families in the buffer zone could be linked with disturbance, as disturbance supports herbs due to open canopy that may also lead to high density. The Simpson dominance index exhibited reverse trend in results with Shannon index of diversity, as it is always found in natural vegetation. The high value of evenness index in both the zones argued uniform distribution of species. *Elatostema sessile*, the dominant species in core zone was replaced by P*teris quadriaurita* in buffer zone. Similarly, Urticaceace, the dominant family in the core zone was replaced by Asteraceace in buffer zone. Moreover, the number of monospecific families was high in buffer zone. The shift in position of species and families and more number of monospecific families in buffer zone could be attributed due to disturbance, as certain species and families are sensitive to the disturbance and eliminated from the habitat. The gaps created due to disturbance and exposed canopy favour survival and growth of certain species, and facilitate introduction of some families and species.

Table 7.5 Family ranking based on species richness in the core zone and buffer zone

Family Rank	Core zone		Buffer zone	
	Family	No of species	Family	No of species
1	Urticaceae	10	Asteraceae	9
2	Araceae	4	Zingiberaceae	6
3	Balsaminaceae	3	Apiaceae	3
4	Zingziberaceae	3	Araceae	3
5	Asteraceae	2	Balsaminaceae	3
6	Convallariaceae	2	Hypoxidaceae	2
7	Hypoxdaceae	2	Poaceae	2
8	Polygonaceae	2	Pteridaceae	2
9	Pteridaceae	2	Urticaceae	2
10	Acanthaceae	1	Amaryllidaceae	1
11	Araliaceae	1	Commelinaceae	1
12	Aspleniaceae	1	Convallariaceae	1
13	Brassicaceae	1	Cypernum	1
14	Costaceae	1	Dioscoreaceae	1

15	Dioscoreaceae	1	Dryopteridaceae	1
16	Liliaceae	1	Lamiaceae	1
17	Marantaceae	1	Malvaceae	1
18	Oxalidaceae	1	Marantaceae	1
19	Poaceae	1	Nartheciaceae	1
20	Scrophulariaceae	1	Oleaceae	1
21	Selaginellaceae	1	Onargaceae	1
22	Solanaceae	1	Oxalidaceae	1
23	Davalliaceae	1	Phyllanthaceae	1
24			Piperaceae	1
25			Plantaginaceae	1
26			Rubiaceae	1
27			Scrophulariaceae	1
28			Selaginellaceae	1
29			Violaceae	1

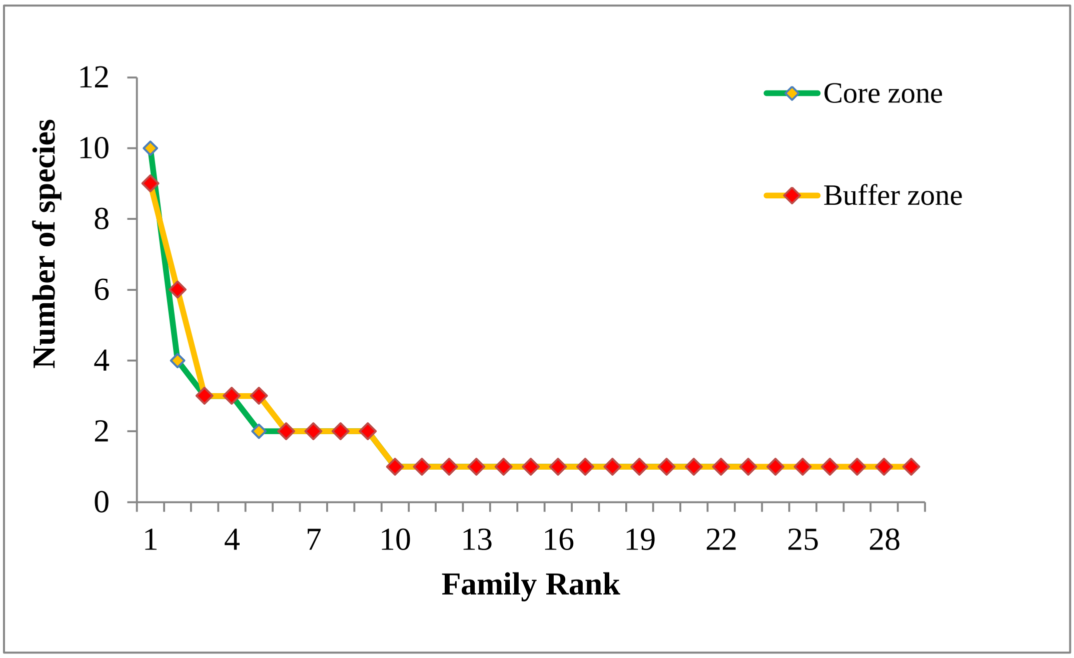


Fig 7.2: Family dominance-distribution curve in core zone and buffer zone

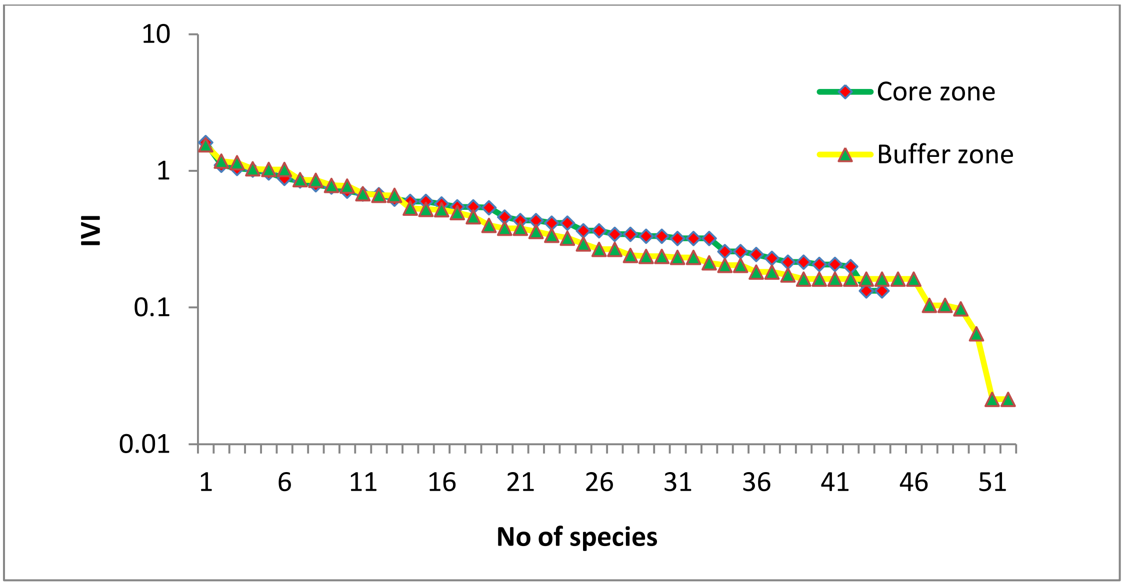


Fig7.3: Species dominance-distribution curve in core zone and buffer zone

Table 7.6: Herbaceous species found only in the core zone

Sl no	Species	Family
1	*Amorphophallus paeoniifolius* (Dennst.) Nicolson	Araceae
2	*Asplenium nidus L.*	Aspleniaceae
3	*Blumea myriocephala* D.C	Asteraceae
4	*Boehmeria macrophylla* Hornem.	Urticaceae
5	*Boehmeria platyphylla* D. Don	Urticaceae
6	*Cardamine indica L.*	Brassicaceae
7	*Caulokaempferia scunda* (Wall) Carsen	Zingiberaceae
8	*Costus speciosus* Koen ex. Retz.	Costaceae
9	*Curcuma sp.*	Zingiberaceae
10	*Davallia trichomanoides* Blume	Davalliaceae
11	*Dioscorea sp.*	Dioscoreaceae
12	*Disporum cantoniense* (Lour.) Merr.	Convallariaceae
13	*Girardinia diversifolia* (Link) Friis	Urticaceae
14	*Laportea crenulata* Gaud	Urticaceae
15	*Panax sp*	Araliaceae
16	*Persicaria capitata* (Buch.-Ham. ex D.Don) H.Gross	Polygonaceae
17	*Polygonum chinensis* L.	Polygonaceae
18	*Pouzolzia hirta* (Blume) Blume ex Hassk.	Urticaceae
19	*Pouzolzia viminea* (Blume) Wedd	Urticaceae
20	*Pteris grandifolia L.*	Pteridaceae
21	*Ruellia prostrata* Poir.	Acanthaceae
22	*Solanum sp.*	Solanaceae

23	*Urtica dioica* L.	Urticaceae
24	*Urtica incisa* Poir.	Urticaceae
25	*Urtica urens* L.	Urticaceae

Table 7.7 Herbaceous species found only in the buffer zone

Sl no	Species	Family
1	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	Asteraceae
2	*Amomum maximum* Roxb.	Zingiberaceae
3	*Ageratina sp.*	Asteraceae
4	*Ageratum conyzoides* (L.)	Asteraceae
5	*Allium tuberosum* Rottler ex Spreng.	Amaryllidaceae
6	*Amomum subulatum* Roxb.	Zingiberaceae
7	*Anisomeles malabarica* (L.) R.Br. ex Sims	Lamiaceae
8	*Bidens pilosa* L.	Asteraceae
9	*Carex crinita* Lam.	Cypernum
10	*Commelina paludosa* Blume	Commelinaceae
11	*Crassocephalum crepidioides* (Benth.) S.Moore	Asteraceae
12	*Curcuma amada* Roxb	Zingiberaceae
13	*Dioscorea bulbifera* L.	Dioscoreaceae
14	*Dryopteris affinis* Fraser-Jenk.	Dryopteridaceae
15	*Eleutheranthera ruderalis* (Sw.) Sch.Bip.	Asteraceae
16	*Eryngium foetidum* L.	Apiaceae
17	*Houttuynia cordata* Thunb	Piperaceae
18	*Hedychium coccinum* Smith	Zingiberaceae
19	*Hydrocotyle javanica* Thunb.	Apiaceae
20	*Jasminum nervosum* Lour.	Oleaceae

21	*Ludwigia octovalvis* subsp. sessiliflora (Micheli) P.H.Raven	Onargaceae
22	*Phyllanthus urinaria* L	Phyllanthaceae
23	*Pilea umbrosa* Blume	Urticaceae
24	*Plantago major* L.	Plantaginaceae
25	*Prismatomeris albidiflora* Thwaites	Rubiaceae
26	*Pteris quadriaurita* Retz	Pteridaceae
27	*Saccharum spontaneum* Linn.	Poaceae
28	*Sida rhombifolia* L.	Malvaceae
29	*Thysanolaena maxima* (Roxb.) Kuntze.	Poaceae
30	*Vernonia silhetensis* (DC.) Craib	Asteraceae
31	*Vernonia volkameriifolia* DC.	Asteraceae
32	*Viola betonicifolia* Sm.	Violaceae
33	*Zingiber zerumbet* Sm	Zingiberaceae

Table 7.8: Species common in the core and buffer zone

Sl no	Species	Family
1	*Aletris gracilis* Lendle	Liliaceae
2	*Alpinia galanga* (L.) Sw.	Zingiberaceae
3	*Arisaema album* N.E. Br	Araceae
4	*Colocasia antiquorum* Schott	Araceae
5	*Colocasia esculenta* (L.) Schott	Araceae
6	*Elatostema sessile* J.R.Forst. & G.Forst.	Urticaceae
7	*Elephantopus scaber* L.	Asteraceae
8	*Impatiens chinensis* L.	Balsaminaceae
9	*Impatiens porrecta* Hook.f. & Th.	Balsaminaceae

10	*Impatiens trilobata* Colebr.	Balsaminaceae
11	*Molineria capitulata* (Lour.) Herb	Hypoxdaceae
12	*Molineria latifolia* (Dryand. ex W.T.Aiton) Herb. ex Kurz	Hypoxdaceae
13	*Oxalis corniculata* L.	Oxalidaceae
14	*Paederia foetida* L.	Poaceae
15	*Peliosanthes teta* Andrews	Convallariaceae
16	*Phrynium capitatum* Willd.	Marantaceae
17	*Pteris sp*	Pteridaceae
18	*Scoparia dulcis* L.	Scrophulariaceae
19	*Selaginella decipiens* Warb	Selaginellaceae

SOIL ANALYSIS

8.1 Soil moisture

Soil moisture content decreased with increase in depth in both the Eastern and Western site. In the core zone, soil moisture content varied from 26-40 % in 0-15cm soil depth and 22.5 % to 34 % in 15-30 cm soil depth. In the buffer zone, it varies from to 21 -35% in 0-15cm soil depth and 19-33 % in 15 – 30 cm soil depth **(Fig 8.1**). The top soil has higher moisture content than the sub soil. The core zone has more moisture content than the buffer zone. High moisture content was recorded in the monsoon season (July to August). Lowest moisture content was recorded in Post- Monsoon Season from (November to December).Spatial distribution of the soil moisture (%) in the core and buffer zones of the study site revealed that soil moisture is comparatively higher in the western site of the study area than the eastern sites except the upper depth of soil in East during the post monsoon season.

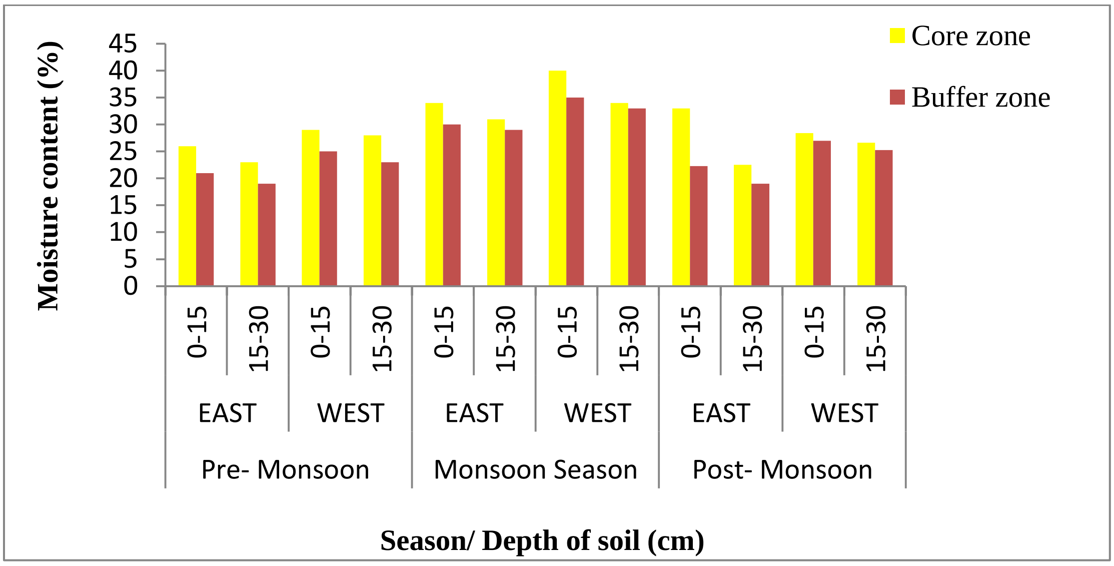


Fig 8.1: Soil moisture content in the Eastern and Western site of core and buffer zones of Nokrek Biosphere Reserve

8.2 Soil pH

The soil is acidic in both the stands. The pH increases with the depth of the soil. In the core zone, the pH ranged from 5.2- 6.8 in the upper layer and 5.0-6.7 in the lower layer. Whereas in the buffer, the pH ranged from 5.2-6.7 in 0-15cm soil depth and 5.3-6.8 in 15-30 cm soil depth. The pH of the soil was highest (less acidic) in the monsoon season (**Fig 8.2).** Both Easten and Western site of the soil are acidic. In pre monsoon season the Eastern site of the soil is slightly more acidic than the Western site.

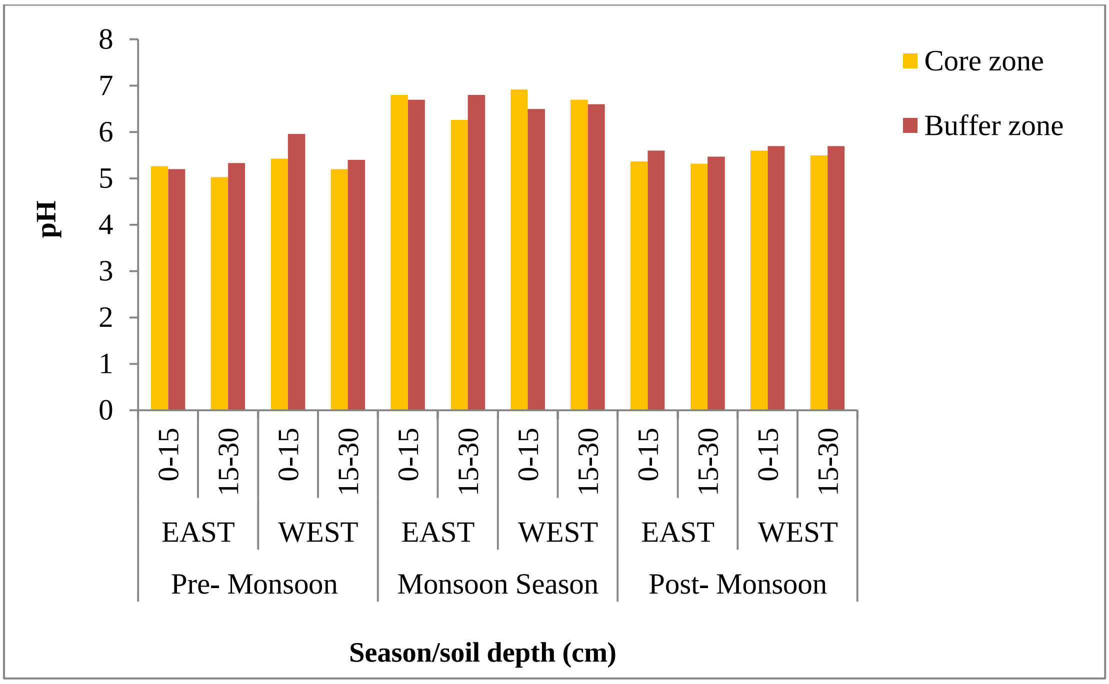


Fig 8.2: Soil pH in the Eastern and Western site of core and buffer zones of Nokrek Biosphere Reserve

8.3 Bulk density

The bulk density of the soil increased from the higher to lower layer of the soil. In the core zone the maximum value was 0.73 gm cm^{-3} and the minimum was 0.482 gm cm^{-3} in the upper layer of 0-15 cm soil depth. In 15-30 cm depth the range was 1.077 gm cm^{-3} -0.96 gm cm^{-3}. Whereas in the buffer zone, the range was 0.88 gm cm^{-3} to 0.61 gm cm^{-3} and 1.10 gm cm^{-3} to 0.70 gm cm^{-3} in the upper and lower layer respectively **(Fig 8.3)**. Bulk density is higher in the lower layer in both Eastern and Western site.

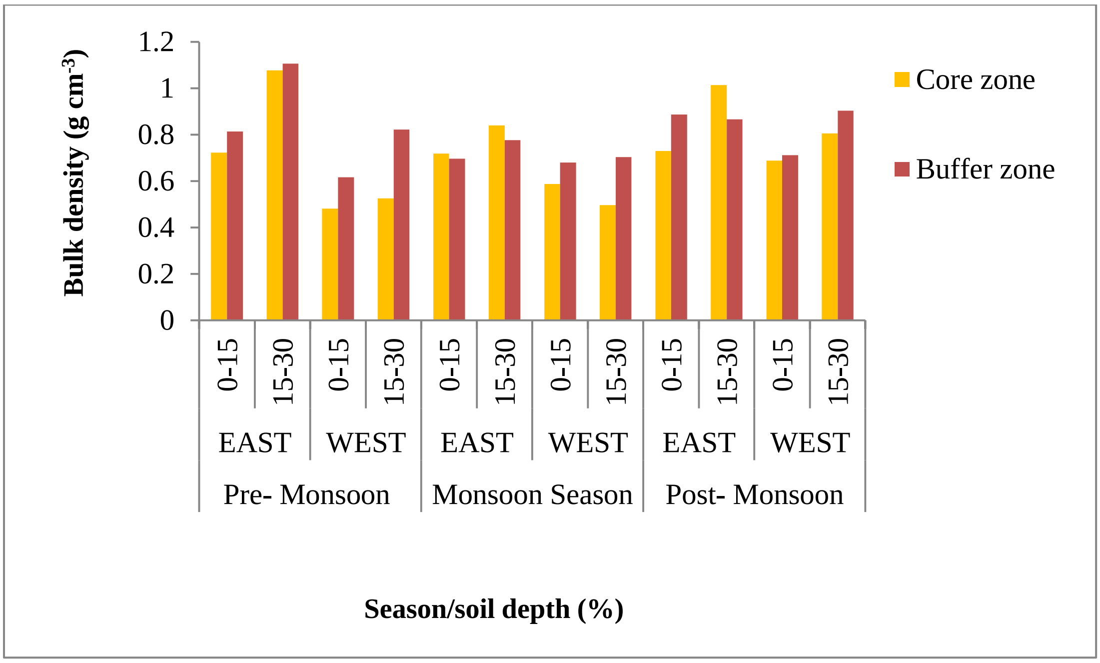


Fig 8.3: Bulk density of soil in the Eastern and Western site of core and buffer zones of Nokrek Biosphere Reserve

8.4 Soil organic carbon

The top soil has higher carbon content in both the stands. The core zone has also higher carbon content compared to the buffer zone. The values in the core zone ranged from 2.28 % -3.27 % in the upper layer and 1.36 % - 2.3 % in the lower layer. In the buffer zone the values ranged from 2.95 % – 1.96 % in 0-15cm soil layer and 1.27 % - 2% in the lower layer of 15-30cm **(Fig 8.4)**. It was high in pre-monsoon season followed by monsoon season. The upper layer of the western site has more carbon content than the lower layers. In the Eastern site only during the pre-monsoon season the carbon content was higher.

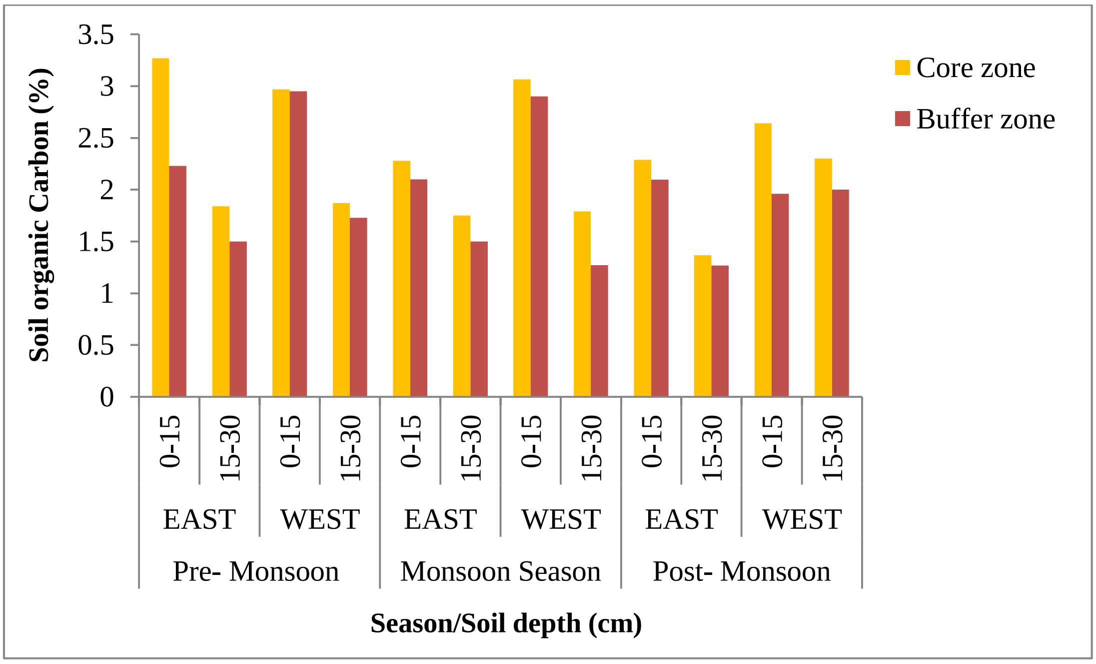


Fig 8.4: Soil organic carbon in the Eastern and Western site of core and buffer zones of Nokrek Biosphere Reserve

8.5 Total Nitrogen

The values of Nitrogen decreased from the upper to lower layer. Core zone showed high Nitrogen content compared to the buffer zone. In core zone it ranged from 0.3%-0.5% and 0.22% - 0.43% in the soil depth of 0-15 and 15-30, respectively. Similarly, in the buffer zone, the Nitrogen ranged from 0.25% - 0.37% in 0-15 cm soil depth and 0.17% - 0.23% in 15-30 cm depth. The Nitrogen content was highest in pre monsoon season **(Fig 8.5)**. The Western site has slightly more Nitrogen content than the Eastern layer.During the pre monsoon season highest Nitrogen content was observed in the upper layer of Western site.

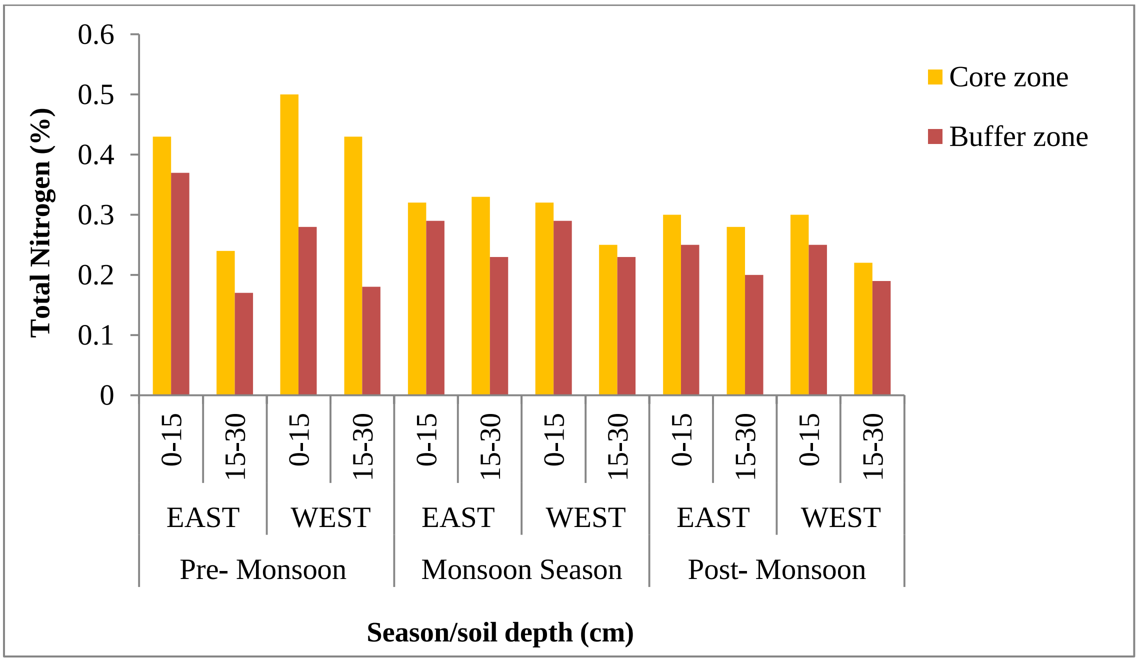


Fig 8.5: Total Nitrogen in the Eastern and Western site of core and buffer zones of Nokrek Biosphere Reserve

8.6 Available Phosphorous

The available Phosphorous varied from 1.56 ppm – 3.06ppm in the soil depth of 0-15cm and 1.1ppm – 2.83ppm in the depth of 15-30cm. In the buffer zone, it varies from 1.1ppm - 3ppm in the upper layer and 0.8ppm - 2.46 ppm in the sub soil. The maximum reading was recorded in post- monsoon season **(Fig. 8.6)**. The western site has more Phosphorous content than the eastern site except during the post monsoon season in the upper layer of eastern site.

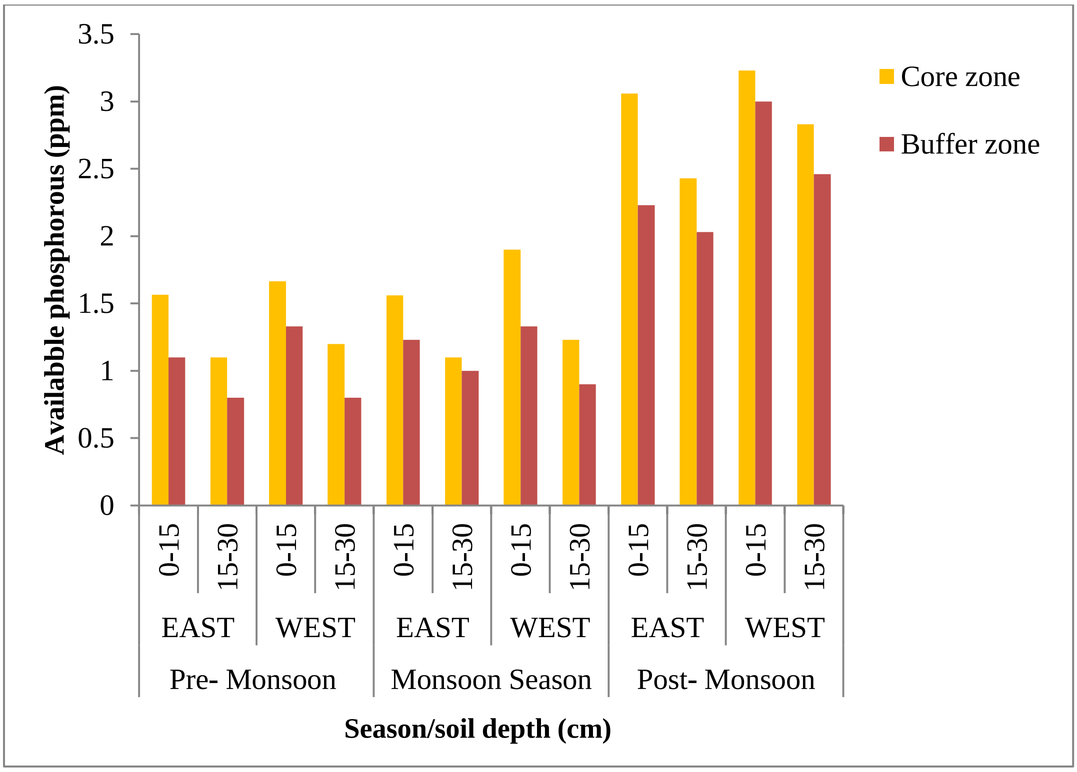


Fig. 8.6: Available Phosphorous in the Eastern and Western site of core and buffer zones of Nokrek Biosphere Reserve

8.7 Exchangeable potassium

In the core zone, the range of exchangeable potassium varies from 168-382.65 kg/ha in the upper layer and 70.93-121.33 kg/ha in the lower layer. It decreased from upper to lower layer in both the core and the buffer zone. In buffer it ranged from 149.33- 280.00 kg/ha and 112-242.67 kg/ha in the depth of 0-15 and 15-30, respectively. It was highest during the pre-monsoon season **(Fig. 8.7)**. The Western site has higher potassium content than the eastern site except during the post-monsoon season.

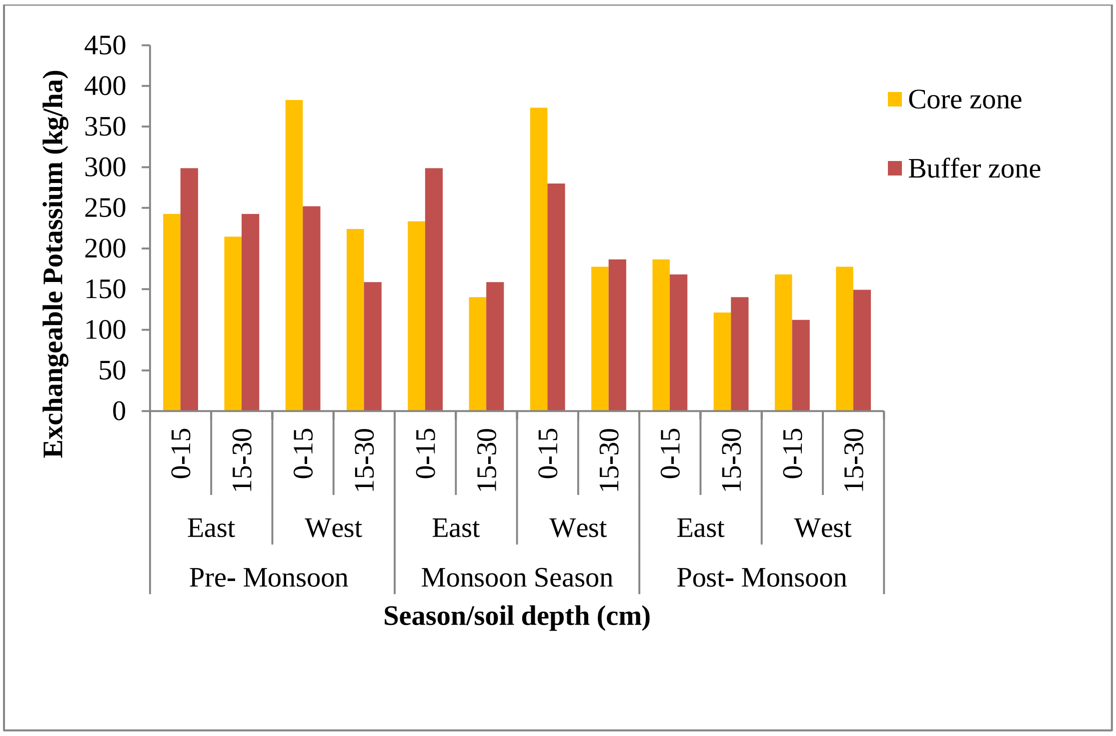


Fig.8.7: Exchangeable potassium in the Eastern and Western site of core and buffer zones of Nokrek Biosphere Reserve

<u>Chapter- 9</u>

SOCIO-ECONOMIC ANALYSIS

9.1 Socio Demographic Profile

The population and number of households of the villages taken for the questionnaire survey according to 2011 census is presented in the table below-

Table 9.1 Village profile

Sl no	Name of the Village	Number of households	Total population	Total Male	Total Female
1	Bandigre	21	112	60	52
2	Mandalgre	58	379	202	177
3	Sakalgre	15	100	44	56
4	Daribokgre	19	125	65	60

Source: Census 2011.

9.1.1 Age group

The age group of the respondent has been grouped into youth (18-34), middle-age (35-59) and elderly (60 and above). This gives the idea about variation in various age groups and could help in targeting the awareness and interest of the people according to their age. The participants were the mostly middle-aged group, followed by youth. The elderly were the lowest (**Table 9.2)**.

9.1.2 Educational Qualification

Educational qualification represents the standard of living, awareness, and perceptions of the environment of the people. Of the respondent that was surveyed, one- third (31%) were illiterate and only 1% has completed their higher secondary depicting the poor state of the educational system in the village. (**Table 9.2)**

9.1.3 Family size

The family size was classified into small (1-3), medium (4-6) and large (7 and above). Most of the families were large (71 %), 27 % falls under medium category and only 2 % categorized as small (**Table 7.2)**. A large size family depicts the picture that there is a rapid growth in population. There were families as large as 13 members (Respondent no 24, village number 4). The rapid rise in population in the area demands for more available resources and could damage the environment with more needs for settlement and food resources.

9.1.4 Occupation

Majority of the respondents (69%) were cultivators, 18% were students and the rest 13% were trader, laborers, craftsman, and few government employees (**Table 7.2)**.

Table 9.2 Socio Demographic profile

Sl No	Characteristics	Name of the Village				Total (%)
		Bandigre	Mandalgre	Sakalgre	Daribokgre	
1	**Age group**					
	Youth (18-34)	9 (36)	10 (40)	13 (52)	9 (36)	63
	Middle age (35-59)	13 (52)	12 (48)	10 (40)	13 (52)	20
	Elderly (60 and above)	3 (12)	3 (12)	2 (8)	3 (12)	17
2	**Educational Qualification**					
	Illiterate	8 (32)	7 (28)	7 (28)	9 (36)	31
	Primary	10 (40)	7 (28)	5 (20)	3 (12)	25
	Middle	5 (20)	7 (28)	8 (32)	9 (36)	29
	Secondary	2 (8)	4 (16)	5 (20)	3 (12)	14
	Higher secondary	0 (0)	0 (0)	0 (0)	1 (4)	1

3	**Family size**					
	Small (1-3)	2 (8)	0 (0)	0 (0)	0 (0)	2
	Medium (4-6)	9 (36)	3 (12)	6 (24)	9 (36)	27
	Large (7 and above)	14 (56)	22 (88)	19 (76)	16 (64)	71
4	**Occupation**					
	Cultivator	21 (84)	18 (72)	14 (56)	16 (64)	69
	Daily wage labourer	0 (0)	0 (0)	1 (4)	2 (8)	3
	Artisan/ craftsman	0 (0)	0 (0)	3 (12)	0 (0)	3
	Trader	1 (4)	2 (8)	0 (0)	0 (0)	3
	Self employed	1 (4)	0 (0)	0 (0)	1 (4)	2
	Student	2 (8)	5 (20)	6 (24)	5 (20)	18
	Government servant	0 (0)	0 (0)	1 (4)	1 (4)	2

Source: Computed. Figures in parentheses are percentages

9.2 Household Livelihood condition

The people mostly rely on the raw materials available around the village. The households are mostly constructed with the locally available materials like bamboo, poles and thatches which are readily available. They also depend on various supplies from government.

9.2.1 Source of Income

The entire village falls under the below poverty line. 80% of the native people depend on shifting cultivation as the main source of livelihood. Only 10 % depend on home gardens as their source of income. Other 10% are into small business, daily laborers and traders **(Table 9.3)**. The rest earn their living as petty business or laborers. Jhum cultivation is most widely practiced in villages which are at a farther distance from the town like Bandigre (92%), Sakalgre (88%). Since home garden leads to mono cropping shifting cultivation is their preferred choice. Mainly seasonal products like cardamom, pepper, vegetables like squash are grown in home gardens. The dependence on shifting cultivation is one of the major reasons for disturbance in the buffer zone. People also depend on livestock as a source of income.

9.2.2 House type

Due to poor connectivity and no extra source of income, most of the people reside in kutcha house made out of local raw materials. 75% of houses are made out of bamboo, 6 % are assam type and 19 % are semi pucca and timber available from the forest which leads to their dependency on the forest. Preferably *Castanopsis indica*, *Quercus lancaefolia*, *Toona ciliata* are used for construction purposes. For construction purposes, the raw materials are mostly collected from the buffer areas due to easy accessibility **(Table 9.3)**

9.2.3 Physical assets of household and livestock

Besides Mandalgre, the other three villages were not electrified so they depend on solar lamp and lamp oils. Assets like TV (34 %) and radio (35 %) are not common in the village. Few people own vehicles (6 %).Use of mobile phones (59 %) can be mostly seen among youngsters than the middle age people **(Table 9.3).**

9.2.4 Source of fuelwood

Firewood is the major source of fuel. It is mainly collected from the nearby forest (45 %) and abandoned jhum (44 %) **(Table 9.3).** This also leads to their heavy reliability on abandoned jhum land. Maximum of the native people rely on firewood from the buffer zone as due to poor road connectivity and insufficient income the native people cannot afford to have LPG connections. The entire village depends on the firewood from the jhum cultivation.

9.2.5 Waste disposal

The waste management system is very poor in the area which is a threat to the environment. Half of the waste generated is disposed off in the wild area and there is no segregation of waste (**Table 9.3)**.

Table 9.3 Household living condition

Sl No	Characteristics	Name of the Village				Total (%)
		Bandigre	Mandalgre	Sakalgre	Daribokgre	
1	**Source of income**					
	Jhum cultivation	23 (92)	22 (88)	19 (76)	16 (64)	80
	Home garden	0 (0)	1 (4)	1 (4)	8 (32)	10
	Business	2 (8)	0 (0)	2 (8)	1 (4)	5
	Labour	0 (0)	0 (0)	3 (12)	0 (0)	3
	Trader	0 (0)	2 (8)	0 (0)	0 (0)	2
2	**Housing type**					
	Kutcha (Local materials)	20 (80)	25 (100)	16 (64)	14 (56)	75
	Semi-pucca	3 (12)	0 (0)	9 (36)	7 (28)	19
	Assam type	2 (8)	0 (0)	0 (0)	4 (16)	6
3	**Physical assets**					
	Solar lamp	0 (0)	3 (12)	24 (96)	18 (72)	45
	Radio	9 (36)	11 (44)	6 (24)	9 (36)	35
	Tv	11 (44)	16 (64)	0 (0)	7 (28)	34
	Mobile	9 (37)	16 (64)	17 (70)	16 (64)	59
	Vehicle	2 (8)	1 (4)	0 (0)	3 (12)	6
	Livestock	20 (80)	22 (88)	24 (96)	15 (60)	81
4	**Source of fuel wood**					
	Abandoned jhum field	12 (48)	10 (40)	20 (80)	2 (8)	44
	Nearby forest	13 (52)	15 (60)	5 (20)	12 (48)	45
	Woodlots	0 (0)	0 (0)	0 (0)	11 (44)	11

5	**Waste disposal**					
	Disposed to wild area	13 (52)	12 (48)	9 (36)	11 (44)	45
	Compost	1 (4)	2 (8)	2 (8)	4 (16)	9
	Burn	5 (20)	7 (28)	11 (44)	10 (40)	33
	Disposed irregularly	6 (24)	4 (16)	3 (12)	0 (0)	13

Source: Computed. Figures in parentheses are percentages.

9.3 Community access to infrastructure

The standard of living and infrastructure is poor. Out of the total of 100 respondents, only 27 % of the respondents agreed on access to water supply in their areas. Only 24 % of the respondents have access to health care facilities with the presence of primary health centres in some areas. Only 42 % of the families have electricity connection. Two villages, Daribokgre and Mandalgre have community halls constructed by the forest department. Only one village Daribokgre has inspection bungalow out of the 4 villages where the survey was carried out. Mandalgre village has a primary health center **(Table 9.4)**. The other 3 villages do not have any access to modern health facilities so they completely depend on traditional healers and medicines from the forest.

Majority of the people (79 %) stated that road connectivity is the main drawback for the people residing in these areas **(Table 9.4)**. The roads are motorable only in the dry season. This creates a huge problem in traveling for their daily needs. The resources obtained from the jhum field sometimes go wasted due to lack of transportation though the products are harvested in surplus. The village-like Bandigre depends on the community-made bamboo bridge for accessing to the nearby towns. The educational status in the village is also par below the point. The SSA schools in the villages face challenges in teacher-student ratio, school infrastructure, and basic amenities.

Table 9.4 Community access to infrastructure

Sl No	Characteristics	Name of the Village				Total (%)
		Bandigre	Mandalgre	Sakalgre	Daribokgre	
1	**Public tap**	1 (4)	9 (36)	15 (60)	2 (8)	27
2	**Community hall**	0 (0)	13 (52)	0 (0)	4 (17)	17
3	**Govt Rest house**	0 (0)	0 (0)	0 (0)	18 (75)	18
4	**Health services**	0 (0)	24 (96)	0 (0)	0 (0)	24
5	**Road , transportation**	0 (0)	11 (44)	6 (24)	4 (16)	21
6	**Electricity**	19 (76)	23 (92)	0 (0)	0 (0)	42
7	**Mass media**					
	Local radio	14 (56)	7 (29)	12 (48)	17 (68)	50
	Television	5 (20)	11 (45)	0 (0)	1 (4)	17
	Neighbor	5 (20)	4 (16)	6 (24)	5 (20)	20
	Local Newspaper	1 (4)	2 (8)	7 (28)	2 (8)	12

Source: Computed. Figures in parentheses are percentages

9.4 Community perception of tourism

During the period when the questionnaire was conducted there was a rare visit from tourists due to fear of militancy problem in all the four villages. Locals also agreed to the fact that the area is explored mostly for sightseeing (59 %) followed by researchers (20 %). People have a positive attitude towards welcoming tourists in the area (85 %). But 15 % were having a negative opinion and this may be due to the thought of harming the environment they reside or exploitation of natural habitats through a collection of medicinal plants or Non timber forest products (NTFPS) like orchids **(Table 9.5)**.

Table 9.5 Community perception on tourism

Sl No	Characteristics	Name of the Village				Total (%)
		Bandigre	Mandalgre	Sakalgre	Daribokgre	
1	**How often does the tourist visit**					
	Frequently	2 (8)	1 (4)	0 (0)	0 (0)	3
	Rarely	14 (56)	22 (88)	21 (84)	24 (96)	81
	Never	9 (36)	2 (8)	4 (16)	1 (4)	16
2	**Why do you think tourists come to NBR?**					
	No	5 (20)	2 (8)	6 (24)	0 (0)	13
	Sightseeing	16 (64)	8 (32)	13 (52)	22 (88)	59
	Educational and historical purpose	0 (0)	0 (0)	1 (4)	2 (8)	3
	Research	1 (4)	13 (52)	5 (20)	1 (4)	20
	Others	3 (12)	2 (8)	0 (0)	0 (0)	5
3	**Would you like to see development in tourism in NBR**					
	Great extent	19 (76)	20 (90)	21 (84)	22 (88)	85
	Some extent	6 (24)	2 (9)	4 (16)	3 (12)	15

Source: Computed. Figures in parentheses are percentages

9.5 Awareness, willingness, and perception of Nokrek Biosphere Reserve

Half of the populations (52 %) were aware of the area as Nokrek National Park. 19 % are aware that it has the highest peak and is considered as a biosphere reserve. 29 % believed that it is a dense forest locally referred to as *"Durama*". The ownership of the land mostly belongs to the community living in the vicinity of the areas. Shifting cultivation (95 %) followed by plantation in home gardens are the major activity carried out in the buffer zone **(Table 7.6)**.

There are negative thoughts (51 %) regarding shifting cultivation as well. There have not been many alternative sources besides few plantations which have been done in the area with the help of various departments. More alternative sources of livelihoods if introduced to them would be beneficial.Regarding the preservation of Nokrek Biosphere Reserve abbreviation the steps taken by the concerned authorities has been said to be unsatisfactory (76 %) and only 14 % finds it satisfactory.

Half of the respondents feel that the government does not have any thoughts regarding the cultivation **(Table 9.6)**. This could be due to the reasons that people are aware of the damage that has been going on in the buffer through jhum activity but there is lack of alternative methods to sustain the livelihood.

Table 9.6 Awareness, willingness and perception of Nokrek Biosphere Reserve

Sl No	Characteristics	Name of the Village				Total (%)
		Bandigre	Mandalgre	Sakalgre	Daribokgre	
1	**Existence of Nokrek is familiar as**					
	Biosphere reserve	0 (0)	3 (12)	0 (0)	3 (12)	6
	National Park	7 (28)	13 (52)	17 (68)	15 (60)	52
	Peak	4 (16)	2 (8)	1 (4)	6 (24)	13
	Thick forest	14 (56)	7 (28)	7 (28)	1 (4)	29
2	**Common activity in buffer zone**					
	Shifting cultivation	24 (96)	25 (100)	23 (92)	23 (92)	95
	Plantation	1 (4)	0 (0)	2 (8)	2 (8)	5
3	**Steps taken up by Government for preservation of NBR**					
	Unsatisfactory	16 (64)	18 (72)	20 (80)	22 (88)	76
	No idea	3 (12)	5 (20)	2 (8)	0 (0)	10
	Satisfactory	6 (24)	2 (8)	3 (12)	3 (12)	14
4	**Opinion on restriction imposed in core zone**					
	Good	18 (72)	23 (92)	23 (92)	21 (84)	85
	No opinion	7 (28)	1 (4)	2 (8)	2 (8)	12
	Not satisfied	0 (0)	1 (4)	0 (0)	2 (8)	3
5	**Opinion on restriction imposed in buffer zone**					
	Good	20 (80)	21 (84)	23 (92)	21 (84)	85
	No opinion	5 (20)	4 (16)	2 (8)	3 (12)	14
	Not satisfied	0 (0)	0 (0)	0 (0)	1 (4)	1

Source: Computed. Figures in parentheses are percentages

From **Table 9.7**, as per the ranking in village of Bandigre, people are willing to preserve the forest areas of Nokrek mostly for research purpose. Secondly, due to the rules laid by the forest department the locals of the area are willing to preserve the areas of the Nokrek biosphere reserve. The area of Bandigre is more remote and isolated compared to the other three villages which were surveyed. Due to the poor accessibility and problems of militancy in the area during the time when the data was collected, there is less flow of tourist in the areas surveyed. Their ranking towards habitat for wildlife and future sustainability is low as their dependency on the natural resources are high and their social-economic conditions are low.

In Mandalgre village people are more concerned with the laws laid down by the forest department. Secondly, ecotourism is important for the local people due to various income generated along with sharing of knowledge through interaction. The least ranking has been given for wildlife and future sustainability mainly due to their direct depency on the forest resources in the area. Based on the ranking conducted the willingness of the people towards conservation varied from village to village. In Daribokgre village people are willing to conserve the area of Nokrek mainly due to the laws laid by the forest department. Secondly, since it is a famous tourist spot with the presence of Nokrek peak, the highest in the Garo hills region.

People mostly agreed for conservation from tourism point of view. Conservation of forest as a habitat for wildlife is of least concern. People seem to abide with the laws laid for mainly due to the presence of National Park around the area. For Sakalgre village the main concern of the people regarding preservation of the forest is mainly for tourism activity as income is generated followed by research purpose. Concern for wildlife and future sustainability seems farsighted as their depency on natural resources is high due to lack of alternative source of livelihood leading to poor growth in the economy of the area.

Table 9.7 Implications for protecting Nokrek Biosphere Reserve

Implications	Bandigre Village					
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank
Habitat for Wildlife	1	2	2	9	11	4
Sustainability	0	1	2	11	11	5
Research Purpose	11	9	5	3	6	1
Eco tourism	8	5	8	2	2	3
Laws governed by the wildlife department	5	8	8	3	4	2
	Mandalgre Village					
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank
Habitat for Wildlife	0	3	6	14	2	4
Sustainability	0	2	2	4	17	5
Research Purpose	9	4	6	3	3	3
Eco tourism	8	10	2	3	4	2
Laws governed by the wildlife department	8	5	9	5	2	1
	Sakalgre village					
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank
Habitat for Wildlife	1	1	5	5	13	5
Sustainability	1	0	5	11	8	4
Research Purpose	12	5	4	3	2	2
Eco tourism	9	9	5	5	2	1
Laws governed by the wildlife department	2	9	6	6	2	3
	Daribokgre village					
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank
Habitat for Wildlife	0	3	4	6	12	5
Sustainability	1	1	3	12	8	4
Research Purpose	7	7	5	3	3	3
Eco tourism	7	5	8	3	5	2
Laws governed by the wildlife department	10	9	4	3	2	1

9.6 Medicinal and timber use

Based on the total species richness, 50 species from 46 genera and 33 families having the medicinal value were found to be most widely used by the people of the study area. Of the total, 33 species are herbaceous in nature and the rest (17) are woody species (trees and shrubs). Species having the medicinal values were encountered with 24 species from the core zone and 39 from the buffer zone **(Table 9.8)**. The family Zingiberacea has the maximum of 7 species (14 %) followed by 5 species of Asteraceae (10 %), 3 species of Araceae (6%). Apiaceae, Convallariaceae, Dioscoreaceae, Phyllanthaceae, Urticaceae are of two species each. 46 genera were recorded. *Colocasia*, *Curcuma*, *Dioscorea* and *Phyllanthus* have 2 genera each and the rest are monospecific. **(Fig9.1)** Herb was the most dominant habit of plants used in the buffer zone (29 species) for the treatment of various diseases followed by trees and shrubs. Similar trend was followed in the core zone **(Fig9.2)** The most common part used for treatment was leaves for both the core (28 %) and the buffer (38 %) zone followed by bark (19 % in core and 12 % in buffer), fruit (13% in core and 10 % in buffer) and rhizome (13 % in core and 12 % in buffer). **(Fig9.3)**

More species from the buffer zone are utilized due to short distance and few can be found in their own home gardens. In core zone Araceae (4 species) was the major family followed by Zingiberaceae and Urticaceae with two species each. Altogether 41 species were having the timber values in the study area and maximum timber species (39 species) were recorded from buffer zone then the core zone (26 species) **(Table 9.9).**

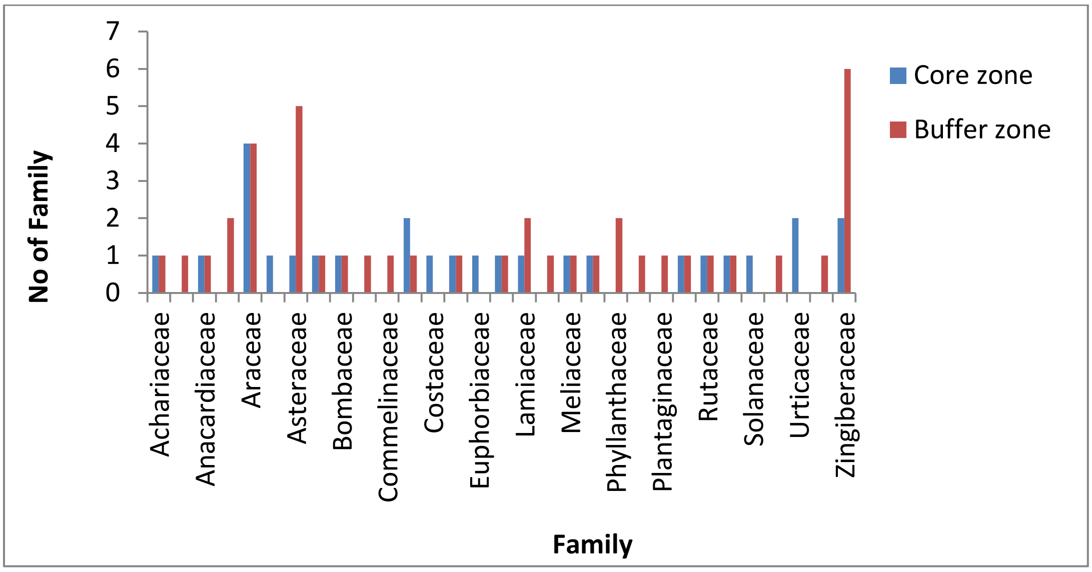


Fig.9.1 Family distribution of medicinal uses in core and buffer zone

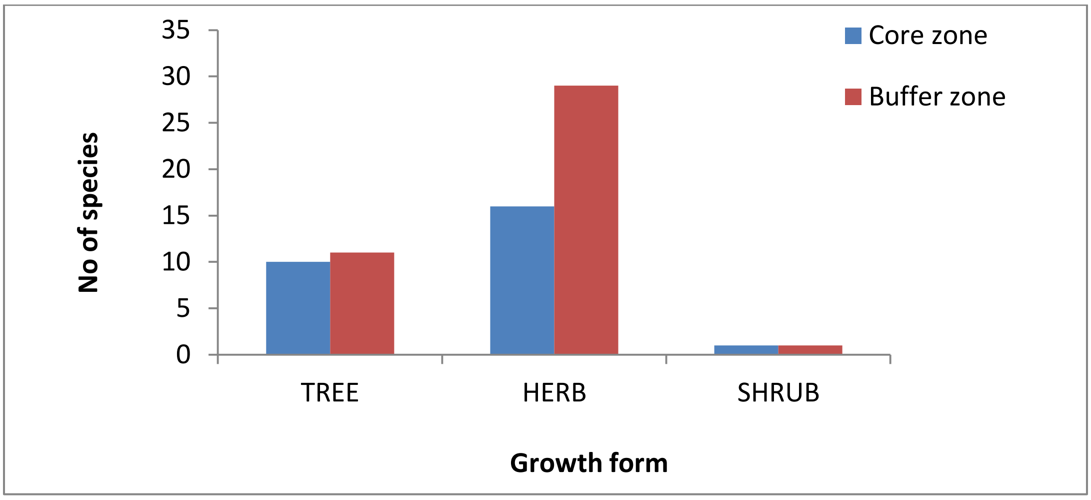


Fig9.2. Distribution of growth forms and number of species

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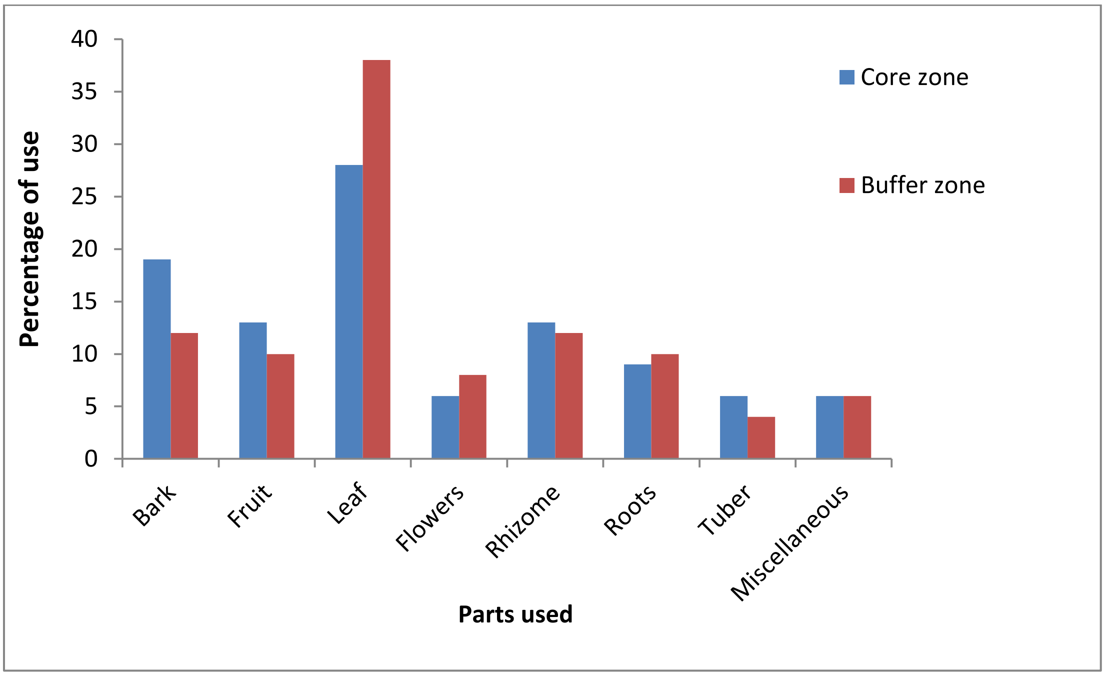

Fig.9.3 Distribution of plant parts used

Table 9.8 Species distribution, habit and parts used for ailment

Sl No	Plant species	Family	Habit	Core zone	Buffer zone	Parts used	Uses
1	*Aesculus assamica* Griff.	Hippocatanaceae	T	+	+	Fruit	Gynaecological problems
2	*Ageratina adenophora* (Spreng) R.M.King & H.Rob.	Asteraceae	H		+	Leaf	antibacterial, skin diseases
3	*Amomum maximum* Roxb.	Zingiberaceae	H		+	Seed	Toothache, indigestion
4	*Ageratum conyzoides* (L.)	Asteraceae	H		+	Leaf, root, flower, seeds	Leaf is used for curing kidney stones, juice of the leaf used for wounds and bleeding, skin diseases
5	*Allium tuberosum* Rottler ex Spreng.	Amaryllidaceae	H		+	Leaves	Decoction is used for urinary tract infection
6	*Alpinia galanga* (L.) Sw.	Zingiberaceae	H	+	+	Fruit and rhizhome	Respiratory problems, Fever, Piles
7	*Amomum subulatum* Roxb.	Zingiberaceae	H		+	Rhizhome, seeds	Wounds, nausea, smallpox, bronchitis, dysentry
8	*Anisomeles malabarica* (L.) R.Br. ex Sims	Lamiaceae	H		+	Leaves	Epilepsy, intestinal worms, arthritis, fever
9	*Arenga pinnata* (Wurmb)Merr	Araceae	T	+	+	Shoot	Psychiatric disorder
10	*Arisaema album* N.E. Br	Araceae	H	+	+	Leaf and root	Snake bite, earache, rheumatism
11	*Betula alnoides* Buch-Ham.ex D.Don	Betulaceae	T	+	+	Bark	Headache, fever

12	*Bidens pilosa* L.	Asteraceae	H		+	Leaves	mouth ulcer, stomach problems,headache
13	*Boehmeria macrophylla* Hornem.	Urticaceae	H	+		Root	Eczema and wounds
14	*Bombax ceiba* L.	Bombaceae	T	+	+	Leaves	Dysentry, Stomach ache
15	*Cinnamonum zeylanica* Breynn Pennel	Lamiaceae	T	+	+	Bark	Dysentry, digestion, antibacterial, cold, sore throat
16	*Citrus indica* Tanaka	Rutaceae	S	+	+	Outer cover of the fruit, bark	Allergic,Gastritis, Epidemic, Postpartum
17	*Colocasia antiquorum* Schott	Araceae	H	+	+	Leaves, corms	Alopecia, internal haemorrhages
18	*Colocasia esculenta* (L.) Schott	Araceae	H	+	+	Rhizome and corm	Paste used as ointment, juice of petiole as astrigent
19	*Commelina paludosa* Blume	Commelinaceae	H		+	Leaf and stem	Paste used for insect bite
20	*Costus speciosus* Koen ex. Retz.	Costaceae	H	+		Root and rhizome	Kidney stones, UTI,Snake bite,skin diseases
21	*Crassocephalum crepidioides* (Benth.) S.Moore	Asteraceae	H		+	Leaves	Headache, stomach pain
22	*Curcuma amada* Roxb	Zingiberaceae	H		+	Rhizome	Dysentry, joint pain, fractures
23	*Curcuma sp.*	Zingiberaceae	H	+		Rhizome	Rheumatism, fractures
24	*Dioscorea bulbifera* L.	Dioscoreaceae	H		+	Tuber	Piles

25	*Dioscorea sp.*	Dioscoreaceae	H	+		Tuber	Gonorrhoea, leprosy, piles
26	*Disporum cantoniense* (Lour.) Merr.	Convallariaceae	H	+		Stem	Rheumatism
27	*Dysoxylum mollissimum* Blume	Meliaceae	T	+	+	Bark	Wounds, Epilepsy
28	*Elephantopus scaber* L.	Asteraceae	H	+	+	Leaves, roots, flowers	snake bite, diarrhoea, skin diseases, bronchitis
29	*Eryngium foetidum* L.	Apiaceae	H		+	Leaf, root	Fever and stomach pain
30	*Garcinia kydia* Roxb.	Clusiaceae	T		+	Fruit	Epidemic
31	*Gynocardia odorata* Roxb	Achariaceae	T	+	+	Fruit, seed	Goitre, skin diseases, leprosy
32	*Houttuynia cordata* Thunb.	Piperaceae	H		+	Leaves	Gonorrhoea
33	*Hedychium coccinum* Smith	Zingiberaceae	H		+	Root, leaves, seed, rhizome	Tonsillitis, sprain, rheumatism, bronchitis
34	*Hydrocotyle javanica* Thunb.	Apiaceae	H		+	Leaves	Blood purifier
35	*Macaranga indica* Wight	Euphorbiaceae	T	+		Bark	Headache, dizziness
36	*Mangifera sylvatica* Roxb	Anacardiaceae	T	+	+	Bark	Gastritis, chronic cough
37	*Oxalis corniculata* L.	Oxalidaceae	H	+	+	Leaf	Fever, Stomach pain, snake bite
38	*Paederia foetida* L.	Poaceae	H	+	+	Leaves	Bruises, rheumatism
39	*Peliosanthes teta* Andrews	Convallariaceae	H	+	+	Tuber	Fever
40	*Phyllanthus urinaria* L	Phyllanthaceae	H		+	Fruit and seed	Jaundice, Gonorrhea
41	*Phyllanthus emblica* L	Phyllanthaceae	T		+	Bark	Cough, diarrhoea, gastritis
42	*Plantago major* L.	Plantaginaceae	H		+	Leaves	Wound, fever

43	*Schefflera elliptica* (Blume) Harms	Araliaceae	T	+		Bark, leaf	Headache, cough, toothache
44	*Schima walllichii* (DC)Korth	Theaceae	T		+	Bark	Urinary tract infection
45	*Scoparia dulcis* L.	Scrophulariaceae	H	+	+	Leave and plants	Eye sore, Fever
46	*Sida rhombifolia* L.	Malvaceae	H		+	Root	Fever, cough, cold
47	*Solanum sp.*	Solanaceae	H	+		Fruit	Used for cough
48	*Urtica dioica* L.	Urticaceae	H	+		Whole herb	Bleeding problems, burns and bruises
49	*Viola betonicifolia* Sm.	Violaceae	H		+	Leaves and flowers	Cough, epilepsy, blood disorder
50	*Zingiber zerumbet* Sm	Zingiberaceae	H		+	Rhizome	Tonsilitis, sprain,rheumatism

Table 9.9 List of timber species available in the core and buffer zone of study area and local uses

Sl no	Scientific name	Family	Core	Buffer	Uses
1	*Albizia odoratissima* (L.f.) Benth.	Mimosaceae		+	Construction
2	*Albizzia chinensis* (Osbeck) Merr.	Mimosaceae		+	Traditional mortar
3	*Aphanamixis polystachya* (Wall.)	Meliaceae	+	+	Construction, poles
4	*Ardisia macrocarpa* Wall.	Myrsinaceae	+	+	Poles
5	*Betula alnoides* Buch. -Ham. ex D.Don	Betulaceae	+	+	Poles
6	*Bischofia javanica* Blume	Euphorbiaceae		+	Construction, fuelwood
7	*Bombax ceiba* L.	Bombacaceae		+	Plank for construction

8	*Callicarpa arborea* Roxb.	Verbanaceae		+	Fuelwood,construction
9	*Calophyllum polyanthum* Wall. ex Choisy	Clusiaceae	+	+	Poles
10	*Castanopsis hystrix* Miq.	Fagaceae	+	+	Construction
11	*Castanopsis indica* (Roxb) D.C.	Fagaceae	+	+	Construction, poles, fuelwood
12	*Castanopsis tribuloides* (Sm.) A.DC	Fagaceae	+	+	Construction, poles, fuelwood
13	*Toona ciliata* M.Roem.	Meliaceae	+	+	Construction
14	*Cinnamonum camphora* (L.)J.Presl.	Lauraceae	+	+	Construction
15	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet	Lauraceae	+	+	Poles
16	*Cordia dichotoma* Forst	Boraginaceae	+	+	Poles, Construction
17	*Diospyros lanceifolia* Roxb.	Symplocaceae	+	+	Poles, animal traps
18	*Duabanga grandiflora (DC.) Walp.*	Lythraceae		+	Furniture
19	*Dysoxylum procerum* Hiern	Meliaceae	+		Construction
20	*Eurya accuminata* DC	Theaceae	+	+	Fuelwood, poles, Construction
21	*Glochidion gamblei* Hook.	Euphorbiaceae		+	Fuelwood
22	*Helicea robusta* wall	Proteaceae		+	Poles
23	*Ligustrum robustum* (Roxb.) Blume	Oleaceae	+		Construction
24	*Lindera heterophylla* Benth	Lauraceae		+	Construction, plank
25	*Macaranga denticulata* (Blume) Müll.Arg	Euphorbiaceae		+	Fuelwood, poles, construction
26	*Mallotus paniculatus* (Lam.) Müll.Arg.	Euphorbiaceae	+	+	Fuelwood
27	*Melia azedarach* L.	Meliaceae		+	Furniture
28	*Mesua ferrea* Linn.	Clusiaceae	+	+	Poles,fuelwood, making pestle
29	*Phoebe attenuata* (Nees) Nees	Lauraceae	+	+	Poles, construction
30	*Ocotea lancifolia* (Schott) Mez	Lauraceae	+		Construction
31	*Quercus glauca* Thunb	Fagaceae	+	+	Construction

32	*Quercus lancifolia* Schltdl. & Cham.	Fagaceae	+	+	Construction
33	*Lithocarpus elegans* (Blume) Hatus. ex Soepadmo	Fagaceae	+	+	Construction
34	*Rhus javanica* L.	Anacardiaceae		+	Poles
35	*Saurauia napaulensis* DC.	Actinidiaceae	+	+	Fuelwood, Construction
36	*Saurauia punduana* Wall.	Actinidiaceae		+	Fuelwood,construction
37	*Schima wallichii* (DC.) Korth	Theaceae		+	Construction,fuelwood
38	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	Myrtaceae	+	+	Furniture, fuelwood
39	*Terminalia citrina* Roxb.	Combretaceae	+	+	Construction, Fuelwood
40	*Toona sureni* (Blume) Merr.	Meliaceae	+	+	Construction
41	*Trema orientalis* (L.) Bl.	Cannabaceae		+	Poles, fuelwood

CHAPTER- 10

DISCUSSION

10.1 Vegetation analysis

Altogether a total of 267 species (trees, shrubs and herbs) with 186 genera and 88 families were recorded both from the core and buffer zone. Out of which 124 were trees, 66 shrubs and 77 herb species.

10.1.1 Tree species richness

In the present study, a total of 124 tree species belonging to 92 genera and 52 families was recorded from the core and buffer zone of Nokrek biosphere reserve in Meghalaya for the one-hectare area study plot. Similarly, a total of 131 tree species was recorded in forest of Garo hills with genera of 107 and 49 families (Upadhya *et al.*, 2015). Total species ranging from 159 -176 was recorded in the study conducted in various parts of Garo hills and Khasi hills (Tripathi, 2002). 160 woody species of 105 genera and 54 families was recorded which is higher in comparison to the present study (Pao and Upadhya, 2017). In a 2 ha sacred groves of Meghalaya 159 woody species was recorded (Upadhya *et al.*, 2004). In the work carried out in Southern part of Meghalaya a lesser number of 117 tree species and 98 genera and 83 species were recorded (Tynsong and Tiwari, 2011). In sub-tropical forest of West Khasi hills in Meghalaya a total of 133 species, 92 genera and 48 famililies was recorded (Mishra *et al.*, 2005) and 159 species in Jaintia hills (Uphadhya *et al.*, 2004) which are higher than the present study. The location of the study area being in one of the hot spot bio geographical location could also be one reason for the richness in species (Tynsong, 2011).

The total number of trees recorded in the core zone was 91 representing an undisturbed area and buffer zone was 82 representing the disturbed stand. Due to rough terrain and geographical condition the core zone has less accessibility compared to the buffer zone. In sacred grove of Meghalaya 80-82 species were recorded (Upadhya *et al.*, 2004). In Siju Wildlife Sanctuary of Garo hills, 67 tree species was recorded which is lower than the present study (Upadhya *et al.*, 2015). Lower species richness in secondary forest of Garo Hills has also been reported (Kumar *et al.*, 2006). 33-61 species was recorded in Reserve forest of Garo hills (Upadhya *et al.*, 2015). In Hollongapar Wildlife Sanctuary of Assam total of 75 tree species of 60 genera and 40 families were recorded (Sarkar and Devi, 2014). In the evergreen forest of Little Andaman Island where 84 tree species was recorded (Rasingam and Parathasarathy, 2009).94 tree species was observed in Namdapha National Park of Arunachal Pradesh (Nath *et al.*, 2005). In undisturbed stand 47 species, 42 genera and 28 families was recorded and in moderately disturbed stand 42 species, 36 genera and 31 families was recorded (Bhuyan *et al.*, 2003). Areas which are inaccessible are known to have higher number of species due to less disturbance and lack of accessibility. In the core zone the vegetation remains intact in its natural form whereas in buffer zone various activities like timber collection, logging are carried out leading to elimination of species. In the study of one-hectare area, Parthasarthy obtained 80-75 species ha^{-1} (Parthasarthy, 1999). The results were similar with the works done in Wet Evergreen forest of Uppangala in Central Western Ghats where 91 species were recorded in 3.12 ha (Pascal and Pelissier, 1996) but higher than the works done by (Chandrashekara and Ramakrishna, 1994) where 30 species ha^{-1} were recorded in Nelliampathy of Western Ghats and 57 species ha^{-1} were recorded in Mylodai Courtallum reserve forest (Parthasarathy and Karthikeyan, 1997). 90 tree species was recorded in 3.82 ha of Kakkachi area in Western Ghats (Ganesh *et al.*, 1996). Tree diversity of the wet evergreen forests in various parts of the world has also been recorded. In Varzea forest of Rio Xingu in Brazil 20 species ha^{-1} was recorded (Campbell *et al.*, 1992) which is lower to the present study. In Amazonian Ecuador 307 species ha^{-1} was reported (Valencia *et al.*, 1994). Rules set up by the forest officials also play a significant role in enhancing the safety of the Biosphere reserve.

10.1.2 Tree density

The tree density in the study area ranged from (733 to 1272) individual's ha^{-1} from core to buffer zone which is comparable to the works carried out in sacred groves of Meghalaya with a density of 898 stems ha^{-1} (Upadhya *et al.*, 2008). Tree density of 1256 ha^{-1} was also recorded in the study on sacred groves of Khasi hills (Mishra *et al.*, 2005) and 938- 1476 ha^{-1} in sacred groves of Jaintia hills (Upadhya *et al.*, 2004). 846 trees ha^{-1} was recorded in Siju Wildlife Sanctuary (Upadhya *et al.*, 2015). 419 trees ha^{-1} reported from Western Ghats which is lower than the present study (Ghate *et al.*, 1998). Work conducted by Upadhya in Swer and Nongkrem also showed similar stem density where it increased in the disturbed stand (954 stems ha^{-1}) than in the undisturbed stand (898stems ha^{-1}). The low density in undisturbed stand is due to increase in girth class of trees in the intermediate class (Upadhya *et al.*, 2008). In addition to the girth size, microclimatic factors like canopy, sunlight are also important for the growth of the individuals. In a study on reserve forest of Meghalaya it was found to be 560 ha^{-1}(Upadhya *et al.*, 2015). Density of 610 trees ha^{-1} was recorded in the undisturbed stand (Nath *et al.*, 2005). Stand density of 720 ha^{-1} was found in undisturbed area (Parthasarathy, 1999) which is similar to the data obtained in the present study with a density of 733 individuals ha^{-1} in the core zone. 750 individual's ha^{-1} was computed with a basal area of 58 m^2 ha^{-1} (Sarkar and Devi, 2014). High density in the buffer zone could be attributed to good coppicing mechanism of certain tree species like *Saurauria* species, *Macaranga denticulata*, *Eurya accuminata*, *Callicarpa arborea*. Mild disturbance and gap also creates a favourable environment for some species. Coppicing is one of the natural forms of regeneration in a human disturbed area (Lévesque *et al.*, 2011).

Tree density and species richness decreased with the increasing girth class of tree species. It follows a reverse J-shaped curve (Mishra *et al.*, 2005; Upadhya *et al.*, 2004).In the buffer zone the timber yielding trees are removed during clearing of the patch for jhum cultivation. Most of the species in the core zone and buffer are timber yielding species but the species in the buffer zone have been over exploited for domestic purpose by the communities. This is one of the main reasons why species are confined only to core zone but eliminated in the buffer zone. *Toona ciliata* is a major timber used for panelling, furniture and construction. *Persea odoratissima* trees are mostly used for construction of houses and furniture. The important and useful species have been used up for domestic purposes. Only few species were kept for purposefully for shade, fodder, medicinal and for extracting other Non timber forest products (NTFP) products. 47 species are common in both the stands and could be due to its ability to withstand the disturbance (Mishra *et al.*, 2005).

In the core zone, the highest tree density was observed in the girth class (121-150) cm indicating fast growth during adult stage. There were trees having gbh greater ≥ 300cm like *Dysoxylum excelsum, Drimycarpus racemosus and Terminalia myriocarpa* supporting the voluminous basal area in the core zone. But none was reported beyond 300 cm gbh in the buffer zone due to felling of trees for poles and other domestic purposes. The extraction of mature trees of huge girth has led to open spaces in the forest which has a close canopy. The canopy cover estimation ranged from (50-75) % in the core zone and (20-40) % in the buffer zone. The disturbance index was also found to be around 7 % in the core zone and around 18% in the buffer zone. As the altitude increases the accessibility and trails to reach the core zone also decreases leading to less anthropogenic disturbance.

Species like *Syzygium cumini, Castanopsis indica, Drimycarpus racemosus* with thick canopy cover aslo refrains the forest from receiving essential sunlight for the growth of the plant. The leaflets of *Castanopsis and Quercus species* also trigger erosion of seedlings in the slopes during huge rain droplets to the low lying areas. In addition, the large girth size and canopy makes the core competitive for survival of new species. This could be another reason for lesser number of individuals in the core zone. In the buffer zone, the density was highest in the lowest girth class of (30-60) cm which then reduced forming a J shaped curve (Sarkar and Devi, 2014; Mishra *et al.*, 2005; Upadhya *et al.*, 2004). In buffer zone, few species of *Castanopsis indica, Betula alnoides* was found to be > 240 cm and this could be due to preference of few species for making a refuge in the form of tree houses in the jhum patch to chase away wild animals like elephants and wild boars which visits during the harvest season. Tree density in the lowest girth glass of the buffer zone is high and this could be due to the good coppicing mechanism and favourable environment (Evans, 1992). Rarely mature trees are retained due to their less economic importance in the buffer zone. Only a very few were kept for aesthetic and medicinal purpose. Almost all mature trees >180 cm which are having economical importance are extracted from the buffer zone. The removal of mature trees gave opportunity for the trees to get adequate sunlight and survive hence more number of individuals of lowest girth class 30-60 cm can be found in the buffer zone.

In the core zone, *Syzygium claviflorum* was the dominant species whereas the genus *Saurauia* comprising of two species - *Saurauia punduana* and *Saurauia napaulensis* was the dominant species in the buffer zone. The shift in position of species could be attributed to disturbance (Singh *et al.*, 2015). Some of the species *Knema linifolia, Kydia calycina, Terminalia myriocarpa* were absent in the buffer zone owning to vulnerability of disturbance. Some of the genera of *Castanopsis* species are the keystone species and are mostly found in tropical ecosystems. They are good timber yielding trees.

The dominant family in the core zone was Lauraceae followed by Fagaceae, Euphorbiaceae and Meliaceae in the core zone. In the buffer zone Lauraceae was replaced by Euphorbiaceae. Similar results relating to shift in families and species was reported in the earlier studies in other parts of Meghalaya (Tynsong and Tiwari, 2011; Mishra *et al.*, 2005, Uphadhya *et al.*, 2004). The study area was mostly dominated by *Castanopsis indica, Syzygium species* in the core zone but in the buffer zone *Callicarpa arborea, Macaranga denticula* were the common species. Large canopy cover restricts the availability of natural light in the core zone. Most of the area of the core zone remains shady even during the day due to large canopy cover by the huge trees. Similarly, the growth of the under canopy plants also gets affected. Nutrients, rainfall and sunlight are the major factors that determine the growth of the species (Hartshorn, 1980).

10.1.3 Basal area

The basal area was recorded as 68.99 m^2 ha^{-1} in core zone to 34.16 m^2 ha^{-1} in buffer zone.In the present study, the tree density though lower in the core zone was compensated by a huge basal area. Similar findings with a basal area of 67.18 m^2 ha^{-1} were reported in Meghalaya (Upadhya *et al.*, 2015). Basal area of 42.8 m^2 ha^{-1} was recorded in a study on sacred grove of West Khasi hills (Mishra *et al.*, 2005). In the work done on the sacred groves the basal area of 58.25 m^2 ha^{-1} was computed in the disturbed stand compared to the undisturbed site 62.42 m^2 ha^{-1} (Upadhya *et al.*, 2008). It is similar to the works carried out in primary forest of the area (Upadhya *et al.*, 2015, Thapa *et al.*, 2011; Baishya *et al.*, 2009) as well as to the tropical forest ranging from 55-94 m^2 ha^{-1}. In the natural forest of Meghalaya 52.26-68.05 m^2 ha^{-1} was recorded (Tynsong and Tiwari, 2011). In tropical wet evergreen forest of Namdapha National Park of Arunachal Pradesh a basal area of 98.58 m^2 ha^{-1} was recorded in the undisturbed stand and 21.38 m^2 ha^{-1} in the moderately disturbed stand (Nath *et al.*, 2005). Work done by (Baithalu *et al.*, 2013) also showed basal area ranging from 25.14-37.5 m^2 ha^{-1}. Along with rough terrain and inaccessibility, buttressed trees and over mature trees with huge girth size are the reasons for high basal area in the core zone. Buttresses were avoided while measuring the girth of the trees. The boles are large and buttresses are formed in most of the trees in the core zone. Other factors may be due to rich and intact soil nutrients availability in the undisturbed core area with lesser number of individuals which leads to surplus absorption of nutients. In tropical wet evergreen forest of Arunachal Pradesh, basal area was high as 104 m^2 ha^{-1} in the undisturbed forest and 18.60$m^2$$ha^{-1}$ in the moderately disturbed stand (Bhuyan *et al.*, 2003).

A huge basal area was recorded in South India which is higher to the data obtained in the present study in the core zone. Basal area of the current study in the core zone of the National Park falls between the values of 61.7 to 94.64 m^2 ha^{-1} in Kalakad wet evergreen forest (Parthasarathy, 1999). 61.9 m^2 ha^{-1} of basal area was recorded in Nelliampathy which is lower than the present study (Chandrashekara and Ramakrishnan, 1994). In the tropical forests of Reunion Islands basal area of 82.67 m^2 ha^{-1} was recorded which is higher than the values obtained in the core zone of 68.99 m^2 ha^{-1} (Strasberg, 1996). Basal area ranged from 52.2 m^2 ha^{-1} - 62 m^2 ha^{-1} (Yamada, 1977).High basal area acts as a good potential for carbon sequestration and is common in primary forest (Nath *et al.*, 2005).

Composition of species in the community is attributed to the productivity, basal area and coppicing mechanism of the trees. Core zone of Nokrek Biosphere Reserve due to rough terrain, distance from the settlement and inaccessibility has no human activity through felling other than natural disturbance in the form of wind breaks which can be one of the reason for healthy growth of tree species with huge diameter and richer number of species. The areas in the buffer zone are mostly maintained by the forest department and by the members of the village. Most of the areas around the buffer zone have been set up as community reserves. From these areas selective felling of economically important species is done for domestic purposes such as construction of houses, furniture and for firewood which inturn leads to presence of individuals with lower girth size. Death of trees due to natural disturbance (diseases, lightening, storms) was observed in the core zone (Nath *et al.*, 2005). Topography plays an important role in selective cutting of trees. When the tree is removed through natural or man-made process, growth and canopy cover is reduced which can create a pathway for open forest (Smiet, 1992).

The girth class is drastically reduced in the buffer zone due to cutting of trees for domestic purposes like firewood, poles for construction and jhum cultivation after every few years. All forest in the buffer site are secondary forest. Trees with smaller girth (30-60) cm classes are mostly found in the disturbed area while large girth class (120-150) cm are found in undisturbed area. However, succession rate is higher in the disturbed site due to sufficient sunlight and less canopy. The removal of mature trees allows the saplings to regenerate. If left undisturbed the trees in the buffer zone can reach to a certain mature height. Due to constant removal by shifting cultivation there is variation in species composition in the buffer zone. The species in the buffer zone mostly consists of light demanding species. Anthropogenic disturbance alters the vegetation (Rao *et al.*, 1990).Disturbance has led to alteration of species richness in the buffer. Disturbance in the buffer zone has led to alteration in the distribution of woody species and the phytosociological attributes (Upadhya *et al.*, 2008). The basal area was almost reduced to half in the buffer zone and species like *Aesculus assamica*, *Knema linifolia*, *Magnolia baillonii* and *Terminalia myriocarpa* are completely eliminated.

Site selection was based on the crown cover using ocular estimation as well as using lux meter. The light intensity was interrupted by about 40-70 % in case of core zone while 10-30 % in case of buffer zone in general. Cut stumps were also enumerated using the field sampling. The number of cut stumps ranged from 3-7 in buffer zone and 0-1 in core zone. Cut stumps were used for calculation of disturbance index and the value ranges from 0-7 in core zone and 30-35 in buffer zone.

10.1.4 Distribution pattern

The distribution pattern was mostly contiguous (Nath *et al.*, 2005, Mishra *et al.,* 2004) following the most common nature of distribution (Odum, 1971). It could also be due to seed dispersal mechanism with the help of frugivores, ungulates, small carnivores and avifauna present in the biosphere reserve or abiotic factors like edaphic, climatic factors and social factors.

10.1.5 Diversity Indices

In the present study, Shannon diversity index (H') value of 3.81 was obtained in the core zone of Nokrek Biosphere Reserve and 3.50 in the buffer zone. The Shannon diversity index for undisturbed forest stand was 3.26 in Nonglang of Meghalaya (Upadhya *et al.*, 2008) which is lower in comparison. The diversity index was 3.7 in the work carried out by Jamir in Jaintia hills (Jamir, 2000). Shannon Diversity index ranging from 3.74-3.87 was also computed for Garo hills region (Tynsong and Tiwari, 2011).Shannon Diversity index of Siju Wildlife sanctuary was 3.87 which is slightly higher than the present study (Upadhya *et al.*, 2015). Studies on Ialong sacred grove were lower with a value of 3.42 in the undisturbed forest stand (Upadhya *et al.*, 2004). Work on the reserve forest of Garo hills falls under the range 1.84-3.54 (Upadhya *et al.*, 2015) similar to the values obtained in the buffer zone. Shannon diversity index was 3.81 in the core zone which is said to be rich according to (Kent and Coker, 1992) but is comparatively low when compared to the work done by Kacholi where the diversity index value was 4.03 (Kacholi *et al.*, 2015). The diversity is said to be relatively poor if it is below 3.5. The low Shannon diversity index in the buffer zone could be due to higher disturbance in the form of logging, encroachment, jhum activity, expansion of agricultural plantation, when compared to the core zone. Primary forests mostly have high Shannon diversity index and low Simpson dominance index in comparison to the secondary forest (Upadhya *et al.*, 2015; Thapa *et al.*, 2011).

Simpson dominance ranged from 0.03-0.05 in the present study on the buffer and core zone. Simpson dominance showed a reverse trend of 0.05 which is higher than 0.06 of undisturbed forests of Nonglang. Simpson's dominance index ranged from 0.034-0.067 in Sacred groves of Jaintia hills (Upadhya *et al.*, 2004) 0.05- 0.09 subtropical forest of Meghalaya (Upadhya, 2015) which is also higher. Simpson's dominance index was 0.02-0.04 (Tynsong and Tiwari, 2011) which is similar to the values obtained in the present study. In the study on three Reserve forest of Garo hills the values ranged from 0.04- 0.39 (Upadhya *et al.*, 2015)

The range of Evenness index in the present study was 0.79-0.85. Evenness index in Siju Wildlife sanctuary was 0.92 which is higher than the present study (Upadhya *et al.*, 2015). Evenness index of 0.78-0.83 was also reported from natural forest of Garo hills (Tynsong and Tiwari, 2011) and 0.50-0.89 in the reserve forest of Garo hills (Upadhya *et al.*, 2015) which falls under the range of the present study. In study on sacred grove of Meghalaya evenness index varied from 0.53- 0.61 which is is lower than the present study (Upadhya *et al.*, 2004). Undisturbed habitat can be one of the major reasons for higher diversity and evenness with the greater number of species. Disturbance and diversity depends on the level of impact. Management of buffer area can also impact the diversity. By understanding the indices we are aslo able to quantify diversity of the community and understand the status of the species. On the contrary some scientist argues that evenness has the probability to increase with disturbance. Structure and function of biological diversity are defined by relative abundance of species and evenness. In the meta-analysis by researchers carried out evenness increases with the level of disturbance (Svensson *et al.*, 2012).

In the core zone, significant positive correlation at 0.01 level was observed between various indices **(Table 5)**. The correlation of density and basal area was higher in the core zone (.875**) than the buffer zone (.790**) and this could be due to greater basal area in the core zone. Whereas when Shannon and Simpson index was correlated with density the buffer zone had higher value and this could be attributed to the higher density value in the buffer zone 1272 (individual's ha^{-1}). But when basal area is compared with Shannon and Simpson index the values were much higher in the core zone and this is mainly due to higher basal area and higher diversity index in the core zone. Disturbance leads to decrease in various attributes of the forest stand (Kacholi, 2013).

The diversity indices were higher in the core zone compared to the buffer zone. These could be attributed to fewer disturbances in the core zone (Tripathi *et al.*, 2010). But Simpson dominance showed a reverse trend. Absence of older trees in the buffer zone is mainly due to felling of trees by the local people for domestic purposes. Succession rate of secondary species is higher in the buffer zone due to less competition, stable elevation and sufficient sunlight. Minimal disturbance in the community leads certain species to dominate (Svensson *et al.,* 2007).

Decrease in basal area around the buffer zone could be due to cutting down of trees for timber (Zhu *et al.*, 2007). Disturbance in the form of shifting cultivation transforms the land permanently.

10.2 Soil Analysis

Soil undeniably is one among the significant non-renewable natural resource of planet earth; with soil forming the very basis of all life on the earth involved either in a direct or indirect manner (Kibblewhite *et al.*, 2007). Plants need minerals from the soil for their proper growth and function. Soil in detail is a complex system, with definable operating restrictions and a distinctive spatial structure (Bünemann *et al.*, 2018). Minerals remain in plant body while the nutrients required by the soil remains locked up. They are usually distinguished based on deviations in physico-chemical properties which are dependent on factors like the climate, source materials and topology (Kibblewhite *et al.*, 2007). Soil's major physical property which is soil structure as well as other chemical properties like pH, carbon, nitrogen, mineral etc. are factors that coincidently affect the extend of plant growth (Alhassan *et al.*, 2018). The leaf litter acts as the storage of the valuable organic carbon. Organic materials act as an important component mainly for Nitrogen. Anthropogenic disturbance has a profound impact on the overall growth and composition of the forest (Rad, 2018). Soil organic matter and nutrients has a profound impact on the vegetation of the area (Salehi *et al.*, 2005).

The soil of Nokrek Biosphere Reserve are said to be ecologically fragile (Singh and Mudgal, 2000). The area receives high rainfall. Heavy precipitation in the area creates more leaching of the soil. Protected forest area that has its core as well as buffer zone does possess variations to its plant habitations. One major reason that could attenuate to this deviation in habitation could be due to variations in soil characteristics at both zones. Hence exploring these factors are important and the major findings are discussed below.

10.2.1 Soil moisture

Soil moisture content decreased with increase in depth in both the core and the buffer zone. Monsoon season recorded the highest moisture content. Post monsoon has the lowest moisture (Devi, 2015). High moisture content may be due to lower bulk density of the soil in the core zone (Malsawmsanga, 2011). It could also be due to increase in altitude (Griffiths *et al.*, 2009).High moisture content was recorded in the monsoon season which could be attributed to rainfall and evaporation (Tiwari and Bansal, 1992). Monsoon creates a favourable environment for growth of microbes and nutrients (Kamei, 2017). Soil moisture content was higher 19-40 % than the studies conducted on the Eastern Himalayas (Yumnam *et al.*, 2013).

10.2.2 pH

Soil ph is acidic and it increases with depth (Arunachalam *et al.*, 2000). It was more acidic in monsoon. Ph of the soil was acidic in both the core and the buffer zone (Malsawmsanga, 2011) and could be due to accumulation of organic matter in the forest soil in the form of dead leaves, roots, twigs (Barbhuiya *et al.*, 2008; Saha *et al.*, 2018).

10.2.3 Bulk density

The bulk density increased with increase in depth (Kumar *et al.*, 2014). The upper layer of 0-15 cm was less compared to the lower layer of 15-30 cm which can be due to soil organic carbon. The bulk density of the soil increased from the higher to lower layer and it could be due to more compactness in the lower layer (Bhuyan, 2014; Bhuyan, 2013).

Bulk density decreased in the core zone 0.73 gm cm^{-3} to 0.482gmcm-^{3} compared to the buffer zone 0.88 gm cm^{-3} to 0.61 gm cm^{-3} which is similar to the values obtained in the study conducted in Siang district of Arunachal 0.68 g cm-^{3} to 0.80 g cm-^{3} (Yumnam *et al.*, 2013). The work done by Arunachalam, was found to be around 1.11gm cm-^{3} which is slightly higher (Arunachalam and Arunachalam, 2000) stated that <1.60 g cm^{-3} is suitable for most of the vegetation and the present study lies within the range. Bulk density was between 1.22 to 1.38 mg m^{-3} (Patel *et al.*, 2017).

10.2.4 Organic carbon

The organic carbon content with the range of 1.27- 3.27 % was similar to the work done by at the values of 2.02 % for the top soil in 0-10cm (Kumar *et al.*, 2014). It was also reported that carbon content decrease with the increase in depth which could be attributed to high decomposition of organic matter in the upper layer of the soil. Work done by (Yunam *et al.*, 2013), was slightly higher 0.32 to 3.60% than compared to the values obtained in the current study with a range of 1.27- 3.27%. It was high in pre-monsoon season followed by monsoon season which could be attributed to accumulation of decay of litter in the sampling area. The values ranged from 1.27- 3.27 % which is similar to the study conducted in the Himalayan region (Gairola *et al.*, 2012). Values of 2.30 and 2.60 % was also observed by (Sharma *et al.*, 2010). Higher carbon content was observed in top soil and this could be attributed to rich organic matter. Organic carbon was higher in the upper layer in both the stand (Bhuyan, 2014).Soil organic carbon was low in the buffer zone than the core zone and this could be due to disturbance in the form of grazing and logging in the areas (Solgi and Najafi, 2014; Barbhuiya *et al.*, 2008).

10.2.5 Total Nitrogen

Total Nitrogen range from 0.17-0.43 % was comparable to previous works. Large litter in the surface layer may be one of the reasons for high Nitrogen content in the upper layer (Gairola *et al.*, 2012). In the buffer zone Nitrogen ranged from 0.25% - 0.37 % in 0-15 cm which is similar to the result obtained as 0.30 % for 0-10 cm soil (Kumar *et al.*, 2014). Nitrogen decreased from the upper to lower layer. The upper layer has more Nitrogen content and this could be due to rich organic matter in the form of litter The range in the current study 0.17-0.43 % is higher than the works done in Arunachal with the range of 0.07-0.40 % The Nitrogen content was lowest in monsoon season and it may be due to precipitation and terrain (Yumnam *et al.*, 2013).

Total Nitrogen and carbon showed positive correlation (0.953).Total Nitrogen and Potassium also showed positive correlation (0.831) and were reported earlier (Gairola *et al.*, 2012). The positive correlation may be due to the presence of humus in the soil.Nitrogen content also gets reduced in areas where disturbance is done in the form of logging and pollarding (Gupta and Sharma, 2009).

10.2.6 Available Phosphorous

Phosphorous occurs in organic and inorganic form in nature. Availability of Phosphorous to soil is controlled by weathering and can alter the carbon phosphorous and Nitrogen-phosphorous content in the soil (Paul and Clark, 1996). Tree species plays an important role in enhancing the soil organic matter (Kamei, 2017). Available Phosphorous decreases with increase in depth despite their disturbance (Kumar *et al.*, 2014). Phosphorous is found to be higher in the lower layer of the soil which could be due to leaching in the hilly areas (Gairola *et al.*, 2012b). Nitrogen and Phosphorous also get impacted by the diversity and distribution of species (Kamei, 2017).

10.2.7 Exchangeable Potassium

The different forms of potassium exist in the soil. Exchangeable potassium is held by negative charges on clay particles. Plants use the available Potassium as well as the less readily potassium. Weathering, mineralogical factors play an important role in the availability of potassium to the plants (Tiwari and Bansal, 1992). For the proper growth of plants and microbes in the soil, exchangeable potassium and non-exchangeable potassium are important. Physical and chemical properties along with environmental conditions play a key role in availability of potassium to the plants. In agricultural lands sometimes potassium is applied artificially to enhance the production of crops. Soils of higher altitudes are known to have more potassium content and this could be due to more organic matter content through litter and dead plants.Potassium is positively correlated with Carbon. Soil properties and their relationship play an important role in distribution of minerals (Bashir *et al.*, 2016).

Vital processes in the plants like enzyme activation is done with the help of potassium. The vegetation present in the soil surface decomposes and plays an important role in the formation of nutrients. Potassium decreased with increase in soil depth (Saha *et al.*, 2018). It decreased from upper to lower layer in both the core and the buffer zone which could be linked to higher organic carbon. Potassium is found to be positively correlated with carbon and nitrogen. Potassium and pH has a positive correlation (Lalitha and Dhakshinamoorthy, 2014). Exchangeable potassium was positive correlated with organic carbon (Nataranjan and Renukadevi, 2003).

Potassium decreased from upper to lower layer in both the core and the buffer zone and could be due to wreathing of rocks or release of soluble Potassium from organic residues (Yumnam *et al.*, 2013). Potassium ranged between 102.29 - 206.22 kg/ha in the work carried out in the Himalayan region (Saha *et al.*, 2018). 325-489 kg/ha was also reported (Patel *et al.*, 2017). The physical and chemical properties of soil are impacted by the disturbance factor and season (Gairola *et al.*, 2012). Forest diversity plays a key role in controlling the physical and chemical properties of soil (Arasa-Gisbert *et al., 2018*). Effect of disturbance on soil has been studied earlier and is related to anthropogenic disturbance (Barbhuiya *et al.*, 2008; Arunachalam and Pandey, 2003). Selective felling of trees for domestic purposes in the buffer zone is one of the main reasons in altering the forest floor and decrease in mature number of trees. Carbon, Nitrogen and Potassium were higher in the core zone than the buffer zone (Barbhuiya *et al.*, 2008). Disturbance affects the nutrient status of soil (Upadhyaya and Arunachalam, 2004).

10.3 Socio-economic Analysis

Based on the study conducted it was observed that the villages in the buffer zone belong to the economically backward section. Socio economic conditions of the area determine the awareness the native people has in relation to conservation and sustainable utilization of the resources (Paul *et al.,* 2017). The livelihood of the people was marginal. The main occupation of the people was jhum cultivation which they acquired through tradition. 98% depend on jhum cultivation. Lack of development in the area impacts the economic life of the people. Literacy rate is low. Secondly, livestock farming is the source of income. The roads connecting the villages are mostly seasonal and face hardships during the rainy season. A large size family depicts the picture that there is a rapid growth in population leading to demands for more available resources and could damage the environment with more needs for settlement, food resources. This could lead to rapid loss of forest with increase in population jhum as well but since there were no better ways of alternative sources they continue to practice. Culturally also the people are attached to the age old practice of jhum as a heritage. Jhum fields also act as a seed bank and leads to multiple cropping whereas home gardens could lead to monocropping. The government provide provisions through ration cards but that alone cannot sustain the entire family.

The people of these areas also depend widely on the available wild medicinal plants as there are no pharmacies or Primary Health Centre (PHC's) available except in Mandalgre village. They also lack proper access to modern health centres hence dependency on medicinal plants is high. Only few public taps have been connected in the villages. Monsoon season causes a problem for potable drinking water along with the road and power connection. Road condition needs to be maintained. Many organic products produced from the village go wasted due to lack of proper road communication.

Encroachment, heavy lopping, human population, lack of awareness are the major anthropogenic disturbances in the area. Heavy dependency on firewood not only damages the forest areas from collection but pollution as well. The management burden on the women of the indigenous group is also very high. Collection of fuel wood leads to disturbance in the forest. Modern methods of cooking appliances and LPGs need to be introduced. Change in climate is also one factor contributing to decrease in agricultural productions which impacts the socio economic conditions of the people and management of resources. Population impacts not only the climate but also the social and economic life of the people (Arya, 2010).

Most of the population belong to young and middle age groups. Literacy is very important for awareness (Paul *et al.,* 2017). For conserving or preserving any forest the indigenous knowledge of the people living around the area is of important (Borthakur, 1992; Ramakrishnan, 1993).75% of the population are agrarians. Awareness of sustainable use of resources and sustainable living should be shared with the native people. Younger generation should be targeted for conservation programmes as they are the hope for the futures. The needs of the community should be kept as utmost priority and all schemes need to be implemented practically.

10.4 Interactions within plant communities

Forest is an important natural renewable resource essential for the survival of biotic and abiotic components (Kala, 2004). Recently, there has been reports on increase destruction in the forest leading to deforestation and fragmentation which has led to loss of species and has threatened most of the species survival (Sarma and Yadav, 2013; Singh, 2011). If the disturbance through extraction of the woody species, selective logging continues rapidly in future, it may risk the whole composition of the forest. It helps in various vital organic infrastructures supporting various life forms. Oxygen, the key source for survival of all living beings is only obtained from plants. Half of the world's species are known to exist in tropical forest of the world. Most of the keystone species are essential for the ecological balance. Economically also biodiversity is important. With the rise in temperature and climate crisis happening at a global scale, forest is one of the refuges acting as a natural carbon sink. Indigenous people living on the forest fringes depend mostly on the naturally available biological resources of the forest for their survival (Upadhaya *et al*., 2014).

A phytosociological analysis of the plant community enables us to predict the pattern of the area and helps in forest classification (Upadhaya *et al*., 2013; Ilorkar and Khatri, 2003). Plant community structures are controlled by soil nutrients, aspect, altitude and climatic conditions (Okland and Eilertsen, 1996). Availability and utilization of various minerals present in the soil is essential for a balanced ecosystem (Merila and Derome, 2008). Plant community and composition depends on factors relating to physical and chemical composition of soil edaphic factors (Salemaa *et al*., 2008). Species of the area helps to determine the nature of plant community (Bliss, 1962).

In the present study a total of 267 species were recorded both from the core and buffer zone (124 trees, 66 shrubs, and 77 herbs) with 186 genera and 88 families. Similar results were reported from a study on Siju Wildlife Sanctuary in South Garo hills recorded a total of 257 species, 213 genera and 83 families (Roy *et al*., 2014). In the three forest stands of the sacred groves of Meghalaya, a total of 132-192 species with the genera of 96-120 and a family of 63 was recorded (Mishra et al, 2004) which is lower. 395 vascular plants, 250 genera and 84 families were recorded in sacred groves of Jaintia hills (Jamir and Pandey, 2003). 125 plant species, 94 genera and 54 families constituting of 99 trees, 16 shrubs 10 were climbers were recorded in Khasi hills of Meghalaya (Upadhya, 2015). In the North eastern states of Arunachal Prasdesh, 200 species comprising of 94 trees, 45 shrubs and 61 herbs with 73 families was recorded (Nath *et al*., 2005). In the tropical forest of Assam, 145 plant species (90 trees, 18 shrubs and 26 herbs) along with 11 lianas and climbers with genera of 112 and 59 families were found (Dutta and Devi,2017). Total of 166 species (80 trees, 20 shrubs, 66 herbs) with genera of 136 and 63 families was also reported from the tropical reserve forest of Assam (Dutta and Devi, 2013).

In the core zone alone, total of 169 species were identified and 185 species in buffer zone which includes trees, shrubs and herbs were found in the present study on the Nokrek Biosphere Reserve of Meghalaya. The number of species was maximum in the buffer zone (82 trees, 51 shrubs and 52 herbs) due to increase in number of understory species (shrubs and herbs). The core zone stand was mostly dominated by trees (91) followed by herbs (44) and shrubs (34).

For tree species, 44 number of species like *Aesculus assamica, Magnolia baillonii* and *Aphanamixis polystachya* are found only in the core zone, 35 species in the buffer zone namely *Macaranga denticulate, Duabanga grandiflora, Lagerstroemia parviflora etc.*. 47 number of species were common to both the stands namely *Saurauia napaulensis, Mesua ferrea, Mallotus paniculatus etc*. For shrubs 18 are found in core zone, 33 are confined to buffer zone and 15 are common to both the core and buffer zone. In case of herbaceous species, 25 are found in core zone, 33 are confined to buffer zone and 19 are common to both the core and buffer zone. Work on plant diversity and the level of disturbance has been attempted by various workers in Meghalaya (Mishra *et al*., 2004; Mishra *et al*., 2003; Upadhyya 2015; Barik *et al*., 1996; Khan *et al*., 1987; Roy *et al*., 2014) as well as in other North eastern regions (Bhutia *et al*., 2019; Gogoi and Sahoo, 2018).

Trees have the higher number of species (124) followed by herbs (77) then shrubs (66). Herbs had the highest stand density (889-914 per 100 m^2) followed by shrubs (1428-3756 individual's ha^{-1}) and then trees (733-1272 individual's ha^{-1}) Moderately disturbed areas are said to be suitable for the growth of herbaceous vegetation and shrubs creating a stable community (Bhuyan *et al*., 2003) but increased degree of disturbance reduces the growth (Mishra *et al*., 2004). Shrubs are mainly used for fuelwood by the farmers and local people and are mostly found in abandoned jhum land and boundaries of settlement areas. They are fast growing species because of their good coppicing ability. Shurbs helps in binding the soil and retains the quality of the soil. It is mainly used as fodder and fuelwood and serves various medicinal purposes (Thakur *et al*., 2017). For the herbaceous species, the species present in core zone appeared to have greater ecological amplitude with respect to disturbance.

On other hand, the species absent in buffer zone appear to be more vulnerable to disturbance. The normal diversity-distribution curves for species and family indicate stability and complexity of community. The earlier workers (Laloo *et al*., 2006, Mishra 2012, Mishra and Jeeva, 2012; Mishra and laloo, 2006; Mishra *et al*., 2003, Mishra *et al*., 2004, Mishra *et al*., 2005) have also reported a similar trend in results from the sacred groves and sub-tropical forests of Meghalaya, North East

India. The work is also in conformity conducted in other North Eastern states (Sangma and Mishra, 2017; Singh *et al*., 2015).

The tree density (733 individual's ha^{-1}) was less in the core zone but it was compensated with a large basal area (68.99 m^2 ha^{-1}) whereas in the buffer zone the tree density was high (1272 individual's ha^{-1}) but the basal area was low (34.16 m^2 ha^{-1}) following a reverse J-shaped curve (Dutta and Devi, 2013). High density was observed in the lower girth class (30-60) cm for both the core and the buffer zone but highest basal area was observed in the middle girth class (121-150) cm for core zone and (30-60) cm girth class in the buffer zone. Basal area tends to get reduced with degree of disturbance (Uniyal *et al*., 2010). Higher density in lower girth classes depicts the growth of the forest (Sarkar and Devi, 2014; Sahu *et al*., 2012). Log normal distribution curve was observed in both the stands with a shorter hook for the buffer zone representing disturbance (Mishra *et al*., 2005).

The core zone has more number of mature trees like *Dysoxylum excelsum, Drimycarpus racemosus and Terminalia myriocarpa* with a girth class greater than 300cm. In buffer zone, trees of lower girth class were high in number representing good coppicing mechanism of trees like *Helicia nilagirica, Callicarpa arborea Duabanga grandiflora, Schefflera elliptica, Saurauia punduana* and *Saurauia napaulensis.*

But as the girth class increases the basal area decreases mainly due to anthropogenic activities. In the core zone the basal area is almost double when compared to the buffer zone. This could be due to formation of the primary forest. These areas act as natural carbon sink and would help in carbon sequestration. The buffer area is low in basal area mainly because of selective felling and lopping. Close canopy in the core zone makes the environment more favourable for tree species to survive along with a rich soil nutrients compared to the higher number of species of shrub and herbs in the buffer zone with an open canopy. Germination of seeds for growth and regeneration of species are more suitable in undisturbed areas than to the disturbed areas in the buffer regions (Arya and Ram, 2011). In the core zone the shrubs and herbs are reduced in density owing to deficient sunlight.

With the process of repeated felling rotation over a period of years for jhum activity the trees in the buffer zone are small in their girth class. Trees with low girth class are removed but certain species like *Betula alnoides* and *Drimycarpus racemosus* are retained because of their medicinal, economical importance or mythical believes. Few of the important trees present were *Castanopsis indica, Betula alnoides* in the core zone and *Toona ciliata* and *Quercus glauca* in the buffer zone. Shrubs and herbs thrive well in mildly disturbed sites. Shrub species like *Phlogacanthus curviflorus, Rauvolfia serpentina* and *Citrus indica* are the dominant species in the core zone and *Rhynchotechum ellipticum, Rubus ellipticus, Clerodendrum infortunatum* in the buffer zone. Sunlight and mild disturbance with less number of mature trees favoured their growth. Mild disturbance through anthropogenic activities has led to alteration and fragmentations of the forest in the buffer zone (Tripathi *et al.*, 2010). This has paved a way for more survival of shrubs and herbs compared to the core zone.

For shrubs, *Phlogacanthus curviflorus* was the species with highest IVI (25.06) and *Grewia nervosa* (0.93) the lowest in the core and Rhynchotechum ellipticum (33.14) was highest and *Citrus maxima* (0.45) was the lowest in buffer zone. Species with the highest importance value index values has better ecological amplitude for their survival (Mishra *et al*., 2004). In order to maintain the species diversity, the species with low IVI should be protected to prevent elimination from the plant community. Species density and diversity varies with rainfall, climatic and edaphic factors (Dutta and Devi, 2013).

The dominant family for trees was Lauraceae followed by Euphorbiaceae and Fagaceae which was also found by other reserachers (Shankar and Tripathi, 2017; Upadhya 2015; Bhutia *et al*., 2019; Singh and Singh, 2016; Upadhya *et al*., 2004) Acanthaceae Lamiaceae Rutaceae are the dominant families for shrubs. Asteraceae, Urticaceae, Zingiberaceae are the dominant families for herbaceous species (Nath *et al*., 2005). Family dominance decreased in the disturbance and this was reported by various workers (Mir and Upadhya, 2017; Singh *et al*., 2015).

Diversity of the area is mainly defined by the species richness, evenness index (Alatalo, 1981). In the present study the Shannon diversity index (H') was found to be inversely proportional to dominance index (CD) (Pande *et al*., 2002; Magurran, 1988). Shannon diversity Shannon diversity index (H') varies from 3.5-3.81 for tress, 3.24-3.25 for shrubs and 3.1-3.21 for herbs. Contagious distribution is most common type of distribution in comparison to regular and random (Odum, 197; Barik *et al*., 1996, Panchal and Pandey, 2004). It could also be due to seed dispersal mechanism (Upadhaya *et al*., 2004; Laloo *et al*., 2006). Gap formation in the forest mainly occurs through death of large trees through natural disturbances like uprooting of age old trees, lightning, and diseases.

This creates a favourable environment for growth of seedlings (Richards, 1996). The ecology of the forest is influenced by the soil and vegetation (Parfitt *et al*., 2005). Microbial activity, weathering and vegetation of the area predict the soil nutrient cycling process (Liebig *et al*., 2004).

10.5 Impact of Vegetation Loss on Consistent Status of Soil

Soil is important medium for survival of plants and their growth (Shameem and Kangroo, 2011). Roots of various plant forms are important in the hydrological cycle of the area. Environmental conditions, micro-organisms, and chemical characteristics of litter are major factors which governs the decomposition process in the forest floor (Berger and Berger, 2012). The physical and chemical properties of the soil are controlled by the organic matter present in the forest floor (Das *et al*., 1980). The debris prevent the soil from splash erosions in the slope, raindrops from trees with large leaves also creates erosion in the slopes. For a complete ecological balance soil and plant relationship is important.

Chemical properties of soil like Carbon, Nitrogen, pH and Phosphorous are the major factors influencing the understory vegetation (Kumar and Kumari, 2019). Phosphorous is obtained mainly through weathering off rocks (Vitousek *et al*., 2010). Nitrogen and Phosphorous are major soil nutrients for the growth of plants (Augusto *et al*., 2017). Increase in soil nutrients is mainly due to the debris present in the forest floor (Shameem and Kangro, 2011). The lower layer had less nutrients compared to the upper layer (Sarkar, 2011). Vegetation of the area determines the carbon content of soil (Zhao *et al*., 2016) Roots and biomass also helps to enrich the soil organic carbon. Nitrogen and soil organic carbon have been known to influence each other. Upper layers of the soil are known to have alterations through different land use systems compared to the deeper layers of soil horizon (Harrison *et al*., 2011).

Seasonal variations alter the characteristics of the soil and diversity of the plant species in terms of herbs. Dry climatic conditions reduce the growth of the species and in turn the diversity also decreases.Edaphic factors along with microclimatic conditions alter the quantitative parameters of the vegetation (Shameem and Kangroo, 2011). Herbaceous plants with their good nitrogen fixing ability help the soil to retain moisture and nutrients like Nitrogen and Carbon have positive correlation. In forest understory most species are light demanding hence shrubs and herbs were mostly found in the buffer zone whereas shade tolerant species have the ability to survive in both the buffer and core zone where sunlight is deficient.

The soil was found to be more disturbed in the buffer areas mainly due to practice of shifting cultivation and lack of mature trees with large canopy cover has led to exposure of soil and reduced the moisture content. Being in the hilly terrain the area is also prone to landslides and erosion (Yadav *et al*., 2012; Kumar *et al*., 2012; Pakrasi *et al*., 2014). Proper conservation measures need to be introduced to maintain the soil-plant relationship. Roots present in the soil also helps in retaining the water and stabilizes cycle of nutrients in the forest ecosystem preventing from erosion, floods and retaining the water from drought.

10.6 Impact of fringe area dwellers on vegetation and soil

From the socio economic survey conducted in the four villages it could be ruled out that the dependency on the forest resources for survival is high. To keep the forest intact, alternative sources of livelihood and sustainable ways of living need to be adopted and encouraged to the people of the fringe villages. The dependency on the natural forest resources needs to be reduced. Mature trees should be preserved as they not only increase the forest canopy cover of the area but also protects the forest from windbreak and act as shelterbelts. Plants of angiosperm origin also help in pollination of bees which is important for survival of species. It also acts as natural noise barriers. Trees are known to absorb water through their root systems reducing run off. Besides these, it also helps in maintaining the nutrients of the soil. As forest alone cannot survive the physical and chemical nutrients of the soil also needs to be maintained. Mild grazing was also observed. Developmental activities in the buffer zone in the form of check dams, expanding roads and cutting of soil for settlement purposes has damaged the landscape and composition of these areas. Low moisture, Carbon and Nitrogen was found in the study conducted on soil. Anthropogenic activities through timber and non-timber forest product collection also affect the forest soil and vegetation (Singh *et al*., 2009).

The Garo tribes residing in the fringe areas of the Biosphere Reserve are tribal people whose livihood, culture and ethnicity are connected deeply with the resources of the forest and jhum activity. They are culturally embedded into this ancestral and traditional practice of jhumming (Momin, 1995; Yadav**,** 2012; Kumar *et al*., 2006, Prabhu, 2010). Clearing of forest for shifting cultivation and then for plantation of economically important species transforms the primary forest into \agroforestry sites (Tripathi *et al*., 2010; Nandy and Das, 2013).

50 species belonging to 46 genera and 33 families of which 17 are woody species (trees and shrubs) and 33 are herbaceous species have been found from the core and buffer zone. Works on medicinal plants and wild edible plants have been also documented in the region (Singh and Borthakur, 2011). For domestic purposes the timbers were mainly obtained from the buffer zone. Study also results that timber species were aslo utilized for other purposes – fuelwood, construction materials like door, windows, table, and pole by the locals than the timber species. Hence all the mature timbers have been removed and only few of the young trees are left or species serving medicinal or fruit bearing trees like *Castanopsis indica*, *Betula alnoides* has been retained (Singh and Debnath, 2008). From the comparative studied carried out in the core zone **(**undisturbed site) and buffer zone (disturbed site) it was observed that the forest in the core area has remained intact and undisturbed mainly due to terrain and inaccessibility (Upadhaya, 2015) whereas the buffer zone seems to be mildly disturbed due to various anthropogenic activities. This has led to decrease in

number of mature trees and species and has given opportunity for increase growth of understory vegetation like shrubs and herbs (Mishra *et al*., 2005; Nath *et al*., 2005).

The work carried out gives the idea about the intensity of disturbance through anthropogenic activities and the measures that needs to be taken for conservation of the primary forest and the forest patches left in the buffer zone. Findings of the quantitative study of vegetation along with physical and chemical properties of soil depicts that the forest is mildly disturbed in the buffer zone. If human activities are under rapid activity, it would create a risk in the future. The secondary forest in the area would also lead to permanent agroforestry systems losing the primary vegetation.

CONSERVATION STRATEGIES

Based on the field work, personal interaction with the native people and various departments the following recommendations are being made for conservation and management of the Nokrek Biosphere Reserve-

Management of the Catchment Area: In the buffer zone plantation of tree species- *Aphanamixis polystachya, Castanopsis indica, Terminalia myriocarpa, Syzygium claviflorum, Saurauia napaulensis, Aesculus assamica* etc. would help in soil infiltration and groundwater recharge.

Restoration of Forest- Establishment of community (supply forest) adjacent to the core zone can reduce pressure on vegetation. Having only the buffer zone may not be enough to keep the forest intact, hence protective buffer area in the form of community reserves is essential to establish in all the villages which lie at the buffer zones of the biosphere reserve. Restoration of forest in the buffer zone with suitable species can be implemented. Restoration of the degraded areas should be done through planting of native species in the gaps. Species attractive to frugivore should be planted to encourage seed dispersal and also species forming mutualistic relationship with animals to enhance wildlife population. Nitrogen fixing species can be planted to improve soil fertility. Economically important and fast growing species can also be grown more widely to provide economic goods.

Strengthening Indigenous Knowledge- Integration of traditional and formal science and launching of integrated management approaches involving Government institutions, NGOs and indigenous tribal community settled in buffer areas of Nokrek Biosphere Reserve. The indigenous people can be rewarded and credited by the Government for their unique knowledge on ethno-medicinal plants, for more effective ‘Traditional Knowledge System’.This may encourage young generation to continue the tradition, which may lead to biodiversity conservation on sustained basis.

V**egetation Conservation and Soil Restoration-** While clearing of forest is done for developmental purpose norms of Environmental Impact Assessment needs be followed. Since soil disturbance through erosion, landslide is common in the hilly region the fallow period can be increased for the soil and vegetation to get replenished. To prevent such disturbance implementation of proper protection measures to facilitate natural regeneration in buffer zone is necessary. Shifting cultivation in the periphery of the rivers up to certain metres needs to be monitored. Dependency on forest products can be reduced with alternative measures. Equal importance needs to be given to the core as well as buffer zone.

Settiong up of Divisonal Forest Office- Presently, the Northern zone of the Biosphere Reserve is being handled by the Divisional Forest Office, East and West Garo hills Wildlife Division at Tura, West Garo hills, Meghalaya. For the people residing in East Garo hills it would have been more commutable if the office was set up in the headquarter of the concerned district.

Proper Implementation of Environment Conservation Laws- Sign board pertaining to laws and regulations needs to be upgraded. The native people residing in the villages of the buffer zone should be made aware of the rules and regulations on conservation of the biosphere reserves and national park through workshop programmes. Volunteers set up among the communities would help in preserving the areas and could keep a check on the illegal activities and report to the concerned authorities. Extraction of resources like canes, NTFP's, logging can be minimized in the buffer zone.

Encouragement of Tourism: Local people of the area should get short term trainings to guide the tourist visiting the area. Training on segregation of waste needs to be introduced in the village. Eco friendly materials like solar panels, biodegradable containers and recycling of waste needs to be introduced in the village. The entry of tourist should also be monitored without exceeding the carrying capacity.

Priority to Socio-Economic Values: Educational institutions and various other infrastructures like road, Primary Health Centre's needs to be upgraded in the area. Livestock farming and direct sell of organic products obtained from cultivation can be encouraged in the area. Use of firewood can be replaced by LPG or electric cooking appliances lowering their dependency on fuelwood.

SUMMARY AND CONCLUSIONS

The present investigation was carried out on the topic entitled "*A study on effect of anthropogenic disturbance on diversity, distribution and community characteristics of plants in the Nokrek Biosphere Reserve of Meghalaya, India*" with the objectives: (i) To determine plant community characteristics, diversity and distribution of plant species in core zone and buffer zone of the Nokrek Biosphere Reserve, (ii) To assess the impact of anthropogenic activities on vegetation, and (iii) To formulate appropriate strategies for biodiversity conservation and management of Nokrek Biosphere Reserve. For vegetation analysis, one hectare area was taken separately for both the core and the buffer zone. 10x 10 m was taken for tree species, 5x5 for shrubs and 1x 1 for herbaceous species. For trees (cbh≥30 cm) was taken. The gbh was measured at a height of 1.37m. For identification the plant samples were taken to Botanical Survey of India, Shillong. The updated version of classification of the plants was followed from the online websites of the Plant List (Version 1.1) and the International Plant Names Index (IPNI). Specimen identification was done with the support of pictures, photographs and old records. IBM SPSS Statistics 23 was used to find out the correlation between various plant indices. To understand the impact on vegetation on soil constituent, the physicochemical properties of soil from selected sites were also studied for moisture content, pH, bulk density. The chemical characteristics like organic carbon, Nitrogen, Phosphorous and Potassium were also tested. The socio-economic survey was carried out to understand the socio economic impact on bio-physical. The methods for management and conservation were formulated.

The major findings can be summarized as below

Overall, a total of 267 species (trees, shrubs and herbs) with 186 genera and 88 families were recorded both from the core and buffer zone.

I. Vegetation analysis of Tree species

1. Altogether a total of 124 tree species belonging to 92 genera and 52 families were recorded from both sites of the core and buffer zone of Nokrek Biosphere Reserve.
2. The tree richness was (91 species, 67 genera and 40 families) in the core zone which is higher than the richness in the buffer zone (82 species, 66 genera and 42 families).
3. The tree density was 733 (individuals ha^{-1}) for core zone and 1272 (individuals ha^{-1}) for the buffer zone.
4. The basal area was 68.99 (m^2 ha^{-1}) in the core zone and 34.16 (m^2 ha^{-1}) in the buffer zone.
5. In the core zone, the family Lauraceae was the dominant family followed by Fagaceae whereas in the buffer zone Lauraceae was the co-dominant family and Euphorbiaceae was the most dominant family.
6. The dominance diversity curve based on IVI was found to be short for the tree species in the buffer zone indicating mild disturbance and instability.
7. *Castanopsis* was the largest genus having the maximum number of species in the core zone whereas in the buffer *Ficus* was the dominant genus.
8. In the core zone, the highest basal area was observed in (121-150) cm gbh class. But in the buffer zone highest basal area was found in (30-60) cm gbh class.
9. In the core zone, *Syzygium claviflorum* has the highest IVI (27.87) whereas in the buffer zone *Saurauia punduana* has the highest IVI (29.25).
10. The co-dominant species were *Macropanax dispermus* (IVI 19.57) and *Castanopsis indica* (IVI 16.11) in the core zone whereas in buffer zone *Saurauia napaulensis* (IVI 22.09), *Eurya accuminata* (IVI 19.40).
11. *Eurya accuminata* and *Terminalia citrina* were the most abundant species in the core zone and *Helicia nilagirica* and *Saurauia napaulensis* in the buffer zone.
12. *Syzygium claviflorum* has the highest basal area (8.40 m^2 ha^{-1}) followed by *Macropanax dispermus* (4.89 m^2 ha^{-1}) and *Castanopsis indica* (4.07 m^2 ha^{-1})

in the core zone and *Castanopsis indica* has the highest basal area of (3.73m^2 ha^{-1}) followed by *Saurauia napaulensis* (2.64 m^2 ha^{-1}) in the buffer zone.

13. In the core zone 98% species exhibited contiguous distribution pattern and 2% were randomly distributed. In the buffer zone, 95% species exhibited contiguous distribution pattern and 5% of the species were randomly distributed. *Macropanax dispermus* and *Ocotea lancifolia* showed random distribution in the core zone and *Callicarpa arborea*, *Eurya accuminata, Glochidion daltonii* and *Schefflera elliptica* in the buffer zone of Nokrek Biosphere Reserve.
14. Shannon diversity indices (H') were higher in the core zone (3.81) than the buffer zone (3.50).
15. Simpson dominance index (CD) followed a reverse trend with the values being lower at the core zone (0.03) and higher at the buffer zone (0.05).
16. Evenness index (E) was greater in the core zone (0.85) than in the buffer zone (0.79).
17. Margalef index of species richness was higher in core zone (13.64) than the buffer zone (11.33).

II. Vegetation analysis for Shrubs

1. Total of 66 shrub species belonging to 63 genera and 30 families of angiosperm was recorded from the sampled area of core and buffer zone of Nokrek Biosphere Reserve.
2. The shrub species richness was 34 species, 28 genera and 18 families in the core zone which is lower than the buffer zone (51 species, 35 genera and 28 families).
3. The shrub density was 1428 (individuals ha^{-1}) for core zone and 3756 (individuals ha^{-1}) for the buffer zone.
4. In the core zone, *Phlogacanthus curviflorus* had the highest IVI (25.06) whereas in the buffer zone *Rhynchotechum ellipticum* had the highest IVI (33.14.)

5. The dominant species was *Phlogacanthus curviflorus* (IVI- 25.06) with density 192 (individuals ha^{-1}) in core zone and *Rhynchotechum ellipticum* (IVI- 33.14) with a density of (812 individuals ha^{-1}) in buffer zone.
6. The dominant family in the core zone was Acanthaceae and is replaced by Lamiaceae in the buffer zone.
7. The Shannon diversity index was found lower in the core zone (3.24) than in the buffer zone (3.25).
8. Simpson dominance index showed a reverse trend in result and value was low in core zone (0.05) than the buffer zone (0.07).
9. The Margalef's index of species richness was also found to be lower in the core zone (5.04) than in the buffer zone (7.30).
10. Higher evenness index value of 0.22 was found in core zone and 0.83 in buffer zone.

III. Vegetation analysis for Herbs

1. Total of 77 herbaceous species belonging to 63 genera and 38 families of angiosperm was recorded.
2. The herb species richness was 44 species, 34 genera and 23 family in the core zone which is lower than the buffer zone (52 species, 44 genera and 29 families).
3. Herb density in the core zone was 889 (individuals per 100 m^2) and 914 (individuals per 100 m^2) in the buffer zone.
4. *Elatostema sessile* was the most dominant species (IVI- 40.48) with density of 247 (individuals per 100 m^2). In buffer zone, the dominant species was *Pteris quadriaurita* (IVI 35.47) with density of 212 (individuals per 100 m^2).
5. Urticaceace, the dominant family in the core zone was replaced by Asteraceace in buffer zone.
6. The Shannon diversity index was lower in the core zone (3.10) than in the buffer zone (3.21).

7. Simpson dominance index showed a reverse trend and the values was higher in the core zone (0.10) than in buffer zone (0.08).
8. The Margalef's index of species richness was lower in the core zone (6.33) than in the buffer zone (7.48)
9. Evenness index (0.82) was same for both the zones.

IV. Soil analysis

1. Soil moisture content in the core zone varied from 26 to 40 % in 0-15cm and 22.5 % to 34 % in 15-30 cm. In the buffer zone, it varies from to 21 -35 % in 0-15cm and 19-33 % in 15-30 cm. Moisture content was more during the monsoon season (July to August).
2. pH ranged from 5.2-6.8 in the upper layer and 5.0-6.7 in the lower layer in the core zone whereas in the buffer, the pH ranged from 5.2-6.7 in 0-15cm and 5.3-6.8 in 15-30 cm soil depth. The pH of the soil was acidic in the monsoon season.
3. In the core zone the bulk density ranged from 0.482-1.077 gm cm^{-3}.In the buffer zone, the range was from 0.61- 1.10 gm cm^{-3}.
4. Carbon content values in the core zone ranged from 2.28-3.27 % in the upper layer and 1.36-2.3 % in the lower layer mainly due to the presence of humus and slow process of decomposition. In the buffer zone the values ranged from 1.96-2.95 % in 0-15cm soil layer and 1.27-2 % in the lower layer of 15-30cm. It was high in pre-monsoon season followed by monsoon season.
5. Nitrogen in the core zone ranged from 0.3-0.5 % and 0.22-0.43 % in the soil depth of 0-15 and 15-30 respectively. In the buffer zone, the Nitrogen ranged from 0.25-0.37 % in 0-15 cm soil depth and 0.17-0.23 % in 15-30 cm depth. The Nitrogen content was highest in pre monsoon season.
6. The available Phosphorous varied from 1.56 ppm – 3.06ppm in the soil depth of 0-15cm and 1.1ppm – 2.83ppm in the depth of 15-30cm.In the buffer zone, it varies from 1.1ppm-3ppm in the upper layer and 0.8ppm-2.46ppm in the sub soil. The maximum reading was recorded in post- monsoon season.

7. In the core zone, the range of exchangeable potassium varies from 168-382.65 kg/ha in the upper layer and 70.93-121.33 kg/ha in the lower layer. It decreased from upper to lower layer in both the core and the buffer zone. In buffer it ranged from 149.33- 280 kg/ha and 112-242.67 kg/ha in both the depths. It was highest during the pre-monsoon season.

V. Socio economic analysis

1. From the household survey in four villages 31% was found to be illiterate with 71 % of the respondents having large family size and majority of them were cultivators.
2. The entire village falls under the below poverty line. 80% of the respondents earn their livelihood from jhum cultivation. 75 % of houses are made out of raw materials available from forest. Major source of fuel is firewood. Species such as *Callicarpa arborea, Macaranga denticulata, Eurya accuminata* are the favorable species.
3. The standard of living is poor with limitations to basic necessities like lack of road connectivity, drinking water,school infrastructure and health centers.
4. The area has high potential for development of tourism. Few tourist areas have been set up and it is another way to earn revenue for the native people of the area. Proper management and demarcation of the areas will help to improve their living conditions through tourism industry.
5. Many traditional healers were also found in the area. Tapping of their knowledge through documentation and awareness programmes will be beneficial both for the society and from conservation perspective.
6. Out of the total of 50 species, 46 genera and 33 family listed in medicinal uses, 33 are herbaceous species and the rest 17 are woody species (trees and shrubs) were found to be most widely used by the people in the village.
7. Altogether 41 species were having the timber values in the study area and maximum timber species (44 species) was recorded from buffer zone then the core zone (28 species).

VI. Impact of disturbance on plant communities and soil

1. The forest in the core zone **(**undisturbed stand) remained intact and undisturbed mainly due to terrain and inaccessibility. In the buffer zone (disturbed stand) mild disturbance due to various anthropogenic activities has led to decrease in number of mature trees and species and has paved opportunity for increase growth of understory vegetation like shrubs and herbs.
2. Tree species like *Aesculus assamica, Magnolia baillonii* and *Aphanamixis polystachya* are found only in the core zone whereas in the buffer zone mainly *Macaranga denticulata, Duabanga grandiflora, Lagerstroemia parviflora.* Few species were common to both the stands namely *Helicia nilagirica, Mesua ferrea, Mallotus paniculatus.*
3. Shrub species like *Phlogacanthus curviflorus Rauvolfia serpentina Citrus indica* are the dominant species in the core zone and *Rhynchotechum ellipticum, Rubus ellipticus, Clerodendrum infortunatum* in the buffer zone.
4. Herbaceous species like *Urtica dioica, Elatostema sessile* are the dominant species in the core zone and *Molineria latifolia, Pteris quadriaurita* in the buffer zone.
5. Soil was found to be more disturbed in the buffer areas mainly due to practice of shifting cultivation and lack of mature trees with good canopy cover causing exposure of soil reducing the moisture content.
6. From the socio economic survey it was found that the dependency on the forest resources for survival is high. Activities through timber and non-timber forest product collection have affected the forest soil and vegetation in the buffer zone. Construction of check dams, expanding roads and cutting of soil for settlement purposes has damaged the landscape and composition of these areas.
7. The settlements in the fringe areas are the Garo tribes and are culturally embedded into this ancestral and traditional practice of shifting cultivation. All mature timbers have been found to be removed and left as a fallow land in the buffer zone.

8. Conservation measures have been suggested for the conservation and management of the forest in the area and to minimize their direct dependency.

The findings of the quantitative study of vegetation along with physical and chemical properties of soil depicts that the forest is mildly disturbed in the buffer zone. The areas in the core zone remained undisturbed except for natural disturbances. If human activities are under rapid activity it would create a risk in the future. The secondary forest in the area would also lead to permanent agroforestry systems losing the primary vegetation. The research work carried out will help to formulate appropriate conservation strategies for the plant community of the area as well as to understand the alterations that have occurred in the soil status. The socio economic conditions help to understand the reliability of the fringe dwellers in the buffer zone. The suggestive conservation strategies for present scenario for proper management of the vegetation of the Nokrek Biosphere reserve may include- strong protection measure and plantation in the gaps with suitable species in the buffer zone. Moreover, integrated management approach involving local community, NGO`s and scientists may be more effective tool for conservation of plant resources of the reserve on sustained basis.

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a. Callicarpa americana

b. *Citrus indica*

c. Engelhardia spicata

d. *Alpinia galanga*

Photo plate 1: Flora of Nokrek Biosphere Reserve

e. Ehretia acuminata

f. Castanopsis indica

g. *Reevesia thyrsoidea*

h. *Gleditsia assamica*

Photo plate 2: Flora of Nokrek Biosphere Reserve

h. *Molineria latifolia*

i. *Rauwolfia serpentina*

j. *Melastoma malabathrichum*

k. *Rubus ellipticus*

l. *Curcuma amada*

m. *Costus speciosus*

Photo plate 3: Flora of Nokrek Biosphere Reserve

a. Betula alnoides

b .Aesculus assamica

c. Gleditsia assamica

d. *Knema linifolia*

Photo plate 4: Tree species of Nokrek Biosphere Reserve

Photo plate 5: A- Measurement of girth of trees. B- Herbarium collected from the field. C- Mounting of species in the herbarium sheet (*Pelisanthes teta*). D- Soil test carried out in District and Local Research Station and Laboratories, Department of Agriculture, West Garo Hills.






Photo plate 6: Non Timber Forest Products of Nokrek area

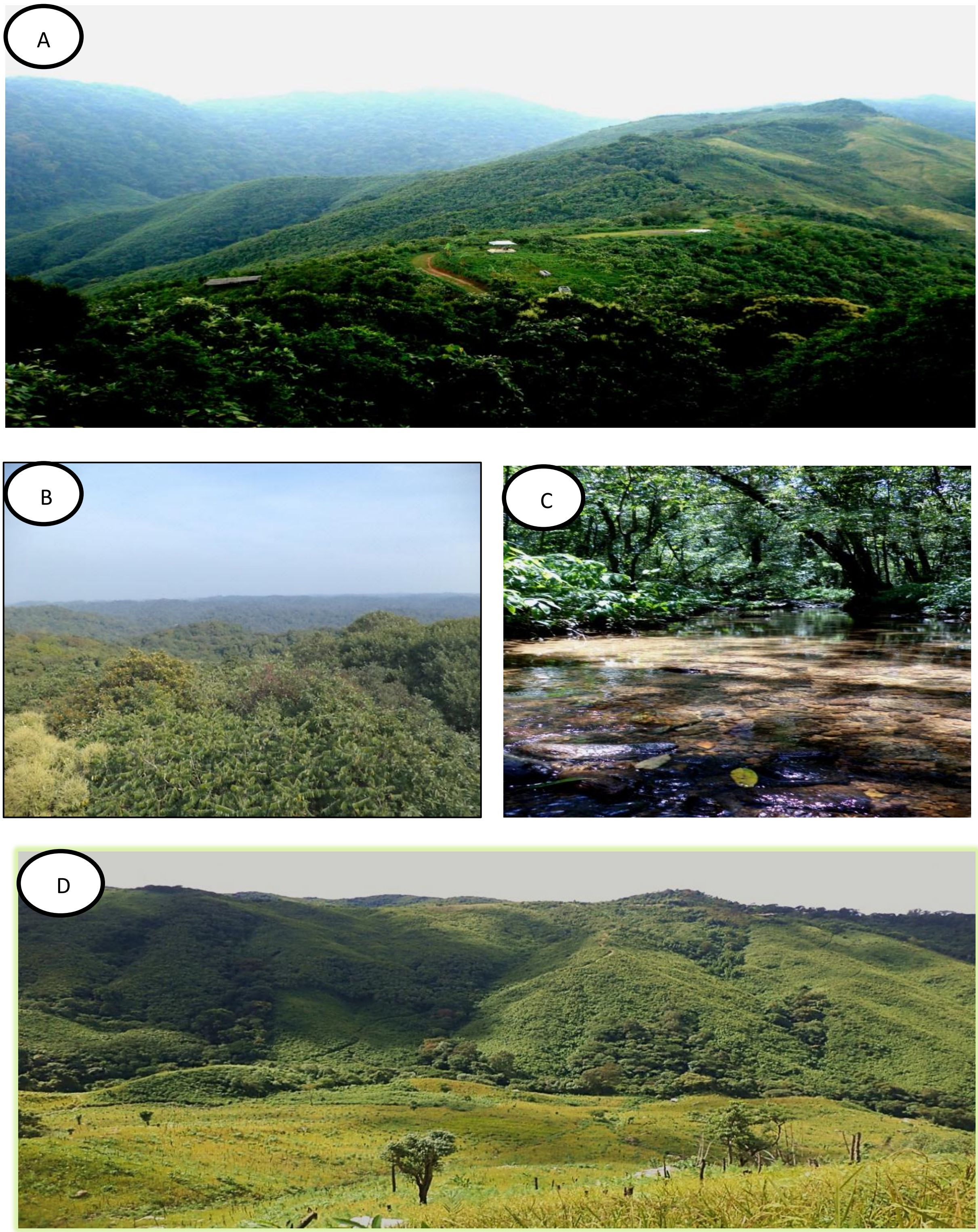

Photo plate 7: A-Birds eye view of Nokrek Biosphere Reserve. B- Canopy view of the core zone from peak. C- Stream source in the core zone. D- View of buffer zone of Nokrek Biosphere Reserve

REFERENCES

Abdelaal, M., Fois, M., and Fenu, G. (2017). The influence of natural and anthropogenic factors on the floristic features of the northern coast Nile Delta in Egypt. *Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology*. **152**(3): 1-9.

Agarwal, KC. (2002). *Global biodiversity* (pp:1-75), Bikaner, India, Nidhi Publishers.

Alatalo, RV. (1981). Problems in the measurement of evenness in ecology. *Oikos*. **37(**2): 199-204.

Alhassan, I., Garba-Gashua, A., Dogo, S., and Sani, M. (2018). Physical properties and organic matter content of the soils of Bade in Yobe State, Nigeria. *International Journal of Agriculture, Environment and Food Sciences,* **2**(4): 160-163.

Allen, RC. (2009). *The British industrial revolution in global perspective* (Vol. 1). Cambridge, UK, Cambridge University Press.

Allen, SE., Grimshaw, HM., Parkinson, JA., and Quarmby, C. (1974). *Chemical analysis of ecological materials*. Hoboken, New Jersey, United States. Blackwell Scientific Publications.

Al-Pavel, MA., Mukul, SA., Uddin, MB., Harada, K., and Khan, MAA. (2016). Effects of stand characteristics on tree species richness in and around a conservation area of northeast Bangladesh. *Journal of Mountain Science*. **13**(6): 1085-1095.

Anderson, JM., and Ingram, JSI. (1993). *Tropical soil biology and fertility: A handbook of methods*. Wallingford, Oxfordshire, United Kindom, CAB International.

Arasa-Gisbert, R., Vayreda, J., Román-Cuesta, RM., Villela, SA., Mayorga, R., and Retana, J. (2018). Forest diversity plays a key role in determining the stand carbon stocks of Mexican forests. *Forest ecology and management*. **415**: 160-171.

Arora, K. (2003). *Forest Laws. The Wildlife Protection Act, 1972 as amended by the Wild (Protection) Amendment Act, 2002*. New Delhi, India, Professional Book Publishers.

Arunachalam, A., and Arunachalam, K. (2000). Influence of gap size and soil properties on microbial biomass in a subtropical humid forest of North-East India. *Plant and soil*, **223**(1-2): 187-195.

Arunachalam, A., and Pandey, H.N. (2003). Ecosystem restoration of Jhum fallows in Northeast India: microbial C and N along altitudinal and successional gradients. *Restoration Ecology*, **11**(2): 168-173.

Arunachalam, A., Arunachalam, K., Bhattacharjee, A., and Nag, A. (2000). Natural revegetation on landslides in humid tropical Arunachal Pradesh: Community dynamics and soil properties. *Journal of Tropical Forest Science*. **12**(4): 682-696.

Arya, N., Tewari, B., and Ram, J. (2012). The effect of natural and anthropogenic disturbance in forest canopy and its effect on species richness in forests of Uttarakhand Himalaya, India. *Russian Journal of Ecology*, **43**(2): 117-121.

Arya, D. (2010). Climate change influence on phonological events and socio-economic status of village communities in Garhwal Himalaya. In: Verma, PD. (Ed.), *Reflections of Climate Change Leaders from the Himalayas, Leadership for Environment and Development (LEAD) Report*, pp. 34-36. New Delhi, India, LEAD-INDIA.

Ashutosh, S. (1998). Nokrek Biosphere Reserve. In: Maikhuri, RK., Rao, KS., and Rai, KR. (Ed.), *Biosphere Reserve and Management in India.* Almora, India, Himvikas Publisher.

Augusto, L., Achat, DL., Jonard, M., Vidal, D., and Ringeval, B. (2017). Soil parent material—A major driver of plant nutrient limitations in terrestrial ecosystems. *Global change biology*. **23**(9): 3808-3824.

Baithalu, S., Anbarashan, M., and Parthasarathy, N. (2013). Two-decadal changes in forest structure and tree diversity in a tropical dry evergreen forest on the Coromandel Coast of India. *Tropical Ecology*. **54**(3): 395-401.

Balakrishnan, NP. (1981–1983). *Flora of Jowai, Meghalaya, Vol. I & II*. Howrah, India, Botanical Survey of India.

Barbhuiya, AR., Arunachalam, A., Pandey, HN., Arunachalam, K., and Khan, ML. (2008). Effect of anthropogenic disturbance on soil microbial biomass C, N and P in a tropical rainforest ecosystem of Assam, NE, India. *Malaysian Journal of Soil Science*, **12**: 31-44.

Barik, SK., Tripathi, RS., Pandey, HN., and Rao, P. (1996). Tree regeneration in a subtropical humid forest: effect of cultural disturbance on seed production, dispersal and germination. *Journal of Applied Ecology*, **33**: 1551-1560.

Baruah, HC., Bora, DK., Baruah, TC., and Nath, AK. (1991). Fixation of potassium in three major soil orders of Assam. *Journal of Potassium Research*. **7**(3): 170-175.

Bashir, U., Ali, T., and Qureshi, F. (2016). Distribution of different forms of potassium under temperature conditions of Kashmir. *International Journal of Agriculture, Environment and Biotechnology*. **9**(2): 213.

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

Borthakur, DN. (1992). *Agriculture of North Eastern Region with Special Reference to Hill Agriculture.* pp. 265. Guwahati, Assam, India, Beecee Prakashan.

Berger, TW., and Berger, P. (2012). Greater accumulation of litter in spruce (*Picea abies*) compared to beech (*Fagus sylvatica*) stands is not a consequence of the inherent recalcitrance of needles. *Plant and Soil*. **358**(1-2): 349-369.

Bharathi, S., and Prasad, AD. (2015). Diversity and regeneration status of tree species in the sacred groves of central western Ghats, India. *Journal of Biodiversity and Environmental Sciences*. **7**(2): 10-21.

Bharathi, S., and Prasad, AD. (2017). Diversity, population structure and regeneration status of arboreal species in the four sacred groves of Kushalnagar, Karnataka. *Journal of Forestry Research*. **28**(2): 357-370.

Bhat, DM., Naik, MB., Patagar, SG., Hegde, GT., Kanade, YG., Hegde, GN., Shastri, CM., Shetti, DM., and Furtado, RM. (2000). Forest dynamics in tropical rain forests of Uttara Kannada district in Western Ghats, India. *Current Science*. **79**(7): 975-985.

Bhutia, Y., Gudasalamani, R., Ganesan, R., and Saha, S. (2019). Assessing Forest Structure and Composition along the Altitudinal Gradient in the State of Sikkim, Eastern Himalayas, India. *Forests*. **10**(8): 633.

Bhuyan, P., Khan, ML., and Tripathi, RS. (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**(8): 1753-1773.

Bhuyan, SI., Khan, ML., and Tripathi, OP. (2013). Soil physico-chemical properties under four agro-ecosystems in Arunachal Pradesh, Eastern Himalaya. *Plant Archives*. **13**(1): 199-206.

Bhuyan, SI., Tripathi, OP., and Khan, ML. (2014). Soil characteristics, dynamics of microbial biomass: a study of hill agro-ecosystems, Eastern Himalaya, India. *International Journal of Current Science*. **12**: 79-86.

Brady, NC. (1996) *The Nature and Properties of Soil, 10th Eds.* Prentice Hall, New Delhi, India, Pearson Education.

Brintha, TSS., James, JE., and Jeeva, S. (2015). Vascular Plants, Scott Christian College, Nagercoil, Tamilnadu, India. *Science Research Reporter*. **5**(1): 36-66.

Brook, BW., Sodhi, NS., and Bradshaw, CJ. (2008). Synergies among extinction drivers under global change. *Trends in Ecology & Evolution*. **23(**8): 453-460.

Bünemann, EK., Bongiorno, G., Bai, Z., Creamer, RE., Deyn, GD., Goede, RD., Fleskens, L., Geissen, V., Kuyper, TW., and Mäder, P. (2018). Soil quality – A critical review. *Soil Biology & Biochemistry*. **120**: 105–125.

Burkey, TV. (1995). Tropical tree species diversity: A test of Janzen- Connel model. *Oecologia*, **97**: 533-540.

Carvalho, FA., Braga, JMA., and Nascimento, MT. (2016). Tree structure and diversity of lowland Atlantic forest fragments: Comparison of disturbed and undisturbed remnants. *Journal of Forestry Research*. **27**(3): 605-609.

CBD. (1992). *Convention on Biological Diversity*. UN Environment Programme. https://www.cbd.int/convention/text/ [Accessed on 21st Jan 2018].

Champion, SH., and Seth, SK. (1968). *A Revised Survey of the Forest types of India.* Manager of Publications, Delhi, India, CRL-E-Resources.

Chandrashekara, UM., and Ramakrishnan, PS. (1994). Vegetation and gap dynamics of a tropical wet evergreen forest in the Western Ghats of Kerala, India. *Journal of Tropical Ecology*. **10**(3): 337-354.

Chaudhary, RP., and Kunwar, RM. (2002). Vegetation composition of Arun valley, East Nepal. In: Chaudhary, RP., Subedi, BP., Vetaas, OR. and Aase, TH., (Ed.), *Vegetation and society: Their interaction in the Himalayas.* pp: 38-55. Tribhuvan University, Kathmandu and University of Bergen, Norway.

Chazdon, RL. (2003). Tropical forest recovery: legacies of human impact and natural disturbances. *Perspectives in Plant Ecology, Evolution and Systematics*. **6**(1-2): 51-71.

Chen, Y., Cai, XA., Zhang, Y., Rao, X., and Fu, S. (2017). Dynamics of Understory Shrub Biomass in Six Young Plantations of Southern Subtropical China. *Forests*. **8**(11): 419.

Chhetri, RB. (2010). Some fodder yielding trees of Meghalaya, Northeast India. *Indian Journal of Traditional Knowledge*. **9**(4): 786–790

Chittibabu, CV., and Parthasarathy, N. (2000). Attenuated tree species diversity in human-impacted tropical evergreen forest sites at Kolli hills, Eastern Ghats, India. *Biodiversity & Conservation*. **9**(11): 1493-1519.

D'Amato, AW., Raymond, P., and Fraver, S. (2018). Old-growth disturbance dynamics and associated ecological silviculture for forests in northeastern North America. In: Barton, AM., and William, SK. (Eds.), *Ecology and Recovery of Eastern Old-Growth Forests* (pp. 99-118).Washington, DC, USA, Island Press.

Daniels, RR. (1993). The Nilgiri Biosphere Reserve and its role in conserving India's biodiversity. *Current Science*. **64**(10): 706-708.

Das, K., Dipak, S., and Nayak, DC. (2000). Forms of potassium and their distribution in some soils representing red and laterite ecosystem of West Bengal. *Journal of Potassium Research*, **16**(1/4): 1-6.

Das, SN., Maiti, TC., and Banerjee, SK. (1980). Genesis of Red and Lateritic Forest Soils of West Bengal on Catenary Basis, Part I - Morphological Studies. *Indian Forester*. **106**(10): 704-714.

Dash, PK., Mohapatra, PP., and Rao, YG. (2009). Diversity and distribution pattern of tree species in Niyamgiri hill ranges, Orissa, India. *The Indian Forester*. **135**(7): 927-942.

Deshmukh, VN., Solanke, BU., Rewatkar, SS., and Gawande, SM. (1991). Forms of potassium in soils of Vidarbha region. *Journal of Soils and Crops*. **1**(2): 175-179.

Devi, GP. (2015). Impact of sandstone quarry on physico-chemical characteristics of Tlawng river and vegetation in catchment area in vicinity of Aizawl city, Mizoram.

Ph.D. Thesis. Department of Environmental Science, Mizoram University, Aizawl, pp: 1-159.

Directorate of Mineral Resources. (2018). Directorate of Mineral Resources (DMR) Profile. Directorate of Mineral Resources, Government of Meghalaya, Shillong, Meghalaya. http://megdmg.gov.in/. [Accessed on 24th Nov 2017]

Dubey, K., and Dubey, KP. (2011). Impact of mining on tree diversity of the silica mining forest area at Shankargarh, Allahabad, India. *Journal of Forestry Research*. **22**(4): 527-532.

Dutta, G., and Devi, A. (2013). Plant diversity, population structure, and regeneration status in disturbed tropical forests in Assam, Northeast India. *Journal of Forestry Research*. **24 (**4): 715-720.

ENVIS. (2016). *Biodiversity Hot spots in India*. ENVIS Centre on Floral Diversity. Ministry of Environment, Forests & Climate Change, Govt of India. http://www.bsienvis.nic.in/Database/Biodiversity-Hotspots-in-India_20500.aspx [Accessed on 12th Jan 2020].

Erenso, F., Maryo, M., and Abebe, W. (2014). Floristic composition, diversity and vegetation structure of woody plant communities in Boda dry evergreen Montane Forest, West Showa, Ethiopia. *International Journal of Biodiversity and Conservation*. **6**(5): 382-391.

Evans, J. (1992). *Plantation forestry in the tropics: tree planting for industrial, social, environmental, and agroforestry purposes*. Oxford, UK, Oxford University Press.

Flenley, JR. (1979). *The equatorial Rain Forest: A geographical history*. London, UK, Butterworths.

Gadgil, M. (1991). Conserving India's biodiversity: The societal context. *Evolutionary Trends in Plants*. **5**(1): 3-8.

Gairola, S., Rawal, RS., and Todaria, NP. (2015). Effect of anthropogenic disturbance on vegetation characteristics of sub-alpine forests in and around Valley of Flowers National Park, a world heritage site of India. *Tropical Ecology*. **56**(3): 357-365

Gairola, S., Sharma, CM., Ghildiyal, SK., and Suyal, S. (2012). Chemical properties of soils in relation to forest composition in moist temperate valley slopes of Garhwal Himalaya, India. *The Environmentalist*. **32**(4): 512-523.

Ganesh, T., Ganesan, R., Devy, MS., Davidar, P., and Bawa, K.S. (1996). Assessment of plant biodiversity at a mid-elevation evergreen forest of Kalakad–Mundanthurai Tiger Reserve, Western Ghats, India. *Current Science*. **71**(5): 379-392.

Gentry, AH. (1992). Tropical forest biodiversity: distributional patterns and their conservational significance. *Oikos*. **63**(1):19-28.

Ghosh, AB., Bajaj, JC., Hasan, R., and Singh, D. (1983). Soil and Water Testing Methods: A Laboratory Manual. *Division of Soil Science and Agricultural Chemistry, IARI*, pp. 1-48, New Delhi, India.

Gillespie, TW., Grijalva, A., and Farris, CN. (2000). Diversity, composition, and structure of tropical dry forests in Central America. *Plant Ecology*. **147**(1): 37-47.

Ghate, U., Joshi NV., and Gadgil, M. (1998). On the patterns of tree diversity in the Western Ghats of India. *Current Science.* **75**: 594-603.

Global Forest Assessment. (2015). *Global Forest Resources Assessment 2015*, Food and Agriculture Organization of the United Nations (FAO), Forest Ecology and Management. http://www.fao.org/3/a-i4808e.pdf [Accessed on 21st Jan 2018].

Global Forest Watch. (2016). *Global Forest Watch* 2016, World Resources Institute.

https://blog.globalforestwatch.org/data/global-tree-cover-loss-rose-51-percent-in-2016 [Accessed on 21st Jan 2018].

Gogoi, PC. (1981). *Tura Ridge Biosphere Reserve (Citrus Gene Sanctuary).* pp: 99. Department of Forests, Government of Meghalaya, Shillong, Meghalaya, India.

Gogoi, A., and Sahoo, UK. (2018). Impact of anthropogenic disturbance on species diversity and vegetation structure of a lowland tropical rainforest of eastern Himalaya, India. *Journal of Mountain Science*. **15**(11): 2453-2465.

Griffiths, RP., Madritch, MD., and Swanson, AK. (2009). The effects of topography on forest soil characteristics in the Oregon Cascade Mountains (USA): Implications for the effects of climate change on soil properties. *Forest Ecology and Management*. **257**(1): 1-7.

Gupta, MK., and Sharma, SD. (2009). Effect of tree plantation on soil properties, profile morphology and productivity index-II. Poplar in Yamunanagar district of Haryana. *Annals of Forestry*. **17**(1): 43-70.

Hajra, PK. and Rao, RR. (1986). *Floristic diversity of Eastern Himalaya in a conservation perspective*, (pp. 103-125), Proceedings of Indian Academy of Sciences (Supplementary- Nov), ISSN: 0370-0097.

Haridasan, K. and Rao, RR. (1985). *Forest Flora of Meghalaya* (Vol. 2). Dehra-Dun, India, M/s Bishen Singh Mahendra Pal Singh Publication.

Harrison, RB., Footen, PW., and Strahm, BD. (2011). Deep soil horizons: contribution and importance to soil carbon pools and in assessing whole-ecosystem response to management and global change. *Forest Science*. **57**(1): 67-76.

Hartshorn, GS. (1980). Neotropical forest dynamics. *Biotropica*. **12**(2): 23-30.

Hengeveld, R. (1996). Measuring ecological biodiversity. *Biodiversity Letters*. **3**: 58-65.

Hobbs, RJ., Hussey, BMJ. and Saunders, DA. (1990). Nature Conservation: The role of corridors. *Journal of Environment Management.* **31**(1): 93-94.

Huang, W., Pohjonen, V., Johansson, S., Nashanda, M., Katigula, MIL., and Luukkanen, O. (2003). Species diversity, forest structure and species composition in Tanzanian tropical forests. *Forest Ecology and Management*. **173**(1-3): 11-24.

Hubbell, SP. and Foster, RB. (1986). Biology, Chance and History and the Structure of Tropical Rain Forest Tree Communities. In: Diamond, JM., and Case, TJ., (Ed.), *Community Ecology*, pp: 314-329, Harper and Row, New York, USA.

IUCN. (1979). *Biosphere Reserves and its relationship to the other protected areas*. International Union for Conservation of Nature (IUCN). https://www.iucn.org/km/content/biosphere-reserve-and-its-relationship-other-protected-areas [Accessed on 12th June 2019]

IUCN. (2018). *International Union of conservation of Nature*: Annual Report. https://www.iucn.org/about/programme-work-and-reporting/annual-reports [Accessed on 10th July 2019]

ISFR. (2019). *Indian State of Forest Report (ISFR) – Meghalaya-Vol II*, Forest Survey of India, Ministry of Environment, Forest and Climate Change, Govt. of India. http://fsi.nic.in/isfr19/vol2/isfr-2019-vol-ii-meghalaya.pdf [Accessed on 16th Dec 2019]

Jain, SK., and Rao, RR. (1977). *Handbook of Plant Collection and Herbarium Techniques*. New Delhi, India, Today and Tomorrow Printers and Publishers

Jamir, SA. (2000). Studies on plant biodiversity, community structure and population behaviour of dominant tree species of some sacred groves of Jaintia hills, Meghalaya, Ph.D. Thesis, North-Eastern Hill University, Shillong, India.

Jamir, SA., and Pandey, HN. (2003). Vascular plant diversity in the sacred groves of Jaintia Hills in northeast India. *Biodiversity & Conservation*. **12**(7): 1497-1510.

Jeeva, S., Mishra, BP., Venugopal, N., Kharlukhi, L., and Laloo, RC. (2006**)**. Traditional knowledge and biodiversity conservation in the sacred groves of Meghalaya. *Indian Journal of Traditional Knowledge.* **5**:563–68.

Junge, RE., Barrett, MA., and Yoder, AD. (2011). Effects of anthropogenic disturbance on indri (*Indri indri*) health in Madagascar. *American Journal of Primatology*. **73**(7): 632-642.

Kacholi, DS., Whitbread, AM., and Worbes, M. (2015). Diversity, abundance, and structure of tree communities in the Uluguru forests in the Morogoro region, Tanzania. *Journal of forestry research*. **26**(3): 557-569.

Kacholi, DS. (2013). *Effects of habitat fragmentation on biodiversity of Uluguru Mountain forests in Morogoro region,* pp: 1-15, Tanzania. Cuvillier, Göttingen.

Kala, CP., and Dubey, Y. (2012). Anthropogenic disturbances and status of forest and wildlife in the dry deciduous forests of Chhattisgarh state in India. *Journal of Forestry Research*. **23**(1): 45-52.

Kamei, J., Pandey, HN., Barik, SK., and Singh, PK. (2017). Nitrogen and phosphorous mineralization and soil microbial biomass carbon, nitrogen and phosphorous in a humid subtropical forest ecosystem of North Eastern India. *International Journal of Applied Research*. **3**(8): 478-487.

Kanjilal, UN., Kanjilal, PC., Das, A., De, RN. and Bor, NL. (1934-1940). *Flora of Assam*. Vols. 1-5. Shillong, India, Published under the authority of the Government of Assam, India, Govt. Press.

Karan, PP. (1994). Environmental Movements in India. *American Geographical Society*. **84** (1): 32–41.

Kayang, H. (2007). Tribal Knowledge on wild edible plants of Meghalaya, Northeast, India. *Indian Journal of Traditional Knowledge.* **6**(1): 177 -181.

Kent, M., and Coker, P. (1992). *Vegetation description and analysis: A Practical Approach***. (**2nd Eds.), pp: 362-363. London, UK, CRC Belhaven Press.

Khan, ML., Menon, S., and Bawa, KS. (1997). Effectiveness of the protected area network in biodiversity conservation: A case-study of Meghalaya state. *Biodiversity & Conservation*. **6**(6): 853-868.

Khonglah, MA., Khan, MA., Karim, MA., Kumar. A., and Choudhury, J. (2008). Geology and structure of the areas in and around Shillong, Meghalaya, Northeast India, Revisited. In: Proceedings of the National Seminar on Geology & Energy Resources of NE India: Progress & Perspectives. pp: 115-139. *Nagaland University Research Journal (ISSN 0973-0346).* Nagaland, India.

Kibblewhite, MG., Ritz, K., and Swift, MJ. (2007). Soil health in agricultural systems. *Philosophical Transactions of the Royal Society of London. Series B, Biological sciences*. **363**(1492): 685-701.

Kolbe, SE., Miller, AI., Cameron, GN., and Culley, TM. (2016). Effects of natural and anthropogenic environmental influences on tree community composition and structure in forests along an urban-wildland gradient in Southwestern Ohio. *Urban Ecosystems*. **19**(2): 915-938.

Kumar, A., Marcot, BG., and Roy, PS. (2008). Spatial patterns and ecology of shifting forest landscapes in Garo Hills, India. In: Lafortezza, R., Sanesi, G., Chen, J., Crow, TR. (Ed.) *Patterns and Processes in Forest Landscapes,* pp: 125-139, Springer, Dordrecht.

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

Kumar, A., Marcot, BG., Talukdar, G., and Roy, PS. (2012). Application of geoinformatics for landscape assessment and conserving forest biodiversity in northeast India. *Asian Journal of Geoinformatics.* **12**(1): 1-13.

Kumar, P., Yadav, BL., Rajput, SG., Yadav, B. and Singh, K. (2014). Status of major nutrient in relation to soil properties of Jaipur district of Rajasthan under groundnut cultivation. *Journal of Soil and Water Conservation*, **13**: 31–35.

Kumari, R., Banerjee, A., Kumar, R., Kumar, A., Saikia, P., and Khan, ML. (2019). Deforestation in India: Consequences and Sustainable Solutions. In: Suratman, MN., Latif, ZA., and De-Oliveira, G. (Ed.) pp: 1-18, *Deforestation Around the World*. IntechOpen, IntechOpen Limited, London, UK.

Kunwar, RM., and Sharma, SP. (2004). Quantitative analysis of tree species in two community forests of Dolpa district, mid-west Nepal. *Himalayan Journal of Sciences*. **2**(3): 23-28.

Kurth, VJ., D'Amato, AW., Bradford, JB., Palik, BJ., and Looney, CE. (2019). Assessing the ecological impacts of biomass harvesting along a disturbance severity gradient. *Ecological Applications*. **30**(2): e02042.

Lalitha, M., and Dhakshinamoorthy, M. (2014). Forms of soil potassium-A review. *Agricultural Reviews*. **35**(1): 64-68.

Laloo, RC., Kharlukhi, L., Jeeva, S., and Mishra, BP. (2006). Status of medicinal plants in the disturbed and the undisturbed sacred forests of Meghalaya, Northeast India: population structure and regeneration efficacy of some important species. *Current Science*, **90**(2): 225-232.

Lamare, RE., and Singh, OP. (2016). Limestone mining and its environmental implications in Meghalaya, India. *ENVIS Bulletin Himalayan Ecology*, **24**: 87-100.

Lele, N., Joshi, PK., and Agrawal, SP. (2008). Assessing forest fragmentation in northeastern region (NER) of India using landscape matrices. *Ecological Indicators*. **8**(5): 657-663.

Lévesque, M., McLaren, KP., and McDonald, MA. (2011). Coppice shoot dynamics in a tropical dry forest after human disturbance. *Journal of Tropical Ecology*. **27**(3): 259-268.

Liebig, MA., Tanaka, DL., and Wienhold, BJ. (2004). Tillage and cropping effects on soil quality indicators in the northern Great Plains. *Soil and Tillage Research*, **78**(2): 131-141.

Linderman, MA., An, LI., Bearer, S., He, G., Ouyang, Z., and Liu, J. (2006). Interactive effects of natural and human disturbances on vegetation dynamics across landscapes. *Ecological Applications*. **16**(2): 452-463.

Liu, Y., Li, J., and Zhang, H. (2012). An ecosystem service valuation of land use change in Taiyuan City, China. *Ecological Modelling*. **225**: 127-132.

Magurran, AE. (1988). *Ecological Diversity and its Measurements*. pp: 170-179, London, UK, Croom Helm Limited.

Maiti, SK. (2003). *Handbook of Methods in Environmental Studies – Vol.2*. Jaipur, Rajastan, India, ABD Publishers.

Majumdar, K., and Datta, BK. (2014). A quantitative checklist of woody angiosperm diversity, population structure and habitat grouping in Trishna Wildlife Sanctuary of Tripura, northeast India. *Check List*. **10**(5): 976-996.

Manikandan, R., and Lakshminarasimhan, P. (2012). Flowering Plants of Rajiv Gandhi (Nagarahole) National Park, Karnataka, India. *Check List*. **8**(6): 1052-1084.

Marcot, BG., Kumar, A., Roy, PS., Sawarkar, VB., Gupta, A., and Sangma, SN. (2002). Towards A Landscape Conservation Strategy: Analysis of Jhum landscape and Proposed Corridors for Managing Elephants in South Garo Hills District and Nokrek area, Meghalaya. *Indian Forester*. **128**(2): 207-216.

Natarajan, S., and Renukadevi, A. (2003). Vertical distribution of forms of potassium in major soil series of Tamil Nadu. *Acta Agronomica Hungarica*. **51**(3): 339-346.

Malsawmsanga, A. (2011). Studies on Plant Diversity of Phawngpui National Park. **Ph.D. Thesis**. Dept. of Environmental Science, Mizoram University, Aizawl, India.

Margalef, R. (1958). Information theory in Ecology. *General Systems.* **3**: 36-71.

Maxwell, JF. (2009). Vegetation and vascular flora of the Mekong River, Kratie and Steung Treng Provinces, Cambodia. *Maejo International Journal of Science and Technology*. **3**(1): 143-211.

MBB Annual Report. (2015). Meghalaya Biodiversity Board Annual Report 2012-2015, Meghalaya Biodiversity Board, Government of Meghalaya. https://megbiodiversity.nic.in/annual-report-2012-2015-0 [Accessed on 15th April 2017].

MBB Annual Report. (2017), Meghalaya Biodiversity Board Annual Report 2017, Meghalaya Biodiversity Board, Government of Meghalaya. https://megbiodiversity.nic.in/annual-report-2012-2015-0 [Accessed on 25th Nov 2018].

Meghalaya Statistics Report (2019). *Meghalaya at a glance*, Directorate of Economics & Statistics, Planning Department, Govt. of Meghalaya, India. [Accessed on 10th Dec 2019]. http://megplanning.gov.in/statistics/At-glance/Glance-2019.pdf

Meghalaya: Socio-Economic-Review. (2004). Socio-Economic-Review (Meghalaya). *Directorate of Economics, Statistics and Evaluation*, Planning Department, Govt. of Meghalaya, Shillong. India. [Accessed on 17th Oct 2018].

http://megplanning.gov.in/statistics/Meghalaya_Socio_Economic_Review.pdf

Menon, V., Tiwari, SK., Ramkumar, K., Kyarong, S., Ganguly, U., Sukumar, R. (2017). Right of Passage - Elephant Corridorrs of India. In: Director, *Conservation Reference Series #3 [2nd Edition]*, (pp. 1-824), Wildlife Trust of India, India.

Mir, AH., and Upadhaya, K. (2017). Effect of traditional management practices on woody species composition and structure in montane subtropical forests of Meghalaya, Northeast India. *Journal of Mountain Science*. **14**(8): 1500-1512.

Mishra, BP., and Jeeva, S. (2012). Plant diversity and community attributes of woody plants in two climax subtropical humid forests of Meghalaya, Northeast India. *Applied Ecology and Environmental Research*. **10**(4): 417-436.

Mishra, BP. (2012). Effect of anthropogenic activities on micro-environment and soil characteristics along disturbance gradient in the sub-tropical forest of Mizoram North east India. *Indian Journal of Plant Sciences*. **1**(2-3): 208-212.

Mishra, BP., and Laloo, RC. (2006). A comparative analysis of vegetation and soil characteristics of montane broad-leaved, mixed pine and pine forests of northeast India. In: Trivedi, PC. (Ed.), *Advances in Plant Physiology,* pp: 185-197, IK International Publishing House, New Delhi, India.

Mishra, BP., Tripathi, OP., and Laloo, RC. (2005). Community characteristics of a climax subtropical humid forest of Meghalaya and population structure of ten important tree species. *Tropical Ecology*. **46**(2): 241-252.

Mishra, BP., Tripathi, OP., Tripathi, RS., and Pandey, HN. (2004). Effects of anthropogenic disturbance on plant diversity and community structure of a sacred grove in Meghalaya, northeast India. *Biodiversity & Conservation*. **13**(2): 421-436.

Mishra, BP., Tripathi, RS., Tripathi, OP., and Pandey, HN. (2003). Effect of disturbance on the regeneration of four dominant and economically important woody species in a broad leaved subtropical forest of Meghalaya, North East India. *Current Science*. **84**(11): 1449-1453.

Misra, R. (1968). *Ecology Work Book*, Calcutta, India, Oxford Publishing Company.

Mittermeier, R.A., Gil, PR., Hoffmann, M., Pilgrim, J., Brooks, TM., Lamoreux, J., and Da-Fonseca, GAB. (2004). Hotspots Revisted: Earth's Biologically Wealthiest and most Threatened Ecosystems. *CEMEX, México DF*. 99-103.

Mittermeier, RA., Turner, WR., Larsen, FW., Brooks, TM., and Gascon, C. (2011). Global biodiversity conservation: The critical role of hotspots. In: Frank E. Zachos, FE., and Habel, JC. (Ed.), *Biodiversity Hotspots* (pp. 3-22). Springer, Berlin, Heidelb.

Mligo, C. (2011). Anthropogenic disturbance on the vegetation in Makurunge Woodland, Bagamoyo district, Tanzania. *Tanzania Journal of Science*. **37**(1): 94-108.

MOEF Annual report, (2019). Ministry of Environment, Forest & Climate Change: Annual report, Ministry of Environment, Forest & Climate Change, Govt of India, ENVIS. http://moef.gov.in/wp-content/uploads/2019/08/Annual-Report-2018-19-English.pdf [Accesed on 22nd Sep 2019]

Momin, KC. (1995). Traditional jhum-based economy of the Garos and its changing patterns. In: Sangma, MS. (Ed.), *Hill Societies and Their Modernisation: A study of North East with special reference to Garo Hills.* pp: 103-109, Omsons Publications, New Delhi, India.

Momin, WG. (2002). Nokrek Biosphere Reserve. Divisional Forest Officer, East and West Garo Hills Wildlife Division Tura, Meghalaya, India. In: Ramakrishnan, PS., Rai, RK., Katawal, RPS., and Mehndiratta, S. (Ed.), *Traditional Ecological Knowledge for managing Biosphere Reserves in South and Asia*, pp: 427-430, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, India.

Morel, JD., Santos, RMD., Fontes, MAL., Garcia, PO., and Souza, FMD. (2015). Floristic comparison between two tree communities associated with habitat descriptor variables. *Cerne*. **21(**4): 601-616.

Morellet, N., Gaillard, JM., Hewison, AJ., Ballon, P., Boscardin, YVES., Duncan, P., and Maillard, D. (2007). Indicators of ecological change: New tools for managing populations of large herbivores. *Journal of Applied Ecology*. **44**(3): 634-643.

Mueller-Dombois, D. and Ellenberg, H. (1974). *Aims and Methods of Vegetation Ecology*, New Jersey, USA, Wiley and Sons.

Muhammed, N., Masum, MFH., Hossain, MM., Chakma, S., Oesten, G., and Von-Detten, R. (2011). Floral composition and biodiversity conservation in homestead forests in Mymensingh, Bangladesh. *International Journal of Biodiversity Science, Ecosystem Services & Management*. **7**(4): 247-257.

Mukherjee, N. (2003). *Participatory Rural Appraisal Methodology and Applications*, New Delhi, India, Concept Publishing Company.

Mukul, SA., and Herbohn, J. (2016). The impacts of shifting cultivation on secondary forests dynamics in tropics: a synthesis of the key findings and spatio temporal distribution of research. *Environmental Science & Policy*. **55**: 167-177.

Murthy, MSR., Giriraj, A., and Dutt, CBS. (2003). Geoinformatics for biodiversity assessment. *Biological Letters*. **40**(2): 75-100.

Myers, N. (1988).Threatened Biotas: 'Hotspots' in tropical forests. *Environmentalist.* **8**: 187-208

Myers, N. (1990). The biodiversity challenge: Expanded hot-spots analysis. *Environmentalist*. **10**(4): 243-256.

Myers, N., Mittermeler, RA., Da-Fonseca, GAB. and Kent, J. (2000). Biodiversity Hotspots for Conservation priorities. *Nature*. **403**(2): 853-858.

Nandy, S., and Das, KA. (2013). Comparing tree diversity and population structure between a traditional agroforestry system and natural forests of Barak valley, Northeast India. *International Journal of Biodiversity Science, Ecosystem Services & Management*. **9**(2): 104-113.

Nath, PC., Arunachalam, A., Khan, ML., Arunachalam, K., and Barbhuiya, AR. (2005). Vegetation analysis and tree population structure of tropical wet evergreen forests in and around Namdapha National Park, Northeast India. *Biodiversity & Conservation*. **14**(9): 2109-2135.

National Wildlife Database. (2019). ENVIS Centre on Wildlife & Protected Areas. Ministry of Environment, Forests & Climate Change, Govt of India. http://www.wiienvis.nic.in/Database/Protected_Area_854.aspx [Accessed on 12th Jan 2020].

Neelamegam, R., Pillai, V., Anishal, A., and Reselin, S. (2015). Status and composition of home garden plants in rural and urban areas in Kanyakumari District, Tamil Nadu, India. *Scholars Academic Journal of Biosciences*. **3**(8): 656-667.

Neelamegam, R., Preetha, MM., Priya, K., Sathiya, B., and Vanaja, L. (2016). Woody Species Composition and Diversity Analysis in the ST Hindu College Campus Located at Nagercoil, Kanniyakumari District, Tamil Nadu, India. *International Journal of Pure and Applied Bioscience*. **4**(6): 193-203.

Nesheim, I., Halvorsen, R., and Nordal, I. (2010). Plant composition in the Maya Biosphere Reserve: Natural and anthropogenic influences. *Plant Ecology*. **208**(1): 93-122.

Nicholls, JA., Fuentes-Utrilla, P., Hayward, A., Melika, G., Csóka, G., Nieves-Aldrey, JL., and Stone, GN. (2010). Community impacts of anthropogenic disturbance: natural enemies exploit multiple routes in pursuit of invading herbivore hosts. *BMC Evolutionary Biology*. **10**(1): 322.

Odum, E.P. (1971). *Fundamentals of Ecology*. Pp: 570-574. Phildelphia, Penasylvania, USA, W.B. Saunders.

Omondi, SF., Odee, DW., Ongamo, GO., Kanya, JI., and Khasa, DP. (2017). Effects of anthropogenic disturbances on natural regeneration and population structure of gum arabic tree (*Acacia senegal*) in the woodlands of Lake Baringo ecosystem, Kenya. *Journal of Forestry Research*. **28**(4): 775-785.

Ormsby, A. (2013). Analysis of local attitudes toward the sacred groves of Meghalaya and Karnataka, India. *Conservation and Society*. **11**(2): 187-197.

Oudenhoven-Van, AP., and De-Groot, RS. (2011). Analysing and monitoring human impacts on biodiversity and ecosystem services. *International Journal of Biodiversity Science, Ecosystem Services & Management*. **7**(4): 245-246.

Pakrasi, K., Arya, VS., and Sudhakar, S. (2014). Biodiversity hot-spot modeling and temporal analysis of Meghalaya using Remote sensing technique. *International Journal of Environmental Sciences*. **4**(5): 772.

Panchal, NS., and Pandey, AN. (2004). Analysis of vegetation of Rampara forest in Saurashtra region of Gujarat state of India. *Tropical Ecology*. **45**(2): 223-232.

Panda, PC., Mahapatra, AK., Acharya, PK., and Debata, AK. (2013). Plant diversity in tropical deciduous forests of Eastern Ghats, India: A landscape level assessment. *International Journal of Biodiversity and Conservation*. **5**(10): 625-639.

Pande, PK., Meshram, PB., and Banerjee, SK. (2002). Litter production and nutrient return in tropical dry deciduous teak forests of Satpura plateau in central India. *Tropical Ecology*. **43**(2): 337-344.

Pandey, HN., Tripathi, OP., and Tripathi, RS. (2003) Ecological analysis of forest vegetation of Meghalaya. In: Bhatt, BP., Bujarbaruah, KM., Sharma, YP., and Patiram (Ed.), *Approaches for increasing agricultural Productivity in Hill and Mountain ecosystem*. ICAR Barapani, Meghalaya, India.

Panwar, HS., and Rodgers, WA. (1988). *Planning Wildlife Protected area network in India*, Wildlife Institute of India, Dehradhun, India.

Pao, NT., and Upadhaya, K. (2017). Effect of fragmentation and anthropogenic disturbances on floristic composition and structure of subtropical broad leaved humid forest in Meghalaya, Northeast India. *Applied Ecology and Environmental Research*. **15**(4): 385-407.

Parejiya, NB., Detroja, SS., and Panchal, NS. (2013). Vegetation analysis at Bandiyabedi Forest in Surendranagar district of Gujarat state of India. *International Journal of Life Sciences Biotechnology and Pharma Research*. **2**(2): 241-247.

Parfitt, RL., Yeates, GW., Ross, DJ., Mackay, AD., and Budding, PJ. (2005). Relationships between soil biota, nitrogen and phosphorus availability, and pasture growth under organic and conventional management. *Applied Soil Ecology*. **28**(1): 1-13.

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**(10): 1365-1381.

Parthasarathy, N., and Karthikeyan, R. (1997). Plant biodiversity inventory and conservation of two tropical dry evergreen forests on the Coromandel coast, South India, *Biodiversity and Conservation.* **6**(8): 1063-1083.

Parthipan BM., Rajeeswari and Jeeva, S. (2016). Floristic Diversity of South Travancore Hindu College (S. T. Hindu College) Campus, Kanyakumari District (Tamilnadu) India. *Bioscience Discovery*. **7**(1): 41-56.

Pascal, JP., and Pelissier, R. (1996). Structure and floristic composition of a tropical evergreen forest in south-west India. *Journal of Tropical Ecology*. **12(**2): 191-214.

Patel, A., Verma, S., Singh, SK., and Kumar, R. (2017). Soil fertility status of Jaunpur District in Eastern Uttar Pradesh. *Journal of Pharmacognosy and Phytochemistry*. **6**(6S): 949-952.

Paul, EA., and Clark, FE. (1996). Soil microbiology and biochemistry. Academic Press, San Diego. *Soil microbiology and Biochemistry.* (Eds. II), San Diego, USA, Academic Press.

Pedro, MS., Rammer, W., and Seidl, R. (2015). Tree species diversity mitigates disturbance impacts on the forest carbon cycle. *Oecologia*. **177**(3): 619-630.

Perrott, KW., Sarathchandra, SU., and Waller, JE. (1990). Seasonal storage and release of phosphorus and potassium by organic matter and the microbial biomass in a high producing pastoral soil. *Soil Research*. **28**(4): 593-608.

Paul, S., Tripathi, AK., Burman, R., Panggam, M., Ray, SK., Kalita, N., Vanlalduati, R., and Singh, AK. (2017). Jhum cultivation and its consequences on forest and environment in Eastern Himalayan tract of India: a participatory Assessment. *Range Manag Agrofor*. **38**(1): 121-126.

Phillips, J. (1959). *Agriculture and Ecology in Africa*. London, UK, Faber and Faber Ltd.

Pielou, EC. (1969). *An Introduction to Mathematical Ecology*. New York, USA, Wiley-Interscience.

Pilania, PK., Gujar, RV., Joshi, PM., Shrivastav, SC., and Panchal, NS. (2015). Phytosociological and Ethanobotanical Study of Trees in a Tropical Dry Deciduous

Forest in Panchmahal District of Gujarat, Western India. *The Indian Forester*. **141**(4): 422-427.

Prabhu, SD., Barik, SK., Pandey, HN., and Tripathi, RS. (2010). Impact of landuse changes on plant species diversity of Nokrek Biosphere Reserve, Meghalaya, India. *Journal of the Bombay Natural History Society*, **107**(2): 146-158.

Premavani, D., Naidu, MT., and Venkaiah, M. (2014). Tree species diversity and population structure in the tropical forests of north central Eastern Ghats, *Notulae Scientia Biologicae*. **6**(4): 448-453.

Pringle, RM. (2008). Elephants as agents of habitat creation for small vertebrates at the patch scale. *Ecology*. **89**(1): 26-33.

Puspwan, KS., Singh, V., and Pandey, BN. (2019). Species richness, plant diversity and composition with respect to altitudinal variation in Western Nayar watershed, Uttarakhand, India. *International Journal of Recent Scientific Research.* **10**(06G): 33177-33182

Rad, JE., Valadi, G., Salehzadeh, O., and Maroofi, H. (2018). Effects of anthropogenic disturbance on plant composition, plant diversity and soil properties in oak forests, Iran. *Journal of Forest Science*. **64**(8): 358-370.

Ralte, V. (2004). Impact of shifting cultivation and mining on land degradation and soil biological processes in Nokrek biosphere reserve of Meghalaya. **Ph.D. Thesis**, North-Eastern Hill University, Shillong, India.

Ramakrishnan, PS. (1993). Shifting agriculture and sustainable development: an interdisciplinary study from North-eastern India. *Man and Book Series 10*. UNESCO, Paris, France, CRC Press.

Rao, P., Barik, SK., Pandey, HN., and Tripathi, RS. (1990). Community composition and tree population structure in a sub-tropical broad-leaved forest along a disturbance gradient. *Vegetatio*. **88**(2): 151-162.

Rao, R. (1981). Ethnobotany of Meghalaya: Medicinal Plants Used by Khasi and Garo Tribes. *Economic Botany*. **35**(1): 4-9.

Rao, S. (2014). Distribution of soil types, vegetation and tree species diversity in Eastern Ghats of Srikakulam District, Andhra Pradesh, India. *International Journal of Biodiversity and Conservation*. **6**(6): 488-494.

Rasingam, L., and Parathasarathy, N. (2009). Tree species diversity and population structure across major forest formations and disturbance categories in Little Andaman Island, India. *Tropical Ecology*. **50**(1): 89-102.

Raturi, GP. (2012). Forest community structure along an altitudinal gradient of district Rudraprayag of Garhwal Himalaya, India. *Ecologia*. **2**(3): 76-84.

Reddy, CS., Sreelekshmi, S., Jha, CS., and Dadhwal, VK. (2013). National assessment of forest fragmentation in India: Landscape indices as measures of the effects of fragmentation and forest cover change. *Ecological Engineering*. **60**: 453-464.

Rennolls, K., and Laumonier, Y. (2000). Species diversity structure analysis at two sites in the tropical rain forest of Sumatra. *Journal of Tropical Ecology*. **16**(2): 253-270.

Richards PW (1996). *The tropical rain forest: An ecological study*, Cambridge University Press, London, UK, Cambridge.

Ricker, JT. (2011). Species Extinction from Anthropogenic Disturbance Versus Habitat Resilience: Despair or Hope for the Planet Earth's Viable Biodiversity. *ESSAI*. **8**(36): 131-133.

Rol, N., Enow, E., and Bechem, E. (2013). Species composition, diversity and distribution in a disturbed Takamanda Rainforest, South West, Cameroon. *African Journal of Plant Science*. **7**(12): 577-585.

Roy, DK., Das, TA., Dutta, CM., and Sinha, BK. (2014). Diversity of angiosperm flora of Siju Wildlife Sanctuary, South Garo Hills district, Meghalaya, India. *Indian Journal of Plant Science*. **3**(3): 87– 101

Roy, PS., Murthy, MSR., Roy, A., Kushwaha, SPS., Singh, S., Jha, CS. Behera, MD., Joshi, PK., Jagannathan, C., Karnatak, HC., Saran, S., Reddy, CS., Kushwaha, D., Dutt, CBS., Porwal, MC., Sudhakar, S., Srivastava, VK., Padalia, H., Nandy, S., Gupta, S. (2013). Forest fragmentation in India. *Current Science*. **105**(6): 774-780.

Sagar, R., Raghubanshi, AS., and Singh, JS. (2003). Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. *Forest ecology and Management*, **186**(1-3): 61-71.

Saha, D., and Sundriyal, RC. (2013). Perspectives of tribal communities on NTFP resource use in a global hotspot: Implications for adaptive management. *Perspectives*, **3**(4): 125-169.

Saha, S., Rajwar, GS., and Kumar, M. (2018). Soil properties along altitudinal gradient in Himalayan temperate forest of Garhwal region. *Acta Ecologica Sinica*. **38**(1): 1-8.

Sahu, PK., Sagar, R., and Singh, JS. (2008). Tropical forest structure and diversity in relation to altitude and disturbance in a Biosphere Reserve in central India. *Applied Vegetation Science*. **11**(4): 461-470.

Sahu, S.C., Dhal, NK., and Mohanty, RC. (2012). Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malyagiri hill ranges, Eastern Ghats, India. *Tropical Ecology*. **53**(2): 163-168.

Salehi, A., Zarin-Kafsh, M., Zahedi-Amiri, AD., Marvi-Mohajer, MR. (2005). A study of soil physical and chemical properties in relation to tree ecological groups in Nam-Khaneh district of Kheirood- Kenar forest. *Iranian Journal of Natural Resources*. **58**: 567–578.

Sangma, TM., and Mishra, BP. (2017) Effect of anthropogenic disturbance on the tree diversity of Nokrek Biosphere Reserve in Meghalaya, India. *Journal of Agroecology & Natural Resource Management*. **4**(3): 196-200.

Sanjay, K and Kumari, R. (2019) Effects of Soil on Understorey Species Composition in Three Forests of Kumaun Himalaya. *Indian Journal of Ecology*. **46**(2): 250-254.

Sapkota, IP., Tigabu, M., and Odén, P. C. (2010). Changes in tree species diversity and dominance across a disturbance gradient in Nepalese Sal (*Shorea robusta* Gaertn. f.) forests. *Journal of Forestry Research*. **21**(1): 25-32.

Sarkar, M. (2015). Vegetation analysis and litter dinamics of hollongapar gibbon wildlife sanctuary Assam. Ph.D Thesis. pp:1-217, Department of Environmental Science, Tezpur University, Assam, India.

Sarkar, M., and Devi, A. (2014). Assessment of diversity, population structure and regeneration status of tree species in Hollongapar Gibbon Wildlife Sanctuary, Assam, Northeast India. *Tropical Plant Research*. **1**(2): 26-36.

Sarma, K., and Yadav, PK. (2013). Relentless Mining in Meghalaya, India. *Conservation Science*. **1**(1): 5-12.

Sati, VP. (2014). *Towards sustainable livelihoods and ecosystems in mountain regions* (pp. 1-205). Cham, Germany, Springer International Publishing.

Schaaf, T. (2002). Man and Biosphere (MAB) Programme of UNESCO: An Introduction. Division of Ecological Sciences, UNESCO Paris, France. In: Ramakrishnan, P.S., R.K.Rai, R.P.S. Katawal and S. Mehndiratta. (Ed.), *Traditional Ecological Knowledge for managing Biosphere Reserves in South and Asia* (pp. 3-8). Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi, India.

Sen, N. (2013). Nokrek biosphere reserve-An overview. In: Director, *Fauna of Nokrek Biosphere Reserve, (Meghalaya), Conservation Area Series* **45**: 1-124, Plates I-XV. Zoological Survey of India, Kolkata, India.

http://faunaofindia.nic.in/PDFVolumes/cas/045/index.pdf

Sergio, F., Newton, IAN., Marchesi, L., and Pedrini, P. (2006). Ecologically justified charisma: Preservation of top predators delivers biodiversity conservation. *Journal of Applied Ecology*. **43**(6): 1049-1055.

Shameem, SA., and Kangroo, IN. (2011). Comparative assessment of edaphic features and phytodiversity in lower Dachigam National Park, Kashmir Himalaya, India. *African Journal of Environmental Science and Technology*. **5**(11): 972-984.

Shankar, U. and Tripathi, AK. (2017). Rainforests north of the Tropic of Cancer: Physiognomy, floristics and diversity in 'lowland rainforests' of Meghalaya, India. *Plant Diversity*. **39**(1): 20-36.

Shannon, CE., and Weiner, W. (1963). *The Mathematical Theory of Communication*. Champaign, Illinois, USA, University of Illionis Press.

Sharma, CM., Baduni, NP., Gairola, S., Ghildiyal, SK., and Suyal, S. (2010). Effects of slope aspects on forest compositions, community structures and soil properties in natural temperate forests of Garhwal Himalaya. *Journal of Forestry Research*. **21**(3): 331-337.

Sharma, S., and Roy, PS. (2007). Forest fragmentation in the Himalaya: A Central Himalayan case study. *The International Journal of Sustainable Development & World Ecology*. **14**(2): 201-210.

Shulka, G., Subba, M., Dey, T., Rai, P., Puri, A., and Chakaravarty, S. (2014). Tree Diversity Pattern in Sub-Humid Tropical Foothill Forest of Indian Eastern Himalayas. *Journal of Tree Sciences*. **33**(1): 69-77.

Simpson, EH. (1949). Measurement of Diversity. *Nature.***163**:688.

Singh, SB., Mishra, BP., and Tripathi, SK. (2015). Recovery of plant diversity and soil nutrients during stand development in subtropical forests of Mizoram, Northeast India. *Biodiversitas Journal of Biological Diversity*, **16** (2): 205-212.

Singh, B., and Borthakur, SK. (2015). Forest issues and challenges in protected area management: A case study from Himalayan Nokrek national park and biosphere reserve, India, *International Journal of Conservation Science*. **6**(2): 233-252.

Singh, BK. (2016). A floristic account of Nokrek Biosphere Reserve Meghalaya India. **Ph.D. Thesis**. pp: 1-612. Department of Botany. The University of Burdwan. West Bengal, India. https://shodhganga.inflibnet.ac.in/handle/10603/122714

Singh and Ramakrishnan, PS. (1982). Structure and function of a sub- tropical humid forest of Meghalaya. Vegetation, biomes and its nutrients. *Proceedings of the Indian Academy of Sciences - Section B. Part 3, Plant Sciences*. **91**(3): 241-253.

Singh, B. (2011). Arboreal flora of Nokrek biosphere reserve Meghalaya. Ph.D. Thesis, Gauhati University, Gauhati, India.

Singh, BK., and Debnath, HS. (2008). Wild plants used by the tribes of Nokrek Biosphere Reserve, Meghalahya and their conservation. *Journal of Economic and Taxonomic Botany*. **32:** 364-367.

Singh, B., and Borthakur, SK. (2011). Wild medicinal plants used by tribal communities of Meghalaya. *Journal of Economic and Taxonomy Botany*, **35**(2): 331-339.

Singh, B., and Singh, B. (2016). Fagaceae contribution to floral wealth of Himalaya: Checklist on diversity and distribution in North-eastern states of India. *Current Life Sciences*. **2**(3): 72-78.

Singh, B., Phukan, SJ., Sinha, BK., Singh, VN., and Borthakur, SK. (2011). Conservation Strategies for Nepenthes Khasiana in The Nokrek Biosphere Reserve of Garo Hills, Northeast, India. *International Journal of Conservation Science*. **2**(1): 55-64.

Singh, H., Kumar, M., and Sheikh, MA. (2009). Distribution pattern of Oak and Pine along altitudinal gradients in Garhwal Himalaya. *Nature and Science*. **7**(11): 81-85.

Singh, JN., and Mudgal, V. (2000). Assessment of mineral content of tree leaf litter of Nokrek biosphere reserve and its impact on soil properties. *Tropical Ecology*. **41**(2): 225-232.

Singh, JS. (2002). The biodiversity crisis: A multifaceted review. *Current Science*. **82**(6): 638-647.

Singh, SB., Mishra, BP., and Tripathi, SK. (2015). Recovery of plant diversity and soil nutrients during stand development in subtropical forests of Mizoram, Northeast India. *Biodiversitas Journal of Biological Diversity*. **16**(2): 205-212.

Singh, V., Srivastava, SK., and Tewari, LM (2016). Floristic assessment of different habitats of Parvati Aranga wildlife sanctuary and adjacent Tikri forest area, Gonda, Uttar Pradesh, India. *Tropical Plant Research*. 3(3): 543–550.

Singh, B., Sinha, BK., Phukan, SJ., Borthakur, SK., and Singh VN. (2012). Wild edible plants used by Garo tribes of Nokrek Biosphere Reserve in Meghalaya, India. *Indian Journal of Traditional Knowledge.* **11**:166–171.

Singh, B., Borthakur, SK., and Phukan. SJ. (2014). A survey of ethnomedicinal plants utilized by the indigenous people of Garo Hills with special reference to the Nokrek Biosphere Reserve (Meghalaya), India. Journal of Herbs, Spices & Medicinal Plants. **20**:1–30.

Slingenberg, A., Braat, L., Van-der-Windt, H., Rademaekers, K., Eichler, L., and Turner, K. (2009). Study on Understanding the Causes of Biodiversity Loss and the Policy Assessment Framework. *European Commission Directorate-General for Environment*. [Accessed on 8th March 2019]

https://ec.europa.eu/%20environment/enveco/biodiversity/pdf/causes_biodiv_l

Smiet, AC. (1992). Forest ecology on Java: human impact and vegetation of montane forest. *Journal of Tropical Ecology*. **8**(2): 129-152.

Solgi, A., and Najafi, A. (2014). The impacts of ground-based logging equipment on forest soil. *Journal of Forest science*. **60**(1): 28-34.

Stapanian, MC., Casell, DL., and Cline, SP. (1997). Regional pattern of local diversity of trees; association with anthropozenies disturbance. *Forest Ecology and Management*. **93**: 33- 44.

State of Forest Report. (2017). Forest Report (SFR) 2017, Forest Survey of India, Ministry of Environment and Forests, Government of India. (pp. 1-363). http://fsi.nic.in/forest-report-2017 [Accessed on 29th April 2018].

Strasberg, D. (1996). Diversity, size composition and spatial aggregation among trees on a 1-ha rain forest plot at La Réunion. *Biodiversity & Conservation*. **5**(7): 825-840**.**

Sukumar, R., Dattaraja, HS., Suresh, HS., Radhakrishnan, J., Vasudeva, R., Nirmala, S., and Joshi, NV. (1992). Long-term monitoring of vegetation in a tropical deciduous forest in Mudumalai, southern India. *Current Science*. **62**(9): 608-616.

Sunil, C., Somashekar, RK., and Nagaraja, BC. (2011). Impact of anthropogenic disturbances on riparian forest ecology and ecosystem services in Southern India. *International Journal of Biodiversity Science, Ecosystem Services & Management*, **7**(4): 273-282.

Svensson, JR., Lindegarth, M., Jonsson, PR., and Pavia, H. (2012). Disturbance–diversity models: what do they really predict and how are they tested?. *Proceedings of the Royal Society B: Biological Sciences*. **279**(1736): 2163-2170.

Svensson, JR., Lindegarth, M., Siccha, M., Lenz, M., Molis, M., Wahl, M., and Pavia, H. (2007). Maximum species richness at intermediate frequencies of disturbance: consistency among levels of productivity. *Ecology*. **88**(4): 830-838.

Swamy, PS., Sundarapandian, SM., Chandrasekar, P., and Chandrasekaran, S. (2000). Plant species diversity and tree population structure of a humid tropical forest in Tamil Nadu, India. *Biodiversity & Conservation*. **9(**12): 1643-1669.

Takhtajan, A. (1969). *Flowering plants, Origin and Dispersal*. Washington, USA, Smithsonian Institution Press.

Thakur, NS., Attar, SK., Hegde, HT., and Bhusara, JB. (2017) Diversity and Importance of Shrubs in Traditional Agroforestry Systems in India. In: Gupta, SK., Panwar, P., and Kaushal, R. (Ed.), *Agroforestry for Increased Production and Livelihood Security*, pp: 379-400, New India Publishing Agency, New Delhi, India.

Tilman, D., May, RM., Lehman, CL., and Navak, MA. (1994). Habitat destruction and extinction. *Nature*. **371**:65-66.

Tiwari, AK., and Bansal, KN. (1992). Vertical distribution of forms of potassium in some soil series of Northern Madhya Pradesh. *Journal of Potassium Research*. **8**: 223-230.

Tiwari, BK., Tynsong, H., and Lynser, MB. (2010). Forest management practices of the tribal people of Meghalaya, North-East India. *Journal of Tropical Forest Science*. **22**(3): 329-342.

Tole, L. (2002). Habitat loss and anthropogenic disturbance in Jamaica's Hellshire Hills area. *Biodiversity & Conservation*. **11**(4): 575-598.

Tripathi, OP., and Tripathi, RS. (2010). Community composition, structure and management of subtropical vegetation of forests in Meghalaya State, Northeast India, *International Journal of Biodiversity Science, Ecosystem Services & Management*. **6**(3-4): 157-163.

Tripathi, AK., and Shankar, U. (2014). Patterns of species dominance, diversity and dispersion in 'Khasi hill sal' forest ecosystem in northeast India. *Forest Ecosystems*. **1**(1): 23.

Tripathi, KP., and Singh, B. (2009). Species diversity and vegetation structure across various strata in natural and plantation forests in Katerniaghat Wildlife Sanctuary, North India. *Tropical Ecology*. **50**(1): 191.

Tripathi, OP., Pandey, HN., and Tripathi, RS. (2008). Effects of Human Activities On Structure and Composition of Woody Species of the Nokrek Biosphere Reserve of Meghalaya, Northeast India. *植物生态学报*. **32**(1): 73-79.

Tripathi, OP. (2002). *Study of distribution pattern and ecological analysis of major forest types of Meghalaya,* **Ph. D Thesis**. North-Eastern Hill University, Shillong, India.

Tripathi, OP., Upadhaya, K., Tripathi, RS., and Pandey, HN. (2010). Diversity, dominance and population structure of tree species along fragment-size gradient of a subtropical humid forest of northeast India. *Research journal of Environmental and Earth sciences*. **2**(2): 97-105.

Tynsong, H., and Tiwari, BK. (2011). Diversity and population characteristics of woody species in natural forests and arecanut agroforests of south Meghalaya, Northeast India. *Tropical Ecology*. **52**(3): 243-252.

Uddin, MB., Steinbauer, MJ., Jentsch, A., Mukul, SA., and Beierkuhnlein, C. (2013). Do environmental attributes, disturbances and protection regimes determine the distribution of exotic plant species in Bangladesh forest ecosystem?. *Forest Ecology and Management*. **303**: 72-80.

UNESCO. (1996). Man and the Biosphere Programme, In: *Biosphere reserves: The Seville Strategy and the Statutory Framework of the World Network*. UNESCO, Paris. https://unesdoc.unesco.org/ark:/48223/pf0000103849 [Accessed on 11th May 2017]

UNESCO. (1995). International Conference on Biosphere Reserves, Seville, Final report. https://unesdoc.unesco.org/ark:/48223/pf0000103544?posInSet=1&queryId=N-EXPLORE-ab0d24fd-53f3-496b-85c0-4feb771f27e0 [Accessed on 7th Aug 2017]

UNESCO-MAB. (1974). Working Group on Project 6 - Impact of Human Activities on Mountain Ecosystems. Final Report. *MAB Report Series No. 14*. Paris, UNESCO. http://www.fao.org/3/x0963E/x0963e08.htm [Accessed on 11th May 2017]

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.

Upadhaya, A., Chaturvedi, SS., and Tiwari, BK. (2016). Utilisation of wild Citrus by Khasi and Garo tribes of Meghalaya. *Indian Journal of Traditional Knowledge*. **15**(1): 121-127.

Upadhaya, K. (2015). Structure and floristic composition of subtropical broad-leaved humid forest of Cherapunjee in Meghalaya, Northeast India. *Journal of Biodiversity Management & Forestry.* **4**:(4): 1-8.

Upadhaya, K., Barik, SK., Pandey, HN., and Tripathi, OP. (2008). Response of woody species to anthropogenic disturbances in sacred forests of northeast India. *International Journal of Ecology and Environmental Sciences*. **34**(1): 245-257.

Upadhaya, K., Pandey, HN., Law, PS., and Tripathi, RS. (2004). Diversity and population characteristics of woody species in subtropical humid forests exposed to cultural disturbances in Meghalaya, Northeast, India. *Tropical Ecology*. **45**(2): 303-314.

Upadhaya, K., Thapa, N., and Barik, SK. (2015). Tree diversity and biomass of tropical forests under two management regimes in Garo hills of north-eastern India. *Tropical Ecology*. **56**(2): 257-268.

Upadhaya, K., Thapa, N., Lakadong, NJ., Barik, SK., and Sarma, K. (2013). Priority areas for conservation in northeast India: a case study in Meghalaya based on plant species diversity and endemism. *International Journal of Ecology and Environmental Sciences*. **39**(2): 125-136.

Upadhyaya, K., and Arunachalam, A. (2004). Immediate effect of clearfelling on soil C, N and P in a humid tropical forest in Arunachal Pradesh. *Journal of Tropical Forest Science*. **16**(1): 136-139.

Valencia, R., Balslev, H., and Miño, GPY. (1994). High tree alpha-diversity in Amazonian Ecuador. *Biodiversity & Conservation*. **3**(1): 21-28.

Van-Cuong, C., Dart, P., and Hockings, M. (2017). Biosphere reserves: Attributes for success. *Journal of Environmental Management*, **188**: 9–17.

Vidyarthi, S., Samant, SS., and Sharma, P. (2013). Traditional and indigenous uses of medicinal plants by local residents in Himachal Pradesh, North Western Himalaya, India. *International Journal of Biodiversity Science, Ecosystem Services & Management*, **9**(3): 185-200.

Vieira, DL., and Scariot, A. (2006). Principles of natural regeneration of tropical dry forests for restoration. *Restoration Ecology*. **14**(1): 11-20.

Vitousek, PM., Porder, S., Houlton, BZ., and Chadwick, OA. (2010). Terrestrial phosphorus limitation: mechanisms, implications, and nitrogen–phosphorus interactions. *Ecological applications*. **20**(1): 5-15.

Westman, WE. (1990). Managing for biodiversity. *BioScience*. **40**(1): 26-33.

Whitford, PB. (1949). Distribution of woodland plants in relation to succession and clonal growth. *Ecology*. **30**:199-208.

Williams, CA., Gu, H., MacLean, R., Masek, JG., and Collatz, GJ. (2016). Disturbance and the carbon balance of US forests: A quantitative review of impacts from harvests, fires, insects, and droughts. *Global and Planetary Change*. **143**: 66-80.

Williams, LG. (2002). Tree species richness complementarity, disturbance and fragmentation in a Mexican tropical montane cloud forest. *Biodiversity & Conservation*. **11**(10): 1825-1843.

Xiongwen, C. (2001). Change of tree diversity on Northeast China Transect (NECT). *Biodiversity & Conservation*. **10**(7): 1087-1096.

Yadav, PK., Kapoor, M., and Sarma, K. (2012). Impact of Slash-And-Burn Agriculture on Forest Ecosystem in Garo Hills Landscape of Meghalaya, North-East India. *Journal of Biodiversity Management & Forestry*. **1**(1- 2): 1-6.

Yadav, PK., Sarma, K., and Mishra, AK. (2013). Geospatial Modeling to assess Geomorphological Risk for Relentless Shifting Cultivation in Garo Hills of Meghalaya, North East India. *International Journal of Environment*. **2**(1): 91-104.

Yamada, I. (1977). Forest ecological studies of the montane rainforest of Mount Pangrango, W. Java. Part IV: Floristic composition along the altitude. *Southeast Asian Studies*. **15**: 226-254.

Yumnam, JY., Tripathi, OP., and Khan, ML. (2013). Soil dynamic of agricultural landscape in East Siang District of Arunachal Pradesh, Eastern Himalaya. *African Journal of Plant Science*. **7**(1): 43-52.

Zhao, W., Zhang, R., Huang, C., Wang, B., Cao, H., Koopal, LK., and Tan, W. (2016). Effect of different vegetation cover on the vertical distribution of soil organic and inorganic carbon in the Zhifanggou Watershed on the loess plateau. *Catena*. **139**: 191-198.

Zhu, J., Mao, Z., Hu, L., and Zhang, J. (2007). Plant diversity of secondary forests in response to anthropogenic disturbance levels in montane regions of North-eastern China. *Journal of Forest Research*. **12**(6): 403-416.

BIO-DATA

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Research interest: Plant Ecology, Biodiversity, Wildlife conservation, Medicinal plants.

ACADEMIC QUALIFICATION

2013-2019: PhD Research Scholar, Department of Environmental Science, Mizoram University. Thesis topic "*A study on effect of anthropogenic disturbance on diversity, distribution and community characteristics of plants in the Nokrek Biosphere Reserve in Meghalaya, India*".

2010-2012: Masters in Forestry with specialization in Forest Ecology, Mizoram University

2006-2010: Bachelors of Science in Botany, North Eastern Hill University (NEHU), Shillong.

PRESENTATIONS

1) Presented project report on ***"Conservation Significance of Community Reserve in and around Nokrek Biosphere Reserve of Meghalaya"*** on commemoration of UNESCO's Man and Biosphere Programme, Nokrek Biosphere Reserve, India in "World Network of Biosphere Reserve Workshop Cum Stakeholders Consultation" 27th and 28th May, 2019, East and West Garo Hills Wildlife Division, Tura, Meghalaya.

2) Presented poster on the topic ”***Diversity of trees in Nokrek National Park of Meghalaya, India”*** in Student Conference on Conservation Science (SCCS), Bengaluru, India on 27th to 30th September 2018.

3) Presented Paper on ***“Effect of anthropogenic disturbance on the tree diversity of Nokrek Biosphere Reserve in Meghalaya, India”*** on International Conference on Contemporary issues in Integrating Climate Change, Kalimpong Science Centre, Kalimpong, May 2017.

4) Presented speed cum talk poster on **“*Diversity and distribution of trees in the core and buffer zone of the Nokrek Biosphere Reserve of Meghalaya, India”*** in Young Ecologist Talk And Interact (YETI), Amity University, Noida held on 17th -21st January 2016.

RESEARCH PUBLICATIONS AND ARTICLES

1) **Sangma, T. M.,** & Mishra, B. P. Effect of Anthropogenic Disturbance on the Tree Diversity of Nokrek Biosphere Reserve in Meghalaya, India. *variations*, *7*, 9. Journal of Agroecology and Natural Resource Management Volume 4, Issue 3; April-June, 2017, pp. 196-200

2) Mishra B.P and **T. M Sangma**. Effect of Disturbance on Diversity and Distribution of Herbaceous Vegetation in Nokrek Biosphere Reserve, Meghalaya, North-East India Environment and Ecology 37 (4) : 1186—1196, October—December 2019

3) B.Gopichand, **T.M.Sangma** and B.P.Mishra Sacred groves in India- An overview. SOV-01. Indian Science Congress-Imphal Chapter. Regional Science Congress. North Eastern Region. 30th and 31st December, 2013. Innovations in Science and Technology for Inclusive Development. ISCA

4) The Shillong times edition, June 18, 2014 **‘’*Is Garo hills already another desert ?*“** online: https://theshillongtimes.com/2014/06/18/environmentalist-changingspots/?fbclid=IwAR2ebzqq05rwaM5Rb4QTJoOUtnnz49QTqKKqsL-Eyq48zd218_OlvMVa_qk

SEMINAR AND WORKSHOPS ATTENDED

1) Training on "***Stakeholder engagement and effectively Managing people and teams***" 30 January—1 February, 2020 at Nature Conservation Office, Mysore.
2) Course on ***"Remote Sensing and GIS Applications in Forestry and Ecology"*** at North Eastern Space Applications Centre (NESAC), Umiam, Meghalaya 21st to 25th October, 2019.
3) Training program on ***‘’Biostatistics’’*** held from 5th to 9th August 2019 at Salim Ali Centre for Ornithology and Natural History (SACON), Anaikatty, Coimbatore.
4) Participated in Workshop on **"Ecosystem Approaches to Water and Food Security for Rural Wellbeing"** jointly organized by the Ashoka Trust for Research in Ecology and the Environment (ATREE) and the Indian Institute of Technology – Guwahati (IIT-G)on September 9th - 14th at IIT-Guwahati.
5) Participated in workshop "***Angiosperm taxonomy, Bio resource Conservation and Utilization***". December 3rd-7th, 2018 at IIE, Guwahati organized by Ashoka Trust for Research in Ecology and the Environment (ATREE).
6) Participated at **"National Seminar on Issues of Wildlife Conservation in India"** held on 24th-25th April, 2014 at Mizoram University, Aizawl, Mizoram.
7) Participated in One day workshop on "***Environmental Impact Assessment***" at Aijal Club, Aizawl on 11th November, 2016.
8) Participated in UGC-Sponsored National Level **"Interaction Programme for PhD Scholars"** organized by Mizoram University during 23rd-12th October ,2015

PARTICULARS OF THE CANDIDATE

NAME OF THE CANDIDATE: TREMIE M SANGMA

DEGREE: PH.D

DEPARTMENT: DEPARTMENT OF ENVIRONMENTAL SCIENCE

TITLE OF THESIS: A STUDY ON EFFECT OF ANTHROPOGENIC DISTURBANCE ON DIVERSITY, DISTRIBUTION AND COMMUNITY CHARACTERISTICS OF PLANTS IN THE NOKREK BIOSPHERE RESERVE OF MEGHALAYA, INDIA.

DATE OF ADMISSION: 13/08/2012

APPROVAL OF RESEARCH PROPOSAL: 5/4/2013

1. DRC: 22/3/2013

2. BOS: 5/4/2013

3. SCHOOL BOARD: 13 /5/2013

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PhD REGISTRATION NUMBER & DATE: MZU/PhD/580 of 13.5.2013

EXTENSION (IF ANY): 12.05.2020

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A STUDY ON EFFECT OF ANTHROPOGENIC DISTURBANCE ON DIVERSITY, DISTRIBUTION AND COMMUNITY CHARACTERISTICS OF PLANTS IN THE NOKREK BIOSPHERE RESERVE OF MEGHALAYA, INDIA

(ABSTRACT)

A THESIS SUBMITTED IN PARTIAL

FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF DOCTOR OF PHILOSOSPHY

TREMIE M SANGMA

(MZU REGISTRATION NO. 151 OF 2011)

(PH.D REGISTRATION NO. 580 OF 13.5.2013)

DEPARTMENT OF ENVIRONMENTAL SCIENCE

SCHOOL OF EARTH SCIENCES AND NATURAL RESOURCES

MANAGEMENT

APRIL, 2020

Biodiversity has turned out to be the topic of worldwide attention because of increasing awareness of its significance and its rapid depletion globally. The richness in biodiversity is mainly due to vast variation in vegetation type, topography, edaphic and climate conditions coupled with diverse ecological habitats. However, unplanned land use, alien species, pollution, toxicity and climate change due to anthropogenic disturbance are the main causes of loss in biodiversity. Biodiversity is observed mainly at three levels- gene, species and ecosystem. Biosphere reserves extend over terrestrial areas and coastal ecosystems.

India, the tenth among the twelve mega diversity countries of the world depend largely on biodiversity in many ways. As per ISFR 2019, about 21.67 % of the geographical area in the country is covered by the forest. India has one of the richest biodiversity and heritage of the world covering tropical rain forest, alpine vegetation and coastlands. There are 701 Biosphere Reserves globally and. India has 18 Biosphere Reserves. There are three distinct zones in a Biosphere reserve- the core zone, buffer zone and the transition zone.

The Nokrek Biosphere Reserve of Meghalaya covering an area of 820 km^2 was recognized by the UNESCO's World Network of Biosphere Reserve on 26th May, 2009.The core zone is the Nokrek National Park covering an area of 47.48 Sq Km and the buffer zone has an area of 227.92 sq. km. TheNokrek Biosphere Reserve acts as a principal watershed for all the rivers of Garo Hills.

Meghalaya has a total forest area of 17,217 km^2 and having sites for conservation of biodiversity are community reserves, sacred groves, national parks and biosphere reserve. Recently, the number of settlement in vicinity of Nokrek Biosphere reserve has increased anthropogenic activities in the buffer zone, causing threat for loss of biodiversity and depletion of dense forest cover.

In view of the above, the present investigation has been carried out with an aim to study the effects of anthropogenic disturbances on vegetation of Nokrek Biosphere reserve with the following objectives:

(i) To determine plant community characteristics, diversity and distribution of plant species in core zone and buffer zone of the Nokrek Biosphere Reserve,

(ii) To assess the impact of anthropogenic activities on vegetation, and

(iii) To formulate appropriate strategies for biodiversity conservation and management of Nokrek Biosphere Reserve.

Meghalaya being situated in the North East India Bio-geographic zone represents an important part of the Indo-Burma biodiversity hotspot. According to Kanjilal, the types of forest found in Meghalaya are- Tropical Evergreen Forests, Tropical Semi-Evergreen Forests, Tropical Moist and Dry Deciduous Forests, Grasslands and Savannas, Temperate Forests and Sub-tropical Pine Forests. Nokrek Biosphere Reserve (NBR) is located overlapping with parts of three districts, i.e. East, West and South Garo Hills. The highest point is the Nokrek peak 1412m. The Reserve recognized by the UNESCO's World Network of Biosphere Reserve spreads over an area of approximately 820 sq. km of which 47.48 sq. km is the Nokrek National Park (NNP) constituting the core area of the Nokrek Biosphere Reserve. The Nokrek National Park area remains comparatively undisturbed, consisting of primary evergreen forests and is accessible only on foot. All the major rivers like Simsang, the biggest and the longest river, Ganol and numerous streams of the three districts of Garo Hills originate from this area. The last remaining primary forests are also believed to be found in this area.

For vegetation analysis, one-hectare area was taken separately for both the core and the buffer zone. Quadrat of 10m x 10 m was taken for tree species, 5x5m for shrubs and 1x 1m for herbaceous species. For trees, cbh≥30 cm was taken in consideration and gbh was measured at a height of 1.37m. For identification, the collected plant samples were taken to Botanical Survey of India, Shillong.

The updated version of classification of the plants was followed from the online websites of the Plant List (Version 1.1) and the International Plant Names Index (IPNI). Specimen identification was also done with the support of pictures, photographs and old records. IBM SPSS Statistics 23 was used to find out the correlation between various plant indices. To understand the impact on vegetation on soil constituent, the physicochemical properties of soil for moisture content, pH, and bulk density, organic carbon, Nitrogen, Phosphorous and Potassium were also tested. The socio-economic survey was carried out to understand the socio economic impact on bio-physical.

The major findings can be summarized as below:

Overall, a total of 267 species (trees, shrubs and herbs) with 186 genera and 88 families were recorded both from the core and buffer zone.

I. Vegetation analysis of Tree species

1. Altogether a total of 124 tree species belonging to 92 genera and 52 families were recorded from both sites of the core and buffer zone of Nokrek Biosphere Reserve.
2. The tree richness was (91 species, 67 genera and 40 families) in the core zone which is higher than the richness in the buffer zone (82 species, 66 genera and 42 families).
3. The tree density was 733 (individuals ha^{-1}) for core zone and 1272 (individuals ha^{-1}) for the buffer zone.
4. The basal area was 68.99 (m^2 ha^{-1}) in the core zone and 34.16 (m^2 ha^{-1}) in the buffer zone.
5. In the core zone, the family Lauraceae was the dominant family followed by Fagaceae whereas in the buffer zone Lauraceae was the co-dominant family and Euphorbiaceae was the most dominant family.
6. The dominance diversity curve based on IVI was found to be short for the tree species in the buffer zone indicating mild disturbance and instability.
7. *Castanopsis* was the largest genus having the maximum number of species in the core zone whereas in the buffer *Ficus* was the dominant genus.
8. In the core zone, the highest basal area was observed in (121-150) cm dbh class. But in the buffer zone highest basal area was found in (30-60) cm dbh class.

9. In the core zone, *Syzygium claviflorum* has the highest IVI (27.87) whereas in the buffer zone *Saurauia punduana* has the highest IVI (29.25).
10. The co-dominant species were *Macropanax dispermus* (IVI 19.57) and *Castanopsis indica* (IVI 16.11) in the core zone whereas in buffer zone *Saurauia napaulensis* (IVI 22.09), *Eurya accuminata* (IVI 19.40).
11. *Eurya accuminata* and *Terminalia citrina* were the most abundant species in the core zone and *Helicia nilagirica* and *Saurauia napaulensis* in the buffer zone.
12. *Syzygium claviflorum* has the highest basal area (8.40 m^2 ha^{-1}) followed by *Macropanax dispermus* (4.89 m^2 ha^{-1}) and *Castanopsis indica* (4.07 m^2 ha^{-1}) in the core zone and *Castanopsis indica* has the highest basal area of (3.73m^2 ha^{-1}) followed by *Saurauia napaulensis* (2.64 m^2 ha^{-1}) in the buffer zone.
13. In the core zone 98% species exhibited contiguous distribution pattern and 2% were randomly distributed. In the buffer zone, 95% species exhibited contiguous distribution pattern and 5% of the species were randomly distributed. *Macropanax dispermus* and *Ocotea lancifolia* showed random distribution in the core zone and *Callicarpa arborea*, *Eurya accuminata*, *Glochidion daltonii* and *Schefflera elliptica* in the buffer zone of Nokrek Biosphere Reserve.
14. Shannon diversity indices (H') were higher in the core zone (3.81) than the buffer zone (3.50).
15. Simpson dominance index (CD) followed a reverse trend with the values being lower at the core zone (0.03) and higher at the buffer zone (0.05).
16. Evenness index (E) was greater in the core zone (0.85) than in the buffer zone (0.79).
17. Margalef index of species richness was higher in core zone (13.64) than the buffer zone (11.33).

II. Vegetation analysis for Shrubs

1. Total of 66 shrub species belonging to 63 genera and 30 families of angiosperm were recorded from the sampled area of core and buffer zone of Nokrek Biosphere Reserve.
2. The shrub species richness was 34 species, 28 genera and 18 families in the core zone which is lower than the buffer zone (51 species, 35 genera and 28 families).
3. The shrub density was 1428 (individuals ha^{-1}) for core zone and 3756 (individuals ha^{-1}) for the buffer zone.
4. In the core zone, *Phlogacanthus curviflorus* has the highest IVI (25.06) whereas in the buffer zone *Rhynchotechum ellipticum* has the highest IVI (33.14.)
5. The dominant species were *Phlogacanthus curviflorus* (IVI- 25.06) with density 192 (individuals ha^{-1}) in core zone whereas and *Rhynchotechum ellipticum* (IVI- 33.14) with a density of (812 individuals ha^{-1}) in buffer zone.
6. The dominant family in the core zone was Acanthaceae and is replaced by Lamiaceae in the buffer zone.
7. The Shannon diversity index was found lower in the core zone (3.24) than in the buffer zone (3.25).
8. Simpson dominance index showed a reverse trend in result and value was low in core zone (0.05) than the buffer zone (0.07).
9. The Margalef's index of species richness was also found to be lower in the core zone (5.04) than in the buffer zone (7.30).
10. Higher evenness index value of 0.22 was found in core zone and 0.83 in buffer zone.

III. Vegetation analysis for Herbs

1. Total of 77 herbaceous species belonging to 63 genera and 38 families of angiosperm were recorded.

2. The herb species richness were 44 species, 34 genera and 23 family in the core zone which is lower than the buffer zone (52 species, 44 genera and 29 families).
3. Herb density in the core zone was 889 (individuals per 100 m^2) and 914 (individuals per 100 m^2) in the buffer zone.
4. *Elatostema sessile* was the most dominant species (IVI- 40.48) with density of 247 (individuals per 100 m^2). In buffer zone, the dominant species was *Pteris quadriaurita* (IVI 35.47) with density of 212 (individuals per 100 m^2).
5. Urticaceace, the dominant family in the core zone was replaced by Asteraceace in buffer zone.
6. The Shannon diversity index was lower in the core zone (3.10) than in the buffer zone (3.21).
7. Simpson dominance index showed a reverse trend and the values were higher in the core zone (0.10) than in buffer zone (0.08).
8. The Margalef's index of species richness was lower in the core zone (6.33) than in the buffer zone (7.48)
9. Evenness index (0.82) was same for both the zones.

IV. Soil analysis

1. Soil moisture content in the core zone varied from 26 to 40 % in 0-15cm and 22.5% to 34 % in 15-30 cm. In the buffer zone, it varies from to 21 -35% in 0-15cm and 19-33 % in 15-30 cm. Moisture content was more during the monsoon season (July to August).
2. pH ranged from 5.2-6.8 in the upper layer and 5.0-6.7 in the lower layer in the core zone whereas in the buffer, the pH ranged from 5.2-6.7 in 0-15cm and 5.3-6.8 in 15-30 cm soil depth. The pH of the soil was acidic in the monsoon season.
3. In the core zone the bulk density ranged from 0.482-1.077 gm cm^{-3}.In the buffer zone, the range was from 0.61- 1.10 gm cm^{-3}.

4. Carbon content values in the core zone ranged from 2.28-3.27 % in the upper layer and 1.36-2.3 % in the lower layer mainly due to the presence of humus and slow process of decomposition. In the buffer zone the values ranged from 1.96-2.95 % in 0-15cm soil layer and 1.27-2 % in the lower layer of 15-30cm. It was high in pre-monsoon season followed by monsoon season.
5. Nitrogen in the core zone ranged from 0.3-0.5 % and 0.22-0.43 % in the soil depth of 0-15 and 15-30 respectively. In the buffer zone, the Nitrogen ranged from 0.25-0.37 % in 0-15 cm soil depth and 0.17-0.23 % in 15-30 cm depth. The Nitrogen content was highest in pre monsoon season.
6. The available Phosphorous varied from 1.56 ppm – 3.06ppm in the soil depth of 0-15cm and 1.1ppm – 2.83ppm in the depth of 15-30cm.In the buffer zone, it varies from 1.1ppm-3ppm in the upper layer and 0.8ppm-2.46ppm in the sub soil. The maximum reading was recorded in post- monsoon season.
7. In the core zone, the range of exchangeable potassium varies from 168-382.65 kg/ha in the upper layer and 70.93-121.33 kg/ha in the lower layer. It decreased from upper to lower layer in both the core and the buffer zone. In buffer it ranged from 149.33- 280 kg/ha and 112-242.67 kg/ha in both the depths. It was highest during the pre-monsoon season.

V. Socio economic analysis

1. From the household survey in four villages 31% was found to be illiterate with 71 % of the respondents having large family size and majority of them were cultivators.
2. The entire village falls under the below poverty line. 80% of the respondents earn their livelihood from jhum cultivation. 75 % of houses are made out of raw materials available from forest. Major source of fuel is firewood. Species such as *Callicarpa arborea*, *Macaranga denticulata*, *Eurya accuminata* are the favorable species.
3. The standard of living is poor with limitations to basic necessities like lack of road connectivity, drinking water, and school infrastructure and health centers.

4. The area has high potential for development of tourism. Few tourist areas have been set up and it is another way to earn revenue for the native people of the area. Proper management and demarcation of the areas will help to improve their living conditions through tourism industry.
5. Many traditional healers were also found in the area. Tapping of their knowledge through documentation and awareness programmes will be beneficial both for the society and from conservation perspective.
6. Out of the total of 50 species, 46 genera and 33 family listed in medicinal uses, 33 are herbaceous species and the rest 17 are woody species (trees and shrubs) were found to be most widely used by the people in the village.
7. Altogether 41 species were having the timber values in the study area and maximum timber species (44 species) were recorded from buffer zone then the core zone (28 species).

VI. Impact of disturbance on plant communities and soil

1. The forest in the core zone **(**undisturbed stand) remained intact and undisturbed mainly due to terrain and inaccessibility. In the buffer zone (disturbed stand) mild disturbance due to various anthropogenic activities has led to decrease in number of mature trees and species and has paved opportunity for increase growth of understory vegetation like shrubs and herbs.
2. Tree species like *Aesculus assamica*, *Magnolia baillonii* and *Aphanamixis polystachya* are found only in the core zone whereas in the buffer zone mainly *Macaranga denticulata, Duabanga grandiflora, Lagerstroemia parviflora.* Few species were common to both the stands namely *Helicia nilagirica, Mesua ferrea, Mallotus philippensis.*
3. Shrub species like *Phlogacanthus curviflorus Rauvolfia serpentina Citrus indica* are the dominant species in the core zone and *Rhynchotechum ellipticum, Rubus ellipticus, Clerodendrum infortunatum*in the buffer zone.

4. Herbaceous species like *Urtica dioica, Elatostema sessile* are the dominant species in the core zone and *Molineria latifolia, Pteris quadriaurita* in the buffer zone.
5. Soil was found to be more disturbed in the buffer areas mainly due to practice of shifting cultivation and lack of mature trees with good canopy cover causing exposure of soil reducing the moisture content.
6. From the socio economic survey it was found that the dependency on the forest resources for survival is high. Activities through timber and non-timber forest product collection have affected the forest soil and vegetation in the buffer zone. Construction of check dams, expanding roads and cutting of soil for settlement purposes has damaged the landscape and composition of these areas.
7. The settlements in the fringe areas are the Garo tribes and are culturally embedded into this ancestral and traditional practice of shifting cultivation. All mature timbers have been found to be removed and left as a fallow land in the buffer zone.

V. Conservation and management strategies

From the investigations carried out, the following recommendations are being made for conservation and management of the Nokrek Biosphere Reserve-

1. Management of the Catchment Area: In the buffer zone plantation of tree species- *Aphanamixis polystachya, Castanopsis indica, Terminalia myriocarpa, Syzygium claviflorum, Saurauia napaulensis, Aesculus assamica* etc. would help in soil infiltration and groundwater recharge.

2. Restoration of Forest- Establishment of community (supply forest) adjacent to the core zone can reduce pressure on vegetation. Restoration of the degraded areas should be done through planting of native species in the gaps. Species attractive to frugivores should be planted to encourage seed dispersal.. Nitrogen fixing species can be planted to improve soil fertility. Economically important and fast growing species can also be grown more widely to provide economic goods.

3. Strengthening Indigenous Knowledge- Integration of traditional and formal science and launching of integrated management approaches involving Government institutions, NGOs and indigenous tribal community settled in buffer areas of Nokrek Biosphere Reserve.

4. V**egetation Conservation and Soil Restoration-** While clearing of forest is done for developmental purpose norms of Environmental Impact Assessment can be followed. Since soil disturbance through erosion, landslide is common in the hilly region the fallow period can be increased for the soil and vegetation to get replenished. To prevent such disturbance implementation of proper protection measures to facilitate natural regeneration in buffer zone is necessary. Shifting cultivation in the periphery of the rivers up to certain metres needs to be monitored.

5. Proper Implementation of Environment Conservation Laws- Sign board pertaining to laws and regulations needs to be upgraded. The native people residing in the villages of the buffer zone should be made aware of the rules and regulations on conservation of the biosphere reserves and national park through workshops.

6. Encouragement of Tourism: Local people of the area should get short term trainings to guide the tourist visiting the area. Training on segregation of waste needs to be introduced in the village. Eco friendly materials like solar panels, biodegradable containers and recycling of waste can be introduced in the village.

7. Priority to Socio-Economic Values: Educational institutions and various other infrastructures like road, Primary Health Centre's needs to be upgraded in the area. Livestock farming and direct sell of organic products obtained from cultivation can be encouraged in the area. Use of firewood can be replaced by LPG or electric cooking appliances lowering their dependency on fuelwood.

The findings of the quantitative study of vegetation along with physical and chemical properties of soil depicts that the forest is mildly disturbed in the buffer zone. The areas in the core zone remained undisturbed except for natural disturbances. If human activities are under rapid activity, it would create a risk in the future. The secondary forest in the area would also lead to permanent agroforestry systems losing the primary vegetation. The research work carried out will help to formulate appropriate conservation strategies for the plant community of the area as well as to understand the alterations that have occurred in the soil status. The socio economic conditions help to understand the reliability of the fringe dwellers in the buffer zone. The suggestive conservation strategies for present scenario for proper management of the vegetation of the Nokrek Biosphere reserve may include- strong protection measure and plantation in the gaps with suitable species in the buffer zone. Moreover, integrated management approach involving local community, NGO`s and scientists may be more effective tool for conservation of plant resources of the reserve on sustained basis.