DECLARATION

I, Anu Paudyal, hereby declare that the work presented in this dissertation is my own original work and has not been submitted for any other academic degree. All the sources of information have been specifically acknowledged by reference wherever adopted from other sources.

Thank You.

……………………

Anu Paudyal

December, 2019

TRIBHUVAN UNIVERSITY
Institute of Science and Technology
Amrit Campus
Department of Botany, Thamel, Kathmandu
Tel No: 4410408, 4411637

December, 2019

RECOMMENDATION

This is to certify that the dissertation work entitled **"***Tree Diversity and Carbon Stock in Bolbum Community Forest and Brahmakumari Global ReligiousForests of Rupandehi, Nepal***"** has been carried out by **Anu Paudyal** under my supervision. This work has been completed by candidate's original research work based on field sampling and laboratory work. To the best of my knowledge, this research has not been submitted for any other academic degree. I recommend this dissertation work to be accepted as a partial fulfillment of the requirements for Masters' degree in Botany at Institute of Science and Technology, Tribhuvan University.

………………………..

Supervisor
Prof. Dr. Mukesh K. Chettri
Professor
M.Sc. Coordinator
Department of Botany
Amrit Campus

TRIBHUVAN UNIVERSITY

Institute of Science and Technology

Amrit Campus

Department of Botany, Thamel, Kathmandu

Tel No: 4410408, 4411637

December, 2019

LETTER OF APPROVAL

The dissertation work entitled **"***Tree Diversity and Carbon Stock in Bolbum Community Forest and Brahmakumari Global Religious Forests of Rupandehi, Nepal***"** submitted by **Anu Paudyal** has been accepted for the examination and submitted to the Department of Botany, Amrit Campus, Tribhuvan University for the partial fulfillment of the requirements for Masters' degree in Botany.

....	……………………….
Prof. Dr. Kanta Poudyal	**Prof. Dr. Mukesh K. Chettri**
Head of the Department	M.Sc. Coordinator
Department of Botany	Department of Botany
Amrit Campus	Amrit Campus
Tribhuvan University	Tribhuvan University
Thamel, Kathmandu, Nepal	Thamel, Kathmandu, Nepal

TRIBHUVAN UNIVERSITY
Institute of Science and Technology
Amrit Campus
Department of Botany, Lainchaur, Kathmandu
Tel No: 4410408, 4411637

December, 2019

CERTIFICATE OF ACCEPTANCE

This dissertation work entitled **"***Tree Diversity and Carbon Stock in Bolbum Community Forest and Brahmakumari Global Religious Forests of Rupandehi, Nepal***"** submitted by **Anu Paudyal** has been examined and accepted for partial fulfillment of the requirements of Masters' degree in Botany.

Evaluation Committee

....

Supervisor **Head of the Department**

Prof. Dr. Mukesh K. Chettri
Amrit Science Campus
Department of Botany

Prof. Dr. Kanta Poudyal
Amrit Science Campus
Department of Botany

……………………….. ………………………

Internal Examiner **External Examiner**

Prof. Dr. Kanta Poudyal
Amrit Science Campus
Department of Botany

Dr.Anjana Devkota
Central Department of Botany
Tribhuwan University Kritipur

ACKNOWLEDGEMENT

Firstly, I would like to express my gratitude to Amrit Campus, Tribhuvan University for providing me opportunity to conduct the M.Sc dissertation research which helped to develop my research and analytical skills.

I am deeply indebted to my respected supervisor Prof. Dr. Mukesh K. Chettri, for his valuable comments and suggestions to prepare this research work. I would like to convey my deep gratitude to him for guiding me and encouraging me throughout the study.

I am very much thankful to Prof. Dr. Kanta Poudyal, Head of the Department of Botany, Amrit Campus, Tribhuvan University for her valuable suggestion and administrative help.

Similarly, I would like to thank all the teachers and staff of Department of Botany, Amrit Campus for their valuable suggestion and guidance.

I am very much thankful to my friends Manu Dahal, Susmita Simkhada, Bindu KC and all botany team for their constant support and also thankful to those supportive hands for their direct or indirect help during the study.

I am thankful to authorities of Bolbum Community Forest and Brahmakumari Global Religious Forest, Rupandehi District Forest Office and Sector Forest Office for allowing me to conduct research and also providing valuable information. I would also like to thank Department of Hydrology and Metrology for providing me necessary data.

Last but not the least, I would like to extend my special thanks to my father and all my family members for their precious support and guidance throughout my study and this research work.

Anu Paudyal

ABSTRACT

Forests are one of the most important natural resources of the ecosystem which contribute in biodiversity conservation as well as play significant role in maintaining the earth's climate by sequestrating atmospheric carbon. Tropical forests are rich in biodiversity and store large amount of carbon than elsewhere. The studied Bolbum Community forest (BCF) and Brahmakumari Global Religious Forest (BGRF) lie in tropical region at an altitude 120 to 300meter in Rupandehi District of Nepal. The main objective of the present study is to assess and compare Tree diversity and carbon stocks in two different management regimes namely Community forest and Religious forest.

Stratified random sampling technique was used for assessing tree diversity and carbon stock in both forests. The allometric equation Biomass-diameter regression (Model II) developed by Chave *et al*., (2005) was used for estimation of carbon stock of tree species and tree species diversity by Simpsons and Shannon-Wiener indices. The carbon stock value was found to be 27.15 t/ha in BCF and 40.94 t/ha in BGRF. Community forest found to have lower value of tree carbon stock than the carbon stock of Religious forest. But in case of tree diversity it was recorded high in BCF (25) than in BGRF (20).

Shorea robusta was found to be the single dominant species in BGRF with higher basal area (102.24 m^2/ha) and contributed 56 % of the carbon stock. The basal area of *Shorea robusta* and *Anogeissus latifolius* were found to be 16.42% and 14.6% respectively in BCF. The contribution of carbon stock of two co-dominant tree species in BCF are 32% of *Shorea robusta and 26% Anogeissus latifolus*. Higher value of basal area in both forest types in the present study suggests that both the forests are in a mature developmental phase. There was significant (*P=0.05*) positive relationship of carbon stock with basal area and DBH in both forest types.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ANNEXES

ACRONYMS AND ABBREVIATIONS

ºC	Degree Celsius
%	Percentage
ANOVA	Analysis of Variance
ANSAB	Asia Network for Sustainable Agriculture and Bio-resources
asl	above sea level
BCF	Bolbum Community Forest
BGRF	Brahmakumari Global Religious Forest
C	Carbon Stock
CF	Community Forest
CFUGs	Community Forest Users Groups
cm	centimeter
CFM	Collaborative Forest
COP	Conference of Parties
DBH	Diameter at Breast Height
DFO	District Forest Office
DFRS	Department of Forest Resources
DHM	Department of Hydrology and Meterology
DOF	Department of Forest
et al.,	and others
FAO	Forest and Agriculture Organization
GF	Government Forest
GHG	Green House Gases
GoN	Government of Nepal

HMG	His Majesty's Government of Nepal
ha	hectare
ha^{-1}	per hectare
IPCC	Intergovernmental Panel on Climate Change
Kg	Kilogram
m	meter
m^2	meter square
REDD	Reducing emissions through deforestation and forest degradation
RF	Religious Forest
UNFCCC	United Nations Framework Convention on Climate Change

CHAPTER 1: INTRODUCTION

1.1 Background

Nepal is a biodiversity rich country that represents a significant share of global biodiversity; in just comprises 0.09% of global land area (ICIMOD, 2007).It is situated on the central part of the world's top 20 hottest global biodiversity hotspots, the Himalayas. Biodiversity is globally significant and locally important as biodiversity is the important source of livelihoods and income generation. Biodiversity conservation and sustainable utilization of biological resources have been mainstream agenda after rectification and enforcement of more about 20 international treaties and agreements related to biodiversity and environment conservation including Convention of Biological Diversity (GoN, 2009). Biodiversity conservation is a high priority in the forest sector policy of Nepal (HMG, 2000).

Carbon stock refers to the amount of carbon stored, mainly in living biomass and soil, but to a lesser extent also in dead wood and litter. Stock of carbon represents the net exchange of carbon fluxes in an ecosystem (net ecosystem exchange) (Keith *et al*., 2009). In the total ecosystem (living plus dead biomass plus soil), the carbon stock is determined by the balance between the fluxes of carbon gain by Net Primary Productivity and carbon loss by decomposition of dead biomass and heterotrophic respiration. Ecosystem carbon stocks vary because environmental conditions influence the carbon fluxes of photosynthesis, decomposition and autotrophic and heterotrophic respiration differently (Keith *et al*., 2009).

The major cause of Global warming and climate change is accelerated input of gaseous carbon to the atmosphere. The increased input of carbon to the atmosphere is mainly due to anthropogenic activities such as fuel combustion, transportation, deforestation, shifting trend and land use changes (Shrestha, 2009).

Forests play a significant role in offsetting carbon dioxide emission; the primary anthropogenic GHGs. Forests in the United States alone sequester about 200 million metric tons of carbon each year (Chavan, 2010). In forest ecosystem, atmospheric carbon is captured and fixed biomass. Therefore growing trees can be a potential contribution in reducing the concentration of carbon dioxide in atmosphere by its accumulation in the form of biomass (Chavan, 2010). Tropical riverine and *Alnus nepalensis* forest types demonstrated the highest carbon sequestration rates in Nepal (Baral *et al*., 2009). The value of forests and trees in sequestering carbon and reducing carbon dioxide emission to the atmosphere is being recognized increasingly the world over. Forests play an important role in the carbon cycle as they sequester CO_2 from the atmosphere through photosynthesis (Kolshus, 2001).

Nepal has tropical forest that lies between 100 to 1000 meter above sea level (m asl) which is characterized by high species diversity. Tropical forests are characterized by high species richness, composition, standing biomass and productivity (Finegan, 2015, Baniya *et al*. 2010, O'Brien 1993, Jordan 1983) due to favorable climatic condition. Warm temperature, fast nutrient turnover rate, humid climate and long duration of precipitation throughout the year are some environmental factors for high species diversity, richness and biomass in the tropical lowland. Tropical forest are well known for high rates of net primary production and store approximately 216 Pg carbon in the above ground biomass (Brown *et al*., 1993; Dixon *et al*., 1994; Silver *etal*., 2000). Tropical forests are located in the Terai and the region is highly disturbed due to over increasing human population. *Shorea robusta* is the most successful and highly important timber species of this forest. Deforestation and destruction is common in Sal forests that directly and indirectly affect the other ecosystem and also contributes in global warming.

Vegetation composition depends on local environmental variables like altitude, aspects, moisture, climate and soil. Altitude is one of the most important factors that determine the vegetation type in Nepal (Bhatta, 1977 and Shrestha, 1982). Besides the topographic factors, biological factor like disturbances is also looked upon as a major factor affecting species diversity pattern (Hutson, 1994). For better exploration and utilization of natural resources, scientific studies regarding the vegetation dynamics and habitat diversity are necessary.

Species diversity in an ecological community incorporates both richness and evenness of species abundances. Diversity is measured to determine if an environment is degrading and to compare two or more environments. Diversity indices provide important information about the composition of community. Species diversity can be expressed in a single index number. Ecologists have developed many indices of species diversity among which

Simpsons index (Simpsons 1949) and Shannon-Wiener Index (Shannon and Weaver 1949) are the most commonly used indices. Simpson's index reflects dominance while Shannon-Wiener Index reflects both evenness and species richness, without favouring either dominant or rare species. The value of diversity index was higher in species rich forest than in forest dominated by single species (Magurran 1988 cited in Nakakaawa *et al*., 2010).

1.1.1 Forest and carbon stock

Total forest area of Nepal is 12, 87,000 thousands ha in Terai and the forest and shrub lands in the Mountain is about 3, 96,000 thousands ha which cover non cultivated inclusions (NCI) of 517 thousands ha and cultivated inclusions of 211 thousands ha (DOF 2012).

The concept of REDD is based on governing the forest resources as long as the carbon reservoirs for the future by reducing the rate of deforestation and forest degradation. (Pokheral and Baral, 2009). REDD is Primarily about the reducing atmospheric carbon dioxide emission as an element of a comprehensive approach mandated by Bali Action Plan in Dec 2007 (Cop 13 at the Conference of Party of United Nations Framework Convention on Climate Change (UNFCCC) meeting in Bali, Indonesia). Later it was termed as REDD+ after COP 15 held in Poland 2008 (Karky and Baskota, 2009; and Manandhar, 2013).

Carbon stock refers to the amount of carbon stored, mainly in living biomass and soil, but to a lesser extent also in dead wood and litter. Stock of carbon represents the net exchange of carbon fluxes in an ecosystem (net ecosystem exchange) (Keith *et al*., 2009). In the total ecosystem (living plus dead biomass plus soil), the carbon stock is determined by the balance between the fluxes of carbon gain by Net Primary Productivity and carbon loss by decomposition of dead biomass and heterotrophic respiration. Ecosystem carbon stocks vary because environmental conditions influence the carbon fluxes of photosynthesis, decomposition and autotrophic and heterotrophic respiration differently (Keith *et al*., 2009).

To control global warming, there are many options such as the mitigating option-sequestration of carbon dioxide and reduction of emission; the adaptive option – adjustment in ways that reduce the negative impacts of temperature changes on the environment and indirect policies like controlling population growth or changing technologies (Shrestha, 2009). Among the options, forestry is one of the most cost effective mitigating options (IPCC, 1995). Forest covers more than one-third of the world's land area and constitute the major terrestrial carbon pool (Roberntz, 1999). Forests are the most important pool for carbon storage and play an important role in sequestrating the atmospheric carbon into biomass and soil. Forests not only provide various goods and services to the human beings, they are also natural storage for carbon, at the global scale, contributing approximately 80% of terrestrial above ground and 40% of below ground carbon storage (Kirschbaum, 1996). Overall forest ecosystem, stores 20-100 times more carbon per unit area than croplands and are important in reducing ambient carbon dioxide levels, by sequestrating atmospheric carbon in the growth of woody biomass through the process of photosynthesis (Brown and Pearce, 1994). Approximately half the dry weight of a tree's biomass is carbon **(**Johson and Coburn, 2010). Trees, because they sequester atmospheric carbon through their growth process and conserve energy, have been suggested as one means to combat increasing levels of atmospheric carbon (Nowak, 1993).

1.1.2 Community and Religious forest

There are 6 different types of forest management practices in Nepal to conserve the biodiversity (Bhattarai, 2016).

- Government managed forest,
- Leasehold forest,
- Religious forest,
- Protection forest,
- Community forest
- Private forest

There are differences in their forest management practices. There is ambiguity about the extent to which community forestry can support biodiversity conservation because it aims to supply forest products to local users rather than to conserve or maximize biodiversity. It is widely recognized that prevalent forest management strategy of CFUGs is protection-oriented or passive (Acharya, 2002; NPC 2001; Shrestha 2000; Campbell *et al.,* 1996; Karki, et al. 1994) resulting in fewer benefits than otherwise could have. The term "protection-oriented" refers to the forest management system allowing only for the collection of dry wood and twigs as well as certain non- wood forest products such as leaf litter for animal bedding and compost (Campbell *et al.,* 1996). Contrary to protection-oriented forest management system, production-oriented forest management system involves carrying out of silvicultural and harvesting operations as demanded by the forest condition to improve forest productivity (Acharya 2003b).

The community forestry program was initiated in 1978 on the ground of rapid decline of forests area and biodiversity. It is a partnership between local communities and the government for protection, management, and sustainable utilization of forest products and ecosystem services to meet the daily need of local community. Master Plan for Forestry Sector (MoFSC, 1989) fully recognized the need of peoples' participation, and Forest Act (1993) provided detailed guidelines and policy framework for community forestry. The main components of the program are : formation of community forest users' groups (CFUGs), the preparation of operational plan, approval of the operation plan by district forest office_ (DFO), and hand over of the forest to the community (HMG, 2002).

Sacred groves or religious forest are forest patches having traditions and cultural values of local and indigenous people who protect the groves with their strong socio-religious beliefs and taboos (Khumbongmayum *et al*., 2006). Sacred groves have received considerable attention, as a pioneer of community managed natural resource management regime in Nepal.

The practices of maintaining and managing religious forest and its potential to incorporate to community forestry have been seen as an important way to manage forest in Nepal (Ingles,1994) argued that religious beliefs and practices affect the way forests are perceived and managed in Nepal. Forests are also affected by activities such as tree worship; establishment and maintenance of scares sites in forests, religious festivals and rituals conducted within the forest. Moreover, religious forests provide refugia for species, which may otherwise have become locally extinct. Religious forests are not harvested and there is a belief that it is devoted in the name of the god (Acharya, 2003a).

1.2 Justification of study

Rupandehi district of Lumbini zone is in the verge of rapid developmental processes. The development process directly or indirectly affects the nature. Increase in level of carbondioxide results global warming and climate change. To control the carbon emission to the atmosphere forest plays an important role. Forests are an important part of the planet's carbon cycle, and sequester a substantial amount of the CO_2 released into the atmosphere by human activities. Bolbum Community Forest of Sainamaina Municipality and Bhramakumari Global Religious Forest of Butwal Sub-metropolitan city also play important role in carbon cycle as other forest, but the quantity of carbon stored in that forest is still unknown. Research work related to carbon stock in this forest has not been done before. Beside this the management practices in Bolbum Community Forest and Brahmakumari Global Religious Forest is quite different.

In Bolbum Community Forest, forest users groups allowed to collect fire wood, litters, and fodders once in a week and are also uses plants and their products for the purpose of religious rituals like *Bratabanda, Chaurasi Pooja, Bibaha* etc. Users group of community forest also use silviculture practices like thinning, pruning signaling etc. But in Brahmakumari Global Religious Forest people only collect the fallen twigs and branches and there is no silvicultural practices and fodder collection. Hence it is expected that the management practices will influence the carbon stock and tree diversity. Similarly, impact of forest management practices on tree diversity has not been investigated in this region. Hence, estimation of carbon stock and status of tree diversity of these forests is very significant to know their contribution in the process of climate change mitigation.

1.3 Hypothesis

Because of differences in forest management practices, it is hypothesized that Bolbum Community Forest have high Tree diversity and Religious Forest have high Carbon stock.

1.4 Objectives

The general objective of the study is to understand the role of forest management practices on Tree diversity and Carbon stock in two different forests

Specific objectives are

- to enumerate tree species in both religious and community managed forest;
- to calculate carbon stock in both religious and community managed forest;

1.5 Limitations

- Biomass of seedlings, shrubs, herb and litter was not included.
- Other soil parameters such as Nitrogen and pH were not analyzed.
- Only tree carbon stock was calculated
- only tree diversity was included

CHAPTER 2: LITERATURE REVIEW

Giri et al., (1999) assessed vegetation composition, biomass production and regeneration of tree species in Terai *Shorea* forest and *Shorea-Terminalia* forest in the South-Western part of the Royal Bardia National Park, Nepal. Their result showed that both the forests were mainly dominated by *Shorea robusta* and *Terminalia alata* with 28 tree species in Terai *Shorea* forest and 49 tree species in *Shorea-Terminalia* forest. The common dominant species in both forests were *Buchanania latifolia*, *Lagerstroemia parviflora*, *Dillenia pentagyna*, *Mallotus phillippensis*, *Careya arborea*, *Bauhinia malabarica*, *Casearia tomentosa*, *Garuga pinnata* etc. Their study recorded highest above ground biomass in *Shorea-Terminalia* forest 384.02 t/ha followed by Terai *Shorea robusta* forest 330.87 t/ha. In both forest *Shorea robusta* had the greatest number of seedlings and saplings.

IPCC (2000) estimated about 19% of the carbon in earths biosphere is stored in plants and 81% in the soil. Tropical, temperate and boreal forests together are believed to store approximately 31% of the carbon in biomass and 69% in the soil. Tropical forests alone stored approximately 50% of carbon as biomass and 50% in soil and he also defines carbon sequestration as an increase in carbon stock in forest than in atmosphere. Forests acts as natural carbon storage. Forests play vital role in the global carbon cycle by reducing carbondioxide from the atmosphere and storing it in the biosphere.

Poudel (2000) compared the vegetation structure and soil characteristics in community and government managed forests in the Udayapur district, Nepal. He concluded that relatively large number of plant species were present in the community forest than in the government forest except the number of tree species were found higher in national forest than in community forest. Community forest was highly dominated by *Shorea robusta* whereas the national forest was equally dominated by *Terminalia tomentosa* and *Shorea robusta*. Soil pH ranged from 4.33-5.33, organic matter 1.01% to 2.43%, nitrogen 0.056% to 0.01%, phosphorus 76.64 to 126.81 Kg/ha and potassium 196.80 to 267.73 Kg/ha.

Shakya *et al*., (2000) enumerated flowering plants of Butwal area and documented 155 plant species belonging to 130 genera and 54 families. Family leguminosae comprised maximum number of species.

Marasini (2003) analyzed vegetation in different forest habitats with special reference to facial aspects in Rupandehi. He found *Shorea robusta* was the most dominant tree species with the highest IVI value in all the three studied sites whereas among the shrubs the IVI value of *Woodfordia fructicosa* was the highest. From soil analysis he found that soil texture was sandy loam type in all the three sites consisting pH value ranged from 4.6 - 5.5, water holding capacity 38.5% - 48.00%, soil moisture 10.90% - 30.75%, organic matter 1.21% - 2.45%, nitrogen content 0.052% -0.153%, phosphorus 6.86 kg/ha – 30.00 kg/ha and potassium 128 – 468 kg/ha found in two different seasons.

Shrestha *et al*., (2004) studied population structure of *Quercus semecsrpifolia* Sm. in mature forest of Shivapuri Hill (Shivapuri National Park, Kathmandu), Central Nepal. The result indicated the study site had old growth mature forest with comparatively low tree density (203 ha^{-1}) but high basal area (50m^2 ha^{-1}). The result showed the forest had abundant number of small seedlings (density 3807 ha^{-1}) but saplings were very rare (density 62 ha^{-1}).

Baral *et al*., (2009) assessed the study on above ground carbon stock in five major forest types, representing two physiographic regions and four districts of Nepal and found that rate of carbon sequestration by different forest types dependent on the growing nature of the forest stands. Tropical riverine and *Alnus nepalensis* forest types demonstrated the highest carbon sequestrastion rates in Nepal. Result shows that above ground carbon stock of hill Sal forest and riverine forest were found to be higher that is 97.86 ton/ha and 80.47 ton/ha, respectively whereas the above ground carbon of *Schima castanopsis, Pine* and *Alnus nepalensis* forests were lower i.e.34.3, 38.7 and 34.6 ton/ha respectively.

Shrestha (2009) selected *Schima-Castanopsis* forests for the study in Palpa district with the objectives of quantifying the total carbon sequestration and evaluation of aspect and elevation on carbon storage. He found the total biomass carbon in *Schima-Castanopsis* forest was higher in northern aspect but soil carbon sequestration was higher in western aspect. Likewise, total carbon sequestration in western aspect was found 1.17 times higher compared to northern aspect at an elevation range 1100-1200m. Similarly, total carbon sequestration was found 1.13 times higher at an elevation range 1350-1500m than 1100-1200m.

Oli and Shrestha (2009) studied forest cover and carbon storage in different forests of Nepal and found that forest covered nearly 40% of the total land area of the country. Carbon storage in the above ground and below ground biomass, dead wood, litter and forest soil was 897 million metric tons in the year 2005. Community managed forest covered about 1.2 million ha with contribution of 183.3937 million tons of carbon while government managed forest covered 3.9 million ha with contribution of 596.0296 million tons of carbon and protected forest covered 0.71 million ha with contribution of 108.508 million tons of carbon but other types of national forest i.e. leasehold, religious and private forest had low contribution to carbon as compared to above mentioned forest types.

Khanal *et al.*, (2010) studied soil and vegetation carbon pools in two community forests of Palpa district, Nepal found that above ground and below ground (root) carbon pools in Jarneldhara CF were 36.6 ± 3.4 t ha^{-1} and 10.5 ± 1.0 t ha^{-1}, respectively; while those on Lipindevi Thulopakho CF were 40.2 ± 4 t/ha and 11.4 ± 7.4 t ha^{-1} respectively. Soil organic carbon pool in Jarneldhara and Lipindevi Thulopakho CF were 121.4±7.4 t ha^{-1} and 94.6 ± 4.4 t ha^{-1} respectively. From this he concluded that CFs had high potential to offset large portion of carbon emission through sequestration into both soil and vegetation, and act as a natural carbon sink.

Shrish (2012) estimated carbon stock of selected tree species in a community managed tropical forests of Rupandehi district. Her study found that total mean biomass carbon stock was not significantly different in sites dominated by *Dalbergia sissoo* (221.70 C Mg/ha) and *Shorea robusta* (188.55 C Mg/ha). The mean soil carbon stock in *Shorea robusta* dominated sites of the forest were significantly higher (81.40 Mg/ha) than in the *Dalbergia sissoo* dominated sites (51.00 Mg/ha).

Mandal *et al.*, (2012) studied the effects of deforestation and forest degradation on forest carbon stocks in three collaborative forests of Mahottari district, Nepal. Three collaborative forests namely Gadhanta-Bardibas, Tuteshwarnath and Banke- Mahara CFMs were selected for the study. Highest carbon stock was found to be 274.66 t ha^{-1} in Gadhanta-Bardibas CFM while it was lowest about 197.10 t ha^{-1} in Banke-Mahara CFM and the estimated carbon stock of Tuteshwarnath CFM was found about 222.580 t ha^{-1}. The findings showed that the levels of carbon stocks in the three studied CFMs were different depending on how the drivers and management units influence them.

International Panal on Climate Change (IPCC) (2013) aspects that climate change will affect the carbon cycle processes in a way that will result in an excess amount of CO_2 in the atmosphere. The atmospheric concentrations of carbondioxide, methane and nitrous oxide have increased to levels as never before in at least the last 800,000 years. Carbon dioxide concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions.

Mandal *et al*., (2013) studied relationship between carbon stock and plant biodiversity in three collaborative forests (CFMs) in terai, Nepal. Three collaborative forests namely Gadhanta-Bardibas, Tuteshwarnath and Banke- Mahara CFMs were selected for research site. Highest carbon stock was found to be 274.66 t ha^{-1} in Gadhanta-Bardibas CFM while it was lowest about 197.10 t ha^{-1} in Banke-Mahara CFM. The findings showed that there was positive and very weak relationship between carbon stock and species richness of collaborative forests; it showed nearly hump-shaped relationship. However, the opposite hump-shaped relationship was found between values of Simpson's evenness and carbon stock. So, from the study it was indicated that the forest carbon enhancement cannot assure the biodiversity conservation and promotion.

Gaire (2015) studied on tree regeneration, diversity and carbon stock in two community managed forests of Tanahun district. In his study, ANOVA test showed significant difference between mean values of carbon stock and diversity among the strata of Fulbari CF (log carbon, p=0.00 and log H1, p=0.001) while T- test did not show significant difference in mean values of carbon stock (p=0.001) but significant difference in diversity (p=0.0045) among the strata of Taldanda CF. *Shorea robusta* was found the single dominant species in Fulbari C F (higher value of Simpsons index and basal area) and contributed about 64 % of carbon stock while in Taldanda CF *Shorea robusta* contributed 44 % of carbon stock.

Pathak (2015) studied plant species diversity and tree carbon stock in a *Shorea robusta* Gaertn. Community forest of Nawalparasi district. This study documented a total of 68 vascular plant species under 41 families and 61 genera. Fabaceae was the most dominant family (9 species) followed by Araceae (3 species). The average carbon stock value found to be 115 tons per hectare and tree stem volume was measured as 225.2 cubic meter per hectare.

Poudel and Sah (2015) compared the structure, composition and diversity of trees, shrubs and saplings, seedlings and herbaceous species of community and government managed forests in the lowlands of Eastern Nepal. Result suggested that among the trees, the community forest was dominated by a single species, *Shorea robusta*. However, *Shorea robusta* and *Terminalia myriocarpa* were codominant in the government forest. He found that tree density and basal area were higher in the government forest, but shrub/sapling density and basal area were higher in the community forest, suggesting a positive effect of community management on tree regeneration. From the result, the dominance of *Shorea robusta* trees in the community forest suggests that people involved in managing forest may be more interested in a limited number of economically valueable species while removing less important trees.

Sharma *et al*., (2015) assessed the forest diversity and carbon sequestration in Resunga religious forest of Gulmi, Nepal. The result recorded nineteen tree species from Rhododendron and Oak forests. He compared the forest types and found that Rhododendron forest was more diverse (H=1.0) than Oak forest (H=0.9). Similarly, tree species were more evenly distributed (0.87) in the Oak forest than that of Rhododendron forest (0.77). According to his calculation, vegetation carbon stock of Rhododendron forest was lower (101.8 t/ha) than that of Oak forest (153.8 t/ha) and average carbon recorded in the forest was 127.75 t/ha.

Mandal *et al*., (2016) assessed and compared the current annual carbon increament (CACI) in three community managed forests (CFs) and three collaborative forests (CFMs) and also evaluated the carbon sequestration potentials in these forests. The result revealed that estimated CACI was 2.85 t ha^{-1} in Chyandanda CF however leakage was -1.68 t ha^{-1} in Banke-Mahara CFM. Moreover, the multiple comparisons Tukey’s test showed that there were significant differences in CACIs among the forests. The worth of carbon sequestration potential was US$ 11613.41 in these community and collaborative forests.

Pandey and Bhusal (2016) estimated total biomass and carbon sequestration in two different ecological regions of Nepal. The result revealed that the total carbon stock in the community managed forests (CFs) of the terai and the hills were found to be 479.29 t/ha and 234.54 t/ha respectively. The biomass carbon stock density was higher in *Shorea robusta* CFs of terai 384.20 t/ha than of hill forest 123.15t/ha. Carbon densities of different carbon pools such as tree, sapling, leaf litter, grass and herbs were significantly higher ($p < 0.05$) in the Terai than in the hill forest whereas dead wood and stumps and the soil organic carbon density were not found to be significantly different in these regions.

Paudyal (2016) assessed the regeneration status of Sal (*Shorea robusta*) seedlings, its growth and plant diversity in Pragatisil community forest of Kaski District, Western Nepal. The result showed that there was significant ($p \leq 0.05$) effect of slope on DBH and basal area whereas there was no effect of aspect on growth parameters measured in the Pragatisil community forest. He found that the regeneration of Sal was satisfactory (6,126 seedlings/ha) and recorded 32 plant species in the Pragatisil community forest of Kaski District.

Shrestha and Devkota (2016) estimated the total vegetation carbon stocks in Oak and Pine forests in Salyan District of Nepal. He found the total biomass carbon stocks in Oak and Pine forests were 90.37 and 24.82 t/ha, respectively. Similarly, the soil carbon stocks in the Oak and Pine forests were 60.82 and 46.12 t/ha, respectively.

Ghimire (2017) studied diversity and tree carbon stock in danphe community forest of Dang. From the study he found an average of 62.34 t/ha of carbon stock in the year 2013 and 64.86 t/ha in year 2014 that is increase in 2.52 t/ha of carbon stock per year. A total of 89 plant species in 39 families and 80 genera were documented by this study. Poaceae was found as the richest family with 13 species followed by family Fabaceae with 9 species. Herb was the dominant life form with 41 species followed by tree (21), shrub (16), climber (9) of angiosperms and Pteridophytes (2) species.

Ghimire *et al*., (2018) assessed carbon stock in *Shorea robusta* forest of tropical region and *Pinus roxburghii* forests of sub-tropical region in Makwanpur District of Nepal. The total biomass carbon estimated in *Shorea robusta* and *Pinus roxburghii* forest were 170.75 t/ha and 144.96 t/ha, respectively. Similarly, the soil carbon sequestration in *Shorea robusta* and *Pinus roxburghii* forest was found 58.82 t/ha and 43.94 t/ha, respectively. He found that total carbon sequestration in *Shorea robusta* forest was 1.21 times higher than in the *Pinus roxburghii* forest.

Sharma et, al.,(2015),studied forest diversity and carbon sequestration in Resunga sacred grove, Gulmi, Nineteen tree species were recorded from Rhododendron and Oak forests. Comparing the forest types, Rhododendron forest was more diverse (H = 1.0) than Oak forest (H = 0.9). Similarly, tree species were more evenly distributed (0.87) in the Oak forest than that of *Rhododendron* forest (0.77). The vegetation carbon stock of Rhododendron forest was lower (101.8 t/ha) than that of Oak forest (153.8 t/ha). Overall, the average vegetation carbon stocks in the Resunga Sacred Grove (RSG) was 127.75 t/ha.

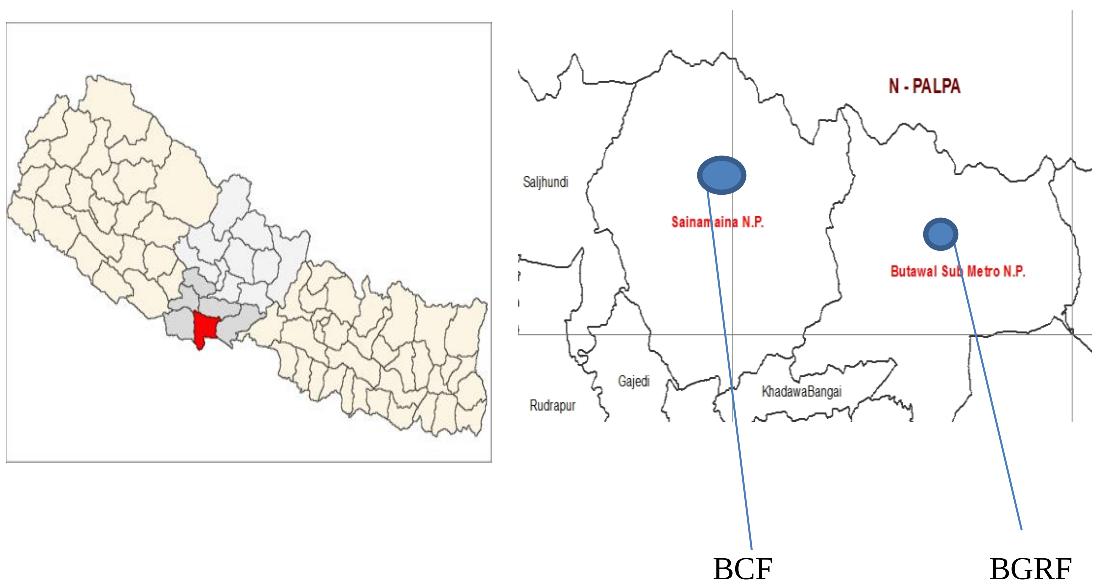
Acharya (2003a) studied the Religious and spiritual value of forest plants in Nepal. The study was conducted in Kusma, Siwalaya Village Development Committee, Parbat of western development region of Nepal. Different plants and their products were essential with no replacement to perform various religious rituals. This practice was higher particularly in rural areas in that study area. Some plants species were highly scared and worshipped such as *Ficus religiosa, F. bengalensis, F. glomerata, Magnifera indica, and F. glaberrima, Dsemotachya bipinnata, Ocimum spp* and *Phyllanthus emblica.*

CHAPTER 3: MATERIALS AND METHODS

3.1 Study Area

3.1.2 Description of the study Area

Mainly the study area of Bolbum Community Forest lies in Sainamaina Municipality, and Brhamakumari Global Religious Forest lies in Tamnagar Municipality, now change into Butwal sub metropolitan city, Rupandehi. The study area lies in tropical region below 1000m, and is dominated by *Shorea robusta.*



3.1.3 Community forest

The Bolbum community managed forest is located 14 km west from Butwal Sub-metropolitan city. This community forest lies on Sainamaina Municipalities ward no. 1, 4, 5 and 7 of Rupandehi district. The Community Forest covers an area of 623.03 hectares and represents natural tropical forests and altitude varies from 120 meters to 300 meters. This study covered approximately only 150 hectors of the Bolbum Community Forest because of accessibility. Only accessible areas were considered for the study as all the forest area of Brahmakumari Global religious Forest are easily eccessible. The main tree species found in this forest are *Shorea robusta, Buchanania latifolia, Wendlandia exserta, Semecarpus anacardium* and *Terminalia alata.* The forest was handed over to the community in 2002 and altogether 1,180 households were involved in the management of the forest. The management committee of the community forest user group consists of 23 members including 5 women members.

3.1.4 Religious forest

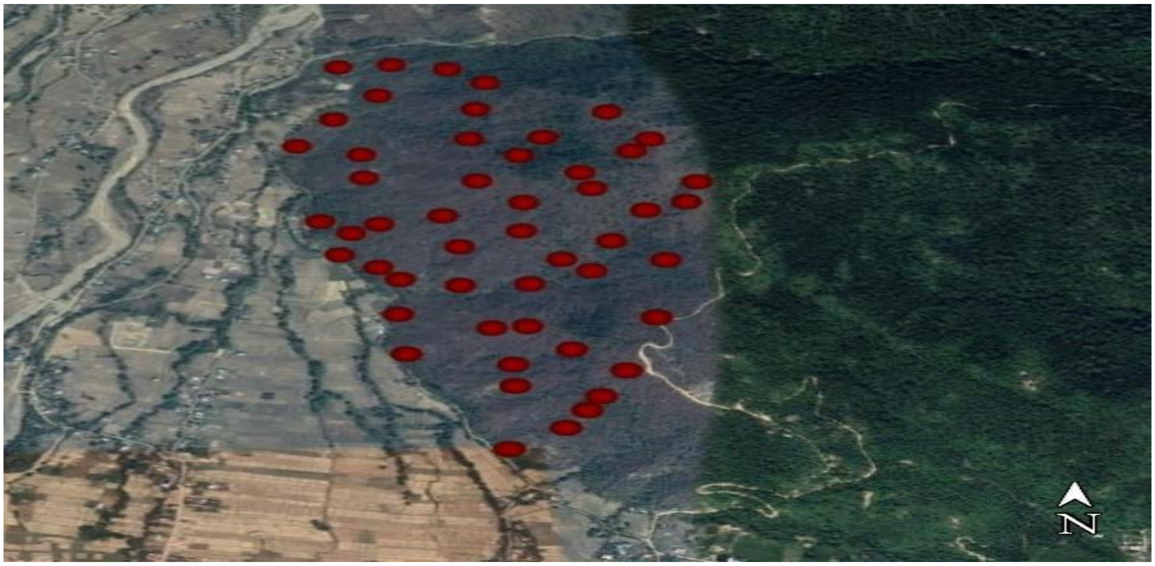
The Religious Forest named Brahmakumari Global Peace Park was established in 2006, lies in ward no 14 of Butwal sub-metropolitan of Rupandehi district covers the area of 10.35 hectors. It lies 7 km west from Butwal city along the north of Mahendra Highway. The forest is in adjoining areas with other community forest of small village like Charpala community forest of Tamnagar municipality which is 8 km far from Butwal city in west. The forest also lies in tropical region and altitude varies from 120 meters to 300 meters. This is one of the peace land managed by Brahmakumari. The main species found in this forest are *Shorea robusta, Wendlandia exserta, Semecarpus anacardium, Terminalia alata* and *Lagestroemia parviflora.*

Forest management practices Of BCF and BGRF

In Bolbum Community Forest, silviculture activities like thinning, pruning, singling, plantation etc are practiced. Forest users groups are allowed to enter the forest once in a week for collection of fodder, firewood and litter throughout the year but for firewood collection they are allowed only for three days in a year in winter season. Some of the users are entirely dependent on forest resources to fulfill their basic needs by selling firewood and green leaf of *Shorea robusta.* In winter season, it is estimated that approximately 17,700 kg firewood are collected from the forest, considering 30 Kg firewood collection by 50% households only. Because of the large area of Bolbum CF, there are incidences of timber smuggling, illegal firewood collection and tree cuttings every year.

In case of Brahmakumari Global Religious Forest there is no silviculture practice. The forest is guarded by devotees of Brahmakumari and do not allow the collection of fodder, firewood or timber. They only collect the fallen twigs and branches from the forest during winter season (personal observation).

a) **BCF**



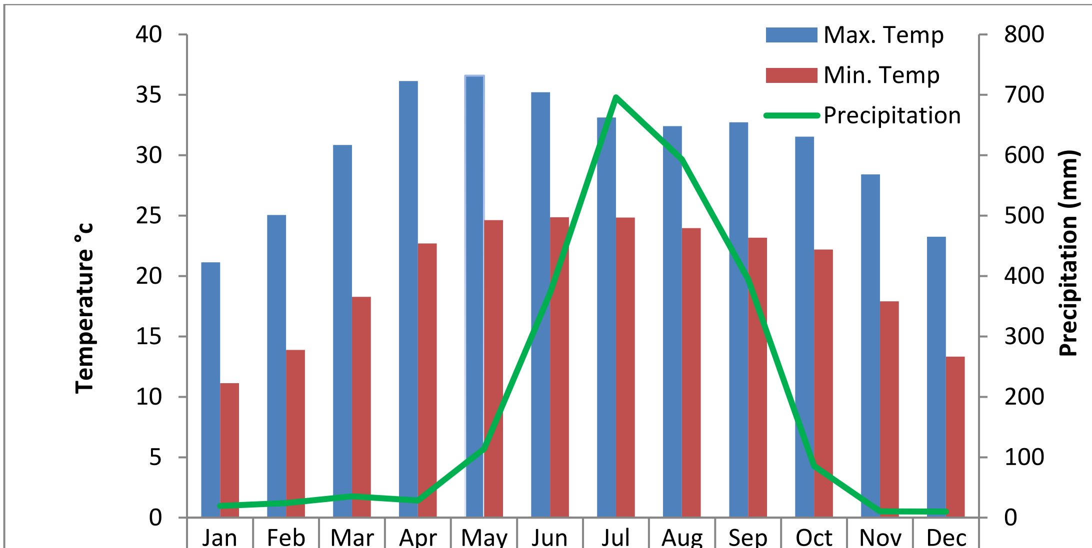
(b) BGRF

Figure 1 Map of study area showing sampling plots (a) BCF and (b) BGRF

(Source: Google Earth)

3.1.5 Climate and Hydrology

Rupandehi district exhibits tropical type of climate dominated by southwest monsoon. The area is characterized by four distinct seasons. Pre-monsoon from March to May, monsoon from June to September, post-monsoon from October to November and winter from December to February. The summer season of this region is very hot and winter is very cold. In summer the temperature rises up to 40°c and in winter the temperature falls below 10°c. There is high variation in the annual temperature and precipitation. The average annual temperature was 25.2 in Butwal (Climatological data 1988-2017). As shown on the Table the average maximum temperature was 36.5°c in May and minimum temperature was 11.1°c in January. Average monthly rainfall recorded was 198.48 mm. and average annual rainfall recorded was 2381.87 mm. Average maximum and minimum rainfall recorded was 695.8 mm in July and 9.97 mm in December. More than 80% of annual rainfall occurs during the rainy season (monsoon rainfall) i.e. from June to September (fig: 1).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max. Temp	21.13	25.05	30.85	36.13	36.59	35.22	33.13	32.41	32.73	31.53	28.41	23.25
Min. Temp	11.12	13.89	18.29	22.69	24.64	24.88	24.85	23.97	23.17	22.2	17.91	13.32
Precipitation	19.19	24.07	34.97	28.59	113.9	372	695.8	593.3	394.6	85.47	10.5	9.97

Months

Figure 1. Variation in monthly average (minimum and maximum) temperature and precipitation of last 30 years (1988-2017) at Butwal.

Source: Department of Hydrology and Meterology (DHM, 2018).

3.2 Methods of data collection

Primary and secondary data were collected for research work. Primary data were collected from field observation, direct measurement and laboratory analysis while the secondary data and information were gathered from internet, books, reports, journals and forest users committee in order to meet the research objectives.The management plan of both Bolbum Community Forest and Brahmakumari Global Religious Forest are collected to understand their forest management practices.

3.2.1 Sampling design

The survey of the study sites was undertaken in August, 2017. Then field work was carried out during the month of October and November, 2017 (before winter season) and March and April, 2018 (after winter season) with total one and half month duration. Stratified random sampling was applied for collection of data in both Community Forest and Religious Forest. All together 100 plots were studied of which 50 plots were in Bolbum community forest and 50 were Brahmakumari Global religious forest. Distance between two plots was about 20 m approximately. Latitude and Longitude of the plots were recorded using GPS receiver, the plot centre was navigated in the field. Quadrates of size for trees 10m × 10m sample plot was laid in both community and religious forest. Each tree was recorded using its local name/ scientific name. Diameter at breast height (DBH, 1.3m above the ground) of all trees equal to and greater than 10 cm was measured to determine the above ground biomass and below ground biomass. The height of the tree was measured by using clinometer. The clinometer determines the angle from the eye of the observer to the tip of the tree based on fixed distance to the target tree (Hairiah *et al*., 2001). Using trigonometric formula height of the tree was determined, other parameters like altitude and direction of slope in each plot were also recorded.

3. 2.2 Plant collection and Identification

All plant species encountered inside each plot were identified with the help of the field guides (Shrestha 1998; Siwakoti and Varma 1999) and local experts. The local names of the most specimens were recorded by consulting local villagers and later identified with the help of field guides as mentioned above. Further confirmation of each plant specimen were done by consulting relevant taxonomic literature and experts.

3.2.3 Vegetation Analysis

The method proposed by Misra (1968) was carried out for vegetation analysis.

3.2.3.1 Density and Relative Density

Density is the number of individuals per unit area. It represents the numerical strength of the species in the community. It is usually expressed as number per hectare. It was calculated by using the following formula of Zobel *et al*. (1987).

$$\text{Density (pl/ha)} = \frac{\text{Total no. of plant species}}{\text{Total no. of quadrates studies} \times \text{area of quadrates}} \times 10{,}000$$

Relative density is the density of a species with respect to the total density of all species.

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

3.2.3.2 Frequency and Relative Frequency

Frequency is defined as the number of sampling units in which the particular species occur, thus it shows degree of dispersion of a species in terms of percentage occurrence. The frequency of each species is calculated by using the formula of Zobel *et al.*(1987).

$$\text{Frequency (\%)} = \frac{\text{Number of plots in which species occurred}}{\text{Total number of plots taken}} \times 100$$

Relative frequency is frequency of a species in relation to all the species.

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

3.2.3.3 Abundance and Relative Abundance

Abundance of any individual species is expressed as a percentage of the total number of species present in community and therefore it is the relative representation of a species. It is usually measured as the number of individuals found per sample.

$$\text{Abundance} = \frac{\text{Total no. of plant species}}{\text{No. of plots in which species occurred}} \times 100$$

Relative abundance is the total number of individual species to the total number of individual of all species.

$$\text{Relative Abundance (\%)} = \frac{\text{Total no. of individual species}}{\text{Total no. of individual of all species}} \times 100$$

3.2.3.4 Importance Value Index

The overall picture of ecological importance of a species in relation to the community structure can be obtained by adding values of relative density, relative frequency, relative coverage or relative abundance or relative dominance and known as importance value index of the species. In this research work it was calculated by following formula.

Importance Value Index (IVI) = RD + RF + RA

Where,

RD = Relative Density

RF = Relative Frequency

RA = Relative Abundance

3.2.3.5 Plant diversity Index

Common measures of diversity include counts of number of species (species richness) and use of indices such as Shannon–Wiener’s index (Shannon and Weaver 1949) or the Gini–Simpson index (Simpson 1949), which further on are referred to as Shannon’s and Simpson’s diversity indices, respectively.

Species diversity was calculated based on Shannon diversity index using the general formula:

$$H = -\sum pi \times lnpi$$

Where H = Shannon's diversity index,

Pi = species proportion (based either on species

Count or species basal area) and ln = natural logarithm.

Simpson's (1949), diversity index gives the probability that two individuals selected at random will belong to the same species.

It was calculated as $D = 1/ pi^2$

Where pi is the proportion of individuals in species community

3.2.3.6 Index of Similarity (IS)

The inter-specific association can be evaluated by calculating the index of similarity. It gives the degree of similarity between any two stand, which depends on the quantitative phytosociological characters of species common to both stands. It is utilized to compare two existing groups. It was calculated by applying the formula given by Sorenson's index modified by Gerg Smith (1964).

$$IS = \frac{2C}{A + B} \times 100$$

Where,

A = Total number of species in one sample

B = Total number of species in another sample

C = Total number of common species in both the sample

3.2.3.7 Basal Area

Basal area refers to the ground, actually penetrated by the stems in the soil. It is expressed in square meters. Basal area is regarded as an index of dominance of a species. Higher the basal area, greater is the dominance. Basal area of a tree species was determined by measuring either the diameter or circumference of the average tree at the breast height (1.37m) and was calculated using the following formula of Zobel *et al.* (1987).

Basal Area (m^2) = $\frac{\pi D^2}{4}$

Where,

π = 3.14

D = Diameter at breast height

Basal area in each plot was obtained by the summation of Basal Area of all trees in the plot and is given as m^2/ha.

3.2.4 Estimation of Carbon Stock

Estimation of Above Ground Biomass

The mathematical equation has been developed and used by many researchers for biomass estimation of trees (Brown *et al*., 1989; Negi *et al*., 1988) cited in Chavan *et al*. (2010). For the present study, the allometric equation Biomass-diameter regression (Model II) developed by Chave *et al*. (2005) for moist forest stand was used to estimate above ground tree biomass. This equation is suitable for this study as average rainfall of the study area from 1988 to 2017 A.D. was 2381.87 mm between (1500-3000) mm.

The allometric equation for above ground biomass is as follows:-

AGTB = $0.0509 \times \rho D^2 H$ (Chave*et al*.2005)

Where,

AGTB = Above Ground Tree Biomass

P = Wood density

H = Height of tree (m)

D = Diameter at breast height

The wood density value was extracted from published literatures (MPFS 1989 cited in Sharma and Pukkala, 1990; Browm *et al*., 1997 and Zanne *et al*., 2009).

Estimation of Below-Ground Biomass

The biomass of root system of tree was estimated by assuming that it constitutes 15% of the above ground biomass Root: Shoot ratio = 0.10 or 0.15 (Mac Dicken 1997).

Below-Ground Biomass = 0.15 × above Ground Biomass

Estimation of Total Biomass and Carbon Stock

Total biomass was obtained by adding above ground biomass and below ground biomass. The below ground biomass was taken as 15% of above ground biomass. Total biomass (above ground biomass + below ground biomass) was converted into carbon stock by multiplying it with 0.47 which is the default carbon fraction in tree biomass (IPCC 2006).After taking the sum of all individual weights (in kg) of a sampling plot and dividing it by the area of sampling plot ($10 \times 10 m^2$), the biomass stock density was converted to kg/m^2.This value can be converted to t/ha by multiplying it by 10.

Carbon Stock of Species

Similarly carbon stock of individual tree species was determined by summing up density values of whole forest for that particular species.

Percentage of contribution carbon stock of each species of trees in a forest was calculated by taking the proportion of sum of carbon stock per ha of all species in forest to the sum of carbon stock of a particular species on the same forest.

$$\text{Carbon stock of a species (\%)} = \frac{\text{Sum of carbon stock of a species per ha}}{\text{Sum of carbon stock of all species per ha}} \times 100$$

3.2.5 Data Analysis Method

All statistical analyses were performed using SPSS16.0. Mean values of carbon stock Basal area and DBH were analyzed by using simple descrivetive one way ANOVA at $P=0.05$. Regression analysis was used to show the relationship of carbon stock with other variables like DBH, basal area and density.

CHAPTER 4: RESULT

4.2 Plant Diversity

In the present study, the number of species recorded in BCF were 25 tree species under 17 families and in BGRF 20 tree species under 15 families. In BCF, tree of *Leguminosae* was highest with 5 species followed by *Combretaceae* with 3 species and *Moraceae* with 2 species; however, in BGRF, *Combretaceae* was the highest family with 3 species followed by *Anacardeaceae, Leguminosea* and *Rubiaceae* with 2 species each.

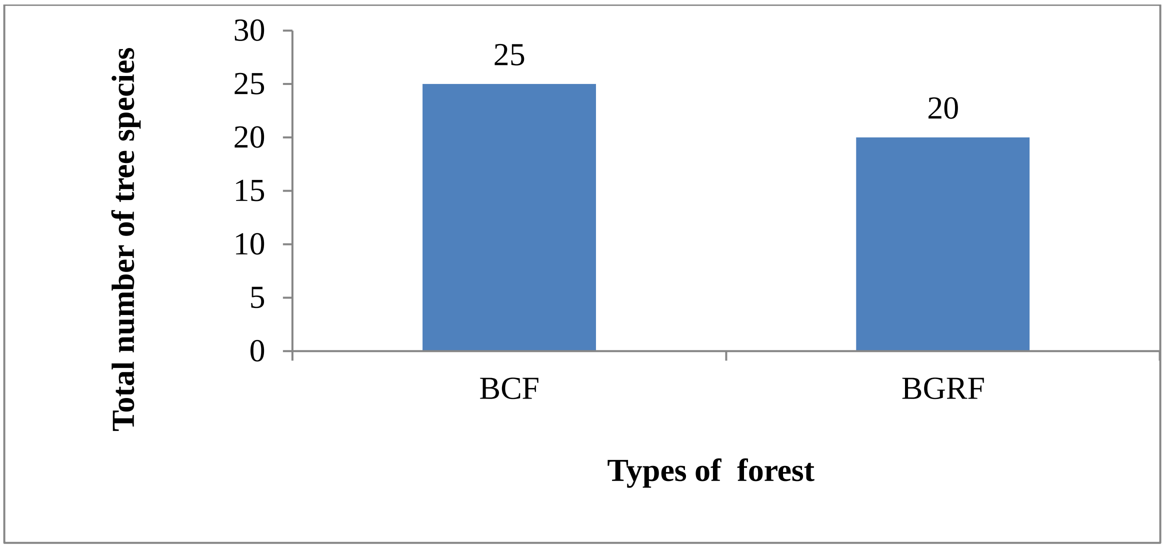


Figure 2. Tree species richness in Bolbum CF and Brahmakumari Global RF

4.3 Distribution of plants

Altogether 25 tree species were recorded in Bolbum CF and 20 tree species were recorded in Brahmakumari Global RF. List of trees found in Bolbum CF and Brahmakumari Global RF are given in annex 1. In both forests plant distribution in below 1000m altitudinal range were studied. The numbers of tree species in Bolbum CF is higher than in Brahmakumari Global RF. Tree species such as *Shorea robusta, Syzygium cumini, Tecctona grandis, Terminalia alata* etc were recorded in BCF. Likewise riverine tree species (like *Acacia catechu, Bombax ceiba, Dalbergia sisoo* and *Dalbergia latifolia*), medicinal plants (such as *Agle marmelos, Azadirecta indica, Phyllenthus emblica* and *Terminalia bellirica)* and other plants (like *Diospyros malabarica, Ficus benghalensis, Ficus religiosa, Mangnifera indica* etc) were recorded in BCF.

In Brahmakumari Global Religious Forest tree species like *Anogeissus latifolius, Ficus religiosa, Lagerstroemia parviflora, Mangifera indica* etc were recorded in BGRF. The riverine tree species (such as *Bombax ceiba, Dalbergia sissoo* etc) medicinal plant (such as *Phyllenthus emblica*, *Terminalia bellirica*, *Terminalia chebula* etc) and in other common plant (like *Mangifera indica*, *Mallotus phillippensis, Shorea robusta, Syzygium cumini, Wendlandia exserta* etc) were recorded in BGRF.

4.4 Importance Value Index (IVI)

Trees

IVI value of tree species at of Bolbum Community Forest and Brahmakumari Global Religious Forest are given in figure 4 and figure 5. In Bolbum community Forest, the IVI value of tree was recorded highest *for Anogeissus latifolius* followed by *Shorea robusta, Buchanania latifolia, Terminalia alata, Acacia catechu* (Figure 4). Very low IVI values was obtained for most of the tree species like *Terminalia bellirica, Tectona grandis, Syzygium cumini, Schleichera oleosa, Phyllenthus emblica, Magnifera indica, Ficus religiosa, ficus benghalensis, Dillenia pantagyna, Dalbergia sisoo, Cassia fistula* and *Azadirecta indica* .

In Brahmakumari Global RF, the highest IVI value of tree was recorded for *Shorea robusta* followed by *Buchanania latifolia* and *Terminalia alata*. Low IVI value was obtained for most of the trees like *Terminalia bellarica, Terminalia chebula, Tectona grandis, Schleichera oleosa, Phyllanthus emblica, Melia azedirachta*, *Magnifera indica, Mallotus phillippensis, Ficus religiosa and Bombax ceiba.*

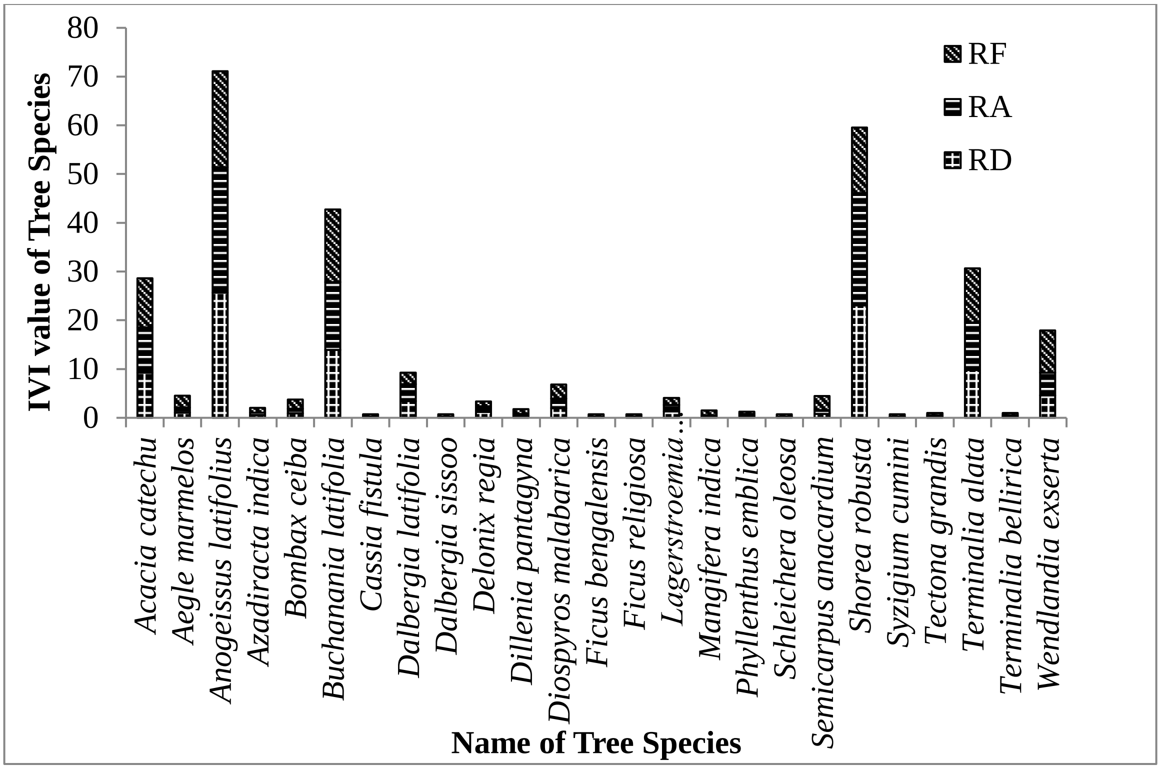


Figure 3. IVI value of Tree Species showing RD, RF and RA of Bolbam CF

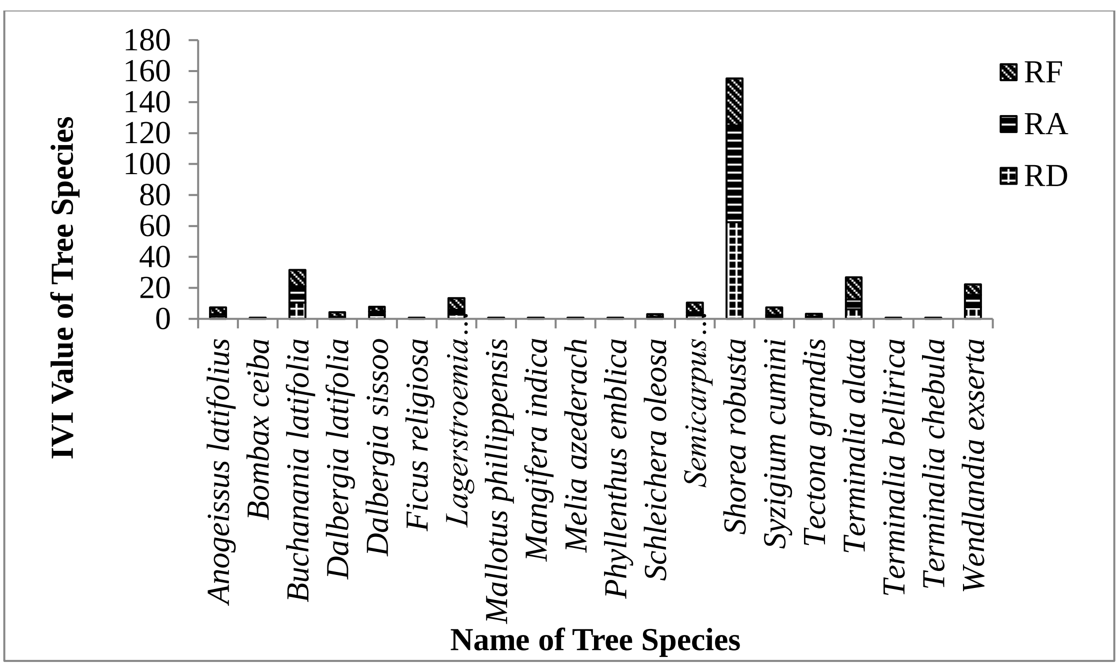


Figure 4. IVI value of Tree Species showing RD, RF and RA of Brahmakumari Global RF

4.5 Plant Diversity Index:

Both the diversity indices, Shannon Wiener (H) and Simpson diversity (D) value for trees were higher in Bolbum CF (H=2.1593 and D=6.19156) than in Brahmakumari Global RF (H=1.45063 and D=2.418),(Table;2). The evenness value obtained for BCF (0.670824) was higher than that of BGRF (0.484232). (Table 1)

Table 1. Shannon Wiener index (and evenness) and Simpson index in Bolbum Community Forest and Brahmakumari Global Religious Forest.

Forest Types	Shannon's diversity index (Eveness)	Simpson's diversity index(D)
Bolbum CF	2.1593 (0.670824)	6.19156
Brahmakumari Global RF	1.45063(0.484232)	2.418

4.6 Index of Similarity

BCF and BGRF shared a large number of common tree species and the index of similarity between these two forests was also found to be quite high (75.56 %). (Table 2).

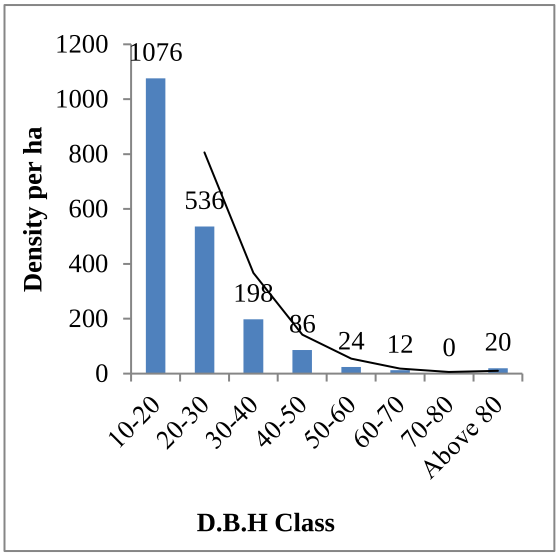
Table 2. Index of similarity by (%) between Bolbum CF and Brahmakumari Global RF.

Habit	Index of similarity (%)
Tree	75.56 %

4.7 Density Diameter Relationship

Tree density (per ha) was highest in density class 10-20 followed by 20-30 (fig.5). This showed that most of the stands were at intermediate stage of growth.

(a)



(b)

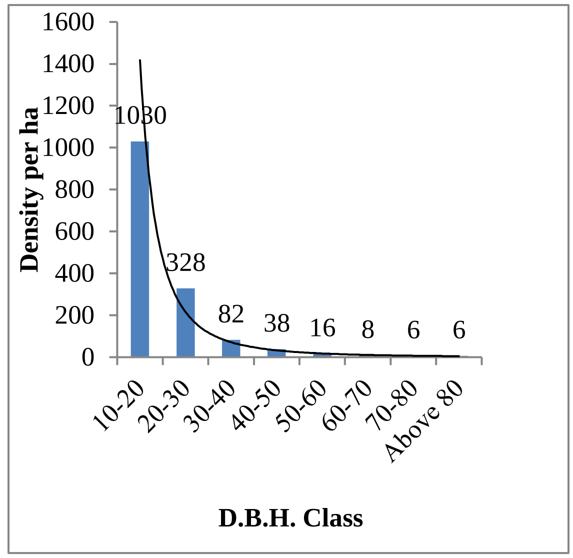
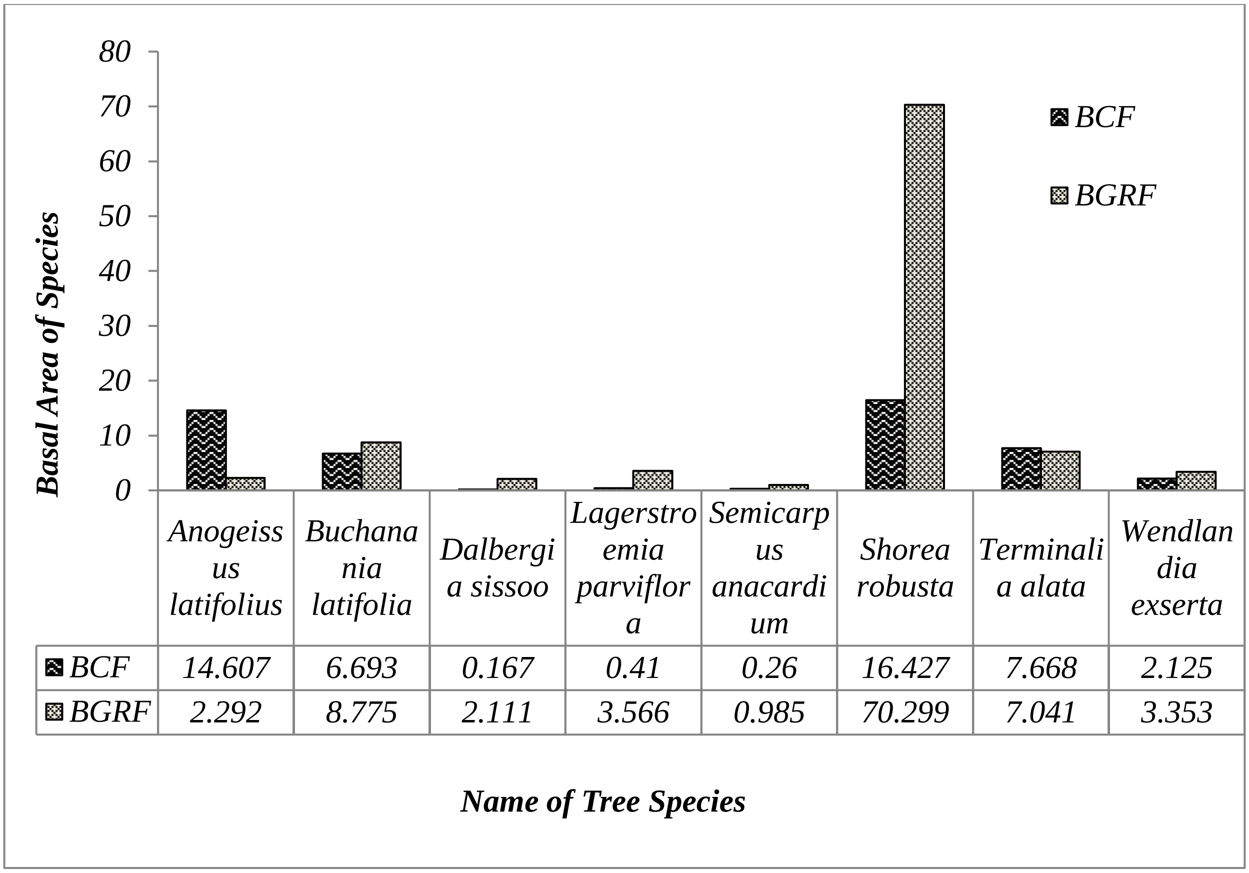


Figure 5.Density Diameter Curve of trees > 10cm in (a) BCF and (b) BGRF

4.8 Basal Area of Species

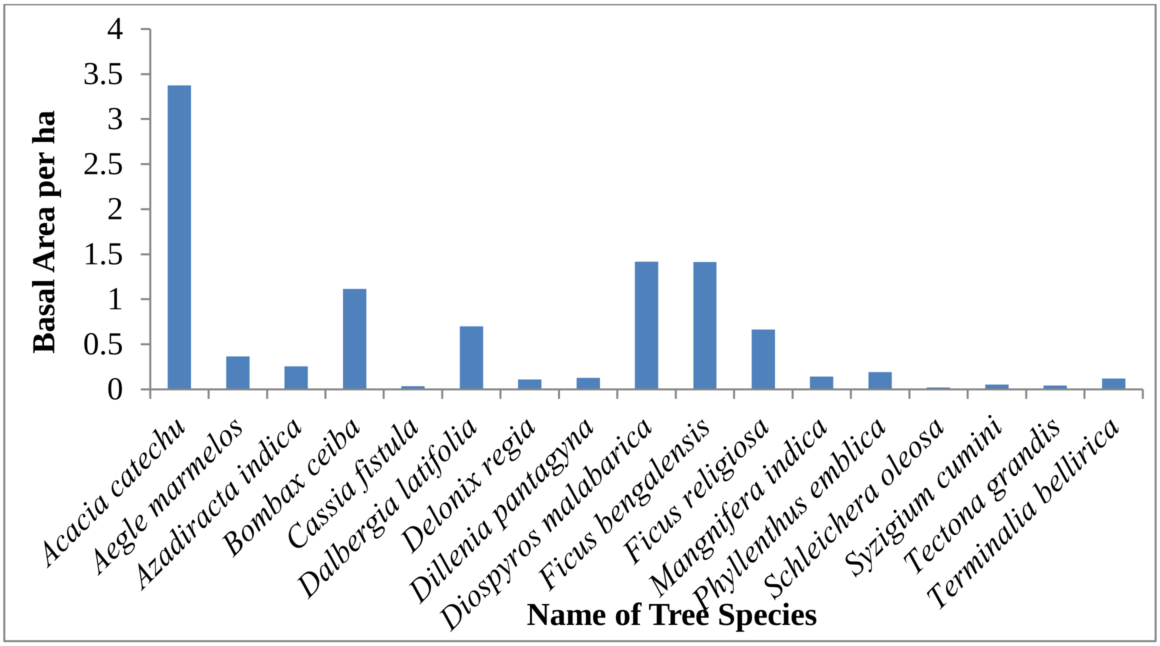
In BCF, the highest basal area (m^2/ha) was recorded for *Shorea robusta* (16.27 m^2/ha) followed by *Anogeissus latifolius* (14.607 m^2/ha), *Terminalia alata* (7.668 m^2/ha) and *Buchanania latifolia* (6.693m^2/ha). Similarly, in BGRF the highest basal area (m^2/ha) was recorded for *Shorea robusta* (70.299 m^2/ha), followed by *Buchanania latifolia* (8.775 m^2/ha), *Terminalia alata* (7.041 m^2/ha) and *Legestroemia parviflora* (3.566 m^2/ha) (fig. 6).



	Anogeissus latifolius	*Buchanania latifolia*	*Dalbergia sissoo*	*Lagerstroemia parviflora*	*Semicarpus anacardium*	*Shorea robusta*	*Terminalia alata*	*Wendlandia exserta*
BCF	14.607	6.693	0.167	0.41	0.26	16.427	7.668	2.125
BGRF	2.292	8.775	2.111	3.566	0.985	70.299	7.041	3.353

Figure 6. Basal Area of common tree species in Bolbum CF and Brahmakumari Global RF

(a) Bolbum Community Forest.



b) Brahmakumari Global Religious Forest.

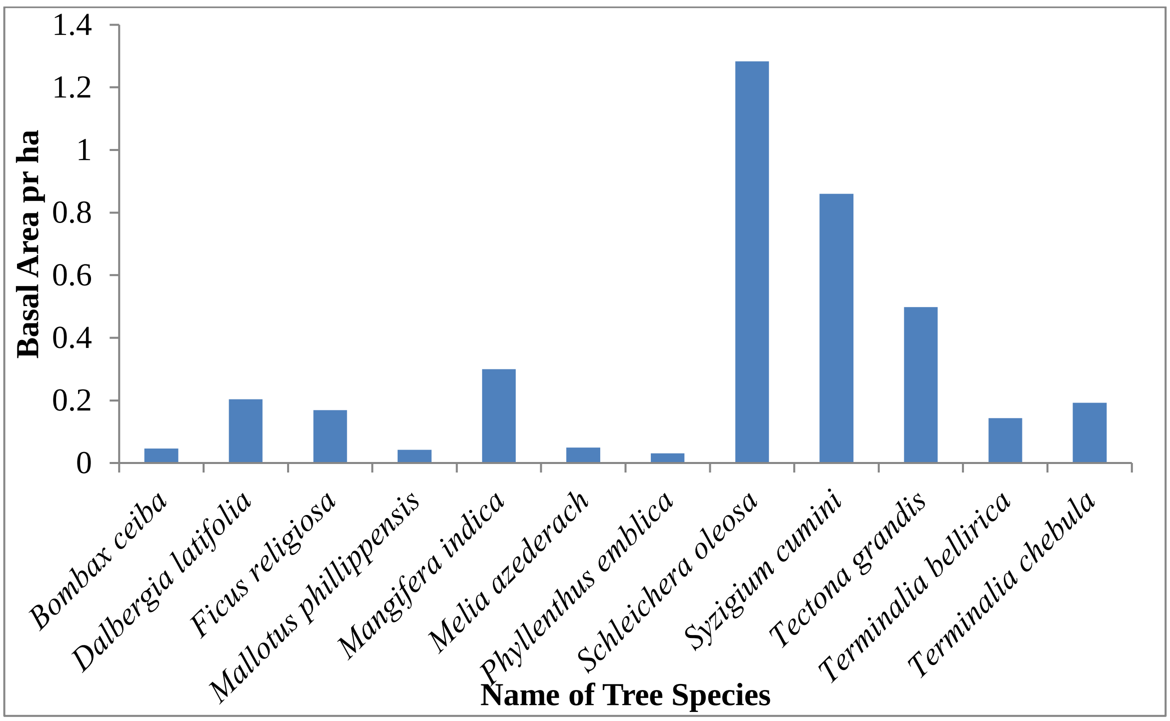


Figure 7. Basal Area of other tree species (a) BCF and (b) BGRF

4.9 Contribution of Species in Tree Carbon Stock

Table 3. Showing carbon stock (t/ha) in hectors in both BCF and BGRF

The table shows the individual tree carbon stock in Bolbum Community Forest and Brahmakumari Global Religious Forest. Total carbon consume by BCF is 27.22 t/ha and in BGRF total carbon consume is 40.94t/ha.

Name of species	Bolbum community Forest Carbon stock in t/ha	Bhramakumari Global religious Forest Carbon stock in t/ha
Acacia catechu	1.633	
Aegle marmelos	0.102	
Anogeissus latifolius	7.088	1.084
Azadiracta indica	0.072	
Bombax ceiba	0.350	0.007
Buchanania latifolia	1.547	1.408
Cassia fistula	0.011	
Dalbergia latifolia	0.260	0.045
Dalbergia sissoo	0.089	0.932
Delonix regia	0.022	
Dillenia pantagyna	0.037	
Diospyros malabarica	0.471	
Ficus benghalensis	0.492	
Ficus religiosa	0.166	0.045

Lagerstroemia parviflora	0.154	1.245
Mallotus phillippensis		0.007
Mangifera indica	0.035	0.084
Melia azederach		0.020
Phyllanthus emblica	0.067	0.007
Schleichera oleosa	0.006	0.654
Semicarpus anacardium	0.074	0.207
Shorea robusta	8.752	30.879
Syzygium cumini	0.014	0.245
Tectona grandis	0.006	0.151
Terminalia alata	4.895	2.948
Terminalia bellirica	0.049	0.050
Terminalia chebula		0.067
Wendlandia exserta	0.767	0.860
Total	**27.22**	**40.94**

The total carbon stock in BCF and BGRF were calculated as 27.22 t/ha and 40.94 t/ha respectively (Table 3). Average contributions were highly skewed in BGRF with maximum carbon stock on *Shorea robusta* (71.42%), and relatively low percentage of carbon stock on *Buchanania latifolia* (3.37%), *Terminalia alata* (6.818%) and *Wendlandia exserta* (1.99%),*Anogeissus latifolius(*2.506*)* but in BCF, carbon stock of *Shorea robusta* (32.22%), *Buchanania latifolia* (5.69%), *Terminalia alata* (18.026) and *Wendlandia exserta* (2.82) *Anogeissus latifolius* (26.10). As a whole carbon stock is higher in *Shorea robusta* than other tree species (fig: 9).

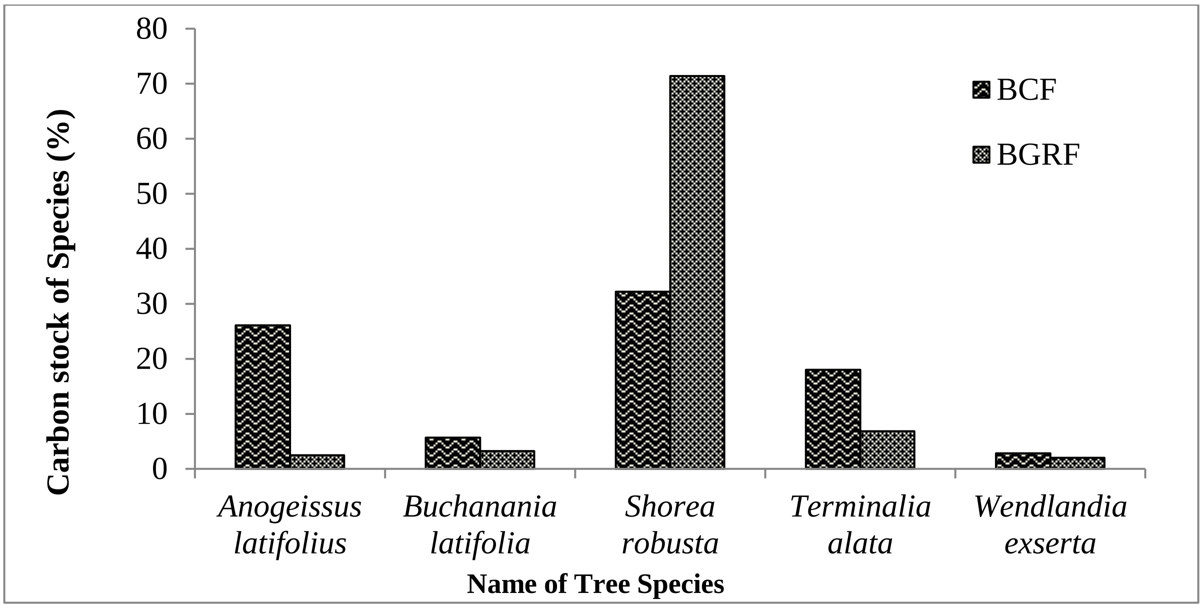
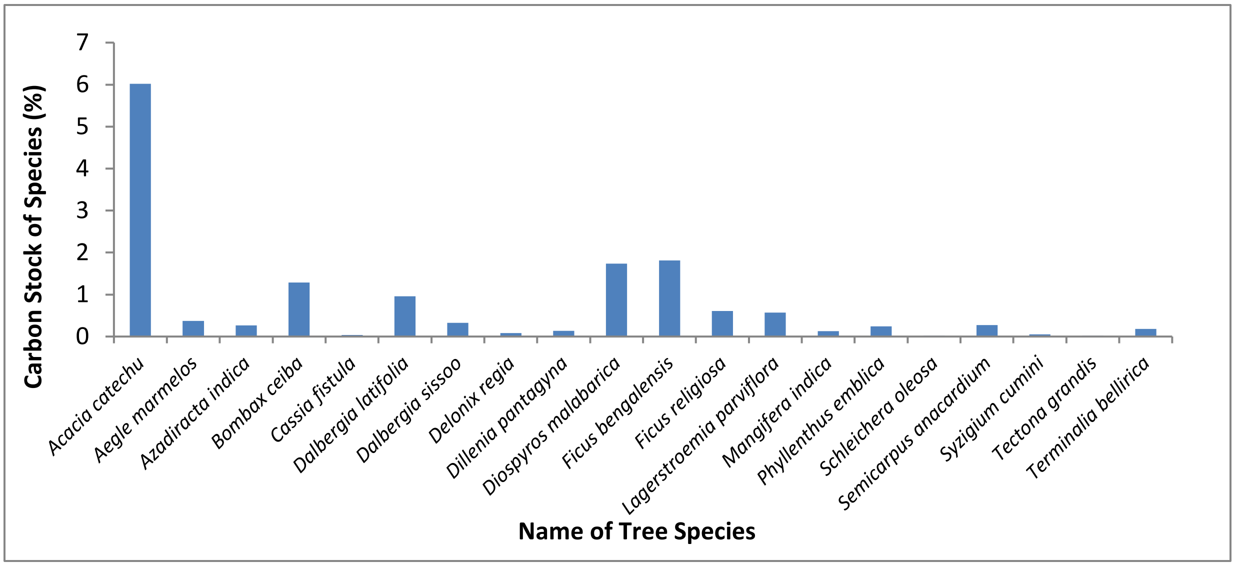


Figure 8. Contribution of common tree species in carbon stock of BCF and BGRF

a) Carbon stock in BCF.



b) Carbon Stock in BGRF

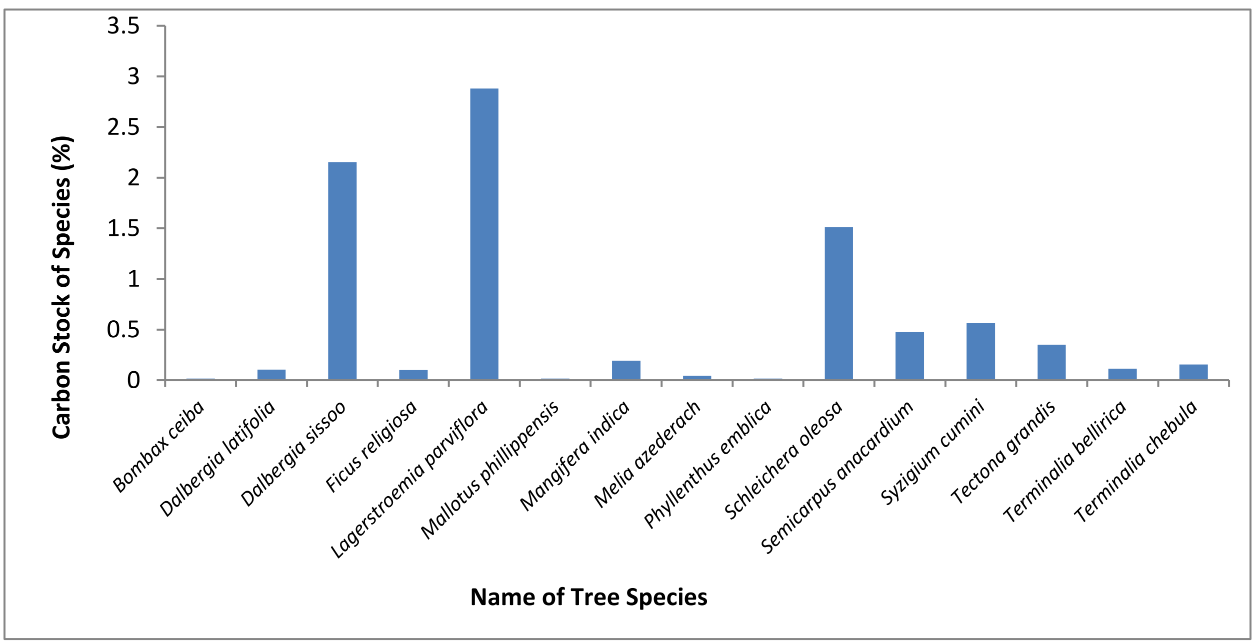


Figure 9. Other Species contribution on carbon Stock in (a) BCF and (b) BGRF

4.10 Comparison between Forest Types

4.10.1 Carbon Stock, Basal Area and DBH

The mean values of carbon stock, basal area and DBH were higher in BGRF than in BCF (Figure13). The mean value of carbon stock of tree species was 27.22±2.38 and 40.94 ±2.89 t/ha in BCF and BGRF respectively. Mean value of basal area was 58.95±4.52 and 102.25±5.30 m²/ha and DBH was 2.97±0.15 and 4.41±0.139m in BCF and BGRF respectively, (Figure 10).

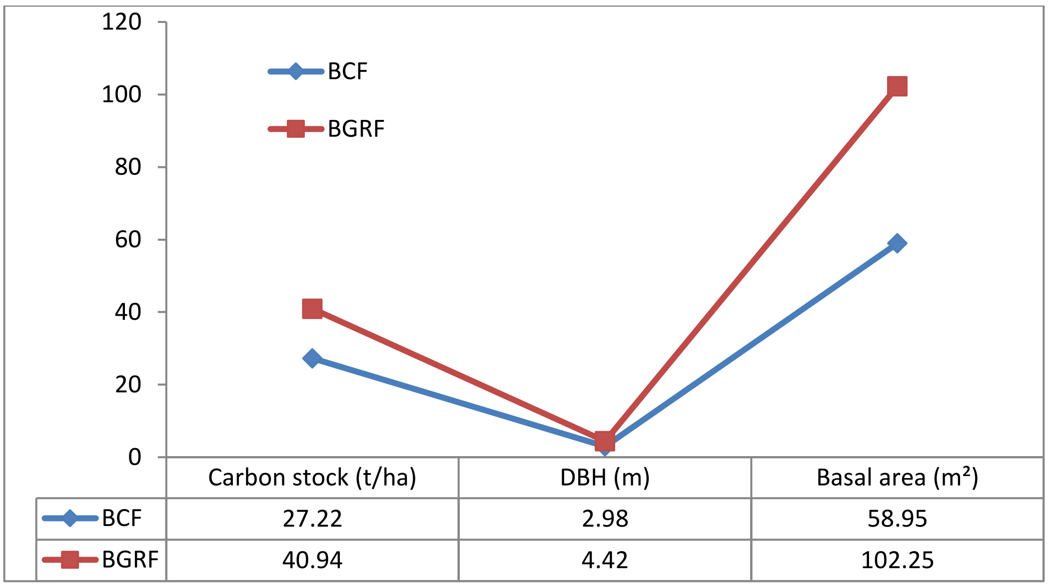


Figure 10. Mean values of carbon stock, DBH and basal area of CF and GF

4.10.2 Relationship between variables of BCF and BGRF

The relationship between the variables like Carbon Stock and DBH, Carbon Stock and Basal Area, Carbon Stock and Density, DBH and Density were calculated on the basis of measurements obtained from each plots.

Relationship of Carbon Stock with DBH

In both BCF and BGRF, carbon stock increased with increase in DBH. Regression analysis showed that there was significant positive relationship between DBH and Carbon Stock in both forest types (*P= 0.0001*). R^2 value was slightly higher in BGRF than in BCF (fig: 11).

(a) (b)

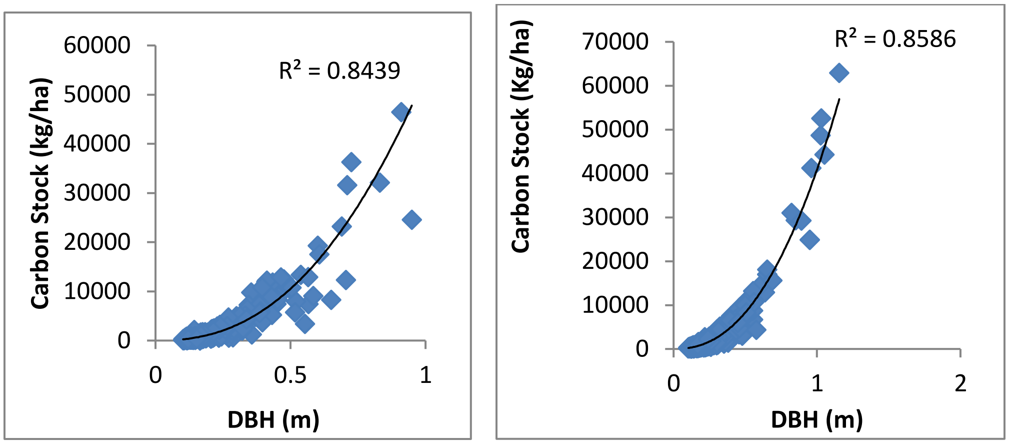


Figure 11. Regression graph showing relationship between Carbon stock and DBH in (a) BCF and (b) BGRF

Relationship of Carbon Stock with Basal Area

In both BCF and BGRF there was increase in carbon stock with increase in basal area. Regression analysis showed significant positive relationship between carbon stock and basal area in both forest types (Fig: 12).

(a) (b)

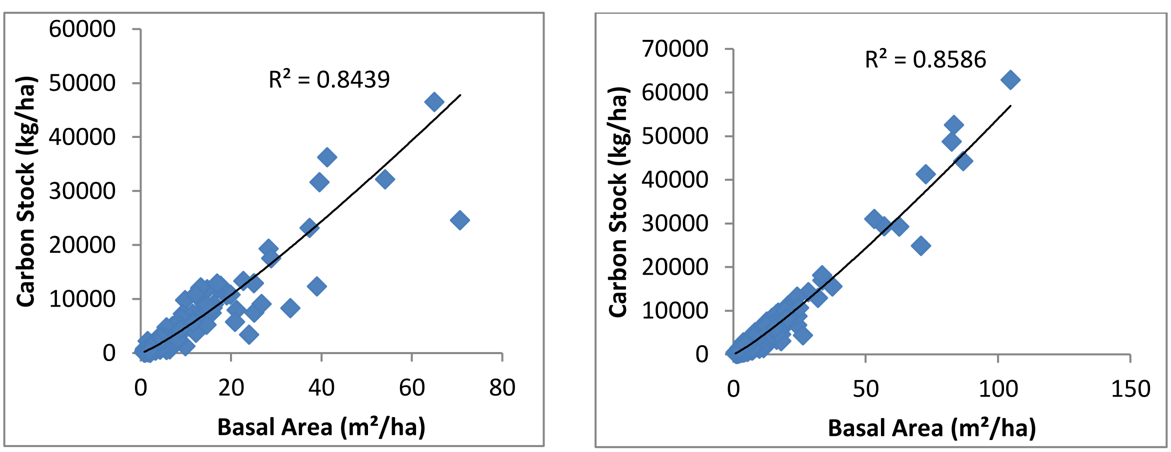


Figure 12. Regression graph showing relationship of Carbon stock with Basal area in (a) BCF and (b) BGRF

Relationship of Carbon Stock with Density

In both BCF and BGRF there was increase in carbon stock with increase in density (fig: 13) Regression analysis showed that there was significant relationship between carbon stock and density in both BCF (R^2=0.273, p=0.001) and BGRF (R^2=0.208, p=0.001).

(a) (b)

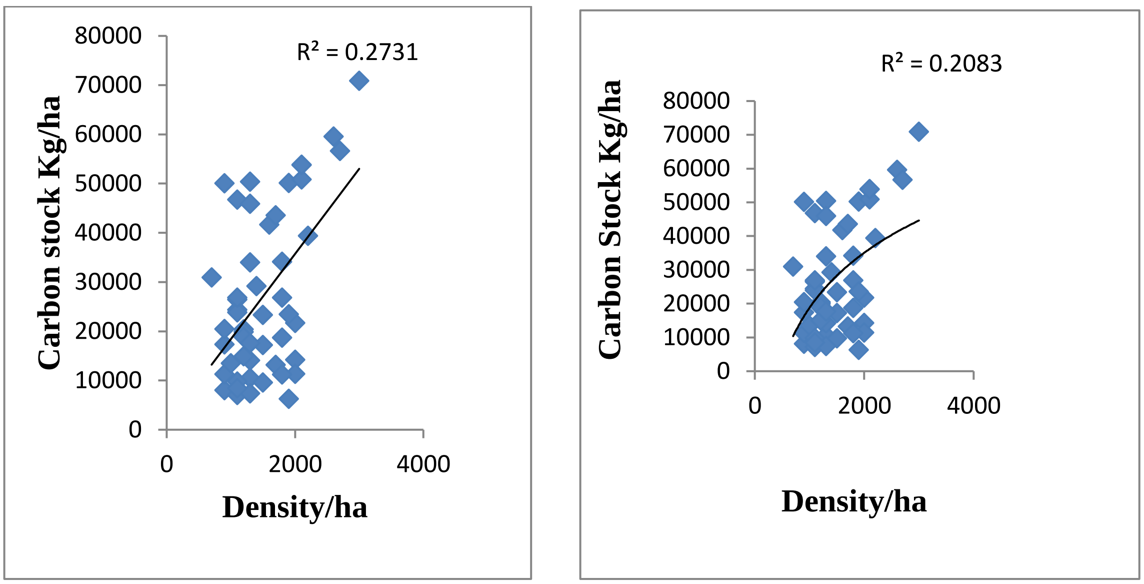
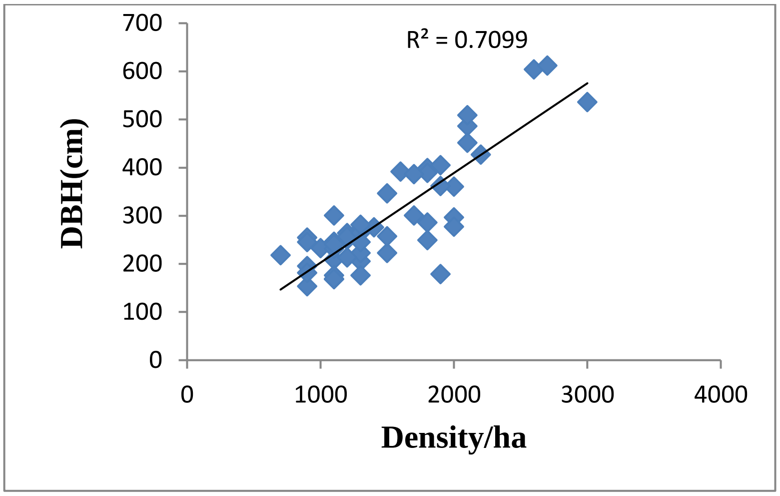


Figure13. Regression graph showing relationship between carbon stock and density in (a) BCF and (b) BGRF

Relationship of DBH with Density

In both BCF and BGRF there was increase in DBH with increase in density. Regression analysis showed significant positive relationship between DBH and density in both forest types (fig: 1.15). Regression analysis showed that there was significant relationship between carbon stock and density in both BCF (R^2=0.709, P=0.001) and BGRF (R^2=0.474, P=0.001).

(a)



(b)

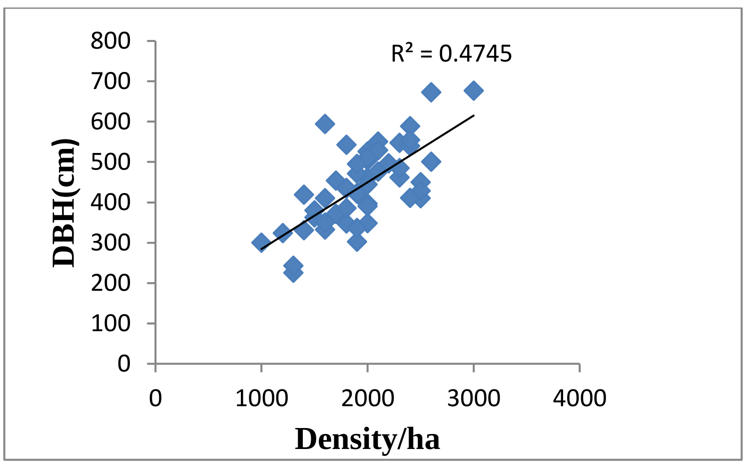


Figure 14. Regression graph showing relationship between DBH and density in (a) BCF and (b) BGRF

CHAPTER 5: DISCUSSION

5.1 Importance Value (IVI) Index and Diversity

The present study showed that Bolbum Community Forest held more number of tree species (25) in comparison to Brahmakumari Global Religious forest (20). This might be due to management practices and plantation. In Bolbum Community Forest silvicultural practices like cutting, pruning, singling, litter and fodder collection, and timber extraction are common. These activities create open space for new species to establish. This might be the reasons for more tree species in BCF than in BGRF.

Similarly in BGRF the IVI value of *Shorea robusta* (155.35), highest followed by *Buchanania latifolia* (31.68) and Wendlandia exserta (22.21), but the importance value index (IVI) of *Anogeissus latifolius* (71.102), highest followed by Shorea robusta (59.5540) and *Buchanania latifolia* (42.718), in BCF. *Shorea robusta* was the most frequent and highly dominant species in Brahmakumari Global Religious Forest but in Community forest *Anogeissus latifolius* is relatively more frequent than *Shorea robusta*, the reason behind this could be preference of CFUGs for *Anogeissus latifolius* than *Shorea robusta*, as *Anogeissus latifolius* is a good sources of fodder for goats.

In BCF the IVI value of *Buchanania latifolia* and *Terminalia alata* was almost half of Anogeissus latifolus. In BGRF the IVI value of *Buchanania latifolia* and *Terminalia alata* is nearly one fifth of the *Shorea robusta*. This indicates the co-dominance of two or more species (*Shorea robusta*, *Anogeissus latifolus*) in BCF while in BGRF *Shorea robusta* was mainly dominant species. Paudel (2000) reported high dominance of *Shorea robusta* in community forest and equal dominance of *Shorea robusta* and *Terminalia tomentosa* in national forest of Udayapur District. Paudel and Sah (2015) reported dominance of *shorea robusta* in community forest while *Shorea robusta* and *Terminalia alata* were codominant in government forest at lowland of Eastern Nepal. Present study differs from the above two studies. In this study *Anogeissus latifolus* and *Shorea robusta* have co-dominance in Bolbum Community Forest and *Shorea robusta* alone has dominance in Brahmakumari Global Religious Forest.

The value of Shannon Weiner index (H) and Simpson index (D) for trees (H=2.159 and D=6.1915) were higher in BCF than in BGRF for trees (H=1.450 and D=2.418).The result indicated high tree diversity in BCF than in BGRF. Simpson Index takes into account both species richness and evenness. The number of tree species in BCF was 25. The Simpson index obtained was 6.15; this indicates that there is evenly distribution of tree species. Similarly the numbers of tree species was 20, in BGRF and Simpson index obtained were2.418, which indicates uneven distribution of tree species. The tree species in BCF were more evenly distributed (0.6708) than in BGRF (0.4842).

Overall tree species diversity was high in BCF than in BGRF. The management practices such as litter collection, tree species selection and collection of herbaceous and shrub by species are common in Community forest. Every year the user groups clear the unwanted plants from forest floor like pteridophytes, climbers, shrubs and herbs in Community forest. Due to such activities low plant diversity was reported in Community forest (Acharya *et al*., 2007). But in Bolbum Community Forest there are silviculture practices (thinning, pruning,singling, litter collection, plantation) and they add saplings of other tree species as well at every 5 years. Hence the tree species with NTFPs value like *Azadirecta indica*, *Agle marmelous, Acacia catechu, Terminallia tomentosa* are planted. Plant diversity was comparatively low in Religious forest (20 plant species). According to Ingles (1994) various social activities like construction of temples, schools, rest houses for pilgrims, construction of drinking water taps, constructing bridges, roads, chautara (resting place) etc, require use of plants or plants products causes low diversity occurs on Religious forest.

The similarity index value of tree between these two forests was 75.56%.The more common species tree was found between the two forest types. These values were close to 80% - 90% for trees reported by Marasini (2009), vegetation analysis of churia hills in Rupandehi district. However, the value was higher than the value reported by Paudel (2000), comparision between Community and National forest in Udayapur district.

5.2 Contribution of Species in Tree Carbon Stock

Variations in carbon stock might be due to some environmental conditions which influence the productivity of forest like warm temperature and high rainfall and fertility of soil (Odum, 1971 and Barbour *et al*., 1999). In the present study both the BCF and BGRF experience more or less same climatic conditions and hence are compared to know the impact of management practices on carbon stock.

Though the IVI value of *Anogeisus latifolius* was high in Bolbum Community Forest but its contribution in carbon stock was lower than *Shorea robusta*. In BCF *Shorea robusta* contributed highest carbon stock followed by *Anogeisus latifolius.* Similarly in Brahmakumari Global Religious Forest where the *Shorea robusta* had highest IVI and dominant contributed high carbon stock. High contribution of carbon stock in BGRF is mainly due to more number of individuals/hectors and high DBH.

High density of tree individuals with 10-20 cm diameter at breast height was observed in both forests. The result showed more number of tree individuals with maximum diameter in BGRF than in BCF. The reason may be due to the felling of large sized trees in BCF because every Thursday Community forest user groups are allowed to enter the forest to collect litter, green leaf of Sal, firewood and timber with some nominal entrance fee. Beside this illegal timber smuggling is quite common.

Higher value of basal area in both forest types of the present study suggests that the forests are in a mature developmental phase. Basal area of *Shorea robusta* was higher (70.299m^2/ha) in BGRF than in BCF (16.42m^2/ha). In BCF *Shorea robusta* are used for timber and hence its basal area are recorded less.

Shorea robusta contributed 32.22% of carbon stock in BCF and 71.42% of carbon stock in BGRF. These value are less than the value obtained for *Shorea robusta* in above ground carbon of Laxmi Mahila CF (95%) and Jalbire Mahila CF (86%) of Gorkha, Nepal (Neupane and Sharma, 2014) whereas the percentage of carbon stock contributed by *Shorea robusta* in BCF of present study was higher than the carbon stock contributed by *Shorea robusta* (65%) in Fulbari CF and (44.7%) in Taldanda CF reported by Gaire (2015) in Tanahun District.

As a whole carbon stocks in the Resunga Sacred Grove (RSG) was 127.75 t/h reported by (Sharma, 2015).Which is much greater value than the present study of BGRF forest (40.94t/ha).Carbon stock in tree species of Brahmakumari Global Religious Forest (BGRF in the present study is 40.94 t/ha which is comparable with 44.33 t/ha of carbon stock in *Schima castonopsis* forest of Palpa (Shrestha, 2009), 36.6 t/ha and 40.2 t/ha of carbon stock in two community forest of Palpa district (Khanal *et al*., 2010).

However carbon stocks in Religious Forest of present study was higher than above ground biomass carbon in Gauradevi Community Forest (28.435 t/ha) of Bhaktapur, Nepal (Khayamali, 2010).Mandal *et al*., (2012) reported that the level of carbon stock in forest is influenced by different drivers and management units. So the difference in carbon stock of present study might be due to the influence of management system in BCF and BGRF.

Pandit (2014) reported vegetation types, age of the stand, the surrounding environment, management activities and other human induced disturbances are the key factors in variation of carbon stock and carbon sequestration in forests. In BCF all silviculture practices (thinning, pruning, singling, litter collection, plantation) are executed but in BGRF the silviculture practices are not executed. Hence this may be the reasons for their difference in carbon stock.

As the diversity is high in Bolbum Community Forest and Carbon stock is high in Brahmakumari Global Religious Forest, hence the hypothesis has been accepted.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Lower the value of carbon stock in BCF than in BGRF indicates that due to the management practices in BCF like thinning, singling, pruning, pole stage thinning, litter collection, firewood collection, timber extraction etc. must have influenced carbon stock in forests. Tree diversity was higher in BCF than in BGRF, plantation of trees with NTFPs values in BCF might have contributed in it. The contribution of *Shorea robusta* was found to be highest in both forests under different management practices. Total 32.22% of carbon stock in BCF and 71.42% of carbon stock BGRF are contributed by *Shorea robusta* alone.

6.2 Recommendations

Global climate change and its impact is one of the topics of great concern. Forests are the only effective mitigate option to climate change. Hence proper management of the forest along with conservation of plant diversity is equally important to keep ecosystem functioning. Therefore, following recommendations have been suggested from the present study.

- CFUGs must allow the regeneration and establishment of all plant species (either commercially important or not) in their community forest.
- Introduction of new tree species with NTFPs value should be avoid to maintain the existing forest environment.

REFERENCES

Acharya, K.P. 2002. Twenty-four years of community forestry in Nepal. International. Forestry Review. 4,149-156. doi:10 1505/IFOR .4.2.149 . 17447

Acharya, K. P. 2003a. Religious and spiritual values of forest plants in Nepal. *A paper Submitted to the XII Forest Congress, Quebec City Canada*. Agriculture, Forestry, And Other Land Uses (AFOLU). Geneva, Switzerland:

Acharya, K. P. 2003b. *Conserving biodiversity and improving livelihoods: the case study of community forestry in Nepal.* Paper presented at The International Conference on Rural Livelihoods, Forests and Biodiversity, Bonn, Germany. pp. 1-20.

Acharya K.P. 2004. Does Community Forests Management supports biodiversity conservation? Evidences from two community forests from the mid hills of Nepal. J. For. Livelihood 4: 44-54.

Acharya, K. P., Goutam, K. R., Acharya, B. K., and Gautam, G. 2007. Participatory assessment of biodiversity conservation in community forestry in Nepal. *Banko Jankari*, ***16***, 46-56.

Baniya, C. B., Solhoy, T., Gauslaa, Y., and Palmer, M. W. 2010. The elevation gradient of lichen species richness in Nepal. *The Lichenologist*, ***42***(1), 83-96.

Baral, S. K., Malla, R., and Ranabhat, S. 2009. Above Ground Assessment in different forest types of Nepal. *Banko Janakari*, ***19***(2), 10-14.

Barbour, M. G., Burk, J. H., Pitts, W. D., Gilliam, F. S., and Schwartz, M. W. 1999. *Terresteial Plant Ecology*. Benjamin/Cummings, an imprint of Addison Wesley Longman, California, USA.

Bhattarai. 2017. Community Forest and Forest Management in Nepal. *American Journal of Environmental Protection* 4.3, 79-91.

Brown, K., and Pearce, D. 1994. The Economic Value of Non-Timber Benefits of Tropical Forests: Carbon Storage. In Weiss, J. (ed.), The Economics of Project Appraisal and the Environment: New Horizons in Environment Economics. Chelttenham (UK).

Brown, S. 1997. Estimating Biomass and Biomass Change of Tropical Forests: a Primer. Forestry Paper 134, FAO, Rome.

Brown, S., Gillespie A. J. R., Lugo, A. E. 1989. Biomass Estimation Methods for Tropical Forests with Applications to Forest Inventory Data. *Forest Science*, ***35***, 881-902.

Brown, S., Iverson, L. R., Prasad, A., and Liu, D. 1993. Grographical Distribution of Carbon in biomass and soils of tropical Asian forests. *Global Environmental Change*, ***8***(4), 45-59.

Campbell,J.Y,Rathore,B.M.S. andBranney, P.1996. The New Silviculture: India and Nepal. In: Hobley, M. (Ed)**,** *Participatory Forestry: the process of change in India and Nepal*, ODI, London. *Pp 175-210.*

Chaudhary, R. P. 1998. *Biodiversity in Nepal: Status and Conservation*. S. Devi, Saharanpur (U. P.), India and Tec. Press Books, Bangkok, Thailand.

Chavan, B.L., and Rasal, G.B. 2010. Sequestered standing carbon stock in selective tree species Grown in University Campus at Aurangabad, Maharashtra, India. *International Journal of Engineering science and Technology*, ***2***(7), 3003-3007.

Chave, J., Andalo, C., Brown, S., Cairns, M. A., Chambers, J. Q., Earnus, D., Folster, H., DFO 2017. *Annual Monitoring and Evaluation of Community Forests*: *An Analysis Report*. District Forest Office (DFO), Rupandehi, Nepal.

Dixon, R. K., Soloman, A. M., Brown, S., Houghton. R. A., Trexier, M. C., and Wisniewski, J. 1994. Carbon Pools and Flux of Global Forest Ecosystems. *Science*, ***263***(5144), 185-190.DOF 2011. *Status of Community Forestry*. Community Forest

Division, Department of Forest, Kathmandu, Nepal. URL: http://www.dof.gov.np

DOF 2012. *Community Forests User Groups Database*. Community Forest Division, Department of Forest, Kathmandu, Nepal. URL: http://www.dof.gov.np.

Finegan, B., Peña-Claros, M., Oliveira, A. de., Ascarrunz, N., Bret-Harte, M. S., Carreño-Rocabado, G., Casanoves, F., Díaz, S., Velepucha, P. E., Fernandez, F., Licona, J. C., Lorenzo, L., Negret, B. S., Vaz, M., and Poorter, L. 2015. Does functional trait diversity predict above-ground biomass and productivity of tropical forests? Testing three alternative hypotheses. *Journal of Ecology* (pp. 1-11).DOI: 10.1111/1365-2745.12346.

Fromard, F., Higuchi, N., Kira, T., Lescure, J. P., Nelson, B. W., Ogawa, H., Puig, H., Riera, B., and Yamakura, T. 2005. Tree allometry and improved estimation of Carbon stocks and balance in tropical forests. *Oecologia*, ***145***(1), 87-99.

Gaire, P. 2015. Tree Regeneration, Diversity and Carbon Stock in two Community Managed Forests of Tanahun District, Nepal. M.Sc. Dissertation Submitted to Central Department of Botany, Tribhuvan University, Kathmandu.

Ghimire, P. 2017. Plant Species Diversity and Tree Carbon Stock in Danphe Community Forest of Kuirepani Dang, Nepal. M.Sc. Dissertation Submitted to Central Department of Botany, Tribhuvan University, Kathmandu.

Ghimire, P., Kafle, G., and Bhatta, B. 2018. Carbon stocks in *Shorea robusta* and *Pinus roxburghii* forests in Makwanpur District of Nepal. *Journal of Agriculture and Forestry University*, ***2***, 241-248, Agriculture and Forestry University, Chitwan, Nepal.

Giri, A., Aryal, B., Ghimire, S.K., Shrestha, K. K., and Jha, P. K. 1999. Vegetation composition, biomass production and regeneration in Shorea robusta forests in the Royal Bardia National Park, Nepal. *Nepal Journal of Science and Technology*, pp. 47-56.

GoN 2009. Fourth National Report to the Convention on Biological Diversity. Government of Nepal, Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

Hairiah, K., Sitompul, S. M., Noordwijk, M. V., and Palm, C. 2001. Methods for sampling carbon stocks above and belowground. International Centre for Research in Agroforestry. Southeast Asian Regional Research Programme, Bogar, Indonesia.

HMG 2000. Forest user groups database record available in MIS. Community Forest Development Project, Ministry of Agriculture, HMGN, Kathmandu, Nepal http://www.dof.gov.np.

HMG 2002. Nepal Biodiversity Strategy, government strategy paper, *Forestry: The Process of Change in India and Nepal.* His Majesty's Government of Nepal/Ministry of Forest and Soil *ODI*, London. 190-210 pp.

Hutson, M. A. 1994. *Biological Diversity*. Cambridge University Press, London.

ICIMOD 2007. Nepal Biodiversity Resource Book (Protected Areas, Ramsar Sites, and World Heritage Sites, ICIMOD, MOEST, GoN, Kathmandu, Nepal

Ingles, I. W.1994. *The Influence of Religious Beliefs and Rituals on Forest Conservation in Nepal.* Intergovernmental Panel on Climate Change.18pp

IPCC 1995. *Climate Change 1995: The Science of Climate Change*. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

IPCC 2000. *Land use, Land use Change and Forestry*. IPCC special report on Land use, Land use Change and Forestry. Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

IPCC 2006. Good Practice Guidance for National Greenhouse Gas Inventories. Volume 4: *Agriculture, Forestry, and Other Land Uses (AFOLU)*. Geneva, Switzerland: Intergovernmental Panel on Climate Change.

IPCC 2013. *Climate Change 2013: The Physical Science Basis Summary for Policymakers*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Johson, I and Coburn, R. 2010. Trees for carbon sequestration. *Primefact* 981, 1-6.

Keith, H., Mackey.B.G and Lindenmayer.D.B. 2009. Re-evaluation of forest biomass carbon stocks and lessons from the world's most carbon-dense forests. *Proceedings of the National Academy of Sciences*. 106 (28 11635-11640).

Khanal, Y., Sharma, R. P., and Upadhyaya, C. P. 2010. Soil and vegetation carbon pools in two Community forests of Palpa district, Nepal. *Banko Janakari*, ***20***(2), 33-40.

Khayamali, B. P. 2010. Assessing carbon benefits from Neelbarahi and Gauradevi community forest of Bhaktapur. M.Sc. Dissertation Submitted to Department of Environmental Science, Khwopa College, Bhaktapur.

Khumbongmayum A.D, M.L.KHAN and R.S.Tripathi 2006.Biodiversity conservation in sacred groves of Manipur, Northest India. Population structure and regeneration status of woody species *Biodiversity and Conservation* 15(8):2439-2456, DOI 10.1007/s 10531-004.6901-0

Kirschbaum, M. U. F. 1996. The carbon sequestration potential of tree plantations in Australia. In Eldridge, K. G., Crowe, M. P., and Old, K. M. (eds.*), Environmental Management: The Role of Eucalypts and other Fast Growing Species. CRISO Forestry and Forest Products*, pp. 77-89.

Kolshus, H.H.2001. *Carbon sequestration in sinks: An overview of potential and costs*. Working Paper 2001:11, Center for International Climate and Environmental Research (CICERO), University of Oslo, Oslo Pp19

Mac Dicken, K. 1997. *A guide to monitoring carbon storage in forestry and agroforestry project*s. Winrock International Institute for Agricultural Development, Arlington, USA, pp. 1-87.

Mandal, R. A., Dutta, I. C., Jha, P. K., and Karmacharya, S. B. 2013. Relationship between carbon stock and plant biodiversity in collaborative Forests in Terai, Nepal. Hindawi Publishing Corporation,International Scholarly Research Notice ISRN Botany. Pp7.http://dx.doi.org/10.1155/2013/625767.

Mandal, R. A., Dutta, I. C., Jha, P. K., and Karmacharya, S. B. 2016. Carbon sequestration potential in Community and Collaborative forest in Terai, Nepal. *Tropical Ecology*, ***57***(4), 665-662.

Mandal, R. A., Dutta, I. C., Jha, P. k., Karmacharya, S. B., Yadav, K., Yadav, B., Thapa, U., and Haque, S. 2012. Effects of Deforestation and forest degradation on forest carbon stocks in Collaborative forests of Nepal. *International Journal of Conservation Science*, ***3***(4), 325-338.

Marasini, S. 2003. Vegetation analysis of churiya forest in Rupandehi District of Nepal. M.Sc. Dissertation Submitted to Central Department of Botany, Tribhuvan University, and Kathmandu.

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

MoFSC 1989. Master Plan for Forestry Sectors. Kathmandu: Ministry

MPFS 1989. Master Plan for the Forestry Sector (MPFS). His Majesty's Government of Nepal, Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

NBS 2002. Nepal Biodiversity Strategy. Ministry of Forest and Soil Conservation,

Negi, J. D. S., Sharma, S. C., and Sharma, D. C. 1988. Comparative assessment of methods for estimating biomass in forest ecosystem. *Indian Forester*, ***114***(3), 136-143. Nepal Australia Community Forestry Project, Kathmandu, Nepal.18 pp.

Nepal, B. K. 2001. Quantitative analysis of vegetation (Trees and Shrubs) along an altitudinal gradient in Annapurna Conservation Area. M.Sc. Dissertation Submitted to Central Department of Botany, Tribhuvan University, Kathmandu.

Nowak, D.J. 1993. Atmospheric Carbon Reduction by Urban Trees. Journal of Environmental Management. 37:207-217.

O'Brien, E. M. 1993. Climatic gradients in woody plant species richness: towards an explanation based on an analysis of Southern Africa's woody flora. *Journal of Biogeography*, ***20***, 181- 198.

Odum, E. P. 1971. Foundamentals of Ecology. W. B. Saunders Company, USA of Forest and Soil Conservation (MoFSC), Government of Nepal.

Oli, B. N., and Shrestha, K. 2009. Carbon Status in Forests of Nepal. *Journal of Forest and Livelihood*, ***8***(1), 62-66.

Pandey, H. P., and Bhusal, M. 2016. A comparative study on Carbon Stock in *Shorea robusta* forest in two different ecological regions of Nepal. *Banko Janakari*, ***26***(1), 24-31.

Pandit, S. 2014. Comparative Assessment of Carbon Stock of Annapurna Conservation Area with Khahatikhola Kaulepani Community Forest in Kaski District, Nepal. M.Sc. Dissertation Submitted to Department of Environmental Science, College of Applied Sciences, Tribhuvan University and Kathmandu.

Pathak, R. P. 2015. Plant Species Diversity and Tree Carbon Stock in a *Shorea robusta* Gaertn. Community Forest of Nawalparasi, Nepal. M.Sc. Dissertation Submitted to Central Department of Botany, Tribhuvan University and Kathmandu.

Paudel, S. 2000. Comparative study of vegetation structure and soil characterstics in community and government managed forest in Udayapur District in Nepal. M.Sc. Dissertation Submitted to Central Department of Botany, Tribhuvan University, and Kathmandu.

Paudel, S., and Sah, J. P. 2015. Effects of different management practices on stand composition and species diversity in sub-tropical forests of Nepal: Implications of Community Participation in Biodiversity Conservation. *Journal of Sustainable Forestry*, ***34***, 738-760.

Paudyal, B. K. 2016. Regeneration, growth of Hill Sal and plant diversity in community forest: A case study from Pragatisil community forest in Kaski District, Western Nepal. *Banko Janakari*, ***23***(2), 37-43.

Pokheral, B. and Baral, J. 2009. From Green to REDD, from Aid to Trade: Translating the Forest Carbon Concept into Practice. *Journal of Forest and Livlihood*, ***8***(1).Ratna Pustak Distribution, Kathmandu, Nepal.

Robertz, P., and Sune, I. 1999. Effects of long term Co_2 enrichment and nutrient availability in Norway spruce. II *Foliar chemistry*, *Trees*, ***14***, 17-27.

Shakya, J. D., Joshi, G. P., and Aryal, B. 2000. Floristic composition of Butwal area and its surrounding hill. *Banko Janakari*, ***10***(1), 42-46.

Shannon, C. E., and Weaver, W. 1949. *The mathematical theory of communication*. University of Illinois Press, Champaign.

Sharma, B. K., Pokheral, C. P., and Shrestha, L. 2015. Forest diversity and carbon sequestration in Resunga Sacred grove, Gulmi, Nepal. *Journal of Natural History Museum*, ***29,*** 60-69.

Sharma, Bhuvan & Prasad Pokharel, Chandra & Shrestha, Laxmi. (2018). Forest Diversity and Carbon Sequestration In Resunga Sacred Grove, Gulmi, Nepal. Journal of Natural History Museum. 29. 60. 10.3126/jnhm.v 29i0.19038.

Sharma, E. R., and Pukkala, T. 1990. Volume equations and biomass prediction of forest trees of Nepal. Forest Survey and Statistics Division, Ministry of Forest and Soil Conservation, Kathmandu, Nepal.

Shrestha, B. B., Sharma, N. P., Uprety, Y., Shrestha, U. B., and Poudel, S. 2004. Regeneration of Quercus semecarpifolia Sm. In Shivapuri Hill, Kathmandu, Central Nepal. *Banko Janakari*, ***14***(20), 25-29.

Shrestha, B. P. 2009. Carbon sequestration in *Schima Castanopsis* Forest. A case study from Palpa district. *The Greenery(A journal of Environment and Biodiversity),* ***7***(1), 34-40.

Shrestha, B. P., and Devkota, B. P. 2016. Carbon stocks in the Oak and Pine forests in Salyan District, Nepal. *Banko Janakari*, ***23***(2), 30-36.

Shrestha, K.R. 1998. Dictionary of Nepalese Plant Names. Mandala Book Point Kantipath, Kathmandu, Nepal.

Shrestha, T. B., and Joshi, R. M. 1996. *Rare Endemic and Endangered Plants of Nepal*. WWF - Nepal Programme Kathmandu.

Shrish, O. 2012. Carbon Stock of selected tree species in a community managed tropical forest of Rupandehi District, Western Nepal. M.Sc. Dissertation Submitted to Central Department of Botany, Tribhuvan University, Kathmandu.

Silver, W. L., Ostertag, R., and Lugo, A. E. 2000. The Potential for Carbon Sequestration through Reforestation of Abandoned Tropical Agricultural and Pasture lands. *Restoration Ecology*, ***8***(4), 394-407.

Simpson, E. H. 1949. Measurement of diversity. *Nature*, ***163***, 688-689.

Siwakoti M. and Varma S. K. 1999. Plant Diversity of Eastern Nepal*: Flora of Plains of Eastern Nepal*. M/S Bishen Singh Mahendra Pal Singh, Dehra Dun, India.University of Illinois Press,Champaign. Working Paper. Pp. 1-11.

Zobel, D. D., Jha, P. K., Behan, M. J., and Yadav, U. K. R. 1987. *A Practicl Manual for Ecology*. Ratna Pustak Distributors, Kathmandu, Nepal.

ANNEXES

Annex 1. 1List of tree species found in Bolbam CF with family and local name

Name of Tree Species	Local Name	Family
Acacia catechu	Khaiyr	Leguminosae
Aegle marmelos	Bel	Rutaceae
Anogeissus latifolius	Banjhi	Combretaceae
Azadiracta indica	Neem	Meliaceae
Bombax ceiba	Simal	Malvaceae
Buchanania latifolia	Piyari	Anacardiaceae
Cassia fistula	Raj Brikchya	*Fabaceae*
Dalbergia latifolia	Satisal	*Fabaceae*
Dalbergia sissoo	Sisau	*Fabaceae*
Delonix regia	Gulmohar	*Fabaceae*
Dillenia pantagyna	Tatari	Dilleniaceae
Diospyros malabarica	Khallu	Evenaceae
Ficus benghalensis	Bar	Moraceae
Ficus religiosa	Pipal	Moraceae
Lagerstroemia parviflora	Bod dhaiyro	Lythraceae
Mangifera indica	Amp	Anacardeaceae
Phyllenthus emblica	Amala	Phyllanthaceae
Schleichera oleosa	Kusum	Sapindaceae
Semicarpus anacardium	Bhalayo	Anacardeaceae
Shorea robusta	Sal	Dipterocarpoceae
Syzygium cumini	Jamun	Myrtaceae
Tectona grandis	Teak (Sagun)	Verbenaceae
Terminalia alata	Saj (Asna)	Combretaceae
Terminalia bellirica	Barro	Combretaceae
Wendlandia exserta	Tilka	Rubiaceae

Annex 1. 2List of tree species found in Brahmakumari Global RF with family and local name

Scientific Name	Local Name	Family
Anogeissus latifolius	Banjhi	Combretaceae
Bombax ceiba	Simal	Malvaceae
Buchanania latifolia	Piyari	Anacardiaceae
Dalbergia latifolia	Satisal	*Fabaceae*
Dalbergia sissoo	Sisau	*Fabaceae*
Ficus religiosa	Pipal	Moraceae
Lagerstroemia parviflora	Bod dhaiyro	Lythraceae
Mallotus phillippensis	Rohini	Euphorbiaceae
Mangifera indica	Amp	Anacardeaceae
Melia azederach	Bakaino	Meliaceae
Phyllenthus emblica	Amala	Phyllanthaceae
Schleichera oleosa	Kusum	Sapindaceae
Semicarpus anacardium	Bhalayo	Anacardeaceae
Shorea robusta	Sal	Dipterocarpoceae
Syzigium cumini	Jamun	Myrtaceae
Tectona grandis	Teak (Sagun)	Verbenaceae
Terminalia alata	Saj (Asna)	Combretaceae
Terminalia bellirica	Barro	Combretaceae
Terminalia chebula	Harro	Rubiaceae
Wendlandia exserta	Tilka	Rubiaceae

Annex 1. 3Density, Relative Density (RD), Frequency, Relative Frequency (RF), Abundance and Relative Abundance (RA) of trees of BCF and BGRF.

Name of Species	Density	RD	Frequency	RF	Abundance	RA
Acacia catechu	140.00	9.27	42.00	10.10	333.33	9.27
Aegle marmelos	16.00	1.06	10.00	2.40	160.00	1.06
Anogeissus latifolius	388.00	25.70	82.00	19.71	473.17	25.70
Azadiracta indica	8.00	0.53	4.00	0.96	200.00	0.53
Bombax ceiba	14.00	0.93	8.00	1.92	175.00	0.93
Buchanania latifolia	210.00	13.91	62.00	14.90	338.71	13.91
Cassia fistula	2.00	0.13	2.00	0.48	100.00	0.13
Dalbergia latifolia	52.00	3.44	10.00	2.40	520.00	3.44
Dalbergia sissoo	2.00	0.13	2.00	0.48	100.00	0.13
Delonix regia	18.00	1.19	4.00	0.96	450.00	1.19
Dillenia pantagyna	6.00	0.40	4.00	0.96	150.00	0.40
Diospyros malabarica	30.00	1.99	12.00	2.88	250.00	1.99
Ficus bengalensis	2.00	0.13	2.00	0.48	100.00	0.13
Ficus religiosa	2.00	0.13	2.00	0.48	100.00	0.13
Lagerstroemia parviflora	20.00	1.32	6.00	1.44	333.33	1.32
Mangifera indica	4.00	0.26	4.00	0.96	100.00	0.26
Phyllenthus emblica	6.00	0.40	2.00	0.48	300.00	0.40
Schleichera oleosa	2.00	0.13	2.00	0.48	100.00	0.13
Semicarpus anacardium	12.00	0.79	12.00	2.88	100.00	0.79
Shorea robusta	348.00	23.05	56.00	13.46	621.43	23.05
Syzigium cumini	2.00	0.13	2.00	0.48	100.00	0.13
Tectona grandis	4.00	0.26	2.00	0.48	200.00	0.26
Terminalia alata	148.00	9.80	46.00	11.06	321.74	9.80

Terminalia bellirica	4.00	0.26	2.00	0.48	200.00	0.26
Wendlandia exserta	70.00	4.64	36.00	8.65	194.44	4.64

Name of Species	**Density**	**RD**	**Frequency**	**RF**	**Abundance**	**RA**
Anogeissus latifolius	30.00	1.54	14.00	4.35	214.29	1.54
Bombax ceiba	2.00	0.10	2.00	0.62	100.00	0.10
Buchanania latifolia	206.00	10.56	34.00	10.56	605.88	10.56
Dalbergia latifolia	12.00	0.62	10.00	3.11	120.00	0.62
Dalbergia sissoo	46.00	2.36	10.00	3.11	460.00	2.36
Ficus religiosa	2.00	0.10	2.00	0.62	100.00	0.10
Lagerstroemia parviflora	58.00	2.97	24.00	7.45	241.67	2.97
Mallotus phillippensis	2.00	0.10	2.00	0.62	100.00	0.10
Mangifera indica	2.00	0.10	2.00	0.62	100.00	0.10
Melia azederach	2.00	0.10	2.00	0.62	100.00	0.10
Phyllenthus emblica	2.00	0.10	2.00	0.62	100.00	0.10
Schleichera oleosa	12.00	0.62	6.00	1.86	200.00	0.62
Semicarpus anacardium	42.00	2.15	20.00	6.21	210.00	2.15
Shorea robusta	1218.00	62.46	98.00	30.43	1242.86	62.46
Syzigium cumini	24.00	1.23	16.00	4.97	150.00	1.23
Tectona grandis	14.00	0.72	6.00	1.86	233.33	0.72
Terminalia alata	122.00	6.26	46.00	14.29	265.22	6.26
Terminalia bellirica	2.00	0.10	2.00	0.62	100.00	0.10
Terminalia chebula	2.00	0.10	2.00	0.62	100.00	0.10
Wendlandia exserta	150.00	7.69	22.00	6.83	681.82	7.69