Tree Species richness,Carbon Stock and regeneration status of Maltol Community Forest And Dhanushdham Protected Forest in Dhanusha, Nepal

A Dissertation Submitted to Partial Fulfillment of the Requirements for the Master's Degree in Botany

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RECOMMENDATION LETTER

This is certified that the dissertation work entitled "**Tree Species richness,Carbon Stock and regeneration status of Maltol Community Forest And Dhanushdham Protected Forest in Dhanusha, Eastern Nepal**" submitted by Sajina Sunar has been carried out under our supervision. To the best of our knowledge, this research has not been submitted for any other degree, anywhere else. We therefore, recommend this dissertation work to be accepted as a partial fulfillment of Masters degree in Botany from Amrit Campus, Tribhuvan University, Kathmandu, Nepal.

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LETTER OF APPROVAL

The dissertation work entitled **“Tree Species richness,Carbon Stock and regeneration status of Maltol Community Forest and Dhanushdham Protected Forest in Dhanusha, Eastern Nepal”** submitted by Sajina Sunar has been accepted for the examination and submitted to the Amrit Campus, Tribhuvan University for the partial fulfillment of the requirements for Masters‟ degree in Botany (Ecology).

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CERTIFICATE OF ACCEPTANCE

This dissertation work entitled **Tree Species richness,Carbon Stock and regeneration status of Maltol Community Forest And Dhanushdham Protected Forest in Dhanusha, Nepal** submitted by Sajina Sunar has been examined and accepted for partial fulfillment of the requirements of Masters‟ degree in Botany (Ecology).

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I, hereby declare that the dissertation work entitled " **Tree Species richness, Carbon Stock and regeneration status of Maltol Community Forest And Dhanushdham Protected Forest in Dhanusha, Nepal "** is carried out by myself and has not been submitted elsewhere for any other academic degree. All the sources of information have been specifically acknowledged by reference wherever adopted from other sources.

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ABSTRACT

Tree species are the dominant component of forest ecosystems which influence most structural and functional attributes of these ecosystems. This study aims to assess and compare tree diversity and carbon stocks in two different management regimes namely Maltol Community forest (MCF) and Dhanushadham Protected forest (DPF). The studied MCF and DPF lied in tropical region at an altitude 80 to 230 masl in Dhanusha District of Nepal. Altogether 120 plot of 25 × 25 m^2 each was established by following the stratified random sampling technique for assessing tree diversity and carbon stock in both forests. Species enrooted and encountered inside the plot were recorded. All tree species (≥6cm DBH) were tagged and their both DBH and height were measured. 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. Descriptive statistics with Pearson correlation and one way ANOVA from SPSS-Software and Microsoft Excel were used to perform the statistical analysis. The carbon stock value was found to be 1.2305t/ha in MCF and 5.592t/ha in DPF. Community forest found to have lower value of tree carbon stock than the carbon stock of protected forest. But in case of tree diversity it was recorded high in MCF (34) than in DPF (29). *Shorea robusta* was found to be the single dominant species in both DPF and MCF with higher basal area (26.802m^2/ha and 6.65m^2/ha) and contributed 87.93% and 61.99% of the carbon stock respectively. The contribution of carbon stock of two co-dominant tree species in MCF are 8.98% of *Terminalia chebula* and 5.18% *Lannea coromandelica*. Lower value of basal area in both forest types in the present study suggests that both the forests are in an immature developmental phase. The size class distribution diagram of all trees showed reverse J shaped pattern indicating a good regenerating capability of the forest. But the regeneration of *Shorea robusta* of both forests in the present study followed the trend as trees density/ha > saplings density/ha > seedlins density/ha indicated the poor regeneration of *Shorea robusta*. There was significant ($P<0.05$) difference between the carbon stock in both forest types.

Key words: species composition, DBH, allometric, carbon stock, dominant,

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LIST OF ABBREVIATION

AGB	Above ground biomass
ANOVA	Analysis of Variance
BA	Basal area
CF	Community Forest
CFUGs	Community Forest Users Groups
DBH	Diameter at Breast Height
DPF	Dhanushadham Protected Forest
IVI	Importance Value Index
KATH	National Herbarium and Plant Laboratories, Godavari, Lalitpur
Masl	Meter above sea level
MCF	Maltol Community Forest
p	Level of Significance
R^2	Coefficient of determination
REDD	Reducing Emissions from Deforestation and Degradation
SPSS	Statistical Package for the Social Science
t ha -1	Ton per hectare

CHAPTER 1

INTRODUCTION

1.1 Background

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Species diversity is the combination of species richness and evenness and regulated by long term factor factors such as community stability and evolutionary time as heterogeneity of both macro and micro climate affects diversification among different community (Krebs, 1972). Intensity of major status and biodiversity of forest ecosystem is directly measured by dominant vegetation and their associated species (Sharma *et al*. 2013).

Carbon stock is the absolute quantity of carbon held within a pool at a specified time whereas carbon sequestration is the process of increasing the carbon content of a carbon pool other than the atmosphere (FAO, 2011). Global forests store 4500 Gt Carbon-dioxide whereas atmosphere store only 3000 Gt Carbon-dioxide (Prentice *et al.,* 2001). Carbon trading and biodiversity conservation are two hot issues in the present global climate change. Carbon stock is valued as worth of each nation. Globally, forest acts as a natural sink for carbon which contributes 80% and 40% of 4500 Gt terrestrial above and below ground storage respectively (Dixon *et al*., 1994). Increasing atmospheric CO2 concentration has predominantly arisen through fossil fuel emissions, deforestation, biomass burning, and land use change (Lal, 2009). The reduction of atmospheric CO2 in order to mitigate climate change can be achieved by various options: (1) carbon capture and storage, (2) improved energy efficiency, (3) the use of low carbon fuels, (4) use of nuclear power, (5) use of renewable energy, (6) enhancement of biological sinks and (7) reduction of non CO2 green house gas emissions.

1.2 Forest and carbon stock

Forests play a profound 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 and Rasal, 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 and Rasal, 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 carboncycle as they sequester CO_2 from the atmosphere through photosynthesis (Kolshus, 2001).

Regeneration is a silvigenesis process through which trees and forests survive over the time (Bhuyan *et al*., 2003). In other word, it is the cost effective natural process by which plants re-establish themselves and with this strategy the plants maintain their diversity and genetic identity (Haneif *et al*., 2016). The forest structures characterized by the presence of sufficient population of seedlings, saplings and adults indicate successful regeneration of forest species (Saxena and Singh, 1984). If seedlings and saplings are less than mature trees, it indicates declining trends in forest and regeneration will be poor (Haneif *et al*., 2016). If the distribution of diameter class is such that maximum number of individuals is present at seedling stage and then decreases subsequently at the next level, the model is named as reverse J-shaped curve. This signifies the good regeneration potential of forest site (Chauhan *et al*., 2008). In addition, there is a possibility of J- shaped curve in an old growth forests as a result of failure of regeneration (Chauhan *et al*., 2008).Regeneration of trees may follow various pathways such as seed rain, soil seed bank and seedling bank and coppice (Mehta *et al*., 2015). Information on tree seedling story can provide option for forest development through improvement in recruitment, establishment and growth of desired species (Swaine, 1996).

In present context, global warming and climate change are being primarily resulted from alleviated Green House Gases (GHGs) due to excessive use of fuels, change in land use patterns and industrialization (Le Quere *et al*., 2015). IPCC (2014) reported CO2 among the GHGs is accounting about 76% of total anthropogenic GHGs emission. Carbon stock in forest ecosystem refers to the amount of C stored in forest ecosystem (UNFCCC, 2007). Estimation of Carbon is important in understanding the role of forests to global Carbon cycle (Kohl *et al*., 2015). It is also one of the important parameters for the better planning of forest resources conservation as well as good mitigation strategy for climate change effects (Khanal *et al*., 2010).

1.3 Community and Protected forest

Forestry sector policy and Forest Act 1993 classified government forest into 7 management categories that are community forest, leasehold forest, government managed forest, collaborative forest, protected forest, national park and protected area and religious forest. The major aim of the community forest and protected forest area practices is to supports the biodiversity conservation and provides the forest products to the stakeholder rather than to conserve or maximize the biodiversity. It is widely recognized that prevalent forest management strategy of CFUGS in protection oriented or passive (Acharya, 2002) resulting in fewer benefits that 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 breeding and compost (Branney, 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, 2003).

It is believed that the goal of reducing carbon sources and increasing the carbon sink can be achieved efficiently by protecting and conserving the carbon pools in existing forest (Brown and Schroeder, 1996). Protected sites are designated with the objectives of conserving biodiversity, but also fulfill an important role in maintaining terrestrial carbon stock, especially where there is little remaining natural vegetation cover. Soil carbon is an important part of terrestrial carbon pool and soils of the world are potentially viable sinks for atmospheric carbon (Bajracharya *et al.*, 1998).

1.4 Justification of study

Regeneration studies have the significant applications on the management, conservation and restoration of degraded natural forests. Sustainable forestry utilization is only possible if adequate information on regeneration dynamics and factors influencing important canopy tree species are available (Mehta *et al.*, 2015). REDD+ scheme provide opportunity for the forest of developing countries like Nepal to get monetary benefit from Carbon that have stored in them (Kohl *et al.,* 2015). It is important to record forest carbon sequestration can be known and claim for Carbon benefit.

The study of regeneration pattern and Carbon stock of forests of different forest types will be the pioneer work in this area for providing baseline information on tree species richness, Carbon stock and regeneration status of different forest types with altitudinal variation. The information obtained will be helpful in planning and implementing the forest restoration, management and conservation strategies at community, regional and national level.

1.5 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 i.e. protected forest and community forest.

Specific objectives

- To enumerate tree species in both protected and community managed forest.
- To calculate carbon stock in both protected and community managed forest.
- To analyze the regeneration pattern of *Shorea robusta* in both forest types.

1.6 Research questions

To fulfill the above objectives, some research questions were developed.

- Do the management practices influence on species richness and diversity of forest?
- Do the tree C stock and soil parameters of forest are affected by management practices?
- What is the regeneration status of *Shorea robusta* in community managed forest and protected forest?

1.7 Limitations

- Biomass of seedlings, shrubs, herb and litter was not included.
- Only tree carbon stock was calculated.
- Only tree diversity was included.

CHAPTER 2

LITERATURE REVIEW

2.1 Biomass and Carbon Stock Estimation in different types of forest

The forest is a reservoir, a component of the climate system where a greenhouse gas is stored, as well as sink, any process that removes GHGs from the atmosphere (IPCC 2000). The role of forests in carbon sequestration is probably best understood and appears to offer the greatest near-term potential for human management as sink. Forests play a prominent role in the global C cycle through exchange of C between the land and the atmosphere (Dixon *et al*., 1994; Pan *et al*., 2011) and acts as sink or source of C (Kohl *et al*., 2015). Forest resource degradation has been one of the major problems in the 21st century. Deforestation and forest degradation alone accounts for 17.4% of the world‟s greenhouse gas emissions (Subedi *et al*., 2010). The problem is serious in tropical and subtropical forests where carbon stocks are decreasing at an alarming rate of 1-2 billion tons a year (Subedi *et al*., 2010). Deforestation is contributing to climate change and because of which forests have been identified as a potential ecosystem for measurement to mitigate climate change (De Fries *et al*., 2000; FAO, 2001; Nizami, 2010). In an average, 50% dry weight of the tree biomass is C (MacDicken, 1997). According to Winjum *et al*., (1992) forest vegetation and soil share 60% of the world's terrestrial C. The world's forest contain up to 80% of all above ground C and nearly 40% of all belowground (soils, litter and roots) terrestrial C (Dixon *et al*., 1994).

Total C-stock in Nepal was 1,157.4 million tonnes (Mts), out of which Forest, Other wooded land and other land constitute 1,055 Mts (177 Mg/ha), 61 Mts (105 Mg/ha) and 42 Mts (8 Mg/ha), respectively. Out of the total forest C-stock, tree, soil and litter/debris components contribute 61.5% (109 Mg/ha), 37.8% (67 Mg/ha), and 0.7% (1.2 Mg ha^{-1}), respectively. Tree, soil and litter/debris components of the OWL contribute 5.8 Mg/ha, 99 Mg/ha and 0.5 Mg/ha, respectively (DFRS, 2015). Above-ground C stock in Nepal was 133 Mg/ha as estimated by FAO, (2015a). To assess the potential of additional carbon sequestration by forest management as part of climate change mitigation strategies, it is necessary to understand the carbon storage in forest biomass, soil and wood products, and the interactions between these compartments.

Forest management interferes with carbon storage through choice of rotation length, thinning intensity, stand density and spacing, and silvicultural practices such as coppicing and soil preparation etc., and may cause both increases and decreases in carbon stocks in forest biomass. For a proper evaluation of the potential for carbon storage, it is important to distinguish these options in relation to species and silvicultural treatment.

Forest ecosystems comprise more than 90 percent of the land sector sequestration capacity (EPA, 2016) and offset about 15 percent of total US fossil fuel emissions (Woodall *et al*., 2015). Deforestation and other changes in land use cause significant exchanges of carbon between the land and the atmosphere. In addition to carbon release from deforestation or clear cutting, degradation of existing forests also contributes to carbon release from grazing, fire, death due to disease and pests, illegal removal of timber, non-sustainable harvest of firewood or timber, etc. Evidence of this is available from various studies (Ravindranath *et al*., 1997; Kaul *et al*., 2009).

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 *et al*., 2000). In context of Nepal Sal (*Shorea robusta*) is the most dominant species of the tropical and subtropical broadleaved forests of Nepal (Jackson, 1994). The *Shorea robusta* forest in Nepal is confined to the Hills and Terai ecological regions. It shares the highest tree volume i.e., 109.4 million m^3 (28.2% of the total tree volume) (Amatya and Shrestha, 2010). *Shorea robusta* forests not only have higher economic value, but also serve as an important ecological benefit in the form of abating global warming and climate change through conserving atmospheric CO2 (Shrestha, 2008).

In Nepal, different researchers have found different amount of C-stock in different types of Sal forest (Terai and Hill Sal forest). According to Thapa Magar and Shrestha (2015) mean vegetation C-stock of nine community managed hill Sal forest of Dhadhing District was 120 Mg/ha which was calculated by using allometric equation of Chave *et al*., (2005) (moist forest model) for tree species and Haase and Haase, (1995) for shrub species and they estimated C sequestration rate of 2.6 Mg C ha^{-1} yr^{-1}. They obtained that vegetation C-stock of the forest increased with the increase in management duration of forest and thus concluded; community management had positive impact on increasing the biomass C-stock of forest.

Malla, (2003) conducted study in fallow land (without trees), Sal stand-1 (planted in 1977) and Sal stand-2 (planted in 1972) to determine the sol nutrients. It was found to be higher in Sal stand than in fallow land which was attributed to regular addition of nutrients in the form of litter in Sal stand due to presence of trees. Similarly, soil nutrients was found to be high in Sal stand-2 than in 1 which was attributed to higher quantity of litter deposition in stand 2 due to its relatively old age.

Poudel, (2000) studied the vegetation structure and soil characteristics in community and government managed forests of Udayapur, Nepal. He found 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. Pathak, (2015) estimated 115 Mg/ha C-stock and 0.8 MgCha^{-1} yr^{-1} C sequestration rate in semi natural tropical Sal forest (where 40% of trees were over the age of 50 yrs) of Nawalparasi District after applying "moist forest" allometric equation of Chave *et al*., (2005) for tree species and concluded mature tropical forest had low C sequestration rate but high sequestered C than the regenerating forest. 8 Similarly, the study carried out by Shrestha, (2009) in sal dominated CF and Schima-Castanopsis dominated CF of Palpa District found that Sal dominated CF had higher total aboveground C-stock (102 Mg/ha) than Schima-Castanopsis dominated CF (44 Mg/ha) where C-stock was calculated by using allometric equation of Sharma and Pukkala, (1990) for tree species.

Acharya, (2003) 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.* Similarly, ICIMOD, (2010), had done baseline study in 104 community forests of three watershed areas of Nepal; Kayarkhola of Chitwan District, Charnawati of Dolakha District and Ludhikhola of Gorkha District. Analysis of the DBH distributions of all strata follows a left-skewed trend, indicating most of the trees in all the strata were younger and there was potential to enhance forest carbon stock by encouraging tree growth. Forest carbon 9 ton/ha stocks in dense and sparse strata of Kayarkhola, Charnawati and Ludikhola watershed were 296.44 ton/ha and 256.70 ton/ha; 228.56 ton/ha 166.75 ton/ha; 216.26 ton/ha and 162.98 ton/ha respectively.

Gairhe, (2015) studied the C-stock in two CF of Tanahun District of which one was natural regenerated or secondary forest and other was natural and primary forest. He found that mean tree layer C-stock in primary forest was 71 Mg/ha whereas C-stock in secondary forest was 110 Mg/ha by applying the "moist forest" allometric equation of Chave *et al*., (2015). Similarly, significant positive correlation between carbon stock and species diversity was found in both types of forests. He concluded that this indicated carbon sequestration has positive impact on biodiversity and also concluded that disturbance level have no any affect on the overall tree carbon and diversity. According to Sharma, (2016) mean C-stock in Sal dominated forests managed by community and government 9 around Bees Hazaare lake of Chitwan National Park was 121.7 Mg/ha, calculated by using "moist forest" allometric equation of Chave *et al*., (2005). He showed that community managed forest (165.2 Mg/ha) had higher C-stock than government managed forest (78.2 Mg/ha) and concluded total C-stock of forest varied with different management regimes of the forest.

Shrestha *et al*., (2012), assessed the net above-ground carbon stock in six community forests of the Dolakha District, Nepal. They noted that, community forests accumulate approximately 2 ton/ha of carbon annually which is equivalent to 117.44 tons of carbon in total. They measure all trees greater than 10 cm in diameter and taking ten plots randomly in each forest except Sitakunda Community forest (16 plots were sampled due to its larger area) used (25 m×10 m) rectangular plots. They have used allometric equation developed by Sharma and Pukkala (1990).They found the value 91.04tC/ha (Simsungure), 87.42tC/ha (Mahankal), 36.41tC/ha (Mathani), 411.32tC/ha (Sitakunda), (21.83tC/ha) Barkhe and 56.6tC/ha (Chyansi). According to them, if community forests were actively managed leading to a sustainable forest institution, which acts as a carbon sink.

2.2 Forest age and carbon stock

Different study showed that C-stock in the forest increases with the age or management duration of forest. Thapa Magar and Shrestha, (2015) found that C-stock increased with increased management period of hill Sal forest of Dhadhing District, Nepal. Similarly, Mbaabu *et al*., (2014) found increased in C-stock with different management regimes of forest in Chitwan, Nepal. Banskota *et al*., (2007) obtained increasing of C-stock with successive increase of age of CFs in India and Nepal. Sharma *et al*., (2013) observed increment in the C-stock with age difference of forest and management period in Canada. Similarly Nizami, (2010) estimated the carbon stocks in subtropical managed and unmanaged forests of Pakistan. The mean carbon stock in managed forests was estimated 114 ± 2.26 tC/ha which comprises of 92 percent in tree biomass and only 8 percent in the topsoil. However, the mean carbon stock in unmanaged forests was estimated 27.77 ± 1.66 tC/ha which comprised of 80.8 % of total tree carbon and soil component represented only 19.2 %.

Jati, (2012) carried out the comparative study of the carbon assessment in Kumvakarna Conservation Community Forest, KCAP, Taplejung. He carried out the comparative study in preserved forest and managed forest and found out the tree biomass carbon to be 109.10 t/ha and 177.44 t/ha respectively. It was concluded that preserved forest was less efficient for carbon storage since it stored 93.88 t/ha less carbon than managed forest though the disturbances such as fuel wood collection, grazing, timber harvesting and fodder collection were found more in managed forest.

Bhat and Ravindranath, (2011) obtained 14.53 Mg/ha C-stock increment in the duration of 25 yrs in tropical rain forest of Uttara Kannada, Western Ghats, India. Besides this, Li *et al*., (2010) and Li *et al*., (2013) showed that C-stock increased with the age of Korean pine (*Pinus koraiensis*) and 17-73 yrs old Japanese red pine (*Pinus densiflora*) forests in Central Korea. Similar result of successive increment in C-stock with the increment in the age of forest in 22-30 yrs old *Betula platyphylla* stands in South Korea and 8-50 yrs managed *Pinus densiflora* forest in Korea was observed by Jung *et al*., (2013) and Noh *et al*., (2010) respectively.

2.3 Forest Management, Climate Change and REDD+

Protected forest is one of the many forest management modalities that are currently being practiced in Nepal. The Forest Act 1993 defines protected forest as a national forest, which is designated as „protected" by the government considering it's environmental, scientific, and cultural and other significance. Similarly, Community forestry is a participatory forest management system in Nepal that was started in the late 1970s. Glimour and Fisher, (1991) defined community forestry as the control, protection and management of forest resources by rural communities for whom trees and forests are an integral part of their farming system. According to Forest Act 1993, community forest is a part or parts of National forest area handed over to a user groups for its development, conservation and utilization for collective benefit of the community. The evolution of community forestry program is considered as one of the most successful natural resource management practice in Nepal in restoring degraded land and habitats, conserving biodiversity, increasing supply of forest products, generating rural income, and developing human resources (Acharya, 2004); also an exemplary case to understand the effects of REDD+ implementation on forest decentralization. In Nepal, the REDD+ development intends to build on the well-established CF program which has been regarded as a key factor for the recovery of once degraded mountains (Niraula *et al*., 2013) leading to the improved provisioning of diverse Ecosystem Services (ES) to fulfill the needs of the local people (Marquardt *et al*., 2016). 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 carbon-dioxide, 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.

Forests are a key source of GHG emissions and CFs are more than a quarter of developing country forests where virtually all net biomass loss is occurring, it is difficult to imagine addressing climate change without bringing CFs into REDD+ (Bluffstone *et al*., 2014). REDD+ is accepted as a cheaper, quicker, significant and win-win strategy (CIFOR, 2008) not only to control land use changes, and reduce deforestation and C emissions (Toni, 2011) but also conserve biodiversity and reduce poverty in developing countries. Increased financial flow through REDD+ implementation is likely to increase the value of forests which provide incentives to the government bureaucracy to recentralize the control (Sandbrook *et al*., 2010). It allows developed countries opportunity and flexibility to adopt emission offset options and developing countries receive increased, unconventional financial incentives for forest management (Eliasch, 2008). Some studies even suggested the risk of the shift in control of forest by local communities towards external actors and interests i.e. international organizations, challenging local control and benefits of CF management (Leach and Scoones, 2015). The goal of REDD+ is to motivate the forests managers and owners by financially incentivizing them either to maintain existing C- stock in the forests or to regenerate additional C- stock (Kanowski *et al*., 2010).

2.4 Regeneration of forest

Forest disturbance can alter environmental conditions by changing light availability and soil conditions (Fredericksen and Mostacedo, 2000). Disturbance also influences processes that can either augment or erode the ecological functions of a forest community (Sagar *et al*., 2003). Both natural and human disturbances influence forest dynamics and tree diversity at local and regional scales (Sheil, 1999; Ramirez-Marcial *et al*., 2001). Knowledge of floristic composition and structure of forest reserves is also useful in identifying important elements of plant diversity, protecting threatened and economic species, and monitoring the state of reserves, among others (Ssegawa and Nkuutu, 2006). Thus, the study of floristic composition and structure of tropical forest becomes more imperative in the face of the ever increasing threat to the forest ecosystem.

Natural regeneration is the only relevant regeneration method for Sal in Nepal (Joshi *et al*., 1995). Although many known and unknown causative factors affect the process of natural regeneration, the major factors include climate, soil, seed, biotic conditions, etc. (Singh *et al*., 1987); and soil moisture and light intensity (Tyagi *et al*., 2011). However, Sal forests in Nepal are shrinking with poor regeneration and there is change in species composition as well (Sapkota *et al*., 2009) which is a challenge for Sal forest management. The regeneration of plant depends mainly upon the average seed output, viability of seeds, seed dormancy, seed dispersal, seedling growth, vegetative growth and reproductive growth and seedling establishment (Basyal *et al*., 2011; Napit, 2015). Study of regeneration pattern in Sal forests from various parts of Nepal has found that regeneration status of Sal was higher than the other associated species. Awasthi *et al*., (2015) and Napit (2015) found that regeneration of sal was higher than other associated species in Lumbini collaborative forests of Rupandehi and Banke National Park, respectively. Regeneration of Sal was higher than other associated species in Terai and Churia forests of Nepal (DFRS, 2014).

Soil organic carbon (SOC) stocks display a high spatial variability (Cannell *et al*., 1999). In fact, most of the studies concern only the topsoil (e.g. 0–30 cm), although carbon sequestration or loss may also occur in deeper soil layers (Bird *et al*., 2002). Sal tree grows in habitats with a wide range of soil types, but not osn very sandy, gravely soils that immediately adjoin rivers or waterlogged areas (Jackson, 1994). It can grow on alluvial to lateritic soils (Tewari, 1995) and prefers slightly acidic to neutral sandy loam (pH = 5.1 – 6.8) (Gangopadhyay *et al*., 1990). Lehman *et al*., (2008) observed that soil C cycling has an important role in the global C cycle because soil organic C (SOC) stocks are almost four times greater than C in the atmosphere, and annual emissions of CO2 from soil are one order of magnitude greater than all anthropogenic CO2 emissions. Therefore, small uncertainties in soil processes may have large effects on climate-change predictions for those general circulation models that incorporate terrestrial biogeochemical cycles.

Light, litter, commencement of monsoon (rain), grazing, fire, looping and litter collection were the environmental and anthropogenic factors that affected the regeneration of Sal (Sagar *et al*., 2003). Moreover, competition for one or more resources (e.g. light, nutrients, and water) is lower in canopy gaps than in intact vegetation environments (Bullock, 2000). Thus, the combined effects of increased light intensity, increased soil temperature and reduced competition increases seedling recruitment and establishment in canopy gaps compared to areas with closed canopies.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

Mainly the study area of Dhanushadham Protected forest that lies in Dhanushadham Municipality and Maltol Community forest also lies in Dhanushadham Municipality, Dhanusha. The study area lies in tropical region below 1000m, and is dominated by *Shorea robusta.*

3.1.1 Dhanushadham Protected forest

Dhanushadham Protected forest (DPF) located in Nepal's eastern region (26°50'29"N to 86°2'54"E) covers 3.6 Km^2 (360 hectares) of land area, the forest area only covers about 1.25 Km^2 (125 hectares) remaining land area occupied by grassland, lake, and wetland; is considered as 8th protected forest of Nepal (KC and Deshar, 2018). The government of Nepal declared this forest as protected forest on 25th February 2014 due to its biological and historical importance. A total of 40 species of trees, total 31 species of shrubs like *Carissa carandas*, *Barleria cristata* and 40 species of herbs like *Ocimum gratissimum*, *Abutilon indicum* were recorded from the studied site. Similarly, 10 species of mammals like *Lepus nigricollis, Boselaphus tragocamelus, Sus scrofa* 39 species of birds like *Threskiornis melanocephalu, Ichthyophaga ichthyaetus*, 14 species of reptiles such as *Melanochelys tricarinata, Naja naja* and 3 species of amphibians like *Hoplobatrachus crassus, Duttaphrynus melanostictus* were recorded. The dominant tree species found in this forest are *Shorea robusta, Schleichera oleosa, Buchanania latifolia, Acacia catechu, Semecarpus anacardium* and *Terminalia alata* etc (KC and Deshar, 2018).

3.1.2 Maltol Community forest

Maltol Community forest is the one of the community forest of Dhanusha District consist 220.25 hectares of forest area. The government of Nepal handed over this to community and was designated as community forest in 2062/01/11 B.S.

The climate of this district is Tropical-monsoon type. The maximum temperature is 30-40 degree Celcius and the minimum temperature is 19-6 degree Celsius. The average annual precipitation rate is 1400 mm with the monsoon period of 3-4 months.

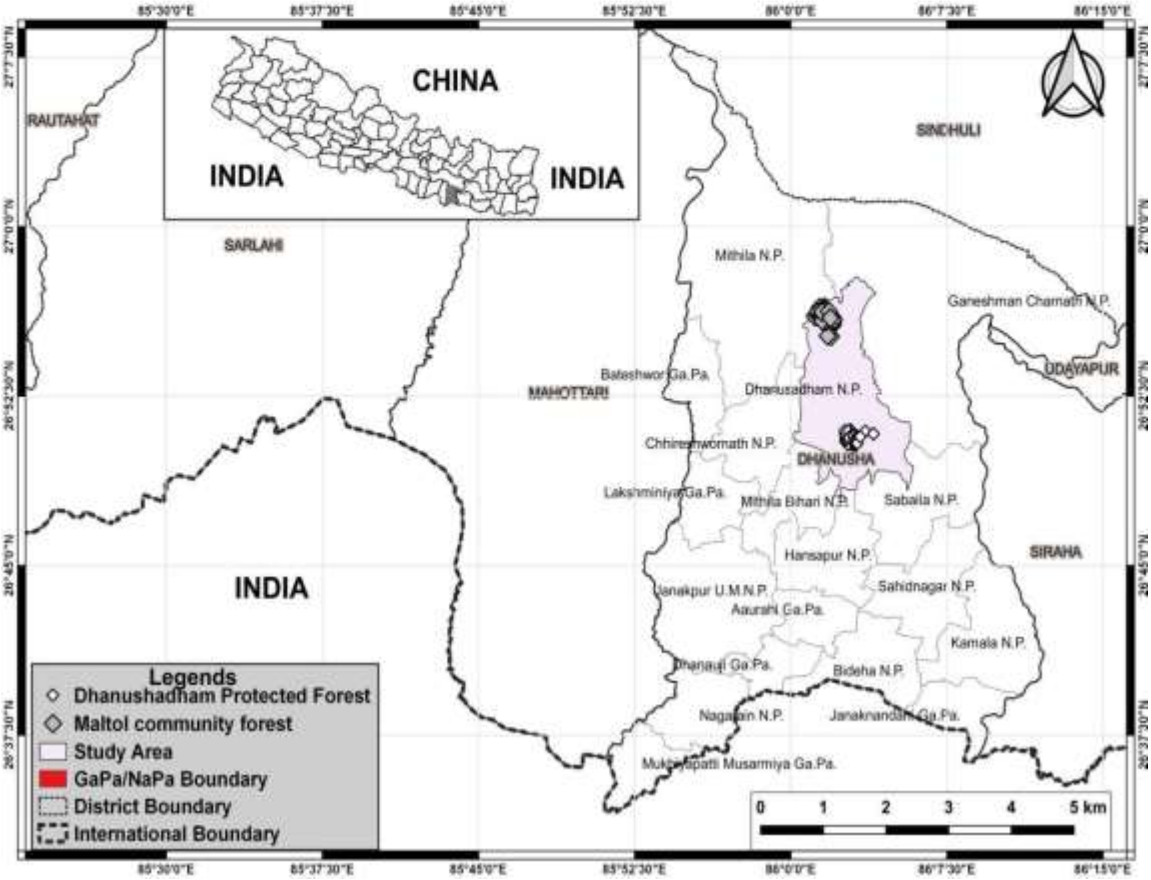


Figure 1: Map of the studied area.

3.1.3 Climate and Hydrology

Dhanusha 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 meteorological data were taken from nearby Hardinath station. The summer season of this region is very hot and winter is very cold. In summer the temperature rises up to 37°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 24.96°C in Dhanushadham (Climatological data 2014-2019, Hardinath). the average maximum temperature was 35.22°C in May and minimum temperature was 9.82°C in January. Average monthly rainfall recorded was 98.94mm. And average annual rainfall recorded was 1187.28mm. Average maximum and minimum rainfall recorded was 382.38 mm in Jul and 0 mm in November. More than 80% of annual rainfall occurs during the rainy season (Pre monsoon to monsoon rainfall) i.e. from May to September (Figure 2). Source: Department of Hydrology and Meteorology, Babarmahal, Kathmandu).

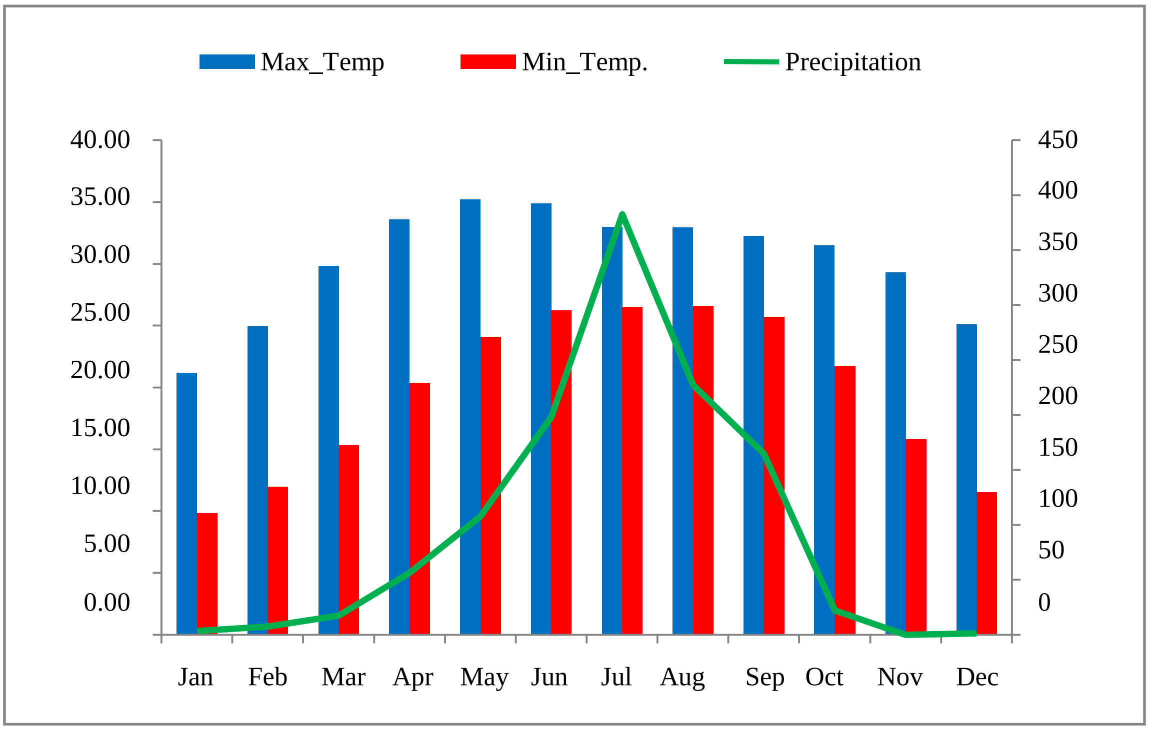


Figure 2: Variation in monthly average (minimum and maximum) temperature and precipitation of last 6 years (2014-2019) at Dhanushadham.

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 Maltol Community forest and Dhanushadham Protected forest are collected to understand their forest management practices.

3.2.1 Sampling Design Methods

The study area was visited twice (post winter, 19th March- 29th March, 2018 and second in autumn season, 12nd September- 20th September, 2019) for data collection. Stratified random sampling method was used for sampling of tree species of both forests. Each forest was divided into different blocks by community forest authority (CF manuals) based upon the geographical location and species composition. Map Required number of plots in each forest types and blocks were determined to be at least 1% (Rana *et al.*, 2008) of the total area of forest (total area of the forest and each blocks was referred from CF manuals of respective forest groups) and proportional number of plots were established in each blocks of the forests.

Sampling plot size of 25×25 m^2 was determined to be appropriate for the sampling the stand with large number of stems small in diameter (Mac Dicken 1997). Altogether 120 plots were established with 60 plots on each forest types. Meanwhile distance of each plot from nearest settlement or road was noted. Sampling design within plots each plot of size of 25×25 m^2 was established with the help of rope and aspect of the plot was maintained with the help of clinometers so that each corner of the plot is 90 degree to each other or plot is perfect square in shape. Distance between each plot was maintained to be 100 m. Within each plot, diameter of each tree was measured at the breast height (1.37m) with the help of DBH tape, angle between observer and tree was measured with the help of clinometers and distance between tree and observer was measured with the help of measuring tape. Tree with DBH less than 6cm was excluded for carbon stock measurement (Chave *et al.*, 2005). Slope was taken with the help of clinometers (Germany), geographical position of the each plot (Latitude and longitude) was taken with the help of Geographical positioning system (GPS,) and altitude was taken with the help of altimeter (Garmin

60csx). Other information of plots such as disturbance activities like fodder collection, timber harvesting, human encroachment, grazing, fire etc were included in by manual observation. To study the regeneration, nested plot of size 5×5 m^2 was established within each plot. Saplings and seedlings were counted in each nested plot which has DBH < 6 cm, (Subedi *et al*., 2010).

3.2.2 Soil collection

Soil sample below 10 cm depth was collected from the four corners of each plot. About 1 kg composite soil sample was packed in a zipper polythene bag for laboratory analysis. Each soil sample was dried properly before laboratory analysis.

3.2.3 Plant collection, herbarium preparation and identification

Herbarium specimen of woody plant species occurring inside the quadrats were collected, tagged, pressed and dried. Digital photographs of live plant specimens were taken in the field. Consulting the local inhabitants, local names of the specimens were recorded. Some of the specimens were identified in the field with the help of (Shrestha, 1998; Siwakoti and Varma, 1999), and its supplement (Stainton, 1988). The other specimens were identified in National Herbarium and Plant Laboratory (KATH). For nomenclature of species APG III system (Chase and Reveal, 2009) and Press *et al*., (2000) were adopted.

3.2.4 Vegetation Analysis

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

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.

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

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.

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

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.

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

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 and relative coverage known as importance value index of the species. In this research work it was calculated by following formula.

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

Where,

RD = Relative Density
RF = Relative Frequency
RC = Relative Coverage

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).

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

Where,

$\pi = 3.14$
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.

Species Diversity

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. The explanatory power of Shannon‟s diversity index based on basal area is superior to a measure based on species count.

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

$H^0 = \sum pi \times lnpi$

Where,

H^0= Shannon‟s diversity index,
pi = species proportion (based either on species Count or species basal area
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

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 phyto sociological 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

3.2.5 Laboratory Work

The soil physicochemical parameters (Soil organic carbon, pH, nitrogen, phosphorous and potassium) were examined during September-20 to October-3, 2019 at Department of Agriculture technology center (ATC) Jhamsikhel, Lalitpur by using following laboratory methods. Soil organic matter (SOM) was estimated by applying Walkey & Black, (1934) method. Soil nitrogen was measured by Kjeldahl method, phosphorous by Bingham and potassium by ammonium acetate method. Soil pH was measured by suspension method.

3.2.6 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; 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 ($10\times10 m^2$), 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 stocks 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.

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

3.2.7 Data Analysis Method

One way ANOVA and descriptive statistics was used by using SPSS version 21 to know the difference between the carbon stocks in the different forest. The density of different DBH class was analyzed to compare the regeneration pattern in the different forests. Pearson correlation was done to analyze the relation between different soil factors and carbon content.

CHAPTER 4

RESULTS

4.1 Family and Genera composition

The study recorded in MCF, a total of 845 tree individuals from under 34 tree species belonging to 29 genera and 20 families. Among 20 families Fabaceae was largest family that contains six genera and seven species, followed by Anacardiaceae with four genera and four species and Combretaceae with two genera and four species. Families such as Moraceae and Myrtaceae got single genera and two species on each. However rest of families like Annonaceae, Apocynaceae, Rutaceae etc contains only single genera with single species (Table 1).

Whereas, study recorded in DPF a total of 1202 tree individuals from under 29 tree species belonging to 23 genera and 16 families. The richest family was Fabaceae with five genera and seven species. The second richest family was Anacardiaceae, Euphorbiaceae and Myrtaceae with two genera and two species each; followed by Moraceae with single genera and five species. Families such as Sapotaceae, Combretaceae, Rubiaceae etc got only single genera with single species each (Table 2).

Table 1: Family, genera,species and individual trees present in the Maltol Community forest.

S.N	Family	Genus	Species	No of Individual
1	Fabaceae	6	7	57
2	Anacardiaceae	4	4	16
3	Combretaceae	2	4	17
4	Annonaceae	1	1	1
5	Apocynaceae	1	1	1
6	Boraginaceae	1	1	1
7	Burseraceae	1	1	1
8	Dipterocarpaceae	1	1	708

9	Ebenaceae	1	1	2
10	Euphorbiaceae	1	1	4
11	Magnoliaceae	1	1	1
12	Malvaceae	1	1	3
13	Moraceae	1	2	2
14	Myrtaceae	1	2	3
15	Phyllanthaceae	1	1	4
16	Rubiaceae	1	1	1
17	Rutaceae	1	1	5
18	Salicaceae	1	1	1
19	Sapindaceae	1	1	14
20	Symplocaceae	1	1	3
		29	34	845

Table 2: : Name of the families, number of genus, species and individual trees present in DPF

S.N	Family	Genus	Species	No of Individual
1	Fabaceae	5	7	221
2	Anacardiaceae	2	2	4
3	Euphorbiaceae	2	2	6
4	Myrtaceae	2	2	7
5	Burseraceae	1	1	18
6	Combretaceae	1	1	2
7	Dipterocarpaceae	1	1	897
8	Lamiaceae	1	1	1
9	Lythraceae	1	1	4
10	Malvaceae	1	1	7
11	Moraceae	1	5	15
12	Phyllanthaceae	1	1	1

13	Rhamnaceae	1	1	6
14	Rubiaceae	1	1	2
15	Sapindaceae	1	1	9
16	Sapotaceae	1	1	2
	16	23	29	1202

4.2 Community structure of tree species

Maltol Community Forest

In the Maltol Community forest thirty four species were recorded. *Shorea robusta* showed the highest frequency 88.33% and relative frequency 38.13%. The lowest frequency and relative frequency were 1.67% and 0.72% respectively. Likewise, the density of individual tree species ranged from 188.8 stem/ha – 0.27 stem/ha. The total density of all tree species was 225.33 stem/ha. The relative abundance of the individual tree species ranged from 22.87% – 1.71%. Similarly the IVI was found to be highest for *Shorea robusta* (144.79) followed by *Acacia catechu* (18.58) and *Dalbergia sissoo* (10.97), while the other species like *Casearia elliptica*, *Michelia excelsa*, *Garuga pinnata*, *Mitragyna parviflolia* etc showed least IVI (2.55). In this community forest canopy was dominated by *Shorea robusta*, *Bombax ceiba* and *Schleichera oleosa* but sub canopy was well dominated by *Acacia catechu* and *Dalbergia sisso.*

Dhanushadham Protected Forest

In the DPF only twenty nine species were recorded. In this protected forest *Shorea robusta* was the highest frequency was achieved as 90% and relative frequency 30.68%. The lowest frequency and relative frequency were 1.67% and 0.57% respectively. Likewise, the density of individual tree species ranged from 239.2 stem/ha – 0.27 stem/ha. The total density of all tree species was 225.33 stem/ha. The relative abundance of the individual tree species ranged from 25.47% – 1.53%. Similarly the important value index was found to be highest for *Shorea robusta* (130.78) and followed by *Acacia catechu* (28.64) and *Schleichera oleosa* (22.60), while the other species like *Bauhinia veriegata*, *Ficus semicordata*, *Phyllanthus emblica* and *Tectona grandis* showed least IVI (2.18). In this protected forest canopy was dominated by *Shorea robusta, Schleichera oleosa* and *Garuga pinnata* but sub canopy was well dominated by *Dalbergia sissoo*, *Acacia catechu* and *Acacia nilotica*

Common Tree Species

Total fifteen tree species were found common in both MCF and DPF. The IVI value of common tree species in MCF and DPF forest was shown in figure (3) below.

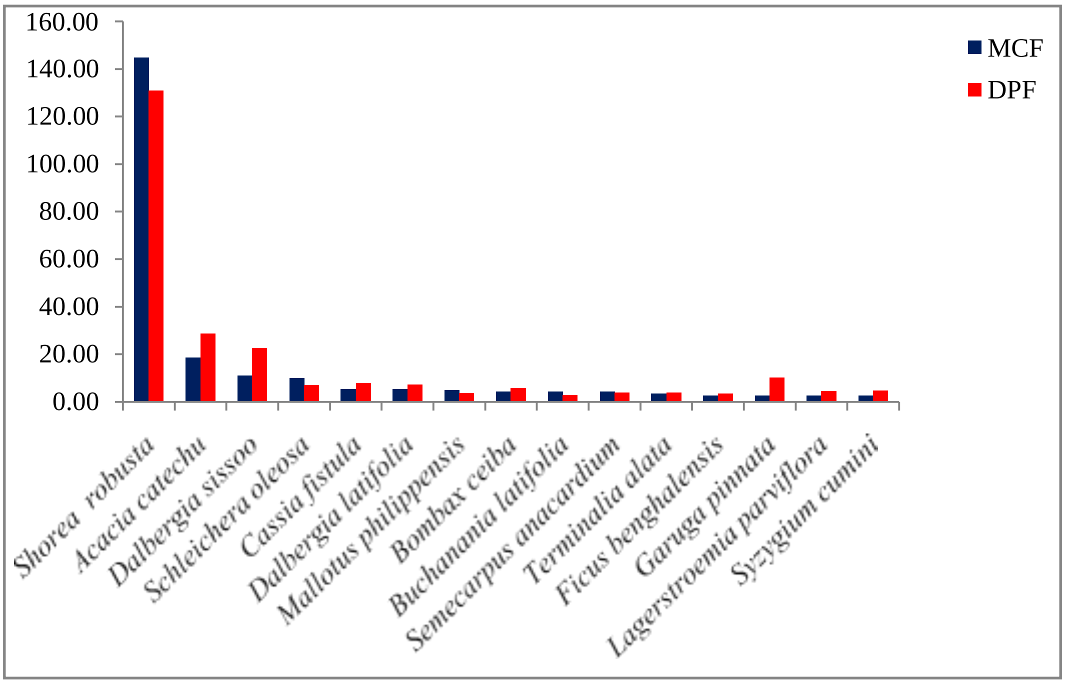


Figure 3: IVI of common tree species in MCF and DPF.

4.3 Basal Area of Species

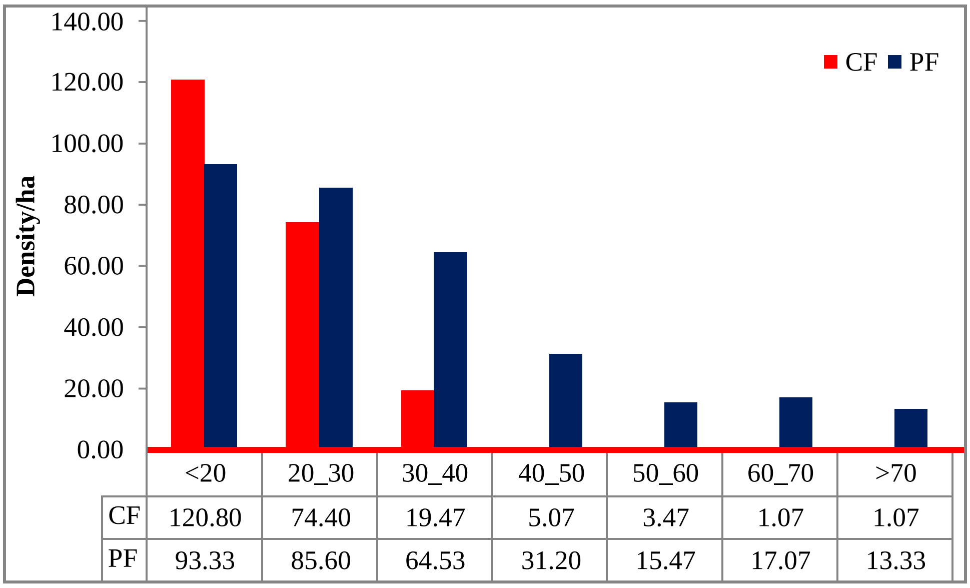
In DPF, the highest basal area (m²/ha) was recorded for *Shorea robusta* (26.802 m²/ha) followed by *Dalbergia sissoo* (0.736 m²/ha), *Acacia catechu* (0.657 m²/ha) and *Schleichera oleosa* (0.529 m²/ha). Similarly, in MCF the highest basal area (m²/ha) was recorded for *Shorea robusta* (6.650 m²/ha), followed by *Dalbergia sissoo* (0.365 m²/ha), *Acacia catechu* (0.292 m²/ha) and *Bombax ceiba* (0.262 m²/ha) (Table 5).

Table 3: Basal Area of common tree species in Dhanushadham protected forest and Maltol community forest.

S.N	Species	DPF (m²/ha)	MCF (m²/ha)
1	*Shorea robusta*	26.802	6.650
2	*Dalbergia sissoo*	0.736	0.365
3	*Acacia catechu*	0.657	0.292
4	*Schleichera oleosa*	0.529	0.202
5	*Garuga pinnata*	0.478	0.027
6	*Bombax ceiba*	0.305	0.262
7	*Ficus benghalensis*	0.302	0.019
8	*Syzygium cumini*	0.135	0.011
9	*Dalbergia latifolia*	0.112	0.026
10	*Buchanania latifolia*	0.103	0.070
11	*Lagerstroemia parviflora*	0.090	0.006
12	*Terminalia alata*	0.052	0.016
13	*Semecarpus anacardium*	0.044	0.019
14	*Cassia fistula*	0.034	0.028
15	*Mallotus philippensis*	0.009	0.037

3.3 Size class distribution and Regeneration

The DBH class distribution of overall tree species showed more or less reversed J shaped (Figure 4) structure within both Maltol Community forest and Dhanushadham Protected forest. Tree species with large size class >70cm were observed lower in Maltol Community forest but found satisfactory in Dhanushadham Protected forest. Similarly tree species with size class <10cm was present highest in both Maltol Community forest and Dhanushadham Protected forest. However, the presence of middle size tree species (30-50cm) was better in Dhanushadham Protected forest in comparison to Maltol Community forest.



	<20	20_30	30_40	40_50	50_60	60_70	>70
CF	120.80	74.40	19.47	5.07	3.47	1.07	1.07
PF	93.33	85.60	64.53	31.20	15.47	17.07	13.33

Figure 4: Density Diameter Curve of trees > 6cm in studied area.

An overall, distinct difference in stem size class distribution was evident in the both studied sites of forest. The size class distribution consistently decreased with increasing size classes of tree from < 20cm to > 70cm DBH. The low size class of < 20cm DBH was more abundant and formed 120.80 stem/ha in Maltol Community forest (MCF), and 93.33 stem/ha in Dhanushadham Protected forest (DPF). Whereas tree density of 20-30cm DBH class was greater 85.60 stem/ha in DPF in comparison to MCF (74.40 stem/ha). Similar result was also performed in size class of 30-40 cm DBH; however the matured tree density size class of >70 cm DBH were more abundant and performed 13.33 stem/ha in DPF but only 1.07 stem/ha for MCF (Figure 4).

Regeneration of *Shorea robusta*

There was 107.20 and 71.20 seedling/ha of *Shorea robusta* observed in DPF and MCF respectively. Similarly 178.93 and 109.33 of *Shorea robusta* sapling/ha were observed but 239.20 and 188.80 trees/ha of *Shorea robusta* were found in DPF and MCF respectively (Figure 5). It indicates the poor regeneration of *Shorea robusta*. The number of seedlings and saplings of *Shorea robusta* were much lower than the number of tree species in both of the studied sites.

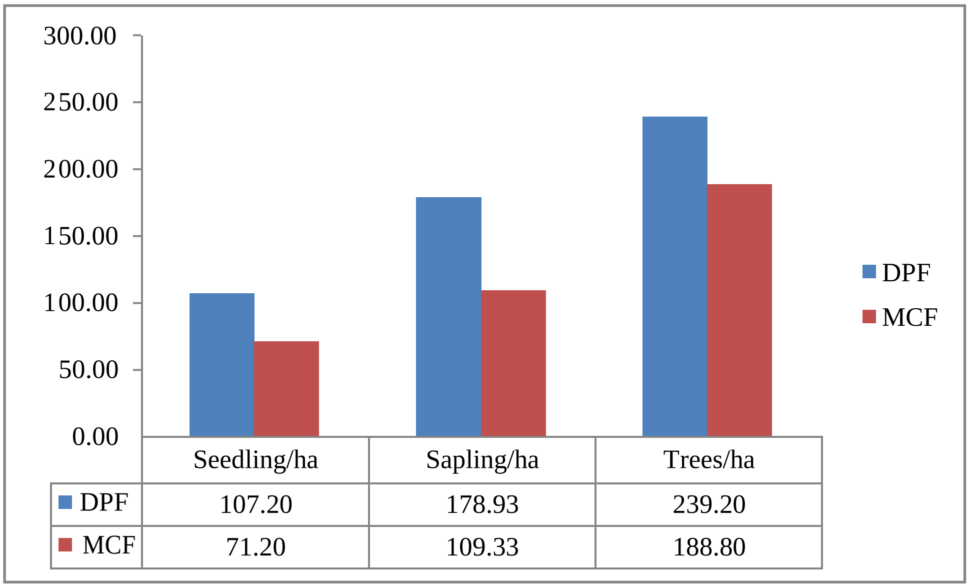


Figure 5: Regeneration pattern of *Shorea robusta*.

3.4 Plant Diversity Index

Table 4: Plant diversity indexes of Maltol Community Forest (MCF) and Dhanushadham Protected Forest (DPF).

Forest Types	Shannon Wiener diversity index (H')	Simpson's Diversity index (D)	Evenness index (Ep)
MCF	0.918	0.704	0.26
DPF	1.149	0.569	0.341

Species diversity is important as it is assumed as index of survival value of community or its relative stability status. The differences in inter-specific associations, the biotic composition of two forest communities are never exactly alike. They may resemble in physiognomy, may have the same dominants but even then like two members of the same family they will differ and show differences in species composition. The attributes of diversity indices of plant community at two study sites (MCF and DPF) have been depicted in Table 6. The value of Simpson's diversity index (D) was 0.704 (MCF) and 0.569 (DPF). The Shannon Wiener diversity index (H') was more at site DPF (1.149) in comparison to site MCF (0.918). However, the value of evenness index (Ep) 0.26 (MCF) and 0.341 (DPF) shown in Table 6.

Index of Similarity

Maltol Community forest and Dhanushadham Protected forest shared an average number of common tree species and the index of similarity between these two forests was also found to be average (47.62 %) shown below (Table 7).

Table 5: Index of similarity by (%) between Maltol CF and Dhanushadham PF.

Habit	Index of Similarity (%)
Tree	47.62

3.5 Contribution of Species in Tree Carbon Stock

The total carbon stock in MCF and DPF were calculated as 1.2305 t/ha in MCF and 5.592 t/ha in DPF respectively (Table 4). As both the forests were *Shorea robusta* dominated, *S. robusta* contribute the highest percentage (%) in carbon pool of both the forests. All the species except *S. robusta* have less than 10% contribution in the carbon pool of both the forests.

In the community forest, *S. robusta* is followed by T*erminalia chebula, Lannea coromandelica, Dalbergia sissoo. Schleichera oleosa, Terminalia bellirica, Acacia catechu and Syzygium* species respectively (Figure 6). Rest other species have the contribution less than 1% and are included as others in common.

In the protected forest, *S. robusta*is followed by *Schleichera oleosa, Ficus* species, *Dalbergia sissoo, Acacia catechu* and *Garuga pinnata* respectively (Figure 7). Rest other species have the contribution less than 1% and are included as others in common.

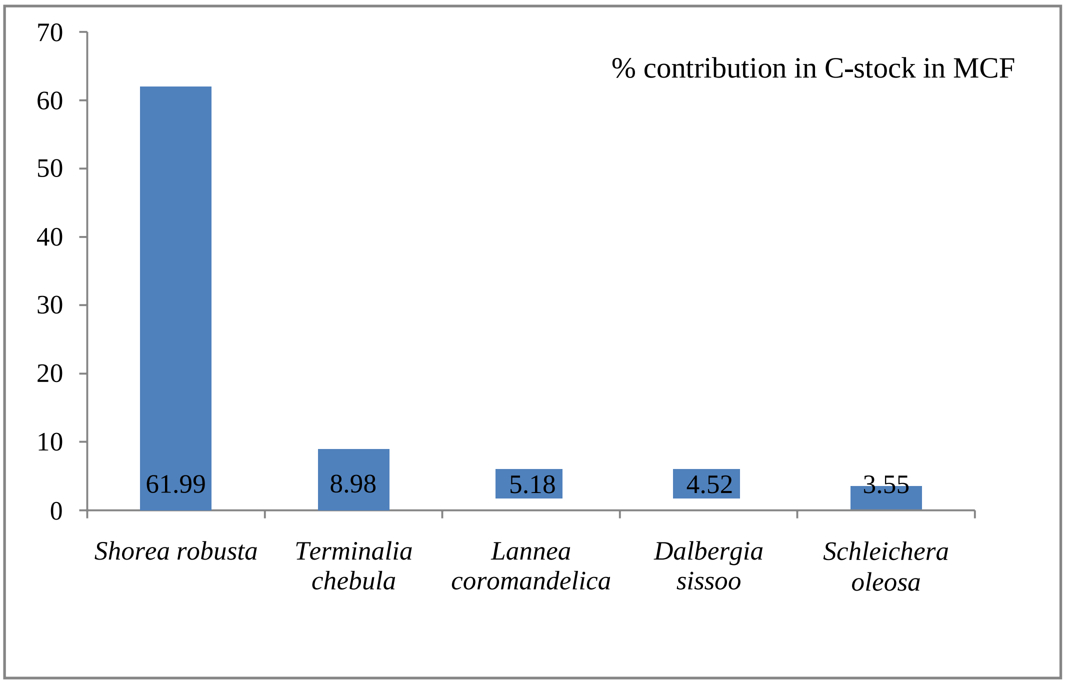


Figure 6: Major species contribution in carbon stock in MCF

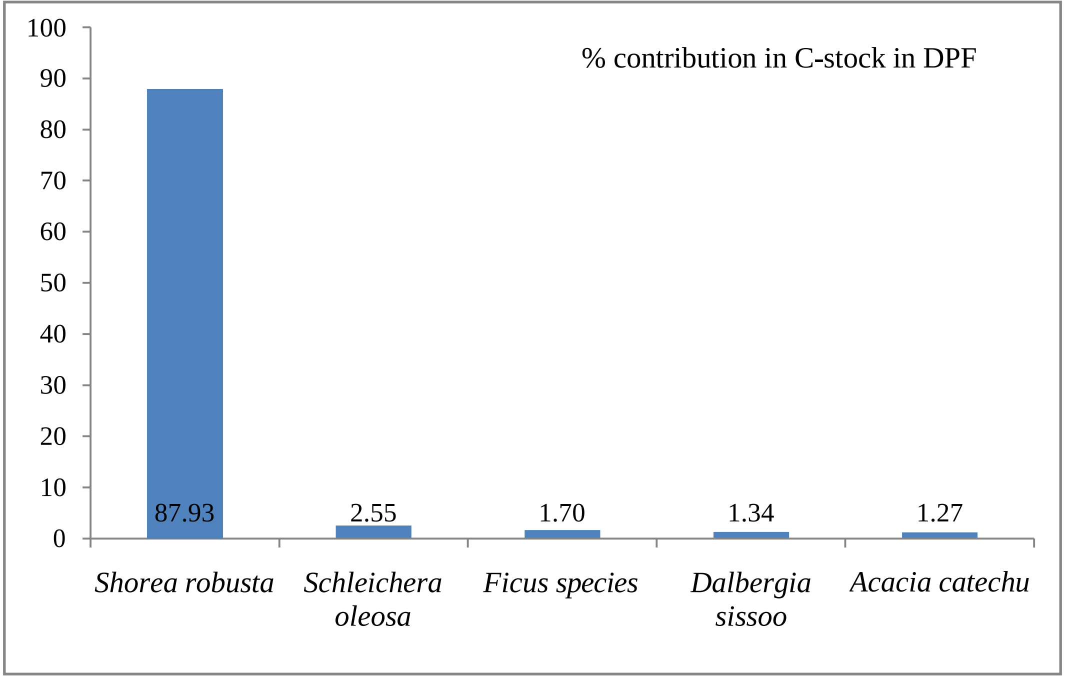


Figure 7: Major species contribution in carbon stock in DPF

Table 6: Contribution of common tree species in carbon stock (t/ha) of MCF and DPF

S.N	Common species	MCF (t/ha)	DPF (t/ha)
1	*Shorea robusta*	0.7624	4.8942
2	*Dalbergia sissoo*	0.0556	0.0746
3	*Schleichera oleosa*	0.0437	0.1419
4	*Acacia catechu*	0.0357	0.0709
5	*Bombax ceiba*	0.0269	0.0261
6	*Buchanania latifolia*	0.0065	0.0116
7	*Mallotus philippensis*	0.0035	0.0005
8	*Garuga pinnata*	0.0031	0.0569
9	*Cassia fistula*	0.0027	0.0021
10	*Dalbergia latifolia*	0.0025	0.0146
11	*Terminalia alata*	0.0019	0.0086
12	*Ficus benghalensis*	0.0017	0.0481
13	*Semecarpus anacardium*	0.0014	0.0056
14	*Syzygium cumini*	0.0013	0.0217
15	*Lagerstroemia parviflora*	0.0003	0.0112

4.7 Descriptive analysis of carbon in the forests

The statistical analysis showed that the mean carbon stock of the protected forest was 0.92781. It was deviated with value 0.0679 from the mean. The value of standard error was 0.0087673, maximum and minimum value was 0.3089 and 0.0004 respectively. Upper bound and lower bound value at 95% confidence interval was 0.110325 and 0.075238 respectively.

Similarly, the mean carbon stock in the community forest was 0.020496. It was deviated with value 0.0189798 from the mean. The value of standard error was 0.0024503, maximum and minimum value was 0.0873 and 0.0010 respectively. Upper bound and lower bound value at 95% confidence interval was 0.025399 and 0.015593 respectively as shown in Table (9).

Table 7: Descriptive analysis of the carbon in two different forests

Descriptive								
Carbon stock (kg/ha)								
	N	**Mean**	**Std. Deviation**	**Std. Error**	**95% Confidence Interval for**		**Minimum**	**Maximum**
					Lower Bound	**Upper Bound**		
MCF	60	.02049	.0189798	.00245	.01559	.02539	.0010	.0873
DPF	60	.09278	.0679112	.00876	.07523	.11032	.0004	.3089
Total	120	.05663	.0615017	.00561	.04552	.06775	.0004	.3089

4.8 Comparison of the carbon stock between community and protected forests

As the P-value < 0.05 (in table 10), the ANOVA test showed that there was significant difference between the carbon stocks in two different forests i.e. community forest and protected forest.

Table 8: Comparison of Carbon stock between two forests

ANOVA					
Carbon stock (t/ha)					
	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Forests	.157	1	.157	63.053	.000
Within Forest	.293	118	.002		
Total	.450	119			

4.9 Relation of the carbon stock with different soil parameters

The Pearson correlation in the table 11 showed that there is significant correlation between different soil factors and carbon stock in the forest at 0.01 levels.

Table 9: Pearson correlation coefficient between different soil parameters and carbon stock

Correlations										
		N%	p2o5	k2o5kg/ha	Coarse	Fine	Clay	Silt	Soil pH	C-stock
N%	Pearson Correlation	1	-1.000**	-1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**
	Sig. (2-		.	.	.	.	.	.	.	.
	N	2	2	2	2	2	2	2	2	2
p2o5 kg/ha	Pearson Correlation	-1.000**	1	1.000**	-1.000**	-1.000**	-1.000**	-1.000**	1.000**	1.000**
	Sig. (2-tailed)	.		.	.	.	.	.	.	.
	N	2	2	2	2	2	2	2	2	2
k2o5kg/ha	Pearson Correlation	-1.000**	1.000**	1	-1.000**	-1.000**	-1.000**	-1.000**	1.000**	1.000**
	Sig. (2-tailed)	.	.		.	.	.	.	.	.
	N	2	2	2	2	2	2	2	2	2
Coarse sand	Pearson Correlation	1.000**	-1.000**	-1.000**	1	1.000**	1.000**	1.000**	-1.000**	-1.000**
	Sig. (2-tailed)	.	.	.		.	.	.	.	.
	N	2	2	2	2	2	2	2	2	2
Fine sand	Pearson	1.000**	-	-1.000**	1.000**	1	1.000**	1.000**	-	-
	Sig. (2-	.	.	.	.		.	.	.	.
	N	2	2	2	2	2	2	2	2	2
Clay	Pearson	1.000**	-	-1.000**	1.000**	1.000**	1	1.000**	-	-
	Sig. (2-	.	.	.	.	.		.	.	.
	N	2	2	2	2	2	2	2	2	2
Silt	Pearson	1.000**	-	-1.000**	1.000**	1.000**	1.000**	1	-	-
	Sig. (2-	.	.	.	.	.	.		.	.
	N	2	2	2	2	2	2	2	2	2
Soil pH	Pearson	-	1.000**	1.000**	-	-	-	-	1	1.000**
	Sig. (2-	.	.	.	.	.	.	.		.
	N	2	2	2	2	2	2	2	2	2

C-stock	Pearson	-	1.000**	1.000**	-	-	-	-	1.000**	1
	Sig. (2-	.	.	.	.	.	.	.	.	
	N	2	2	2	2	2	2	2	2	2

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

CHAPTER 5

DISCUSSION

5.1 Community Attribute

A total of 34 species of tree were recorded in MCF and 29 in DPF. Most of the tree species were represented by less number of individuals. The result of the DPF is similar to 29 tree species reported by Chandra *et al*., (2010) from Garhwal Himalaya. The range of species richness found within a sample plot varied between 1 and 11 in MCF; whereas, it was 1 and 9 species in DPF. The proportion of tree species was higher in MCF than in DPF. Sigdel, (2008) found a total of 36 tree species in Shivapuri National Park in mid-hill of Nepal (1000 to 2000 m elevation). However the tree species richness in both forest were much greater than that of 3 tree species from southern Manang Valley, Nepal (Ghimire *et al*., 2008) and 16 tree species in two community forest of Dolpa District, mid west Nepal (Kunwar and Sharma, 1970).

The importance value index (IVI) of *Shorea robusta* was found highest in both categories of protected and community managed forest (i.e. 130.78 in protected forest and 144.79 in community managed forests). This showed IVI of *Shorea robusta* was almost same among both categories of community managed forests. When mean was taken, *Shorea robusta* alone had 45.95% (mean of 48.3 and 43.59) IVI in present studied forest. High IVI of a species indicated its dominance and ecological success, its good power of regeneration and greater ecological amplitude (Shameem and Kangroo, 2011). This indicates that *Shorea robusta* was the most important and dominant species in both categories of forest which utilize most of the forest area and resources. Other remaining species have 54.05% IVI so forest area and resources left over by *Shorea robusta* were then trapped and utilized by these species which acted as the competitors and the associates. Species preference, management activities, overutilization and removal of other species from a mixed forest stand lead to a monoculture in the forest (Shrestha *et al*., 2010). Similarly, the dominance of *Shorea robusta* depends on age, available resources, associate species, disturbance regime, and successional changes (Mandal and Joshi, 2014). Thus, high IVI of high timber yielding species, *Shorea robusta*, might be due to any one or more of these factors or activities.

5.2 Diversity and Species richness

Species composition and species richness are important indicators for assessing the biodiversity (Husch *et al*., 2002) and may strongly depend and/or be influenced by the applied management practices. Shannon Weiner diversity indices (H') of MCF and DPF were 0.918 and 1.149 respectively. Similarly, the Simpson‟s diversity indices (D) of MCF and DPF were 0.704 and 0.569 respectively. Jha and Acharya, (2008) found the Shannon diversity index of 1.63 in some CFs of mid-hills of Nepal which were already handed over to CFUGs 5 years ago with a diversity index of 1.22. Kharal, (2000) found Shannon diversity index of 1.8 in rural farmlands of Chitwan District, that has similar physiography, elevation and climatic condition with Barandabhar Area.

The evenness value recorded in the two forest sites i.e. 0.26 and 0.341 shows that the evenness values recorded for the protected and community forests are within the range (0.15–0.46) recorded for different altitudinal belts (1100–1700m) in a coniferous forest at Changbai Mountainous landscape by Jing *et al*., (2004). Similarly, these values were lower than the value reported in two different sub-tropical forests of Udayapur District by Paudel and Sah, (2015). However the value was greater than the tropical forest of Barak Valley, Assam reported by Borah and Garkoti, (2011). The similarity index value for tree species between these two forests was 47.62%. This value was lower than 80% - 90% for trees species reported by Marasini, (2003) in Rupandehi District. However Sharma *et al*., (2015) found 50% of tree species were to be similar between Rhododendron and oak forests of Resunga Sacred grove, Gulmi, Nepal. The replacement of non-timber tree species by one or two preferred timber tree species during forest management practices may facilitate recruitment of the unique suite of rare species, thus decrease evenness (Saha, 2003). Boch *et al*., (2013) suggested that the disturbance by management may increase plant species richness. These arguments are supported by the grater community level species for tree diversity in the Maltol CF reported in this study. A moderate level of disturbance in the government and community forest in the form of cattle grazing, fodder collection, anthropogenic and animal movements likely increase the plot level species richness (Hobbs and Huenneke, 1992).

5.3 Contribution of Species in Tree Carbon Stock

Variations in carbon stock might be due to some environmental conditions that influence the productivity of forest such as warm temperature and high rainfall and fertility of soil (Odum, 1971 and Barbour *et al*., 1999). In the present study both the MCF and DPF experience more or less same climatic conditions and hence are compared to know the impact of management practices on carbon stock. The highest density was found of *Shorea robusta* (239.2 and 188.8 trees/ha) followed by *Acacia catechu* (27.2 and 7.73 trees/ha). The species such as *Dalbergia sisssoo, Schleichera oleosa,* were also present with low density. Their density might be low because they are less dominant species with only occasional occurrences in the forest. The population densities of several tree species were lower, so they are rare species of the forest. The forest is dense within the ranged values 390-1460 trees/ha reported by Khadka and Schmidt-Vogt (2008) in forests of Godawari Hills, Kathmandu. Pandey *et al*., (2004) reported the values of density ranging from 140 to 750 trees/ha in Pindari forest Kathmandu. The variation of tree density within the forest could be due to different extent of disturbances exerting by cutting as well as plantation management and protection. However, size class distribution of trees shows that although total density is moderate, most of the trees constitute smaller girth.

Mean basal area in MCF was 9.56 m^2/ha and DPF was 31.48 m^2/ha. Lower value of basal area in both forest types of the present study suggests that the forests are in a deforested and degraded phase. Basal area of *Shorea robusta* was higher (26.802 m^2/ha) in DPF than in MCF (6.65 m^2/ha). In both forest tree species were used for timber and fuel wood, hence its basal area are recorded less. Researchers have suggested that the community attributes such as higher basal area and tree density are indicative of a mature forest (Saha, 2003; Banda *et al*., 2006 and Timilsina *et al*., 2007). Hence above result showed that the protected forest is relatively more mature comparison to community forest this is due to a situation that persists despite the utilization pressure from nearby human settlements. Total basal area recorded for the protected and community forests are below the range recorded for community forests and natural forest (37.2–59.6 m^2/ha), dominated by *Shorea robusta*, in the Siwalik region of central Nepal (Shrestha *et al*., 2000).

Shorea robusta contributed 61.99% of carbon stock in MCF and 87.93% of carbon stock in DPF. The percentage value of carbon stock contributed by *Shorea robusta* in MCF are less than the value obtained for *Shorea robusta* in above ground carbon of Laxmi Mahila CF (95%) and Jalbire Mahila community forest (86%) of Gorkha, District (Neupane and Sharma, 2014). Whereas the percentage of carbon stock contributed by *Shorea robusta* in MCF and DPF of present study were higher than the carbon stock contributed by *Shorea robusta* (44.7%) in Taldanda Community forest reported by Gaire, (2015) in Tanahun District. Similarly, Gairhe, (2015) found *Shorea robusta* contributed 64.5% and 44.7% in C-stock in two community managed forests of Tanahun District. The difference between density of *Shorea robusta* and other species were observed higher in both of the studied forest. However, Gairhe, (2015) found relatively low value of difference between *Shorea robusta* densities along with other species. As a whole carbon stocks in the Resunga Sacred Grove (RSG) was 127.75 t/ha reported by (Sharma *et al.*, 2015). Which is much greater value than the present study of MCF and DPF forest (1.23 and 5.59 t/ha). Similarly, Carbon stocks in Religious Forest of present study was also lower 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 lower value of carbon stock of present study might be due to the influence of weak and failure management system in MCF and DPF. 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 DPF some of silviculture practices (thinning, pruning, singling, litter collection, plantation) are executed but in MCF these practices are not executed. Hence this may be the reasons for their different in carbon stock.

5.4 Size class distribution and regeneration

Biomass of a forest depends upon the condition of forest. The condition of forest is determined by the DBH class distribution. Classification of forests into timber trees, pole trees, and regeneration are made on the basis of DBH class distribution. The managed forests are most effective and reliable sinks of greenhouse gases. The local community has direct benefit sharing from the community forest. Both forests of

Dhanusha District where forest has been found as the pole stage according to their DBH type.

In the study the size class distribution doesn"t indicate different population structure, which may be related to differences in environment and disturbance regimes. The reverse J-shaped size class distribution of trees in a both forest indicates sustainable regeneration (Tripathi, 2001). A similar type of reverse J-shaped curve was also obtained by previous studies from Nepal and India, such as in the Sal forest of Rupandehi (Acharya and Shrestha, 2011). Numbers of individual were found to be decreasing from young regeneration phase to successive development phases in both MCF and DPF. Number of individuals at different phase was affected by the year of management rather than the age of stand as individuals of regeneration phase in Dhanushadham PF were higher than Maltol CF but individuals at pole stage (<30cm) was significantly higher in MCF than DPF. The size class < 20cm DBH consist of maximum number of individuals followed by 21-50cm DBH class within both forest sites; a sufficient young stands to replace the old mature stands. The density diameter curve of trees with DBH>6cm also showed sustainable regeneration in both community and protected forests. Result indicate that old growth forest was more disturbed than regenerated forest in relation to *Shorea robusta* forest of Nawlparasi, Nepal (Sapkota *et al*., 2009) where high density of pole stand were found in disturbed forest stands than other forests. However, in the studied area it was found that both forest lacked the higher DBH classes of tree species (>50cm). Higher stem density in lower girth class is due to the restriction of cutting of small-sized trees and suitability of existing environmental condition to trees, while lower stem density in higher girth class is due to the removal of large-sized trees (Sapkota *et al*., 2009; Sarkar and Devi, 2014).

Regeneration is a key process for the existence of species in a forest stand. The survival of seedlings or saplings determines successful regeneration, which is the single most successful step toward achieving long-term sustainability of forests (Malik and Bhatt, 2016). In this study, the densities of both seedlings and saplings of *Shorea robusta* at both sites weren't good enough for future regeneration from a management perspective, also the density of tree species were higher than seedlings and saplings on both sites. Frequencies of regenerating species (saplings + seedlings) were maximal in protected forest compared to community forest (caused by forest fire, fuel wood collection and cattle grazing). The activities such as cleaning, thinning, weeding, and pruning of forest floor might have also decreased the abundance of smaller diameter sized *Shorea robusta* trees from both forests. The result therefore showed the presence of fewer number of saplings and seedlings of *Shorea robusta* in smallest diameter class to sustain future replacement for poles (<20cm DBH) and large-sized trees (>20cm DBH) in the both sites of forest (which indicated declining *Shorea robusta* population structure). If this trend of decreasing density of smaller diameter class stems continues from anthropogenic disturbances, forest stands *Shorea robusta* will get dominated with mid-sized and mature trees as well as by other tree species.

5.5 carbon stock with different soil parameters

It is found a greater correlation between carbon content with soil structure represented by pore distribution in the soil, probably caused by aggregation of the soil organic matter with clay particles forming micro and macro aggregates, which may cause physical barrier to carbon decomposition. The clay particles of the soil shows significant correlation with soil chemical characteristics reported on the local scale (Gao *et al*., 2014). Our result also showed same. The increasing clay content also increases the water holding capacity; clay content thus interacts with climate to control the accumulation of soil organic content.

Several studies have demonstrated that the change in soil nutrients, caused by variations in the quantity and quality of litter, considerably affects soil organic carbon dynamics (Saiz *et al*., 2012).In our study, SOC was related to TP and TN stocks, indicating the significant correlation with the soil organic carbon. Other studies have reported that P limitation may constrain C accumulation, where the association between phosphorus and iron or aluminum sesquioxides reduces P availability for microbial growth (Gijsman *et al*., 1996; Liu *et al*., 2012).

There was no significant relationship between carbon stocks, soil phosphorous and soil potassium content, pH and particle size (sand, silt, clay) distribution. This suggests that the concentration of phosphorous, potassium, pH, sand, silt and clay of the soil does not affect the carbon stored in the biomass of the trees.

CHAPTER 6

CONCLUSION AN RECOMMENDATIONS

6.1 Conclusion

Dhanushadham Protected forest harbors less number of plant species than Maltol Community forest. The highest IVI among the tree species was for *Shorea robusta* in MCF and DPF indicates both forests were dominated by *Shorea robusta*. Other associated species were *Buchanania latifolia*, *Terminalia alata*, *Dalbergia sissoo*, *Acacia catechu*, *Mallotus philippensis* etc. Number of seedlings and saplings of *Shorea robusta* were higher in DPF than MCF. Similarly the individuals at pole stage and mature trees were also higher in DPF than MCF. Although the diversity of trees were higher in MCF than DPF, tree carbon stock in DPF was recorded higher (5.592t/ha) than in MCF (1.2305t/ha). Higher value of tree diversity but lower value of carbon stock and less number of seedlings and saplings in MCF than DPF showed that the management practices influences plant diversity, carbon sequestration and regeneration in forests. Lowest value of carbon stock in MCF than DPF is due to the settlement area near to the MCF. Regression analysis showed significant positive relationship of carbon stock with basal area and DBH. The dominant species *Shorea robusta* showed significant contribution in carbon stock of both forests (61.99% in MCF and 87.93% in DPF). There was significant contribution of other species like *Terminalia alata* (8.98%), *Lannea coromandelica* (5.18%) and *Dalbergia sissoo* (4.52%) in tree carbon stock of MCF. Acidic soil in both forests may be due to the *Shorea robusta* that was found frequently. SOC was related to TP and TN stocks, indicating the significant correlation with the soil organic carbon.

6.2 Recommendations

- Grazing, Timber, fuel wood and fodder collection seen to be the major human disturbance activities in the studied forests. So these activities should be properly managed. One of the best practices for management of these disturbances may be the agroforestry practices.
- Sustainable utilization of forest resources such as timber, firewood, fodder should be ensured to fulfill the requirement of the local people and maintains the forest for future generation.
- Proper silviculture practices seem to be lacking, so these should be emphasized.
- Afforestation programs should be emphasized in Terai region to enhance the carbon sequestration by the plant biomass and the soil.
- Illegal tree felling must be stopped.
- Plantation of fodder trees and firewood trees around the land must be emphasized which may reduce the dependency on forest.
- Public awareness programs should be conducted to make them aware of the climate change and significant role played by the forest.

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APPENDICES

Appendix 1: List of Tree species found in Maltol Community Forest

S.N	Species name	Local name	Family
1	*Acacia catechu* (L. f.) Willd.	Khair	Fabaceae
2	*Aegle marmelos* (L.) Correa	Bel	Rutaceae
3	*Anogeissus latifolia* (Roxb. ex DC.) Bedd.	Banjhi	Combretaceae
4	*Aporosa octandra* (Buch.-Ham. ex D.	Kalikath	Phyllanthaceae
5	*Bauhinia purpurea* L.	Koiralo	Fabaceae
6	*Bombax ceiba* L.	Simal	Malvaceae
7	*Buchanania latifolia* Roxb.	Chiraunjee	Anacardiaceae
8	*Casearia elliptica* Willd.	Chilla	Salicaceae
9	*Cassia fistula* L.	Rajbrikshya	Fabaceae
10	*Dalbergia latifolia* Roxb.	Satisaal	Fabaceae
11	*Dalbergia sissoo* Roxb. ex DC.	Sisau	Fabaceae
12	*Desmodium oojeinense* (Roxb.) H. Ohashi,	Sandan	Fabaceae
13	*Diospyros tomentosa* Roxb.	Dirghapatrak	Ebenaceae
14	*Ehretia laevis* Roxb.	Charmavriksha	Boraginaceae
15	*Erythrina arborescens* Roxb.	Theki kath	Fabaceae
16	*Ficus benghalensis* L.	Bar	Moraceae
17	*Ficus virens* Aiton.	Pakad	Moraceae
18	*Garuga pinnata* Roxb.	Dabdabey	Burseraceae
19	*Holarrhena pubescens* (Buch.-Ham.) Wall.	Kurau	Apocynaceae
20	*Lagerstroemia parviflora* Roxb.	Botdhayero	Anacardiaceae
21	*Lannea coromandelica* (Houtt.) Merr	Hallunde	Anacardiaceae
22	*Mallotus philippensis* (Lam.) Mull. Arg.	Rohini	Euphorbiaceae
23	*Michelia excelsa* (Wall.) Blume	Rani Chaap	Magnoliaceae
24	*Miliusa velutina* (Dunal) Hook. f. &	Domsal	Annonaceae
25	*Mitragyna parvifolia* Roxb.) Korth.	Kaim	Rubiaceae

26	*Schleichera oleosa* (Lour.) Oken,	Kusum	Sapindaceae
27	*Semicarpus anacardium* Linn.	Bhalayo	Anacardiaceae
28	*Shorea robusta* Gaertn.,	Sal	Dipterocarpaceae
29	*Symplocos ramosissima* Wall. ex G. Don	Kharane	Symplocaceae
30	*Syzygium cumini* (L.) Skeels,	Jamun	Myrtaceae
31	*Syzygium nervosum* A.Cunn. ex DC.	Phadir	Myrtaceae
32	*Terminalia alata* Heyne ex Roth,	Asna	Combretaceae
33	*Terminalia bellirica* (Gaertn.) Roxb.	Barro	Combretaceae
34	*Terminalia chebula* Retz.,	Harro	Combretaceae

Appendix 2: List of Tree species found in Dhanushdham Protected Forest.

S.N	Species name	Local name	Family
1	*Acacia catechu* (L. f.) Willd.	Khair	Fabaceae
2	*Acacia nilotica* (L.) Willd. ex Delile,	Babul	Fabaceae
3	*Adina cordifolia* (Roxb.) Hook. f.	karma	Rubiaceae
4	*Bauhinia veriegata* (L.) Benth.	Tanki	Fabaceae
5	*Bombax ceiba* L.	Simal	Malvaceae
6	*Buchanania latifolia* Roxb.	Chiraunjee	Anacardiaceae
7	*Cassia fistula* L.	Bhojpatra	Fabaceae
8	*Dalbergia latifolia* Roxb.	Satisal	Fabaceae
9	*Dalbergia sissoo* Roxb. ex DC.	Sisau	Fabaceae
10	*Delonix regia* (Bojer ex Hook.) Raf.	Gulmohar	Fabaceae
11	*Eucalyptus camaldulensis*	Masala	Myrtaceae
12	*Ficus benghalensis* L.	Bar	Moraceae
13	*Ficus benjamina* L.,	Shamee	Moraceae
14	*Ficus hispida* L.f.	Dumri	Moraceae
15	*Ficus religiosa* L.	Pipal	Moraceae
16	*Ficus semicordata* Buch.-Ham. ex	Khanyu	Moraceae
17	*Garuga pinnata* Roxb.	Dabdabey	Burseraceae
18	*Lagerstroemia parviflora* Roxb.	Botdhayero	Lythraceae
19	*Madhuca longifolia* (Koenig)	Mahuwa	Sapotaceae
20	*Mallotus philippensis* (Lam.) Mull.	Rohini	Euphorbiaceae
21	*Phyllanthus emblica* L.	Amala	Phyllanthaceae
22	*Schleichera oleosa* (Lour.) Oken,	Kusum	Sapindaceae
23	*Semicarpus anacardium* Linn.	Bhalayo	Anacardiaceae
24	*Shorea robusta* Gaertn.,	Sal	Dipterocarpaceae
25	*Syzygium cumini* (L.) Skeels,	Jamun	Myrtaceae
26	*Tectona grandis* L.f.	Teak	Lamiaceae
27	*Terminalia alata* Heyne ex Roth,	Asna	Combretaceae
28	*Trewia nudiflora* L.,	Gurel	Euphorbiaceae
29	*Ziziphus jujuba* Mill.	Bayer	Rhamnaceae

Appendix 3: Showing carbon stock (t/ha) in hectors in both MCF and DPF

S.n.	Species name	MCF (t/ha)	DPF (t/ha)
1	*Acacia catechu*	0.0357	0.0709
2	*Acacia nilotica*		0.0045
3	*Adina cordifolia*		0.0028
4	*Aegle marmelos*	0.0065	
5	*Anogeissus latifolia*	0.0026	
6	*Aporosa octandra*	0.0059	
7	*Bauhinia purpurea*	0.0002	
8	*Bauhinia veriegata*		0.0075
9	*Bombax ceiba*	0.0269	0.0261
10	*Bombax ceiba*		0.0261
11	*Buchanania latifolia*	0.0065	0.0116
12	*Casearia elliptica*	0.0013	
13	*Cassia fistula*	0.0027	0.0021
14	*Dalbergia latifolia*	0.0025	0.0146
15	*Dalbergia sissoo*	0.0556	0.0746
16	*Delonix regia*		0.0004
17	*Desmodium oojeinense*	0.0003	
18	*Diospyros tomentosa*	0.0038	
19	*Ehretia laevis*	0.0008	
20	*Erythrina arborescens*	0.0028	
21	*Eucalyptus camaldulensis*		0.0061
22	*Ficus benghalensis*	0.0017	0.0481
23	*Ficus benjamina*		0.0184
24	*Ficus hispida*		0.0015
25	*Ficus religiosa*		0.0264
26	*Ficus semicordata*		0.00001
27	*Ficus virens*	0.0011	
28	*Garuga pinnata*	0.0031	0.0569
29	*Holarrhena pubescens*	0.0002	

30	*Lagerstroemia parviflora* Roxb.	0.0003	0.0112
31	*Lannea coromandelica*	0.0638	
32	*Madhuca longifolia*		0.0112
33	*Mallotus philippensis*	0.0035	0.0005
34	*Michelia excelsa*	0.00003	
35	*Miliusa velutina*	0.0001	
36	*Mitragyna parvifolia*	0.0119	
37	*Phyllanthus emblica*		0.0012
38	*Schleichera oleosa*	0.0437	0.1419
39	*Semecarpus anacardium*	0.0014	0.0056
40	*Shorea robusta*	0.7624	4.8942
41	*Symplocos ramosissima*	0.0014	
42	*Syzygium cumini*	0.0013	0.0217
43	*Syzygium nervosum*	0.0307	
44	*Tectona grandis*		0.0065
45	*Terminalia alata*	0.0019	0.0086
46	*Terminalia bellirica*	0.0374	
47	*Terminalia chebula*	0.1104	
48	*Trewia nudiflora*		0.0121
49	*Ziziphus jujuba*		0.0786
	Total	1.2305	5.5920

PHOTOPLATES

Layout of sampling plots

Measuring DBH of tree

Collecting the soil

Recording the plot characteristics

Herberium Preparation

Destruction of forest

Collection of Fire woods & Timbers