Carbon Stock and Regeneration Status of Community Managed Sal (*Shorea robusta* Gaertn.) Forests in Dadeldhura District, Western Nepal

A Dissertation Submitted for the Partial Fulfillment of Master's of Science in Botany

(Plant Ecology and Resource Management)

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May 2016

RECOMMENDATION

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RECOMMENDATION

This is to certify that the M.Sc. dissertation work entitled **"Carbon Stock and Regeneration Status of Community Managed Sal (*Shorea robusta* Gaertn.) Forests in Dadeldhura District, Western Nepal"** has been carried out by Mr. Suresh Prashad Bhatta under my supervision. The work is primarily based on the result of his research work and has not been submitted for any award of any other academic degree. I recommend this dissertation to be accepted for the partial fulfillment of Master's of Science in Botany (Plant Ecology and Resource Management) from Tribhuvan University, Nepal.

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LETTER OF APPROVAL

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LETTER OF APPROVAL

The M.Sc. dissertation entitled **"Carbon Stock and Regeneration Status of Community Managed Sal (*Shorea robusta* Gaertn.) Forests in Dadeldhura District, Western Nepal"** submitted at the Central Department of Botany, Tribhuvan University by Mr. Suresh Prashad Bhatta, has been accepted for the partial fulfillment of requirements for Master's of Science in Botany (Plant Ecology and Resource Management).

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ACKNOWLEDGEMENTS

Firstly, i express my sincere gratitude to my respected Supervisor Dr. Anjana Devkota, Associate Professor, Central Department of Botany, T.U., Kirtipur for her endless support and cooperation to complete this dissertation work. I am indebted for her creative suggestions, excellent guidance and supervision throughout research work.

I am extremely grateful to Prof. Dr. Pramod Kumar Jha, Former Head of Central Department of Botany, T.U., Kirtipur for administrative support during study work. My special thank goes to Prof. Dr. Mohan Siwakoti, Head of Central Department of Botany, T.U., Kirtipur for administrative support and species identification. My sincere thank goes to Central Department of Botany, T.U., Kirtipur for providing necessary instruments during field work. I would like to thank all respected teachers and staffs at Central Department of Botany, T.U., Kirtipur for their helps.

I am very much thankful to my friends Krishna Prasad Sharma, Minu Adhikari and Rajeshwor Pandey for their help during field visit and dealing with difficulty situation in each and every moments throughout research work. I am thankful to my friend Prabin Bhandari for his help during the preparation of map of study area.

My special thank goes to authorities of Sundari community forest, Dansera community forest, Khajurani community forest and Madhuban Mahila community forest and also to District Forest Office, Dadeldhura and Range Forest Office, Jogbuda, Dadeldhura for providing necessary information, place to conduct research and support throughout the study. I am very much thankful to Laxmi Datta Bhattarai, Game Scout of Jogbuda Range Forest Office, Bir Bahadur Khadka, President of Sundari community forest, Hark Bahadur Sakhi, member of Madhuban Mahila community forest and Tikeshwori Madai, member of Khajurani community forest for their support and help during study work. I am very much thankful to Department of Hydrology and Metrology, Babar Mahal, Kathmandu for providing climatic data and Department of Agriculture, Regional Soil Analysis Laboratory, Sundarpur, Kanchanpur for soil analysis.

Finally, I would like to thank my family and relatives for their continuous support during study.

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ABSTRACT

Community forests of developing countries are among the best examples of mitigating global climate change by carbon sequestration. This research compares the carbon stock and assess the regeneration status of community managed *Shorea robusta* (Sal) forests managed for 10-21 yrs in Dadeldhura district of Far Western Nepal. These forests were categorized into two groups according to management duration (≤ 11 yrs and ≥ 20 yrs). The above-ground carbon stock of trees and shrubs were estimated using allometric equations. Regeneration status of forest was estimated by calculating the density of each species in each developmental phases (seedling, sapling and tree).

The mean carbon stock of living biomass of the studied forests was 175 Mg ha^{-1} (148-202 Mg ha^{-1}). The carbon stock in living biomass of the forest managed for ≥ 20 yrs (199 Mg ha^{-1}) was significantly higher than the forests managed for ≤ 11 yrs (151 Mg ha^{-1}) ($P < 0.05$). The carbon stock increased with the increment of soil available potassium but it decreased with increased soil total nitrogen ($P < 0.05$). However, it did not vary significantly with soil organic carbon, soil available phosphorus and soil pH ($P > 0.05$). Similarly, there was no any predictable relationship of carbon stock with litter cover, canopy cover, ground vegetation cover, relative radiation index and species richness. Sal was the highest contributor of tree layer carbon in both categories of forests whereas it was replaced by *Phoenix humilis* (Thakal) in shrub layer in ≤ 11 yrs managed forests. The studied forests had good regeneration status with 9764 seedlings/ha, 1850 saplings/ha and 1263 trees/ha and sal was the dominant species in terms of regeneration. Forests managed for ≥ 20 yrs had greater number of seedling, sapling and tree than the forest managed for ≤ 11 yrs. Thus, the community management has increased the carbon stock of forests and also it had promoted the productivity of forests.

Key words: *Allometric equation, Sal forest, Management duration, Sal seedling and Soil pH.*

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ABBREVIATIONS AND ACRONYMS

AK	Available potassium
AP	Available phosphorus
asl	Above sea level
C	Carbon
CF/s	Community Forest/s
CFUG/s	Community Forest User Group/s
CM	Community managed
DBH	Diameter at breast height
DFRS	Department of Forest Research and Survey
fig.	Figure
FR	Forest ranges
FSI	Forest Survey of India
GHG/s	Greenhouse Gas/es
GM	Government managed
GPS	Global Positioning System
GtC	Gigatonne of Carbon (1 Gt = 1 Pg = 1 Billion tonne = 10^9 tonne)
ha	Hectare (1 ha = 100 × 100 m^2)
IVI	Importance Value Index
Mg	Mega gram (1 Mg = 1 tonne = 1000 Kg)
Mt/s	Million tonne/s = Mega tonne/s (1 Mt = 10^6 tonne)
NA	Not available
NL	National level
NP	National park
OWL	Other Wooded Land
Pl/s	Plant/s
REDD+	Reducing emission from deforestation and forest degradation, conservation of forest carbon stock, conservation and sustainable management of forests and enhancement of forest carbon stocks
RFO	Range Forest Office
RRI	Relative Radiation Index
SM	State managed

SOC	Soil Organic Carbon
Sqrt	Square root
TN	Total nitrogen
UNFCCC	United Nations Framework Convention on Climate Change
VDC	Village Development Committee
WLR	Wild life reserve
yr/s	Year/s

1. INTRODUCTION

1.1. Background

Global warming and climate change are the most widespread, well known and pressing global issues. They are primarily resulted from the alleviated green house gases (GHGs) due to anthropogenic activities like: excessive use of fossil fuel, industrialization and land use change (Le Quere *et al.*, 2015). Of the GHGs, Carbondioxide (CO_2) makes its position on top, accounting for 76% of total anthropogenic GHG emissions (IPCC, 2014). It has been estimated that global release of CO_2 has been increased by 2.2% since 2000 to 2010 (IPCC, 2014). Consequently, mean annual temperature had raised by 0.85^{o}C from 1880 to 2012 (IPCC, 2014). These changes have obvious widespread impacts on human and natural systems (IPCC, 2014). As such, global release of GHGs should be checked for managing widespread impacts.

Forest plays important role in mitigating global climate change (Kaul *et al*., 2010) as it stores 60% of the world's terrestrial carbon (C) in its vegetation and soil which is about 80% of all above ground C and nearly 40% of all belowground (soils, litter and roots) terrestrial C (Dixon *et al.*, 1994). But, due to the population growth, every year 13 million hectares of forest are destroyed or degraded (CBD, 2011) which contribute about 20% of the global GHG (CO_2) emission which is more than the emissions by the whole transportation system (Stern, 2007). In thirteenth conference of parties (COP13) of the United Nations Framework Convention on Climate Change (UNFCCC) held in Bali in 2007 considered the importance of forestry in climate change mitigation by reducing GHGs (especially CO_2) emission from forests via reducing emission from deforestation and forest degradation (REDD) concept (Dahal and Banskota, 2009) which was later broadened and subsequently modified into the REDD+ (in COP15, Copenhagen, 2009 and COP16, Cancun, 2010). The World Bank and the COP19 of the UNFCCC held in 2013 in Warsaw announced payment under the Biocarbon Fund to developing countries like us which can demonstrate the net carbon sequestration through improved forest management (Thapa Magar and Shrestha, 2015).

Community forestry (CF) program in Nepal was introduced in 1978, after the failure of controlling of deforestation and forest degradation by the centralized forest management system, realizing that without involvement of local communities forest cannot be saved. CF program proved this, as it becomes successful in protection, conservation and management of forest thus, in-spite of having debate on the contribution of it to biodiversity conservation (Shrestha *et al.*, 2010), it is considered as one of the most successful natural resource management practice (Acharya, 2004) and which significantly contributes to the reversal of deforestation and forest degradation (Nagendra *et al.*, 2008). These forests acts as major source of C sink storing about 20% of the total C-stock (Pokharel and Byrne, 2009) with a sequestration rate of 1-5 $Mgha^{-1}yr^{-1}$ (Pokharel *et al.*, 2007). The productive and well-managed community forest (CF) has potential to sequestrate good quantity of C but without such management C can be emitted which can contribute in climate change (Pokharel *et al.*, 2007). As the parties of UNFCCC have approved the REDD+ scheme. It provided the opportunities for the Community forests (CFs) of the developing countries to get the monetary benefit from the carbon that have stored in them. For this, forest C-stock and its change should be recorded so that potential of forest C sequestration be known and eligible forest can claim for the carbon benefit.

Carbon stock in forest ecosystem refers to the amount of carbon stored in forest ecosystem, mainly in living biomass and soil, but to a lesser extent also in dead wood and litter. While carbon sequestration is defined as removal of CO_2 from atmosphere (source) and storing it in a reservoir (sink) (UNFCCC, 2007). These sinks can be above-ground biomass (trees) or living biomass below the ground in soil (roots and micro organisms) or relatively stable forms of organic and inorganic C in soils or in deeper sub-surface environments or durable products derived from biomass (timber) (Nair *et al.*, 2009).

Forest carbon estimates enables to understand the contribution of forests to the global C cycle (Kohl *et al.*, 2015). Growing stock and C storage may be considered important parameters, as they indicate whether forests are degraded and to what extent they mitigate climate change (FAO, 2005). In addition, estimates of C sequestration could be important for better planning of natural resources management and making of good mitigation strategy for climate change effects (Khanal *et al.*, 2010). In order to assess the impact of deforestation and re-growth rates on the global C cycle, it is necessary to know the stocks of C as biomass per unit area for different forest types (Shrestha and Devkota, 2013).

Natural regeneration is the process of re-growing or reproduction of plants through their juvenile (Acharya and Shrestha, 2011). It is the most important process to maintain and expand the population of plant species in a community with time and space (Bharali *et al*., 2012). Population structure of a species in a forest can convey its regeneration behavior particularly the reproductive strategy (Singh and Singh, 1992) which in turn demonstrates the development trend of the community (Zhang *et al*., 2007), species composition and stability in the future (Napit, 2015). The regeneration status of a forest indicates its health and vitality while healthy forest ensures good future regeneration (Awasthi *et al*., 2015). Regeneration is measured to determine whether it meets the objective of sustainable forest management, and in particular, whether the productive capacity and biological diversity of forest are maintained (Lutze *et al.*, 2004 as cited by Awasthi *et al*., 2015). The sustainable forest must have good regeneration, proper age class (age-gradation), normal increment and normal growing stock (Subedi, 2011).

Combination of seedling/sapling count and analysis of size-class diagram may give actual situation of reproduction and regeneration pattern (Acharya and Shrestha, 2011). The regenerating and productive character of forest is determined and characterized by the presence of sufficient population of seedlings, saplings and young trees of different age groups from young to old (Chauhan *et al.*, 2008). A population with sufficient number of seedlings and saplings depicts satisfactory regeneration behavior, while inadequate number of seedlings and saplings of the species in a forest indicates poor regeneration (Tripathi and Khan, 2007). 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 the forest site (Chauhan *et al*., 2008). A bell shaped size class distribution has been attributed to disturbed forest, where regeneration is hampered (Saxena *et al.*, 1984). In addition to this sometimes there is possibility of J shape curve in an old growth forest as a result of failure in regeneration (Chauhan *et al*., 2008).

This study investigates the temporal variation in carbon stock potential and regeneration of tropical sal forest of Dadeldhura district of far western region of Nepal. For this four community forests were selected based on management duration category (≤ 11 yrs and ≥ 20 yrs). Population data such as density of individuals, DBH, height, species diversity were taken by quadrat sampling method. Similarly, canopy cover, ground vegetation cover, litter cover, soil samples, GPS points, slope, aspect and silviculture practices were also taken from each sample plots.

1.2. Rationale of Study

There are large number of research works related to forest regeneration and C-stock estimation in CF in various parts of Nepal. But, there are very few research work related to forest regeneration and temporal and managerial variation of C-stock estimation in CF in Far Western region of Nepal. Thus, this study will help to fulfill this gap. So, this inventory will be one of the pioneer work for Far Western Nepal which will give the idea about C-stock and regeneration status of CFs. Thus, this study establish the baseline information for the C-stock and regeneration status of the community managed forests of Far Western Nepal. Similarly, information obtained will be helpful in planning and implementing the forest restoration, management and conservation strategies at community, regional or national level.

1.3. Hypotheses

Following were the research hypotheses:

- Carbon stock in the living biomass increases with the management duration of the community forest.
- Community managed forests have good regeneration status.

1.4. Objectives

General objectives of the study was to compare the variation of total carbon stock and regeneration status of forests with management duration and the specific objectives were:

- To estimate carbon stock in different vegetation layers (shrub and tree) of community managed *Shorea robusta* (Sal) forests of Dadeldhura district.
- To study the variation of total carbon stock in living biomass with soil physio-chemical parameters.
- To study the regeneration pattern of forest and major tree species of community managed forests.

1.5. Limitations

Following were the limitations of the research:

- Site with > 45° slope and without any vegetation was avoided.
- The CFs having equal/ nearly equal size in both the management categories were not found so the size of studied forests differs.
- Condition of forests prior to the community management was not same in all CFs. Only community forests included in the management category of ≥ 20 yrs (Sundari CF and Dansera CF) have same condition as these were managed under the same community forest at the initial step of management.
- Due to the time limit, community forests managed between > 11 yrs and < 20 yrs and herb layer in C-stock estimation were not included in the study.

2. LITERATURE REVIEW

2.1. Forest and Carbon Sequestration

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). The amount of C sequestered in a forest is constantly changing with growth, death, and decomposition of vegetation (Kaul *et al.*, 2010). The biomass and C-stock of forest increases with increasing forest age (Sedjo, 2001; Luyssaert *et al.*, 2008), tree density and area (Sedjo, 2001). The rate of C sequestration is much faster in young and regenerating forest than the old and matured forest but C-stock is more in old and mature forest (Luyssaert *et al.*, 2008; Nair *et al.*, 2009). The C-stock in forest vegetation varies according to geographical location, life zone, forest type, forest structure, plant species, age of the stand and degree of disturbances (Brown *et al*., 1989; Dixon *et al.*, 1994). A tonne of C sequestered in the forest biomass reduces 3.67 tonnes of CO_2 from atmosphere (van Kooten, 2000) and world's forest sink holds more C than the atmosphere (Stern, 2007). 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). C-stock in the world’s forests was 861 GtC, with 383 GtC (44%) in soil (to 1m depth), 363 GtC (42%) in live biomass (above- and below-ground), 73 GtC (8%) in deadwood, and 43 GtC (5%) in litter and net global forest sink was 1.1 $GtCyr^{-1}$ (Pan *et al.*, 2011). Geographically, 471 GtC (55%) is stored in tropical forests, 272 GtC (32%) in boreal and 119 GtC (13%) in temperate forests (Pan *et al.*, 2011).

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^{-1}), 61 Mts (105 Mg ha^{-1}) and 42 Mts (8 Mg ha^{-1}), respectively. Out of the total forest C-stock, tree, soil and litter/debris components contribute 61.5% (109 Mg ha^{-1}), 37.8% (67 Mg ha^{-1}), and 0.7% (1.2 Mg ha^{-1}), respectively. Tree, soil and litter/debris components of the OWL contribute 5.8 Mg ha^{-1}, 99 Mg ha^{-1} and 0.5 Mg ha^{-1}, respectively (DFRS, 2015). Above-ground C-stock in Nepal was 133 Mg ha^{-1} as estimated by FAO (2015a).

2.1.1. Sal forest and carbon sequestration

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^{-1} 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 $MgCha^{-1}yr^{-1}$. 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.

Similarly, Mbaabu *et al.* (2014) estimated C-stock in community managed hill sal forest and government hill sal forest of Karyakhola watershed of Chitwan district as 244 & 140 Mg ha^{-1}, respectively by using "moist forest" allometric equation of Chave *et al.* (2005). From this, they concluded that these two forest management regime had significant difference in C-stock which was attributed to species composition, tree density, canopy density and basal area variation and also concluded that forest management practices affected the C-stock of forest. According to Sejuwal (1994) tree layer of riparian sal forest of Royal Chitwan National Park had 468 Mg ha^{-1} C-stock. He showed that this high value was due to the old growth nature of forest.

Mandal *et al.* (2013) estimated 132-202 Mg ha^{-1} living biomass C-stock in three sal dominated collaborative forest of Mahottari district by using "moist forest" allometric equation of Chave *et al.* (2005) for tree species and Tamrakar (2000) equation for shrub species. And they showed that C-stock had positive and very weak relation with species richness and negative with Simpson's evenness of collaborative forests. Thus, they concluded that the forest C-stock enhancement cannot assured the biodiversity conservation and promotion. Pathak (2015) estimated 115 Mg ha^{-1} 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.

Similarly, the study carried out by Shrestha (2009a) 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^{-1}) than *Schima-Castanopsis* dominated CF (44 Mg ha^{-1}) where C-stock was calculated by using allometric equation of Sharma and Pukkala (1990) for tree species and Haase and Haase (1995) for the perennial woody shrubs. He concluded that total C sequestration in forest varied according to the forest types.

Neupane and Sharma (2014) estimated C-stock in sal dominated Jalbire Mahila CF and Laxmi Mahila CF of Gorkha district as 131.5 & 53 Mg ha^{-1}, respectively by applying the allometric equation of Sharma and Pukkala (1990) for tree species and other undergrowth vegetation was directly harvested from plot (direct method). They justified that higher value of C-stock in Jalbire Mahila CF was due to higher density of large sized trees in that CF than other CF. They also obtained that sal sequestered higher amount of C pool in both CFs and thus they concluded sal was the dominant and valuable timber species on both study sites.

Baral *et al*. (2009) assessed the above-ground C-stock in five major forest types representing two physiographic regions and four district of Nepal. They found variation in age of the stand (18-75 yrs), above-ground C-stock (34.3-97.9 Mg ha^{-1}) and rate of C sequestration (1.3-3.2 $MgCha^{-1}yr^{-1}$), according to different forest types. They found hill sal forest of 75 yrs of age of Chitwan district had highest C-stock (97.9 Mg ha^{-1}) and lowest C-sequestration rate (1.3 $MgCha^{-1}yr^{-1}$) whereas tropical riverine and *Alnus nepalensis* forest of 25 & 18 yrs of age, respectively had highest rate of C sequestration of 3.2 & 2 $MgCha^{-1}yr^{-1}$, respectively. They concluded that C sequestration rate of forest types depended on growing nature of the forest stands.

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^{-1} whereas C-stock in secondary forest was 110 Mg ha^{-1} 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 around Bees Hazaare lake of Chitwan National Park was 121.7 Mg ha^{-1}, calculated by using "moist forest" allometric equation of Chave *et al.* (2005). He showed that community managed forest (165.2 Mg ha^{-1}) had higher C-stock than government managed forest (78.2 Mg ha^{1}) and concluded total C-stock of forest varied with different management regimes of the forest.

Study on C-stock of sal forest from India also showed that these forest contained different amount of C with varying rate of C sequestration. Like, Manhas *et al.* (2006) estimated an average of 22.7 Mg ha^{-1} C-stock in sal forest as national level. According to Sharma *et al.* (2010) C-stock in different category of sal forests of Garhwal Himalaya ranged from 74.5 to 159.4 Mg ha^{-1}. Similarly, C-stock in sal forests of Siwalik hills of Dehradhun ranged from 57.5 to 291 Mg ha^{-1} (Singh, 2010). According to Shahid and Joshi (2015) C-stock in sal dominated moist deciduous forest of Doon valley of western Himalaya, India ranged from 169.2-219.1 Mg ha^{-1} with an average of 199.8 Mg ha^{-1} while Mandal and Joshi (2014a) found 232.5 Mg ha^{-1} C-stock in sal forest of Doon valley. In addition, C-stock in regenerating sal forest of Goalpara district, India was 120 Mg ha^{-1} (Rabha, 2014).

The vegetation C-stock, net primary productivity and net carbon accumulation in the central Himalayan sal forest was 286 Mg ha^{-1}, 9.7 $MgCha^{-1}yr^{-1}$ and 7.4 $MgCha^{-1}yr^{-1}$, respectively (Singh, 1987 cited in Singh and Singh, 1992). Similarly, Rana *et al.* (1989) found C-sequestration rate of 9.3 $MgCha^{-1}yr^{-1}$ and 10.1 $MgCha^{-1}yr^{-1}$ in sal old growth and sal seedling coppice forest of central Himalaya, respectively.

2.1.2. Forest management duration (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. Baral *et al.* (2009) found that 75 yrs old stand of sal had higher C-stock than 18, 25 & 28 yrs old *Alnus nepalensis*, tropical riverine and *Pinus roxburghii* forests of Nepal, respectively. Pine plantation forest of 24 yrs (189.7 Mg ha^{-1}) had higher C-stock than broad leaved natural forest of 16 yrs of Ludhikhola sub-watershed of Gorkha (Pandey, 2012).

Sharma *et al.* (2013) found increment in the C-stock with age difference of forest and management period in Canada. Hunziker (2011) also showed similar increase in C-stock with the increase in forest age of Southern Iceland. He found that C-stock increased in birch forest (*Betula pubescens* Ehrh.) of old plantation of age 10-60 yrs and remnant of original birch woodland of age > 60 yrs. Similarly, Zhang *et al*. (2011) found that C-stock increased in conifer forest of naturally regenerated for 5-310 yrs in Southwest China. Li *et al.* (2010) showed that C-stock increased with the age of Korean pine (*Pinus koraiensis*) plantation forest in Central Korea. Similarly, Bhat and Ravindranath (2011) obtained 14.53 Mg ha^{-1} C-stock increment in the duration of 25 yrs in tropical rain forest of Uttara Kannada, Western Ghats, India. Besides this, Li *et al.* (2013) found increase in C-stock with increase in age of forests in 17-73 yrs old Japanese red pine (*Pinus densiflora*) forests in Central Korea. Jung *et al.* (2013) and Noh *et al.* (2010) also showed the 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, respectively.

2.2. Community Forestry, Climate Change and REDD+

An estimated 15.5% of global forest is under the control of communities while in developing countries more than 30% forests was managed by communities and the trend toward community control is increasing (RRI, 2014). Thus CFs may contain significant C that could be protected under REDD+ mechanism. As 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. 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). The goal of REDD+ is to encourage forest managers/owners by financially incentivizing them either to maintain existing C-stock in the forest or to generate additional C-stock (Kanowski *et al.*, 2010). The experience and traditional knowledge of indigenous peoples have a key role in global forest management, conservation and global climate change mitigation efforts and thus they could significantly contribute to the success of any REDD+ program. Therefore, the long-term success of REDD+ program will stand or fall with local ownership and support (Agrawal and Angelsen, 2009).

In Nepal, community forestry program was introduced on 1978 after the failure of centralized forest management program in controlling serious deforestation and forest degradation and biodiversity loss (Shrestha *et al.*, 2010). With the formation of Forest Act in 1993, it gave a legal basis to CFs handling the national forest to CFUGs. 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). The productive and well-managed CF has an important potential to sequestrate good quantity of C, which can contribute in mitigating the climate change but without such management it is probable that forest biomass would decrease, through forest degradation, leading to additional C emissions which can contribute in climate change (Pokharel *et al.*, 2007). About 1.45 million households or 35% of the population of Nepal is involved in CF management program. A total of 1,798,733.35 hectares of national forest have been handed to 18,960 CFUGs and 2,392,755 households have been benefitted up-to September 2015 (DoF, 2015). In the fiscal year 1994/95, net CO_2 emission from all sectors and land use change and forestry sector in Nepal were estimated to be 9747 & 8117 Gg, respectively (MoPE, 2004). But, CF of Nepal acts as major source of C sink as it stored about 20% of the total C-stock (Pokharel and Byrne, 2009) with a sequestration rate of 1-5 $Mgha^{-1}yr^{-1}$ (Pokharel *et al.*, 2007). Thus it stored high amount of CO_2, which will help in minimizing the climate change processes that other-wise would released into atmosphere and would had helped into climate change.

2.3. Carbon Estimation Models

Different methods have been piloted and tested to estimate forest C at small or large scale that requires for effective implementation of REDD+ and C trade among others. Biomass content within the forest can be measured through direct (destructive) or indirect (non-destructive) methods (Segura and Kanninen, 2005). The indirect method is usually used when the tree has large dimensions, in this case tree dimensions are measured (field measurement) then these measurements are converted to biomass C densities by using biomass factors or allometric equations (Segura and Kanninen, 2005; Keith *et al*., 2009; Latte *et al.*, 2013). Destructive method gives the best and accurate measure but practically it is not possible to apply in each estimate as it is time consuming and expensive (Vieira *et al.*, 2008). Therefore, researchers have used sample destructive method to establish a new allometric equation (non-destructive method) so that the C can be estimated (Latte *et al.*, 2013; Wang *et al*., 2003) or allometric equation can be derived from the literature for supposedly comparable forest types (Hairiah *et al.*, 2010). Beside, allometric equation, remote sensing (Running *et al.*, 2004), computer simulations (Thornton *et al.*, 2002) and regression analysis (Parresol, 1999) were also used for biomass estimation. But, allometric regression models are simple, easy, accurate and scientific for quantifying biomass and C storage in terrestrial ecosystems (Brown *et al.*, 1989; Chave *et al.*, 2005; Litton and Kauffman, 2008). Within the allometric models species- and site-specific models are more accurate (Litton and Kauffman, 2008). But, even a ha of forest shelter 201 different tree species (Milliken, 1998). Instead of species specific regression models mixed species tree biomass regression models must be used (Chave *et al*., 2005) which may give more precise result.

Consistency in the methodology of C inventory is one of the major issues in Nepal as is the case around the globe (MoFSC, 2015). In Nepal, allometric equations as well as remote sensing is being used in the estimation of C-stock in forest. Within the allometric equations, mainly three equations are frequently used in Nepal for the estimation of C in woody vegetation viz. Sharma and Pukkala (1990), Tamrakar (2000) and Chave *et al.* (2005). Beside these, there are some other equations for C estimation like Brown *et al.* (1989) for tree species and Haase and Haase (1995) for shrub species. So, there is a lack of common allometric equation which can be used for C estimation in all types of ecological zones through-out Nepal. With this drawback, there is a need to use the global model for the estimation of C-stock in vegetation. But, most of the REDD+ pilot projects and academic fields have been employing biomass equation given by Chave *et al.* (2005) and forest biomass experts in Nepal believed that this equation can give more reliable results than other equations (Mandal, 2015).

2.4. Regeneration Status of Sal Forest in Nepal

Community forest resource inventory guideline (2004) suggested a criteria based on number of seedling and sapling in forest for evaluating regeneration condition of the forest. Regeneration is said to be good if forest have seedling > 5000 and sapling > 2000 per hectare (HMG, 2004) (cited in Pandey *et al*., 2012). 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, 2014a, b). Similarly, Paudyal (2013) found higher sal regeneration density than other associated species in community managed hill sal forest of Kaski district. Pandey *et al*. (2012) also found higher seedling and sapling density of sal than other associated species in community forests of Gorkha district. In addition, regeneration of sal was higher than other associated species in sal dominated community forest of Rupandehi district (Acharya and Shrestha, 2011) and Government managed sal forest in Palpa district (Basyal *et al*., 2011). Shrestha (2009) observed higher sal density than other associated species in CF and protected forests of Surkhet district. Kandel (2007) also observed the same pattern of higher sal density than other associated species in community managed sal dominated Inner Terai forests of central Nepal. Besides, Timilsina *et al*. (2007) found that sapling and seedling density of sal was higher than other associated species in sal dominated forests of Western Terai of Nepal. Similar result was also found by Giri *et al.* (1999) in Bardia National Park.

2.4.1. Factors affecting regeneration in sal forest

Regeneration is affected directly or indirectly by various climatic as well as edaphic factors (Singh and Singh, 1992). 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). Moreover, plants could generally grow and survive in a limited range of environmental gradients e.g. temperature and light availability (Block and Treter, 2001) and variation in these factors play important roles in shaping the age structure and forest regeneration at different altitudes (Duan *et al*., 2009).

Soil nutrient

Mineral nutrition appears to be an important factor in sal forest productivity (Gautam and Devoe, 2006). Kaul *et al.* (1966) showed that the deficiency of each of these nitrogen, phosphorus, potassium, calcium and magnesium on sal seedlings causes prominent symptoms (e.g. smaller leaves, thin tap root, premature defoliation, slow shoot growth) both on shoot and root. Deficiencies of nitrogen, phosphorus and magnesium affected height growth. Deficiencies of calcium and magnesium produced a shorter tap root and sparse lateral roots while nitrogen and potassium deficient seedlings had thinner and longer tap roots (cited in Gautam and Devoe, 2006). Sal grows on a wide range of soil types, except in the very sandy, gravely soils immediately adjoining rivers and in waterlogged areas (Troup, 1921). It prefers slightly acidic to neutral (5.1-6.8) sandy loam with organic carbon content between 0.11-1.8% (Gangopadhyay *et al.*, 1990) while pH range of 4.5-5.5 was propitious for sal sapling growth (Singh and Singh, 1989 as cited in Paudel and Sah, 2003) and good sal regeneration area have low pH in soils (Bhatnagar, 1965). Soil with higher pH generally have poorer capacity of regeneration (Suoheimo, 1995 as cited in Paudel and Sah, 2003). There is low nitrogen content in good sal dominant and regeneration areas (Bhatnagar, 1965).

Environmental and anthropogenic factors

Light, litter, commencement of monsoon (rain), grazing, fire, looping and litter collection were the environmental and anthropogenic factors that affected the regeneration of sal.

3. MATERIALS AND METHODS

3.1. Study Area

The study was conducted in sal forest of Parasuram municipality-12, Jogbudha of Dadeldhura district in Far West Nepal (Fig. 1). The district covers an area of 1538 Km^2 and expands between $28^o59^'$ to $29^o26^'$ N and $80^o12^'$ to $80^o47^'$ E. The altitude of it ranges from 432-2685 m asl and climatic zone vary from tropical to sub-alpine. Dadeldhura district has total 115,169 ha forest area (including shrub land) which constitutes 75% of district area and there were 449 CFs, four religious forests and 144 leasehold forests (DFO Dadeldhura, 2013/14) (Fig. 2).

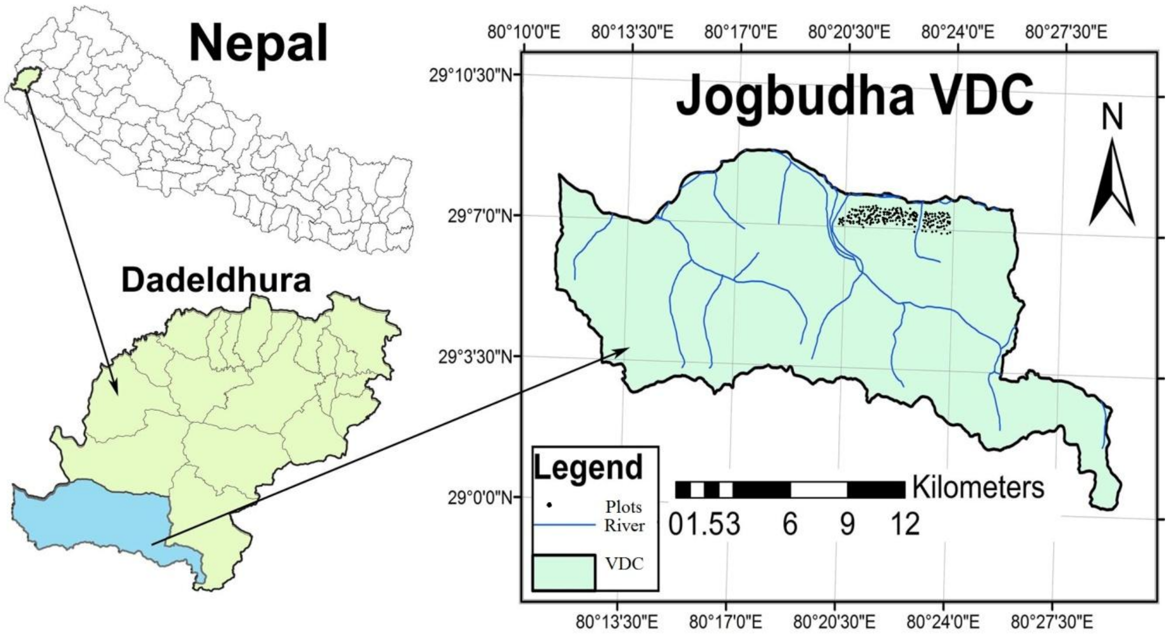

Figure 1. Location map of the study area showing position of plots in the studied community forests in Jogbudha VDC (now Parasuram municipality) of Dadeldhura district, Nepal.

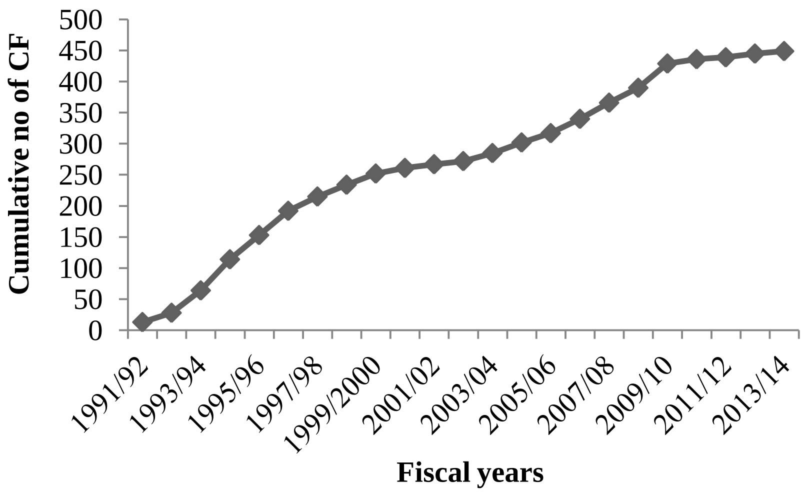

Figure 2. Cumulative number of Community forests (CFs) handed to CFUGs for management in Dadeldhura district up to fiscal year 2013/14. (Source: DFO Dadeldhura, 2013/14).

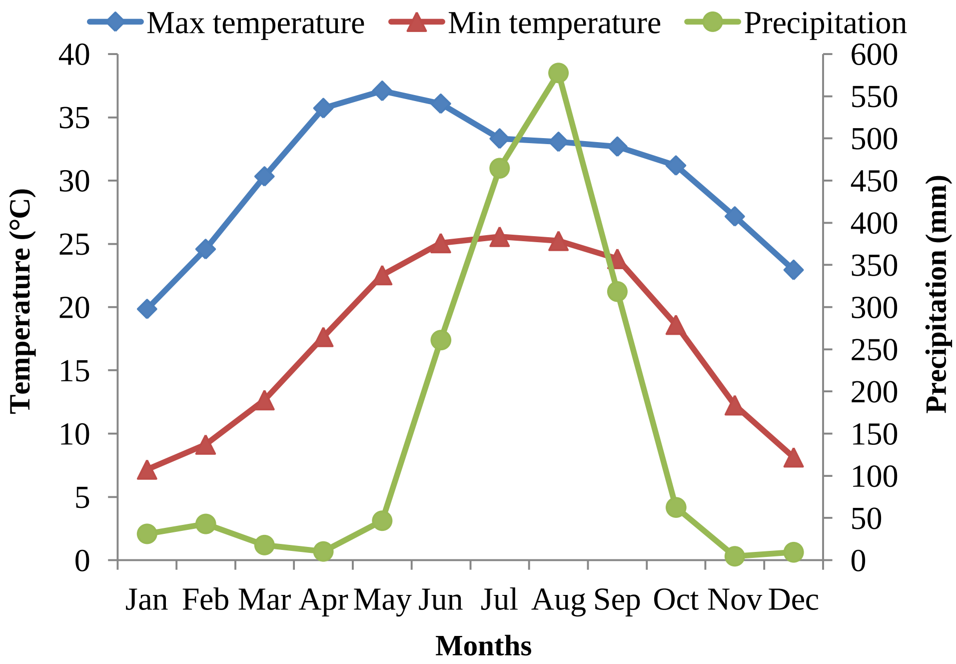

Figure 3. Twenty years (1993-2013) average monthly minimum-maximum temperature and rainfall recorded at Mahendranagar weather station (176 m). (Source: Department of Hydrology and Meteorology, Kathmandu).

Climatic data from 1993 to 2013 showed that the monthly average maximum and minimum temperatures were 37.084^{o}C and 7.179^{o}C in the months of May and January, respectively (Fig. 3). Mean annual rainfall was 1849.406 mm, with the highest monthly rainfall in August (577.567 mm) and the lowest in November (4.833 mm).

3.1.1. Selection of forests

District forest office (DFO) of Dadeldhura was visited in February 8, 2015 to obtain information related to forest and management types. Out of eight range forest office (RFO), *Shorea robusta* (Sal) forest was mainly found in three RFO (Aalital, Jogbuda and Saadani). Out of these three RFO, Jogbuda RFO was selected randomly to carry out vegetation sampling. It was visited in February 10, 2015 to gather the information about CFs which were under its management. Out of 449 CFs in the district, 89 CFs has been managed under Jogbuda RFO (DFO Dadeldhura, 2013/14). These 89 CFs were divided into three categories (i.e. ≤ 11 yrs, between > 11 yrs and < 20 yrs and ≥ 20 yrs) based on the management duration. Then 4 CFs (2 CFs from each category of forest managed for ≤ 11 yrs and ≥ 20 yrs) were selected according to feasibility to carry out vegetation sample by discussing with staffs of Jogbuda RFO and executive members of respective CFs in February 10 & 11, 2015. Vegetation sampling data were collected from February 12-19, 2015. The community forests selected for study was presented in Table 1.

Table 1. Community forests selected for the study (data were taken in 2015).

SN	Name of CF	Name of Municipality	Area (ha)	Year of Handover (A.D)	Management duration (Year)	Category of CF based on management period
1.	Madhuban Mahila	Parasuram-12	49	2004	11	CF managed for ≤ 11 years
2.	Khajurani	Parasuram-12	124.18	2005	10	
3.	Sundari	Parasuram-12	291.73	1994	21	CF managed for ≥ 20 years
4.	Dansera	Parasuram-12	399.23	1995	20	

3.1.2. Study forests

The study was conducted in four community managed sal forests (Madhuban Mahila CF, Khajurani CF, Sundari CF and Dansera CF) located between $29^{o}06^{'}6.90^{''}$ to $29^{o}07^{'}59.9^{''}$ N and $80^{o}20^{'}8.35^{''}$ to $80^{o}23^{'}59.8^{''}$ E in Parasuram municipality of Jogbuda RFO in Dadeldhura district, Farwest Nepal. Condition of forests prior to the community management was not same in both the management category of CFs. Only the CFs included in the management category of ≥ 20 yrs (i.e. Sundari CF & Dansera CF) have same condition as these were managed as one CF at the initial step of management and later they were separated. The study area consists of gentle slopes (1^o) to very steep slopes (45^o) with the altitude ranging from 405-893 m asl.

Tropical type of vegetation with dominance of *Shorea robusta* species was found in all the study areas. Other common associated species were *Mallotus philippensis* (Sindhure), *Semecarpus anacardium* (Bhalayo), *Casearia glomerata* (Bud Kamalo), *Terminalia alata* (Saj/Asna), *Lagerstroemia parviflora* (Bot Dhayaro), *Syzygium cumini* (Jamun) and *Cleistocalyx operculatus* (Kyamun). Cattle grazing and logging were prohibited whereas fodder and firewood collection were seasonally allowed in all four CFs. There is one block in each CF which is stated as protected area where resources extraction were also prohibited. Silvicultural practices were common in all four CFs. Silvicultural practices were thinning, pruning, selective cutting, clearance of bushes and climbers in the blocks except protected block that they had created at the time of CF establishment with the help of DFO. The silvicultural practices were in rotational basis based upon the number of blocks in CF basically once in three to four years in a block.

3.2. Field Sampling

3.2.1. Locating the sample plots (Quadrats)

Stratified random sampling method was used for locating the sampling plots; the forest blocks designated by the CFUGs were considered as strata. Total number of plots to be sampled was proportionately distributed among the blocks based on their area. For locating the position of sample plots in the selected community forest, the map prepared during handover of the forest to community was used. The map was obtained from the office of the Jogbuda RFO at Parasuram municipality-12, Laldhunga, Dadeldhura. First, map was photo copied and then plots to be laid was randomly indicated in map. These plots in the CF were located with the help of member of CF who were familiar with CF.

3.2.2. Sampling and measurements

Carbon stock

To estimate the C-stocks, square quadrat of 10 m × 10 m was defined with the help of clinometers (for maintaining aspect so that each corner of the plot is 90^o to each other), iron peg and rope at each earlier randomly selected location. Each tree and shrub species enrooted inside the plots were recorded. Trees on the border were included if ≥ 50% of their basal area fell within the plot and excluded if < 50% of their basal area fell inside the plot. Thus, trees overhanging the plot were excluded, but trees with their trunk inside the sampling plots and branches outside were included. Tree height (H > 137 cm) and Diameter at breast height (DBH, 137 cm) of all individuals of tree species were measured. While measuring the DBH of trees of unusual shape (like trees with forked stem, trees with bulged or curved stem at 137 cm, trees inclined in ground etc.), a standard forestry practice of MacDicken (1997) was adopted. DBH tape was used for measuring diameter and a reference stick of 5 m was used to estimate the tree height. The 10 m × 10 m quadrat was divided into four subplots of 5 m × 5 m each, and one of them was selected randomly and measured diameter of each stem of shrub species at 15 cm above the ground surface (Shrestha and Singh, 2008). Basal circumference of the individuals of tree species with height < 137 cm and > 15 cm were also measured and considered as shrubs (Thapa Magar and Shrestha, 2015).

Regeneration

Tree and sapling number were acquired from the number of individuals as recorded during C-stock estimation considering individuals with DBH ≥ 5 cm as tree and sapling as DBH < 5 cm (DFRS, 2014a,b; Maren *et al*., 2015). Similarly, seedling of other tree species (other than sal) were also acquired from the number of individuals as recorded during C-stock estimation considering individuals with the height between 15 cm to 137 cm as seedling. But, sal seedling (with H < 137 cm; DFRS, 2014a,b; Maren *et al*., 2015) were counted in 210 plots of 2 m × 2 m (i.e. two diagonally opposite 2 m × 2 m plots were constructed within a 10 m × 10 m plot and seedling were counted in each plot and later counted number was added, averaged and recorded so for calculation 105 plots were considered). So, 105 plots of 10 m × 10 m for tree and sapling, 5 m × 5 m for seedling of other tree species (other than sal) and 2 m × 2 m for seedling of sal were studied. The plot size for counting seedling of sal was different from plot size used for counting seedling of other species it was because actually seedling of sal was counted in field while seedling number of other species were not counted in field rather than number were acquired from C-stock estimation of shrubs. Seedling number were later converted into 10 m × 10 m plot size by multiplying counted number of seedlings of sal with 25 and 4 by seedling of other tree species.

Geographic location (latitude, longitude and elevation) of each plot (10 m × 10 m) was recorded using Global Positioning System (GPS- Garmin etrex) from the center of the plot. Slope and aspect were measured by Clinometer (Silva 360^o). Canopy cover for each plot was estimated by visual estimation method from center of the plot. Ground vegetation cover, ground litter cover, grazing and silvicultural activities were also recorded visually. The sample of field data sheet used for sampling had been presented in Annex 2.

3.2.3. Soil collection

From each quadrat, ca. 200 g soil sample was collected from a depth of 15 cm from the center of plot. The soil samples were air dried in shade for week and packed in air tight plastic bags until laboratory analysis.

3.2.4. Plant collection and identification

Most of the specimens were identified at the time of sampling measurement with the help of field guides, consulting with local experts and officials of Jogbuda RFO. Unidentified species were collected, tagged and pressed with the help of newspaper and herbarium presser in the field. These unidentified species were identified in Tribhuvan University Central Herbarium (TUCH) after consulting the taxonomic experts. References works by Siwakoti and Varma (1999), Malla *et al.* (1986) and Duthie (1903) were used during the identification of plants. For author citation, Annotated Checklist of the Flowering Plants of Nepal (Press *et al.*, 2000) was used.

3.3. Laboratory Work

The soil physicochemical parameters (Soil organic carbon, pH, nitrogen, phosphorous and potassium) were examined during August-6 to September-3, 2015 at Department of Agriculture, Regional Soil Analysis Laboratory Sundarpur, Kanchanpur by using following laboratory methods. Soil organic carbon was determined by Walkley-Black rapid titration method; soil pH by potentiometric method, using a digital pH meter; nitrogen by Kjeldahl method; phosphorus by Olsen's method and potassium by flame photometer method (PCARR, 1980). For complete procedure see Annex 1.

3.4. Quantitative Analysis

3.4.1. Community attributes (Importance value index)

The ecological parameters such as frequency, density and basal area of tree species were determined quantitatively following the method described in Zobel *et al.* (1987). Frequency refers to the degree of dispersion of individual species in a community. It is the percent of the sampling units in an area in which a species occur. It is often used to compare plant communities and to detect the changes in vegetation composition over time. It is also used to describe the distribution of species in a community. It was calculated by the following equation:

$$\text{Frequency (\%)} = \frac{\text{number of plots in which the species ocurred}}{\text{total number of plots taken}} \times 100 \quad \ldots.\ldots\ldots.\ldots \text{(i)}$$

Density is the number of individuals per unit area. It represents the numerical strength of the species in the community. Density was calculated by the following equation:

$$\text{Density (pls/ha)} = \frac{\text{total number of plants in all the studied plots}}{\text{total number of plots taken} \times \text{size of plot } (\text{m}^2)} \times 10000 \quad \ldots\ldots \text{(ii)}$$

Basal area (BA) of a tree species was the cross-sectional area of the tree trunks at 137 cm above the ground and expressed in meter square per hectare of land area. It was calculated from the following equation:

$$\text{Basal area } (\text{m}^2) = \pi \times \frac{(\text{dbh})^2}{4 \times 100 \times 100} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots.\ldots... \text{(iii)}$$

where, dbh = diameter at breast height (cm), and π = 3.14

Basal area of a species in each sampling plot was obtained by the summation of BA of all individuals of a species. BA was expressed in percentage by using the following equation:

$$\text{Basal area of a species (\%)} = \frac{\text{total basal area of a species}}{\text{total area sampled}} \times 100 \; \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

Importance value index (IVI) is used to determine the overall importance of each species in the community structure. It was calculated as the sum of relative values of frequency, density and Basal area (tree species only) or coverage (for shrubs and herbs). IVI of tree species was calculated using following equation:

$$\text{IVI (\%)} = \text{Relative frequency} + \text{relative density} + \text{relative basal area} \; \ldots.\ldots.\ldots\ldots \text{(v)}$$

Relative frequency is the degree of dispersion of individual species in an area in relation to the number of all the species occurred and it was calculated by the following relation:

$$\text{Relative frequency (\%)} = \frac{\text{frequency of individual species}}{\text{sum of the frequencies for all species}} \times 100 \; \ldots\ldots.\ldots.\ldots \text{(vi)}$$

Relative density is the study of numerical strength of a species in relation to the total number of individuals of all the species and it was calculated as:

$$\text{Relative density (\%)} = \frac{\text{density of individual species}}{\text{total density of all species}} \times 100 \; \ldots\ldots\ldots\ldots.\ldots\ldots.\ldots.\ldots. \text{(vii)}$$

Basal area of the individual tree species in relation to the total basal area of all tree species gives the relative basal area and was determined by the equation:

$$\text{Relative basal area (\%)} = \frac{\text{basal area of individual tree}}{\text{total basal area of all trees}} \times 100 \; \ldots\ldots\ldots.\ldots.\ldots\ldots\ldots. \text{(viii)}$$

3.4.2. Species richness

The species richness is the number of species present in a sample plot (Whittaker *et al.*, 2001). For calculating the species richness both tree and shrub species present in a plot were used.

3.4.3. Relative radiation index

Relative radiation index (RRI), which is the relative measure of the substrate's annual exposure to the radiation (the value ranges from -1 to +1) was calculated from the values of aspect (Ω), slope (β) and latitude (Φ). RRI was calculated using the following formula given by Oke (1987).

$$RRI = \text{Cos}(180 - \Omega) \times \text{Sin}\beta \times \text{Sin}\Phi + \text{Cos}\beta \times \text{Cos}\Phi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(ix)}$$

3.4.4. Estimation of biomass and carbon stock

3.4.4.1. Estimation of above-ground biomass

Tree layer

Mean annual precipitation (1849 mm) of near-by weather station was within the range of 1500-3500 mm. The allometric equation (model) developed by Chave *et al.* (2005) for "moist forest" (annual precipitation 1500-3500 mm) was used for estimating the above-ground tree biomass (AGTB). The allometric model developed for moist forest by Chave *et al.* (2005) was:

$$AGB = 0.0509 \times \rho D^2 H \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(x)}$$

where,   AGB = Above-ground biomass (kg), ρ = wood density (g m^{-3}), H = height of tree (m), and D = Diameter of tree at breast height (cm).

For dry wood density of each tree species, the global database presented by Zanne *et al.* (2009) was used. The species which had single entry in database then the same entry was used but for most of the species there were multiple entries; in such case average value of all entries for a particular species was used. In case if the value of density of specific species was not available, than the mean value of the density of other species belonging to the same genus or family was used in the present calculation. For unidentified species, the dry wood density used by Thapa Magar and Shrestha (2015) for species having local name was used (see Annex 5).

Shrub layer

The above-ground biomass of woody perennial shrubs was calculated using the equation developed by Haase and Haase (1995).

$$Y = aD^b \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(xi)}$$

where, Y is the total dry biomass (kg), D is the diameter at 15 cm above the ground (cm) and 'a' and 'b' are the constant whose values were considered as 4.264 and 1.0232, respectively (Haase and Haase, 1995).

3.4.4.2. Estimation of below-ground biomass

The biomass of root system (below-ground) of tree and shrub layers was estimated by assuming that it constitutes 15% of the above-ground biomass (MacDicken, 1997).

3.4.4.3. Estimation of carbon stock

Total tree biomass was obtained by adding the above-ground and below-ground biomass of tree layer and total shrub biomass was obtained by adding the above- and below-ground biomass of shrub layer. When both the biomass was multiplied separately by default carbon fraction 0.47 (IPCC, 2006), gave total C-stock in kg. Obtained value of C-stock in kg was multiplied with hectare (100×100 m^2) and divided by size of plot & 1000 gave the C-stock in Mg ha^{-1}. Total above-ground carbon stock (AGCS) in forest was obtained by adding above-ground tree and shrub C-stock whereas total below-ground C-stock by adding below-ground tree and shrub C-stock.

3.4.4.4. Carbon stock of species

Carbon stock of individual species in a forest was determined by adding the carbon stock values of that particular species in all plots of that forest. Percentage contribution of carbon stock of each species in a forest was calculated by taking the proportion of sum of carbon stock (Mg ha^{-1}) of all species in forest to the sum of carbon stock of a particular species on the same forest. It was calculated by following equation:

$$\text{Carbon stock of a tree species (\%)} = \frac{\text{carbon stock of a particular tree species (ha)}}{\text{sum of carbon stock of all tree species (ha)}} \times 100 \ldots\ldots\ldots\ldots.\ldots \text{(xii)}$$

$$\text{Carbon stock of a shrub species (\%)} = \frac{\text{carbon stock of a particular shrub species (ha)}}{\text{sum of carbon stock of all shrub species (ha)}} \times 100 \ldots\ldots\ldots\ldots \text{(xiii)}$$

3.4.5. Regeneration status of forest (DBH size-class diagram)

To assess the regeneration status of forest, density of seedling, sapling and tree of each tree species were determined separately following the method described by Zobel *et al*. (1987). Then, life form diagram of dominant and co-dominant tree species (considered based on IVI value) were developed separately by putting tree, sapling and seedling along x-axis and number of individuals (density) along y-axis. Density was estimated by following equation:

$$\text{Density (pls/ha)} = \frac{\text{total number of individuals in each life form}}{\text{total number of plots studied} \times \text{size of plot } (\text{m}^2)} \times 10000 \ldots \text{(xiv)}$$

Density of individual species was calculated by the following equation:

$$\text{Density (pls/ha)} = \frac{\text{total no. of individuals of each species in each life form}}{\text{total number of plots studied} \times \text{size of plot } (\text{m}^2)} \times 10000. \text{(xv)}$$

Total number of plants of all species recorded in all 10 m × 10 m plots were divided into different size classes based on DBH of 5 cm intervals. Then, size class diagram of dominant and co-dominant tree species were prepared to analyze the distribution pattern of individuals in DBH classes. Total count of plants were obtained by summation of the number of plants from all sampling plots.

3.5. Statistical Analysis

Descriptive statistics was applied to generate means, range and standard error. The mean values of stand characteristics viz. diameter, height and density of tree, total C-stock in living biomass, C-stock in tree and shrub layer, soil physico-chemical parameters (viz. soil organic carbon, total nitrogen, available phosphorus, available potassium and pH), species richness and canopy cover were compared between the two categories of CFs classified based on the management duration by Independent sample t-test (student t-test), a parametric test. Prior to t-test, the data were tested for the normality (Shapiro-Wilk test of normality, $P > 0.05$). Those data which did not meet the assumption of normality were log or square root transformed following the suggestion of Fowler *et al.* (1998). DBH, height and density of tree and carbon stock in shrub layer were log transformed and carbon stock in tree layer and soil available potassium were square root transformed. Those data which did not meet the assumption of normality even after transformation, like litter cover, ground vegetation cover and RRI, were compared by Mann-Whitney U test, a non parametric test.

Linear regression was carried out only to those data which were normally distributed or were made normal by log or square root transformation and for abnormal data instead of linear regression, scatter plots were presented. Linear regression analysis was carried out to access whether species richness, canopy cover, soil physico-chemical parameters (soil organic carbon, soil total nitrogen, soil available phosphorus, soil available potassium and soil pH) and duration of community management were related with the carbon stock. In addition, linear regression analysis was carried out to know whether shrub layer carbon stock was related with tree layer carbon stock and canopy cover. Similarly, linear regression was applied to know the relationship between density, height and DBH of tree to total living biomass carbon stock. Spearman correlation coefficient was used to show relationship of regeneration with different plot attributes (variables) and soil physico-chemical variables. All these analyses were done using Microsoft-excel 2007 and IBM SPSS (Statistical Package for Social Science) version 20 whereas map of study area was prepared using Arc GIS software.

4. RESULTS

4.1. Properties of Forest Stands

Tree measurements

The mean DBH, height and tree density in two categories of community managed forests (i.e. ≥ 20 yrs and ≤ 11 yrs) ranged from 7.2-10.7 cm, 5.3-7 m, and 20-42 trees/100 m^2 (Fig. 4). The mean DBH and the height of trees in the CFs managed for ≤ 11 yrs were significantly higher than ≥ 20 yrs managed forests (p = 0.000, Fig. 4a & b). However, the tree density was higher in the CFs managed for ≥ 20 yrs (p = 0.000, Fig. 4c).

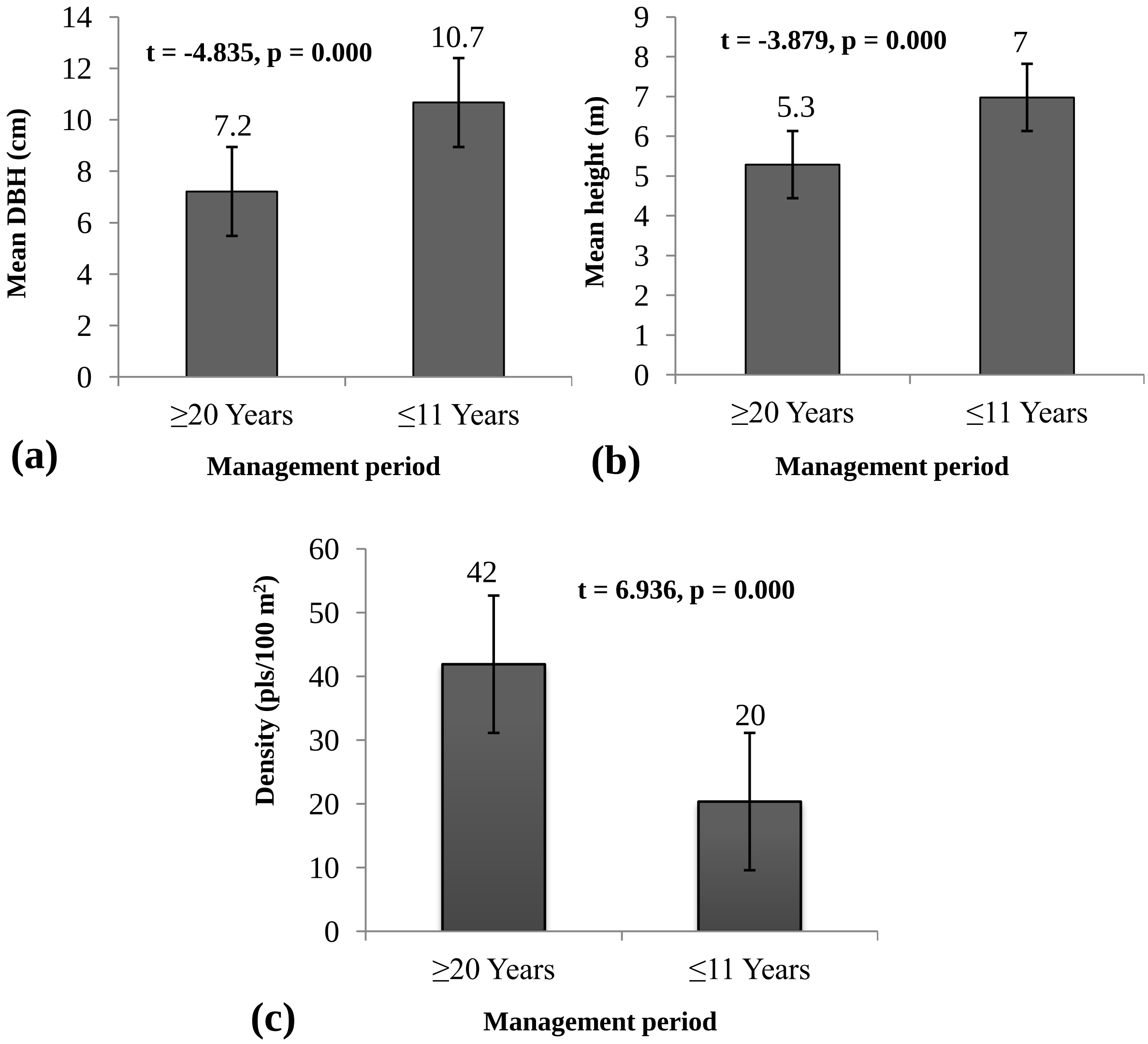

Figure 4. Mean diameter at breast height (a), height (b), and density (c) in two categories of community managed forests in Dadeldhura district.

Community attributes

Sal had the highest Importance value index (IVI) in both category of community managed forests (Fig. 5). In ≥ 20 yrs managed forest, sal had 145 (48.3%) IVI which nearly equal to IVI of same species (147) (49%) of ≤ 11 yrs managed forests. Sal was followed by *Mallotus philippensis* in ≥ 20 yrs managed forest and *Terminalia alata* in ≤ 11 yrs managed forests with IVI 19 & 15, respectively. Similarly, miscellaneous species shared 19 IVI in both categories of managed forests.

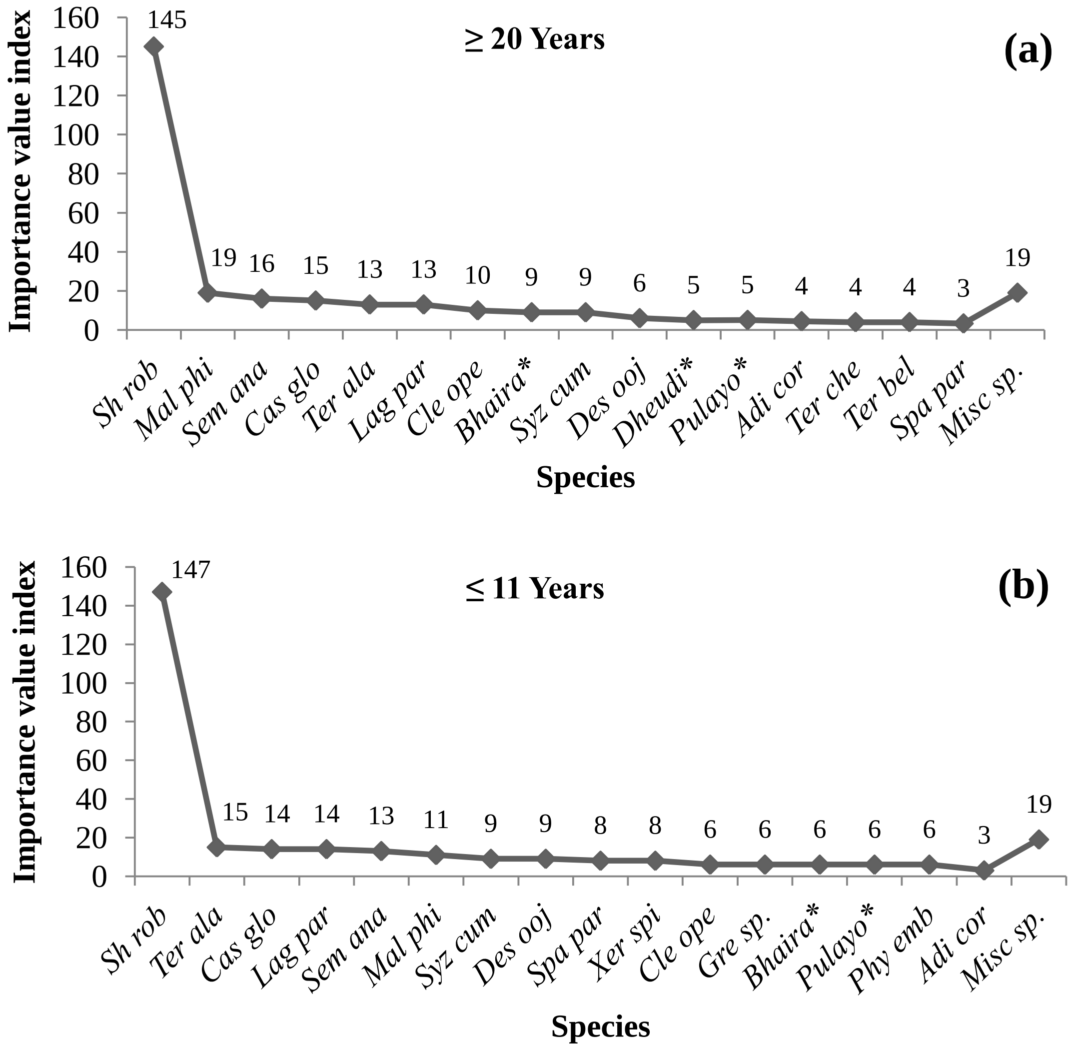

Figure 5. Dominance diversity curve of tree species in two different categories of community managed forest (a) ≥ 20 yrs & (b) ≤ 11 yrs. For complete data see Annex 7.

Where, *Sh rob = Shorea robusta*, *Mal phi = Mallotus philippensis*, *Sem ana = Semecarpus anacardium*, *Cas glo = Casearia glomerata*, *Ter ala = Terminalia alata*, *Cle ope = Cleistocalyx operculatus*, *Des ooj = Desmodium oojeinense*, *Lag par = Lagerstroemia parviflora*, *Syz cum = Syzygium cumini*, *Spa par = Spatholobus parviflorus*, *Xer spi = Xeromphis spinosa*, *Gre sp. = Grewia* sp., *Ter che = Terminalia chebula*, *Ter bel = Terminalia bellirica*, *Adi cor = Adina cordifolia*, *Phy emb = Phyllanthus embilica* & *Misc sp.* = Miscellaneous species. * indicates the local name of species

The variables like canopy cover (CC), ground vegetation cover (GVC) and RRI were significantly higher in forest managed for ≤ 11 yrs ($p < 0.05$) but litter cover (LC) and species richness were statistically same ($p > 0.05$) in both categories of community managed forests (Table 2).

Table 2. Overview of variables measured in sample plots (n = 105) of two different category of community managed forest of Dadeldhura district, Nepal.

Variables	**Management period**		***p***
	≥ 20 years	**≤ 11 years**	
	Mean ± S.E (Min-Max)	Mean ± S.E (Min-Max)	
Canopy cover (%)	52.56 ± 3.06 (6-95)	62.8 ± 2.48 (15-95)	0.012*
Litter cover (%)	62.18 ± 2.6 (20-90)	68.6 ± 2.59 (35-95)	0.111
GVC (%)	51 ± 2.93 (10-95)	63.4 ± 2.8 (20-90)	0.002*
RRI	0.762 ± 0.02(0.35-0.94)	0.815 ± 0.009 (0.6-0.96)	0.001*
Species richness	17.27 ± 0.69 (6-29)	18.48 ± 0.65 (8-28)	0.208

Soil properties

Mean SOC, pH and nitrogen were higher in forest managed for ≤ 11 yrs while potassium and phosphorus were higher in ≥ 20 yrs managed forest. But, statistically both categories of CFs had same soil value except soil pH (Table 3, Annex 6).

Table 3. Soil parameters measured in plots of two different categories of community managed forests of Dadeldhura (n = 105).

Soil parameters	**Management period**		***p***
	≥ 20 years	**≤ 11 years**	
	Mean ± S.E (Min-Max)	Mean ± S.E (Min-Max)	
SOC (%)	2.87 ± 0.17 (0.23-5.22)	3.231 ± 0.23 (0.224-5.92)	0.202
pH	4.8 ± 0.05 (4.2-5.6)	5.0 ± 0.05 (4.1-5.6)	0.047*
N (%)	0.199 ± 0.007 (0.03-0.31)	0.223 ± 0.01 (0.025-0.32)	0.067
K (kg ha^{-1})	288.9 ± 12.7 (101.6-565.9)	285.3 ± 16.5 (59.95-571.82)	0.689
P (kg ha^{-1})	112.89 ± 8.74 (18-274)	104.46 ± 8.64 (18-275)	0.495

In table 2 & 3: RRI = Relative radiation index, GVC = Ground vegetation cover, SOC = Soil organic carbon, K = Potassium, P = Phosphorus, N = Nitrogen, S.E = Standard error, Min = Minimum, and Max = Maximum. * indicates the significance difference.

4.2. Carbon Stock in the Forest

4.2.1. Total carbon stock in living biomass

The mean C-stock in living biomass of community managed forest was 175 Mg ha^{-1}. The C-stock in living biomass varied significantly among the CFs managed for two different duration of time ($p = 0.005$); it was higher in the CFs managed for ≥ 20 yrs (199 Mg ha^{-1}) and lower in the CFs managed for ≤ 11 yrs (151 Mg ha^{-1}) (Fig. 6).

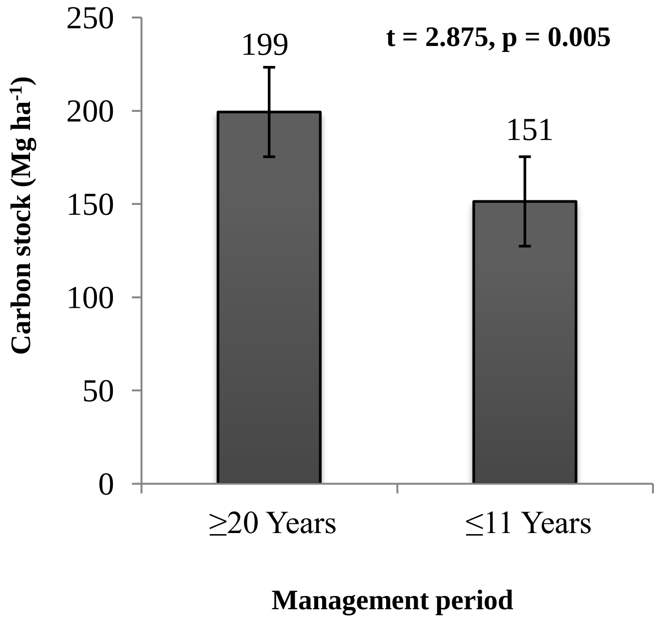

Figure 6. Total carbon stock in two different categories of community managed forests in Dadeldhura district. For complete data see Annex 6.

4.2.2. Distribution of carbon stock in vegetation layers

The vegetation carbon stock in tree and shrub layers in two category of community managed forests differ significantly ($p < 0.05$). Vegetation C-stock in tree and shrub layers in forest managed for ≥ 20 yrs were 153 Mg ha^{-1} and 47 Mg ha^{-1}, respectively, which were significantly higher than tree (112 Mg ha^{-1}) and shrub (40 Mg ha^{-1}) layers of forest managed for ≤ 11 yrs (Fig. 7a & b).

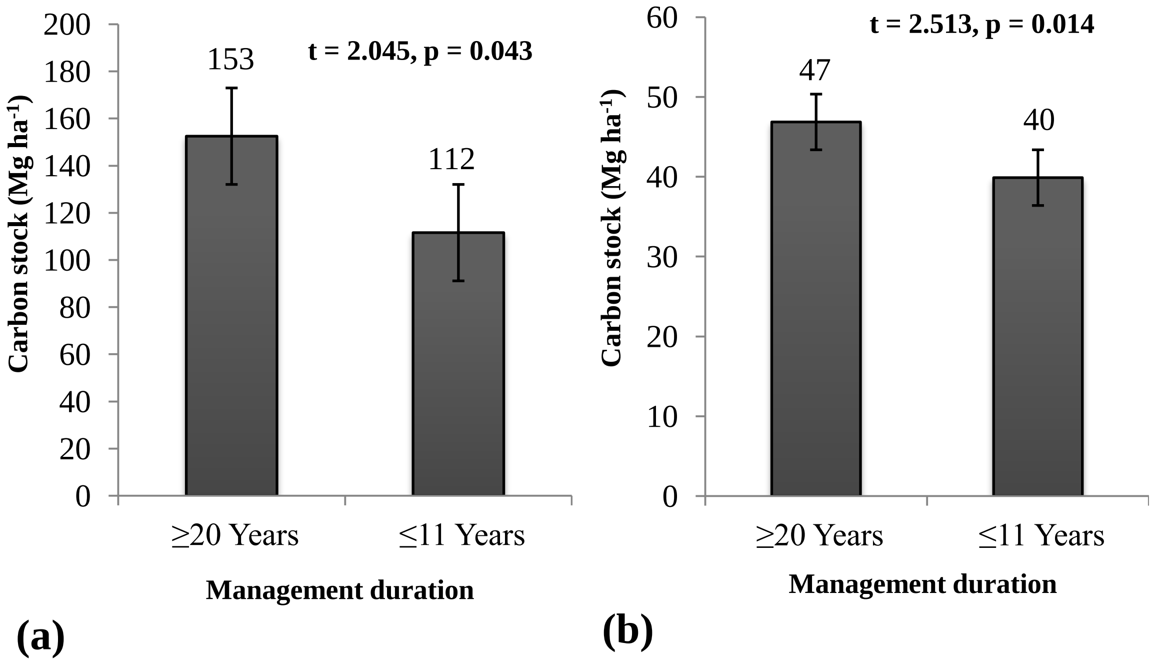

Figure 7. Carbon stock in tree layer (a) and shrub layer (b) of two categories of community managed forests in Dadeldhura district. For complete data see Annex 6.

4.2.3. Contribution of species in carbon stock

For tree level, sal had highest contribution in carbon stock in both categories of community managed forests contributing 91.4% in forest managed for ≥ 20 yrs and 90.5% in forest managed for ≤ 11 yrs. Sal was followed by *Lagerstroemia parviflora* (2.6%) and *Mallotus philippensis* (2.6%) in the forest managed for ≥ 20 yrs and ≤ 11 yrs, respectively (Fig. 8a & b). For shrub level, sal was followed by *Bauhinia vahlii* (Bhorla) which contribute 10% in carbon stock for ≥ 20 yrs. In ≤ 11 yrs managed forests sal was the second highest contributor in carbon stock (11.6%) after *Phoenix humilis* (Thakal) (14.9%). The miscellaneous species also contributed significantly higher percentage in carbon stock in both categories of forests (Fig. 8c & d).

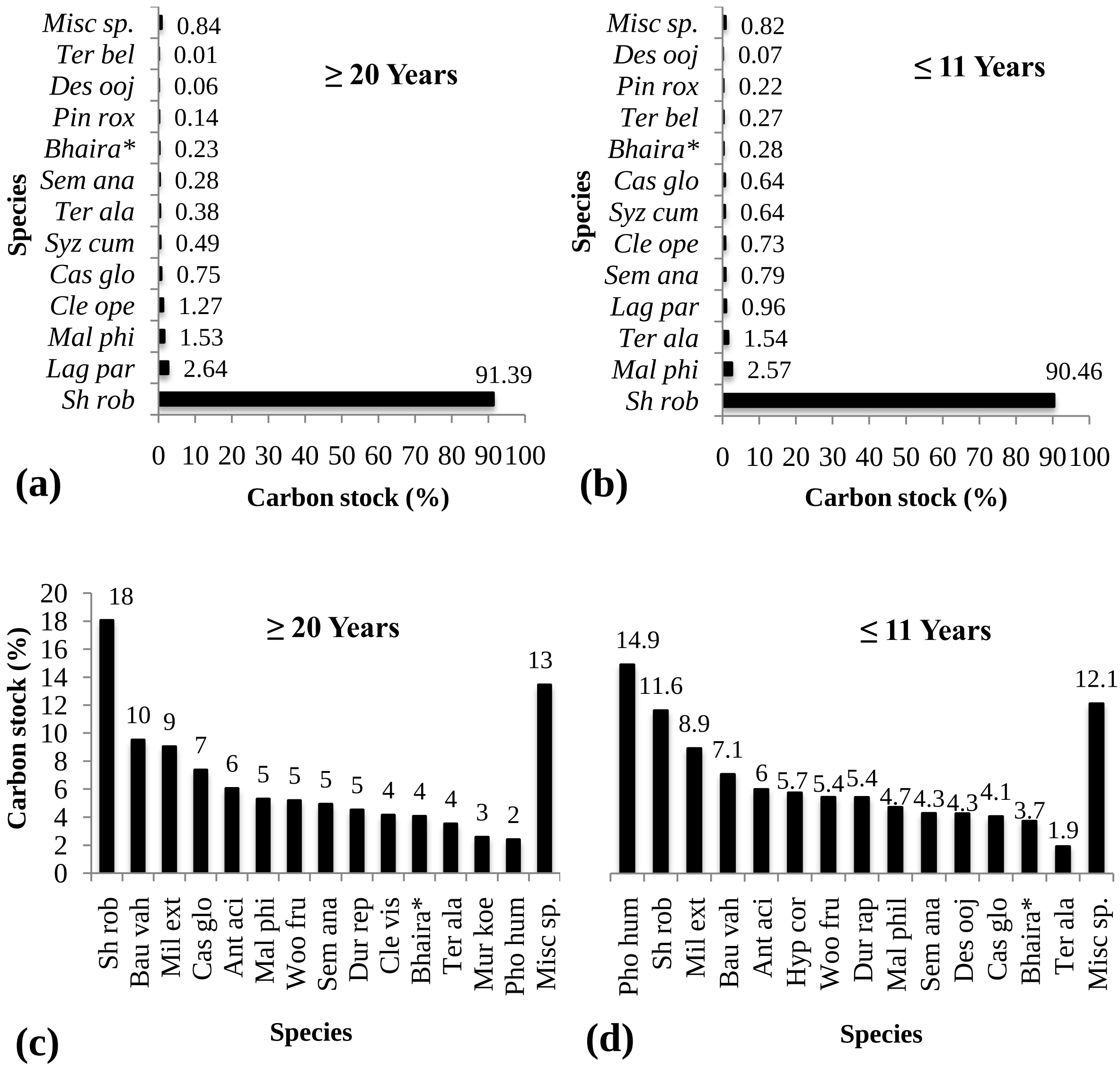

Figure 8. Contribution of tree (a & b) and shrub (c & d) (with seedling of woody tree species, height 15-137 cm) species in carbon stock of two categories of forests.

Where, *Sh rob = Shorea robusta, Mal phi = Mallotus philippensis, Sem ana = Semecarpus anacardium, Ter ala = Terminalia alata, Cle ope = Cleistocalyx operculatus, Des ooj = Desmodium oojeinense, Lag par = Lagerstroemia parviflora, Syz cum = Syzygium cumini, Ter bel = Terminalia bellirica, Pin rox = Pinus roxburghii, Cas glo = Casearia glomerata, Bau vah = Bauhinia vahlii, Mil ext = Millettia extensa, Ant aci = Antidesma acidum, Woo fru = Woodfordia fruticosa, Dur rep = Durenta repens, Cle vis = Clerodendrum viscosum, Mur koe= Murraya koenigii, Pho hum = Phoenix humilis, Hyp cor = Hypericum cordifolium & Misc sp.* = Miscellaneous species. * indicates the local name of species.

4.2.4. Variation of carbon stock with stand characteristics

Total C-stock increased with increasing soil available potassium and decreased with increasing soil total nitrogen ($p < 0.05$) (Fig. 9a & b). While C-stock did not had any significant relationship with other soil parameters (Fig. 9c,d & e). Similarly, C-stock did not showed any significant relationship with species richness, CC, LC, GVC and RRI

(Fig. 9f,10a,b,c & d). In addition, C-stock in shrub layer did not had any significant relationship with the C-stock in tree layer and canopy cover (Fig. 10e & f).

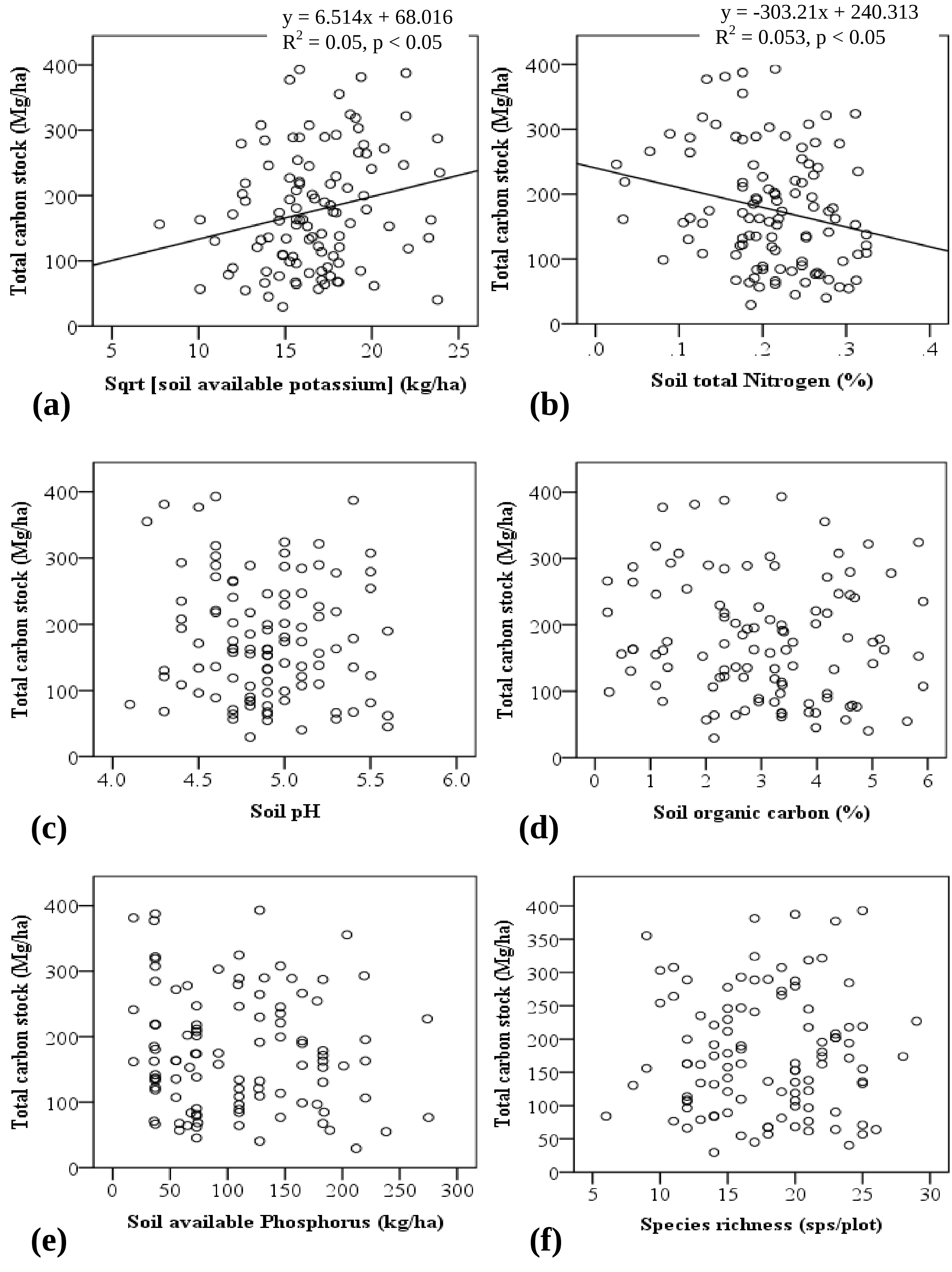

Figure 9. Variation of vegetation carbon stock with soil parameters (a-e) and species richness (f) in two categories of community managed forests in Dadeldhura district.

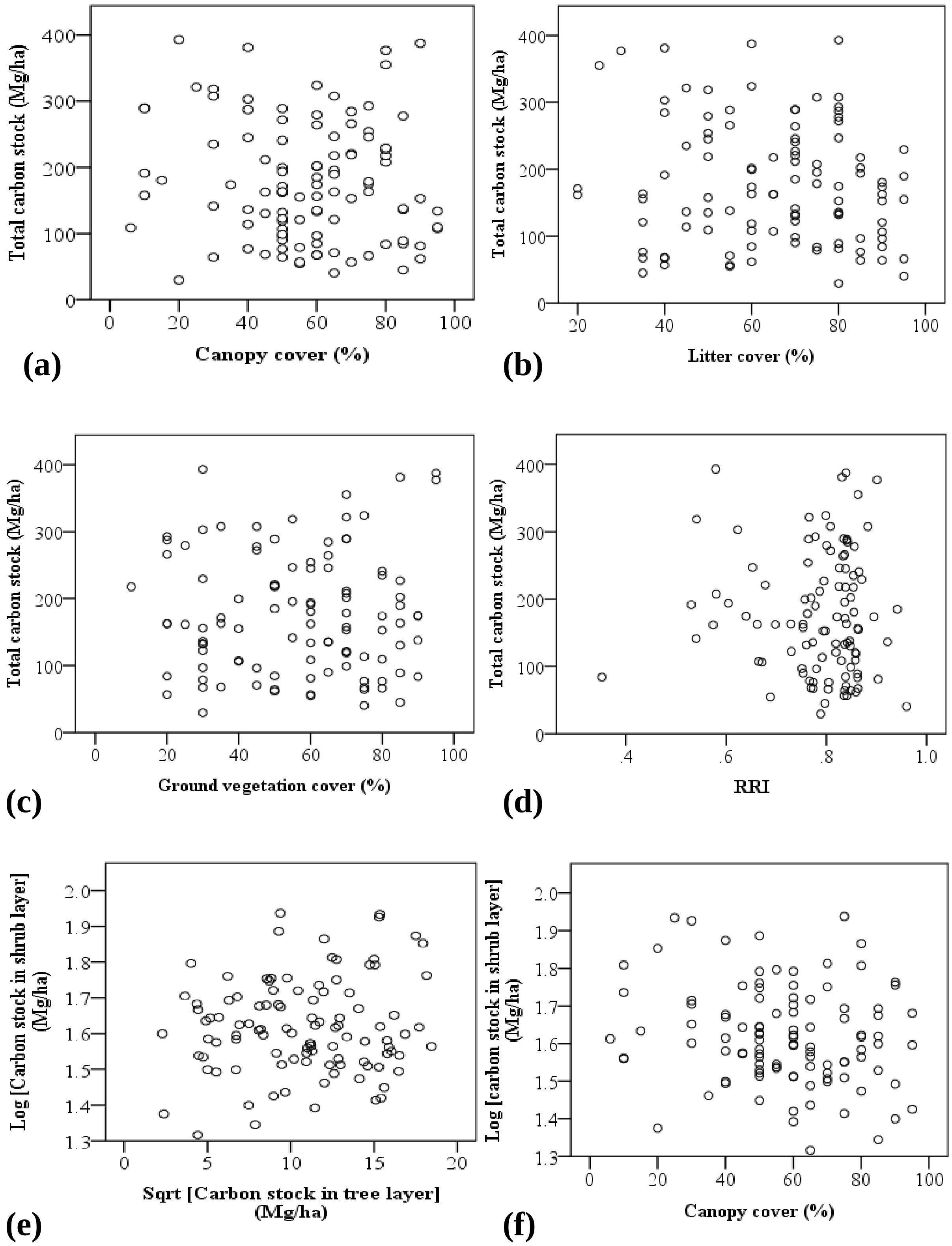

Figure 10. Variation of vegetation carbon stock with canopy cover (a), litter cover (b), ground vegetation cover (c) and RRI (d). Similarly, variation of vegetation carbon in shrub layer with tree layer (e) and canopy cover (f) in two categories of community managed forests in Dadeldhura district, Nepal.

4.3. Regeneration Status of forest

4.3.1. Life form diagram

The total number of seedling, sapling and tree in ≥ 20 yrs managed forests were 12487, 2645 and 1544, respectively, which were higher than total number of seedling (7040), sapling (1054) and tree (982) of ≤ 11 yrs managed forests (Fig. 11a). Density of seedling (11655 pls/ha), sapling (1304 pls/ha) and tree (896 pls/ha) of sal were higher in ≥ 20 yrs managed forest than density of seedling (6366 pls/ha), sapling (398 pls/ha) and tree (620 pls/ha) of same species in ≤ 11 yrs managed forest (Fig. 11b). Similarly, seedling, sapling and tree density of co-dominant species (*Casearia glomerata*, *Terminalia alata*, *Semecarpus anacardium* & *Mallotus philippensis*) were found higher in ≥ 20 yrs managed forests than in ≤ 11 yrs managed forests (Fig. 12). Seedling, sapling and tree density of dominant species (Sal) were relatively very high than seedling, sapling and tree density of co-dominant species (Fig. 11b & 12). But, seedling, sapling and tree density of co-dominant species were within the comparable range in both categories of community managed forest (Fig. 12).

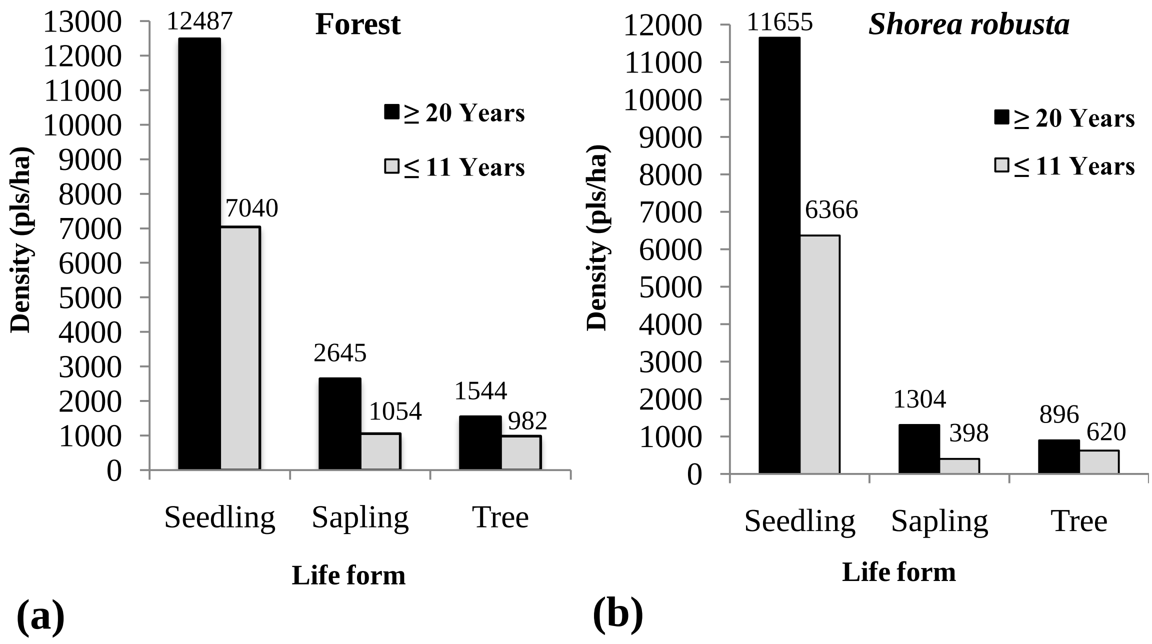

Figure 11. Life form diagram to show the regeneration status of forest (a) and dominant tree species (b) in two different categories of community managed forest. For complete data see Annex 4.

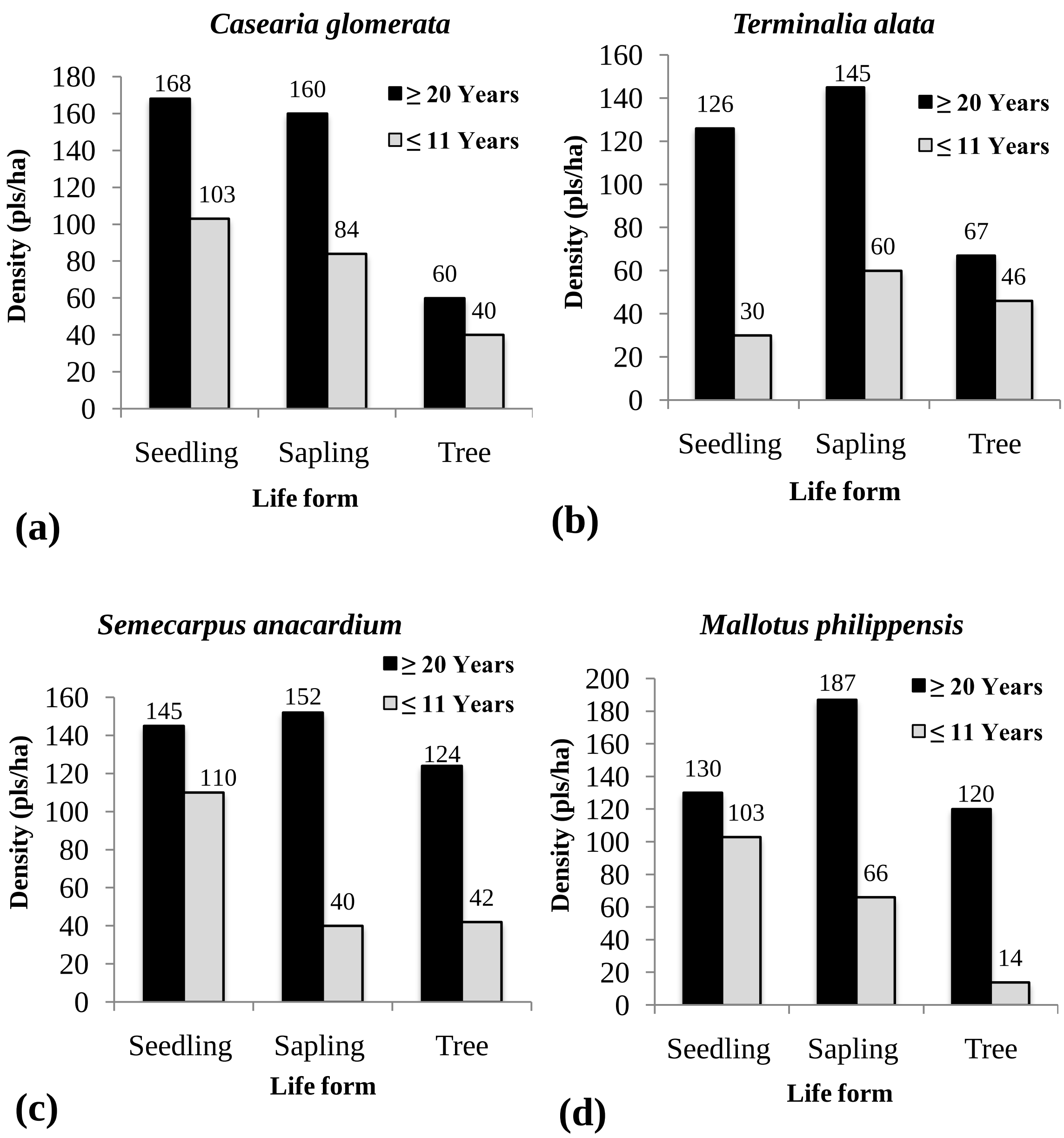

Figure 12. Life form diagram to show the regeneration status of co-dominant tree species in two categories of community managed forest. For complete data see Annex 4.

4.3.2. Size-class distribution diagram

The size class distribution diagram of total number of individuals of tree taller than 137 cm showed reverse J-shaped structure and density of the trees with smaller girth size was higher than that of the larger girth size in both categories of community managed forests (Fig. 13).

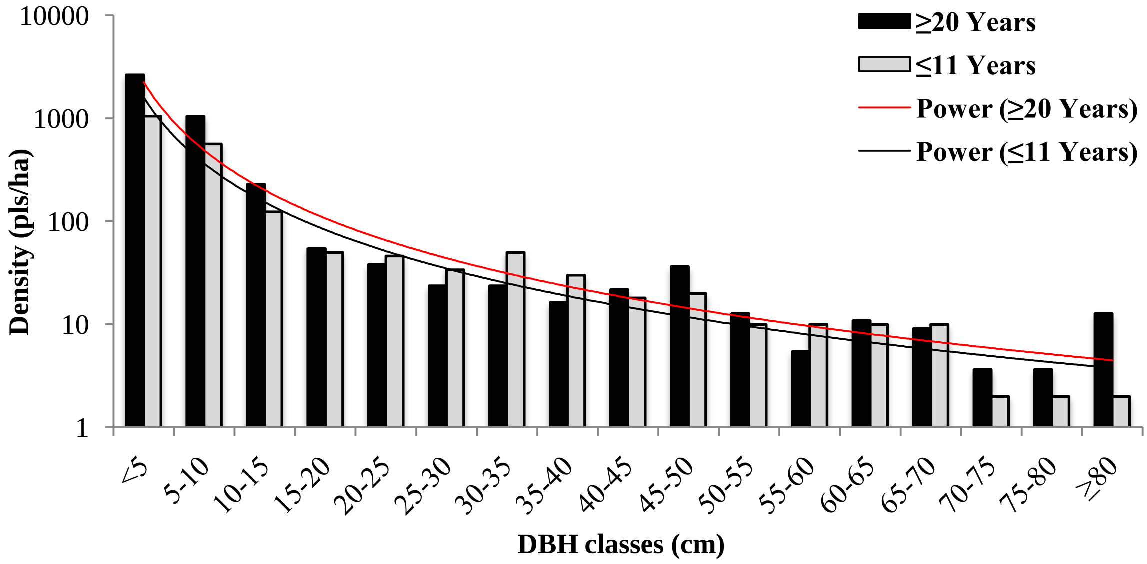

Figure 13. Size-class distributions (expressed in density) of total number of individuals of tree taller than 137 cm in forest managed for two different time duration in Dadeldhura district of Nepal. The data is in logarithm scale. For complete data see Annex 3.

The sal density decreased linearly upto 15-20 DBH classes and above this there was irregular pattern of increase and decrease of density in both categories of forests. In spite of this, the size-class distribution diagram assumed the reverse J shaped structure (Fig. 14). In contrary to this, the size-class distribution diagram of co-dominant species did not showed reverse J shaped curve, rather they showed an interrupted size class distribution (Fig. 15). Individuals were mainly concentrated in 0-5 & 10-15 DBH classes. Above 10-15 DBH class, individuals were either absent or present in few.

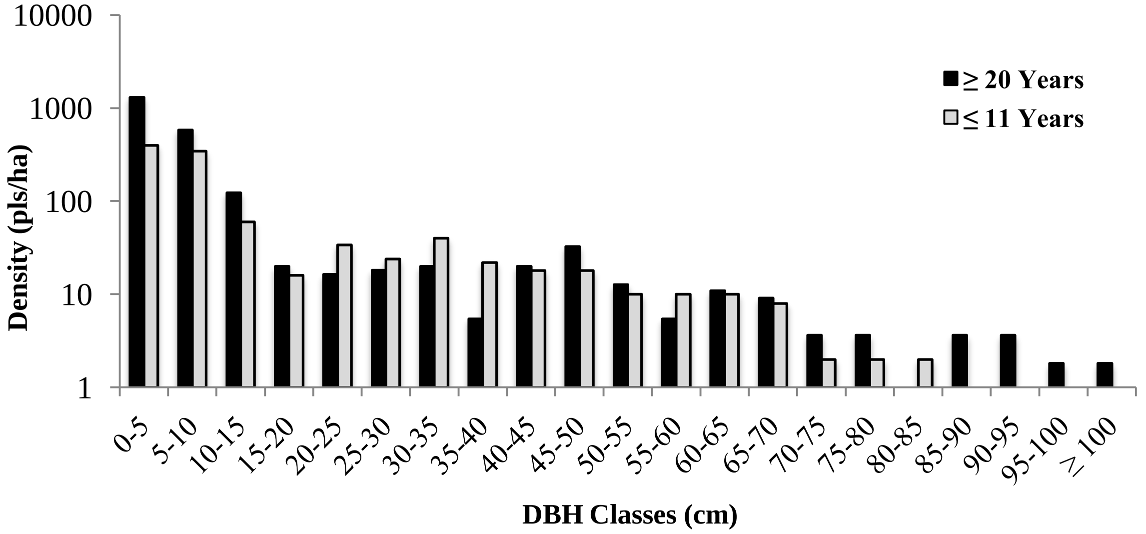

Figure 14. Size-class distribution diagram of dominant species (Sal) taller than 137 cm in two different categories of community managed forests. The data is in logarithmic scale.

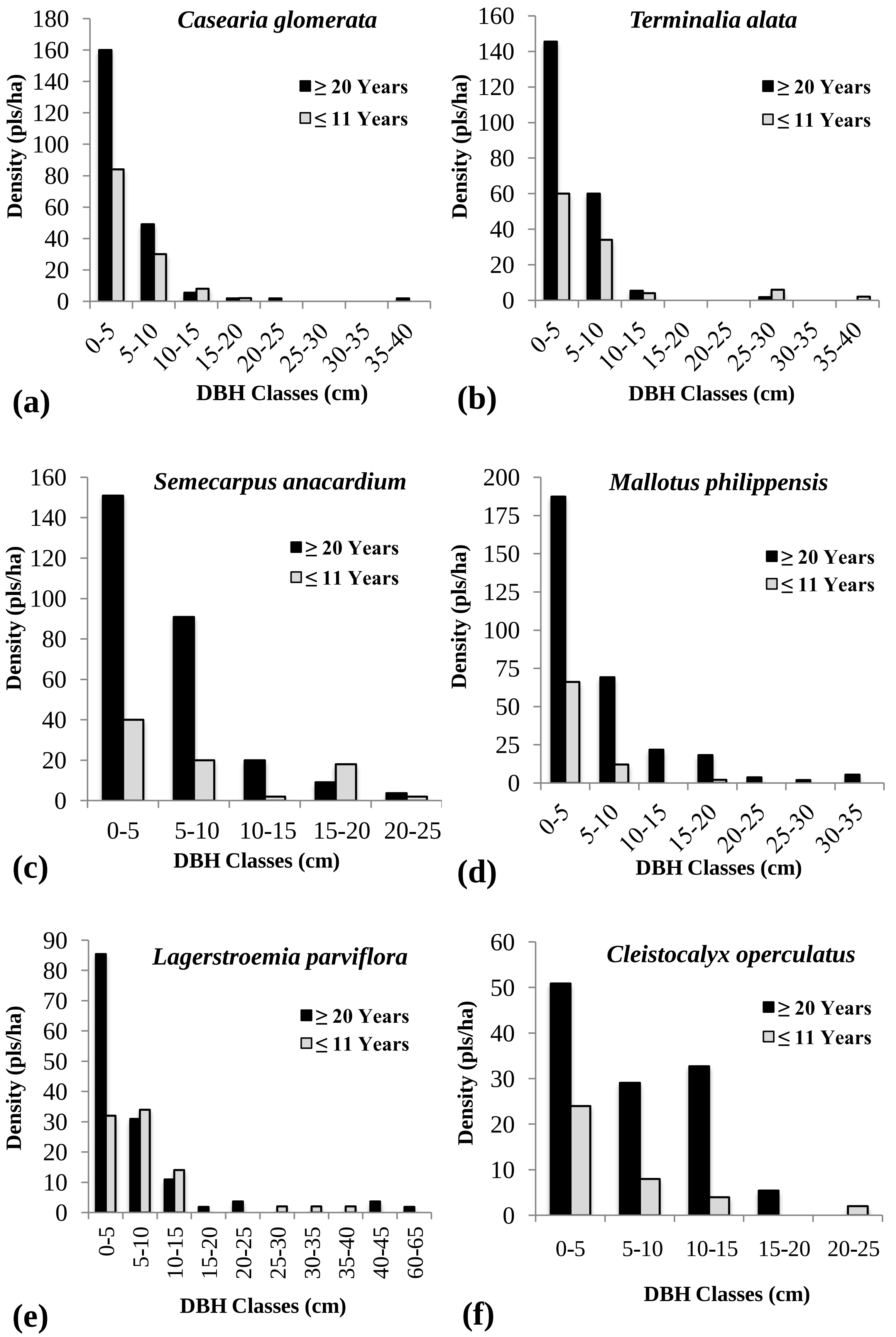

Figure 15. Size-class distribution diagram of co-dominant species taller than 137 cm in both category of community managed forest in Dadeldhura district, Nepal.

4.3.3. Influence of different variables on regeneration status of forest

Sal seedling number decreased with increasing canopy cover and pH whereas sal sapling number increased with increasing number of *Terminalia alata* seedling and decreased with increased RRI (Table 4). Similarly, *Casearia glomerata* seedling number fairly increased with increased number of *Mallotus philippensis* seedling and soil available phosphorus, but it's seedling number decreased with increased soil pH, RRI and species richness. Likely, *T. alata* seedling number increased with increased sal sapling number and decreased with increased RRI. The relationship between *Semecarpus anacardium* seedling number and *M. philippensis* seedling number was inverse. In addition, *M. philippensis* seedling number increased fairly with increased soil available phosphorus but it's seedling number decreased with increased soil pH and species richness.

Table 4. Spearman correlation coefficient between different variables measured in the sample plot and developmental phases of major tree species (n = 105).

	S_{Sed}	S_{Sap}	C_{Sed}	T_{Sed}	Se_{Sed}	M_{Sed}
S_{Sed}	1					
S_{Sap}	-0.009	1				
C_{Sed}	0.092	-0.001	1			
T_{Sed}	0.15	0.247*	0.035	1		
Se_{Sed}	-0.109	0.033	-0.049	-0.118	1	
M_{Sed}	-0.046	-0.078	0.299**	-0.13	-0.338**	1
SOC	-0.096	0.069	-0.092	0.045	0.031	-0.048
AK	-0.176	0.065	-0.035	0.097	0.025	-0.122
TN	-0.182	0.057	-0.092	0.074	0.139	-0.141
AP	-0.187	0.092	0.199*	0.046	-0.098	0.286**
pH	-0.246*	-0.109	-0.255**	0.054	0.175	-0.215*
CC	-0.257**	-0.111	0.097	-0.087	0.089	0.142
LC	0.077	-0.085	0.12	-0.109	0.031	0.013
GVC	-0.096	-0.098	-0.091	-0.155	-0.124	0.138
RRI	-0.151	-0.237*	-0.303**	-0.2*	0.094	-0.108
Sp richness	-0.11	0.077	-0.27**	-0.064	0.112	-0.265**

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Where, S_{Sed} = Sal seedling, S_{Sap} = Sal sapling, C_{Sed} = *Casearia glomerata* seedling, T_{Sed} = *Terminalia alata* seedling, Se_{Sed} = *Semecarpus anacardium* seedling, M_{Sed} = *Mallotus philippensis* seedling, SOC = Soil organic carbon, AK = Available potassium, TN = Total nitrogen, AP = Available phosphorus, CC = Canopy cover, LC = Litter cover, GVC = Ground vegetation cover, RRI = Relative radiation index, and Sp richness = Species richness.

5. DISCUSSION

5.1. Community Attribute

The Importance value index (IVI) of sal was found highest in both categories of community managed forest (i.e. 145 in ≥ 20 yrs managed forest and 147 in ≤ 11 yrs managed forests). This showed IVI of sal was almost same among both categories of community managed forests. When mean was taken, Sal alone had 48.6% (mean of 48.3 & 49) 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 sal 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 51.4% IVI so forest area and resources left over by sal 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 sal depends on age, available resources, associate species, disturbance regime, and successional changes (Mandal and Joshi, 2014b). Thus, high IVI of high timber yielding species, Sal, might be due to any one or more of these factors or activities.

5.2. Carbon Stock

5.2.1. Carbon stock and management category

The potential of forest to sequester C depends on the forest type, age of forest, size of trees, density of trees, stand condition and many others. Similar studies had reported that variations of plants, biomass decomposition, size of trees, age of stands, degree of disturbance affect the C-stock in ecosystem (Brown *et al.*, 1989; Dixon *et al.*, 1994). The mean C-stock in living biomass of community managed sal forest under present study was 175 Mg ha^{-1} (151-199 Mg ha^{-1}). Though the mean value of plant height and plant DBH was low in ≥ 20 yrs managed forest than ≤ 11 yrs managed forest, the C-stock of the community managed forest for ≥ 20 yrs (199 Mg ha^{-1}) was found significantly higher than in forest managed for ≤ 11 yrs (151 Mg ha^{-1}) ($P < 0.05$). Similar variation of C stock with management category was also obtained by Thapa Magar and Shrestha (2015) in the hill sal forest of Dhadhing district of Nepal. The higher value of C-stock in ≥ 20 yrs managed forest may be due to significantly higher mean value of tree density in this category of forest than the other category of forest. Similar result was also obtained by Shrestha (2009a), Baral *et al.* (2009) and Jati (2012) in broad-leaved *Schima-Castanopsis* forest of Palpa, five major forest types of Nepal and CF of Kanchenjunga conservation area, respectively. They found that forest with higher mean DBH and mean height had less above-ground C-stock than forest with lower mean DBH and mean height which was similar to present study. Similarly, result of present study was also in accordance with Mbaabu *et al.* (2014) as they also obtained higher C-stock in forest having lower mean tree height and DBH and higher mean stand density and vice versa.

Berenguer *et al*. (2014) found edge effect to be one of the significant factor for variation in C-stock in living tree biomass as C-stock increased with increased distance from the forest edge in human modified tropical forests of Brazil. In the present study villages situated within and edge of CFs acted as factor of edge effect. In ≤ 11 yrs managed forest villages were situated within and edge of CFs but in ≥ 20 yrs managed forest villages were situated only at the edge of CFs. This difference might had resulted higher edge effect in ≤ 11 yrs managed forests than ≥ 20 yrs managed forests which might had contributed lower C-stock in ≤ 11 yrs managed forests than ≥ 20 yrs managed forests.

5.2.2. Carbon stock and stand properties

Similarly, canopy cover, ground vegetation cover and RRI were statistically different in both categories of community managed forests but litter cover and species richness were statistically same in both categories of forests. Relation of these stand characteristics with total C-stock was found to be statistically insignificant similar to Thapa Magar and Shrestha (2015). Pathak (2015) also obtained the insignificant relationship between species richness and C-stock in community managed tropical sal forest of Nawalparasi district. Similarly, Sharma (2016) showed insignificant relation of C-stock with canopy cover similar to present study. But, Mandal *et al.* (2013) obtained weak positive relationship between C-stock and species richness in three collaborative forests of Mahottari district, Nepal.

5.2.3. Carbon stock and soil parameters

Soil physico-chemical parameters like soil organic carbon (SOC), total nitrogen (TN), available potassium (AK) and available phosphorus (AP) were not significantly different between two categories of community managed forests but soil pH was significantly different between forest categories which showed no significant relation with total C-stock. SOC and AP also had insignificant relation with C-stock. But, C-stock significantly decreased with increasing TN and increased with increasing AK. The relation of C-stock with SOC of present study was in contrast with Thapa Magar and Shrestha (2015) which showed increasing C-stock with increased SOC. Pathak (2015) showed that C-stock increased with increasing in soil AK in community managed tropical sal forest of Nawalparasi district, Nepal which was similar to present study. But relation of C-stock with soil pH of present study was different than Pathak (2015) which showed +ve relation of C-stock with soil pH.

5.2.4. Carbon stock and sal forest

The mean total C-stock in living biomass (tree and shrub) of present study was higher than the C-stock estimated by many researchers in pure sal or sal dominated forests of Nepal and outside Nepal. But, some researchers found higher value of C-stock than present study and some similar to present study. Following table (Table 5) shows the C-stock in sal forest under different management type as reported by different researchers from Nepal and India.

The standing C-stock of trees varies with the successional stage of forest and potential of forest to sequester C depends on the forest type, age of forest, size of trees, density of trees and stand condition (Brown *et al.*, 1989; Dixon *et al.*, 1994). With the increasing age of forest the C sequestrated by plants are stored as biomass. This is why the standing C-stock of old-growth forest is higher than the newly regenerating forest (Singh and Singh, 1992). Several assumptions like site comparability, plot size, DBH measurement, selection of the DBH-biomass regression model, belowground estimation of biomass and the overall C content in trees, and the C content in soil organic matter might induce large biases or variation in C-stocks when estimating the C-stock in forests (Saner *et al.*, 2012). So, the reason of variation of C-stock of present study with above referred study might be due to variation in one or more factors and assumptions in estimating C-stocks.

Table 5. Carbon stock in sal forests under different management type.

Forest type (Location)	**Forest management (no. of forest studied)**	**Elevation (m asl)**	**C-stock (Mg ha^{-1})**	**Allometric model used**	**Reference**
Inner Terai sal (Dadeldhura)	Community managed; CM (4 CFs)	405-893	175	Chave *et al.* (2005)	Present study
Hill sal (Dhadhing)	CM (9 CFs)	443-1081	120	Chave *et al.* (2005)	Thapa Magar and Shrestha (2015)
Hill sal (Chitwan)	CM (1 CFs)	NA	97.9	Brown *et al.* (1989)	Baral *et al.* (2009)
Hill sal (Gorkha)	CM (2 CFs)	600 & 900	52.9 & 131.5	Sharma & Pukkala (1990)	Neupane and Sharma (2014)
Hill sal (Palpa)	CM (1 CFs)	NA	101.2	Sharma & Pukkala (1990)	Shrestha (2009a)
Hill sal	CM	400-1100	219	Sharma & Pukkala (1990)	Shrestha and Singh (2008)
Tropical sal (Nawalparasi)	CM (1 CFs)	195-220	115	Chave *et al.* (2005)	Pathak (2015)
Tropical sal (Mahottari)	Collaborative (3 CFMs)	NA	131.8-202	Chave *et al.* (2005)	Mandal *et al.* (2013)
Hill sal (Tanahun)	CM (2 CFs)	490-560	71.1 & 109.8	Chave *et al.* (2005)	Gairhe (2015)
Tropical sal (Chitwan)	CM & Govt. managed; GM	NA	165.2 & 78.2	Chave *et al.* (2005)	Sharma (2016)
Hill sal (Gorkha)	CM (2 CFs)	650-1100	117.8	Chave *et al.* (2005)	Pandey *et al.* (2012)
Hill sal (Chitwan)	CM (5 CFs) & GM	245-1944	244 & 140	Chave *et al.* (2005)	Mbaabu *et al.* (2014)
Tropical moist sal (Assam, India)	SM (Forest reserve)	NA	120	FSI (1996)	Rabha (2014)
Siwalik sal (Dehradun, India)	SM	NA	57.5-291	Negi (1984) & FSI (1996)	Singh (2010)
Moist Bhabar sal (Garhwal, India)	SM	450-600	159.4	FSI (1996)	Sharma *et al.* (2010)
Dry Siwalik sal (Garhwal, India)	SM	800-1200	83.2	FSI (1996)	Sharma *et al.* (2010)
Moist sal (Garhwal, India)	SM	350-460	119.2	FSI (1996)	Sharma *et al.* (2010)
Riverine sal (Garhwal, India)	SM	450-610	107.3	FSI (1996)	Sharma *et al.* (2010)
Dry sub-deciduous sal (Garhwal, India)	SM	800-1100	74.5	FSI (1996)	Sharma *et al.* (2010)
Moist deciduous sal (Doon valley, India)	State managed; SM (3 forest ranges; FR)	NA	169.2-219	Forest survey of India; FSI (1996)	Shahid and Joshi (2015)
Moist deciduous sal (Doon valley, India)	SM (6 FR)	NA	232.5	Heng and Tsai (1999)	Mandal and Joshi (2014a)
Humid tropical sal (Meghalaya, India)	SM (2 forests)	208-295	203.2	Chambers *et al.* (2001)	Baishya *et al.* (2009)
Indian sal (national level)	NA	NA	22.7	NA	Manhas *et al.* (2006)
Central Himalayan sal	NA	NA	285.6	NA	Singh (1987) as cited in Singh and Singh (1992)

5.2.5. Contribution of species on carbon stock

Sal was the highest contributor of C-stock in tree layer with 91.4% & 90.5% in ≥ 20 yrs & ≤ 11 yrs managed forests, respectively. This was in accordance with sal dominated two CFs of Gorkha where sal contributed 95% & 86% in C-stock (Neupane and Sharma, 2014). In contrary to this, Gairhe (2015) found sal contributed 64.5% & 44.7% in C-stock in two community managed forests of Tanahun district. In present study the difference between density of sal and other species were higher whereas in study of Gairhe (2015) difference between sal density and density of other species were relatively low.

5.3. Regeneration

5.3.1. Variation of regeneration with different attributes

Seedling, sapling and tree density was higher in ≥ 20 yrs managed forests and ≤ 11 yrs managed forests. In ≤ 11 yrs managed forests canopy cover and ground vegetation cover was higher than ≥ 20 yrs managed forests. Low canopy cover (high canopy gap) favours the regeneration of light demanding species like sal (Sapkota *et al.*, 2009). They concluded that moderate disturbance intensity not only ensures high stand density, but also enhances the advanced regeneration of socio-economically important tree species and affects their dispersion patterns. 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) which might have acted as restriction factor for seedling growth in ≤ 11 yrs managed forests. Thus, the combined effects of increased light intensity, increased soil temperature, reduced competition and moderate disturbances might have increased seedling recruitment and establishment in canopy gaps (≥ 20 yrs managed forests) compared to areas with closed canopies (≤ 11 yrs managed forests).

Sal constitutes higher density in all the three life form than other associated species. Higher density of sal might be due to presence of sufficient canopy gaps which allowed sufficient light to reach the forest understory and made the light environment favourable for abundant growth of sal seedlings and saplings. Thus, light is considered very important in the development of sal stands which mainly played two roles, increasing photosynthesis and ground temperature, which in turn accelerates litter decomposition (Sapkota *et al*., 2009).

5.3.2. Variation of regeneration with soil parameters

In addition to this, pH value within the range of 4.5-5.5 which was considered as good for sal sapling growth (Singh and Singh, 1989 as cited by Paudel and Sah, 2003) and soil with higher pH was considered to have a poor capacity of sal regeneration (Suoheimo, 1995 as cited in Paudel and Sah, 2003). Bhatnagar (1965) showed that TN content and soil pH was low whereas AK was high in good sal dominant and regeneration areas.

So, increased litter decomposition, reduced competition, moderate disturbances, low pH (within 4.5-5.5), low TN and high AK content might have facilitated the growth of sal. And, also lower density of associated species might be due to the over-exploitation and selective logging in the past and continuation in the present and competitive inability with sal.

5.3.3. Regeneration status of sal forest in Nepal

The present study on regeneration status of forests shows similar or different pattern than the study from different parts of country. Following table (Table 6) shows the regeneration status of sal forests (& sal species) under different management category from different parts of Nepal. Community forest resource inventory guideline (2004) suggested a criteria based on number of seedling and sapling in forest for evaluating regeneration condition of the forest. Regeneration status of the forest is said to be good if forest have seedling > 5000 and sapling > 2000 per hectare (HMG, 2004) (cited in Pandey *et al*., 2012). And higher density of trees with smaller girth size than that of the larger girth size also indicates the good regeneration state of forest (Basyal *et al*., 2011). Result of regeneration status of forests of present study was in accordance with above mentioned criteria so it can be said that regeneration status of present studied forests is satisfactory or good. The variation in regeneration pattern of present study with above presented results of different researchers may be due to variation in any one of the factors like topography, climate, stand, intensity and type of disturbances and soil nutrients of study site as different study (like Sapkota *et al*., 2009; Gautam and Devoe, 2006) showed regeneration of sal was either positively or negatively affected by these factors.

Table 6. Regeneration status of sal forests and sal species under different management category of Nepal.

Forest type (Location)	Management type	Forest regeneration (pls/ha)			Sal regeneration (pls/ha)			Reference
		Seedling	Sapling	Tree	Seedling	Sapling	Tree	
Inner Terai sal (Dadeldhura)	CM	9764	1850	1263	9011	851	758	Present study
Tropical sal (Rupandehi)	Collaborative	13035-21022	Not available (NA)	66-552	6445-13977	1055-3022	NA	Awasthi *et al*. (2015)
Tropical sal (Bardia NP, Suklaphanta WLR & 2 CFs from Kanchanpur)	CM & GM	79072	1798	220	70462	1431	64	Timilsina *et al*. (2007)
Tropical & sub-tropical sal (Banke NP)	GM	6367-59236	260-5809	83-634	27153	201	46	Napit (2015)
Tropical sal (Palpa)	GM	NA	3438	3-209	4375	2563	209	Basyal *et al*. (2011)
Hill sal (Rupandehi)	CM	97900-108600	4138-4708	453-595	15208-24792	744-1228	172-178	Acharya and Shrestha (2011)
Hill sal (Gorkha)	CM	32522	2696	1469	NA	NA	NA	Pandey *et al*. (2012)
Hill sal (Kaski)	CM	NA	NA	NA	6126	NA	NA	Paudyal (2013)
Inner Terai sal (Chitwan & Nawalparasi)	CM	NA	NA	NA	43000	2974	192	Kandel (2007)
Tropical sal (Bardia NP)	GM	NA	NA	NA	11185	321	95	Giri *et al*. (1999)
Sal (Surkhet)	CM	NA	NA	NA	6758	4484	962	Shrestha (2009)
Sal (Surkhet)	Protected	NA	NA	NA	4422	422	1008	Shrestha (2009)
Churia (National level; NL)	NA	19805	958	731	12140	227	223	DFRS (2014a,b)
Terai (NL)	NA	29649	1662	583	18686	358	188	DFRS (2014a,b)
Churia (NL)	CM	22294	1216	NA	NA	NA	NA	DFRS (2014a,b)
Terai (NL)	CM	25469	1866	NA	NA	NA	NA	DFRS (2014a,b)
Churia (Far west)	NA	12661	491	NA	NA	NA	NA	DFRS (2014a,b)
Terai (Far west)	NA	40621	1463	NA	NA	NA	NA	DFRS (2014a,b)

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The C-stock increased with the increased management duration of forest while status of seedlings, saplings and trees in present studied CFs were in the order of seedlings > saplings > trees. Therefore, the hypothesis that the biomass C-stock of community managed forest increases with the management duration and community managed forest have good regeneration status had been accepted.

The C-stock of community managed forests for ≥ 20 yrs was higher than community forests managed for ≤ 11 yrs. Thus, management duration had significant positive impact on increasing the C-stock of community managed forest. While, species richness, canopy coverage, litter coverage, ground vegetation coverage, relative radiation index, soil organic carbon, soil available phosphorus and soil pH had insignificant effect on C-stock of the present studied community managed forests. But, soil total nitrogen and soil available potassium had significant negative and positive effect on the C-stock, respectively. Sal contributed highest percentage of C-stock in tree layer in both categories of CF whereas in shrub layer it only contributed highest percentage in ≥ 20 yrs managed forest while in ≤ 11 yrs managed forest it was replaced by *Phoenix humilis* (Thakal).

The number of seedling, sapling and tree were more in ≥ 20 yrs managed forest than ≤ 11 yrs managed forest. Number (density) of sal seedlings, saplings and trees were higher than other associated species in both categories of forests. Sal was followed by *Casearia glomerata, Terminalia alata, Semecarpus anacardium* and *Mallotus philippensis*. So, we can say that community management had significant positive impact on regeneration of forest, and thus, productivity of the forest.

6.2. Recommendations

- These forests should be initiated for inclusion in REDD+ scheme so that these can get the carbon credit benefits which will helps in improvement of forest condition and livelihoods of local community.
- Timber, fuelwood 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 practice for management of these disturbances may be the agroforestry practices.
- Proper silviculture practices seem to be lacking, so these should be emphasized.

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ANNEXES

Annex 1. Procedure applied for analyzing the soil physico-chemical parameters.

Soil organic carbon

Soil organic carbon was determined by Walkley-Black Method. In this method, 1.0 g air dried soil was taken in a dry conical flask (500 ml). Then 10 ml 1N potassium dichromate ($K_2Cr_2O_7$) was pipetted in and swirled a little. To the mixture 20 ml of concentrated sulphuric acid (Conc. H_2SO_4) was added and again swirled a little. The flask was allowed to cool down for 30 minutes and then 200 ml distilled water was added. After that 10 ml orthophosphoric acid and 1 ml diphenylamine indicator were added successively in the conical flask containing the mixture. Finally, the content was titrated with 0.5N ferrous ammonium sulphate (till the colour changed from blue violet to green). A blank was also run simultaneously.

$$\text{Organic carbon in soil (\%)} = \frac{\text{N(B} - \text{S)} \times 0.003 \times 100}{\text{Mass of dry soil (g)}}$$

where, N = Normality of ferrous ammonium sulphate (0.5N).

B = Volume of ferrous ammonium sulphate for blank titration (ml).

S = Volume of ferrous ammonium sulphate for sample titration i.e. soil (ml).

Soil pH

Soil pH was determined by electric pH meter. 20 g soil was taken in a beaker and prepared a paste by adding 20 ml distilled water gradually into it. pH meter was allowed to warm for 15 minutes and then pH meter was calibrated to buffer solution of pH 7.0, 4.0 and 9.2. After that electrodes was immersed in the beaker containing soil paste and pH meter reading was recorded.

Soil Total Nitrogen

The soil nitrogen was determined by Micro-Kjeldahl method. This method includes the following steps: Digestion, Distillation and Titration.

Digestion: 1.0 g air dried and sieved soil (0.5 mm sieve) was taken in a dry Kjeldahl digestion flask (300 ml). Then 3.5 g potassium sulphate (K_2SO_4) and 0.4 g copper sulphate ($CuSO_4.5H_2O$) i.e. catalyst were added to the Kjeldahl flask containing soil. After it, 10 ml conc. sulphuric acid (H_2SO_4) was added to the same flask and mixed with swirling. Then the flask was placed on a pre-heated (30^oC) heating mantle for digestion. The temperature was raised to about 300^oC (30 min heating). Near the end of digestion process, the color of sample changed from black to brownish and at the end it becomes greenish (turquoise) (45 minutes). Then the flask was removed immediately from the mantle and allowed to cool for 5 min. 50 ml distilled water was added to the digest and the mixture was shaken. A blank without soil was prepared as a reference solution.

Distillation: The diluted digest was transferred to Kjeldahl distillation flask. A beaker (100 ml) with 10 ml boric acid indicator was placed below the nozzle of the condenser in such a way that the end of nozzle dipped into the indicator. After the digest becomes warm, 30 ml 40% NaOH was added. The distillate began to condense and the color of boric acid changed from pink to green. The distillation was continued until the volume of distillate in the beaker reached to about 50 ml.

Titration: The distillate was titrated with 0.1N HCl and the volume of HCl consumed was noted. The volume of acid consumed by blank was also recorded and the total nitrogen content (%) was calculated by using following formula:

$$\text{Soil total nitrogen (\%)} = \frac{(T - B) \times N \times 1.401}{\text{Weight of soil taken(g)}}$$

where, T = Volume of HCl consumed with sample (ml).

B = Volume of HCl consumed with blank (ml).

N = Normality of HCl.

Soil Available Phosphorus

Available phosphorus in soil was determined by Olsen's method. In this method, 2.0 g air dried soil sample was taken in a 125 ml Erlenmeyer flask and added a 1.0 g charcoal in it. After it, 40 ml sodium bicarbonate ($NaHCO_3$) solution was added and shaken for 30 min on a reciprocating shaker at 120 strokes per minute. Extract was filtered using Whatman No. 40 filter paper. Pipetted 10 ml aliquot of the extract (filtrate) in a 50 ml volumetric flask and added 10 ml distilled water and one drop of p-nitrophenol indicator. Now content was acidified to pH 5.0 by adding 2.5M sulphuric acid (H_2SO_4) drop-wise till the colour disappeared. Now added 8.0 ml of Murphy-Riley solution and made the final volume to 50 ml by adding distilled water. After 15 min, intensity of blue color (absorbance) was read on spectrophotometer at 730 nm.

$$\text{Soil available phosphorus (kg ha}^{-1}) = C \times \frac{E}{A} \times \frac{2.24}{\text{Mass of soil (g)}}$$

where, C = µg P in the aliquot [obtained from standard curve plotted between absorbance values and the concentration of P in standards (0, 0.1, 0.2, 0.3, 0.4 and 0.5 µg P/ml or ppm of P)].

E = Volume of extractant added i.e. $NaHCO_3$ (ml).

A = Volume of aliquot of extract (ml).

Soil Available Potassium

The available potassium was determined by flame photometer method. It involves the following process: Ammonium acetate extract of soil and determination of potassium by flame photometer using K filter.

Ammonium acetate extract of soil: It was obtained by shaking followed by filtration. In this method, 2.0 g air dried soil was placed in a 150 ml Erlenmeyer flask and poured 18 ml (1:9 soil to extractant) of neutral normal ammonium acetate (1N CH_3COOHN_4) so that volume of solution becomes 20 ml. Then it was shaken for 5 min and immediately filtered through Whatman No. 1 filter paper and collected the filtrate.

Determination of K by flame photometer: K filter was set, started the compressor and lighted the burner of flame photometer. Air pressure was kept at 5 lbs and adjusted the gas feeder so as to have a blue sharp flame comes. Adjusted the zero reading on the scale by feeding extract solution (CH_3COOHN_4) in the flame photometer. Then, feeded standard KCl solution of the highest value in the standard series (25 ppm K) and adjusted the flame photometer to read full scale i.e. 100 reading. After that, reading was taken for each standard solution (0, 5, 10, 15, 20 and 25 ppm K) which were used for plotting standard curve. Then, extract of sample (filtrate) was feeded in the flame photometer and noted the reading. Similarly, blank reading was also noted and corrected reading was calculated by subtracting blank reading from sample reading. Now, standard curve was plotted between concentration on x-axis and flame photometer readings on y-axis of standard K solution and determined the K content in the sample with the help of standard curve.

$$\text{Soil available potassium (kg ha}^{-1}) = \frac{C \times E}{\text{Weight of soil taken (g)}} \times 2.24$$

where, C = ppm of K (obtained from standard curve).

E = Volume of extractant added i.e. CH_3COOHN_4 (ml).

Annex 2. Geographical position of plots with different variables measured in these plots.

Where, Plot No 1-27: Dansera CF; 28-55: Sundari CF; 56-81: Khajurani CF & 82-105: Madhuban Mahila CF. Dansera CF & Sundari CF were managed for ≥ 20 yrs whereas Khajurani CF & Madhuban Mahila CF were managed for ≤ 11 yrs (Alt = Altitude, RRI = Relative radiation index, CC = Canopy cover, GVC = Ground vegetation cover & LC = Litter cover).

Plot No	**Alt (m)**	**Latitude**	**Longitude**	**Aspect**	**Slope (^{o})**	**RRI**	**CC (%)**	**GVC (%)**	**LC (%)**	**Species richness (sps/plot)**
1	430	$29^{0}07'671''$	$80^{0}21'755''$	40^{0}NE	45	0.35	85	20	90	6
2	415	$29^{0}07'639''$	$80^{0}21'918''$	351^{0}NW	21	0.64	75	90	80	14
3	442	$29^{0}07'627''$	$80^{0}21'750''$	312^{0}NE	2	0.84	50	50	55	17
4	457	$29^{0}07'565''$	$80^{0}21'853''$	336^{0}NW	12	0.76	50	30	80	14
5	442	$29^{0}07'626''$	$80^{0}22'085''$	22^{0}NE	4	0.84	65	50	65	24
6	463	$29^{0}07'576''$	$80^{0}22'123''$	42^{0}NE	5	0.84	50	35	20	24
7	483	$29^{0}07'537''$	$80^{0}22'109''$	20^{0}NE	6	0.82	95	60	80	13
8	537	$29^{0}07'431''$	$80^{0}22'030''$	20^{0}NE	20	0.66	45	20	90	12
9	478	$29^{0}07'542''$	$80^{0}21'905''$	326^{0}NW	11	0.78	75	20	80	16
10	479	$29^{0}07'483''$	$80^{0}21'976''$	360^{0}N	18	0.68	70	50	70	14
11	488	$29^{0}07'473''$	$80^{0}22'043''$	60^{0}NE	6	0.84	40	20	80	20
12	515	$29^{0}07'405''$	$80^{0}22'150''$	354^{0}NW	22	0.62	40	30	40	10
13	516	$29^{0}07'404''$	$80^{0}22'151''$	28^{0}NE	20	0.67	50	40	90	12
14	437	$29^{0}07'682''$	$80^{0}22'183''$	340^{0}NW	12	0.76	50	40	60	12
15	432	$29^{0}07'626''$	$80^{0}22'193''$	18^{0}NE	7	0.81	65	35	80	11
16	455	$29^{0}07'552''$	$80^{0}22'195''$	336^{0}NW	10	0.78	50	45	90	12
17	478	$29^{0}07'470''$	$80^{0}22'198''$	326^{0}NW	12	0.77	60	70	60	23
18	507	$29^{0}07'497''$	$80^{0}22'287''$	40^{0}NE	29	0.58	80	70	75	23
19	487	$29^{0}07'516''$	$80^{0}22'138''$	360^{0}N	12	0.75	60	30	85	21
20	475	$29^{0}07'513''$	$80^{0}22'206''$	306^{0}NW	10	0.81	50	45	80	21
21	501	$29^{0}07'479''$	$80^{0}22'493''$	350^{0}NW	12	0.75	10	70	50	15
22	511	$29^{0}07'484''$	$80^{0}22'294''$	324^{0}NW	5	0.83	10	70	70	18
23	527	$29^{0}07'421''$	$80^{0}22'366''$	28^{0}NE	5	0.83	6	60	60	12
24	494	$29^{0}07'473''$	$80^{0}22'519''$	303^{0}NW	7	0.83	60	65	70	11
25	477	$29^{0}07'503''$	$80^{0}22'581''$	10^{0}NE	11	0.76	10	70	70	12
26	485	$29^{0}07'543''$	$80^{0}22'276''$	40^{0}NE	32	0.54	30	55	70	15
27	451	$29^{0}07'596''$	$80^{0}22'293''$	28^{0}NE	12	0.76	75	60	50	10
28	435	$29^{0}07'471''$	$80^{0}20'835''$	36^{0}NW	10	0.79	20	30	80	14
29	467	$29^{0}07'417''$	$80^{0}20'841''$	336^{0}NW	4	0.84	60	50	60	14
30	506	$29^{0}07'371''$	$80^{0}20'879''$	334^{0}NW	4	0.84	90	95	60	20
31	507	$29^{0}07'321''$	$80^{0}20'899''$	304^{0}NW	8	0.9	80	95	30	23
32	522	$29^{0}07'263''$	$80^{0}20'950''$	360^{0}N	4	0.84	30	75	90	23
33	544	$29^{0}07'173''$	$80^{0}20'965''$	360^{0}N	12	0.75	50	65	70	23
34	411	$29^{0}07'577''$	$80^{0}20'957''$	360^{0}N	2	0.85	80	10	85	21
35	423	$29^{0}07'461''$	$80^{0}21'008''$	318^{0}NE	10	0.8	80	85	70	29
36	454	$29^{0}07'429''$	$80^{0}21'008''$	302^{0}NW	34	0.58	20	30	80	25
37	442	$29^{0}07'435''$	$80^{0}21'091''$	355^{0}NW	28	0.54	30	55	50	21
38	433	$29^{0}07'465''$	$80^{0}21'010''$	240^{0}SW	28	0.88	30	45	75	19

39	553	$29^{0}07'253''$	$80^{0}21'147''$	17^{0}NE	17	0.7	50	60	65	22
40	729	$29^{0}07'032''$	$80^{0}21'346''$	217^{0}SW	15	0.94	60	50	70	16
41	678	$29^{0}07'065''$	$80^{0}21'391''$	143^{0}SE	39	0.92	40	30	45	18
42	666	$29^{0}07'080''$	$80^{0}21'400''$	350^{0}NW	26	0.57	50	25	20	13
43	561	$29^{0}07'214''$	$80^{0}21'431''$	10^{0}NE	29	0.53	10	60	40	14
44	435	$29^{0}07'545''$	$80^{0}21'062''$	330^{0}NW	12	0.76	25	70	45	22
45	475	$29^{0}07'470''$	$80^{0}21'240''$	28^{0}NE	5	0.83	40	85	40	17
46	503	$29^{0}07'370''$	$80^{0}21'428''$	276^{0}SW	20	0.8	60	25	50	20
47	536	$29^{0}07'376''$	$80^{0}21'467''$	360^{0}N	10	0.77	60	30	40	18
48	537	$29^{0}07'393''$	$80^{0}21'503''$	270^{0}NW	28	0.77	45	35	40	20
49	511	$29^{0}07'418''$	$80^{0}21'490''$	331^{0}NW	4	0.84	65	45	55	25
50	525	$29^{0}07'451''$	$80^{0}21'457''$	336^{0}NW	4	0.83	70	50	50	25
51	482	$29^{0}07'502''$	$80^{0}21'499''$	360^{0}N	5	0.84	65	55	75	22
52	456	$29^{0}07'577''$	$80^{0}21'566''$	16^{0}NW	4	0.83	70	20	40	18
53	440	$29^{0}07'599''$	$80^{0}21'684''$	350^{0}NE	4	0.8	85	85	35	17
54	427	$29^{0}07'693''$	$80^{0}21'566''$	44^{0}NE	10	0.79	40	75	45	12
55	405	$29^{0}07'703''$	$80^{0}21'450''$	320^{0}NW	10	0.86	80	70	25	9
56	415	$29^{0}07'622''$	$80^{0}23'060''$	340^{0}NW	1	0.86	60	30	35	9
57	441	$29^{0}07'756''$	$80^{0}23'132''$	344^{0}NW	1	0.85	30	80	45	13
58	454	$29^{0}07'752''$	$80^{0}23'197''$	334^{0}NW	2	0.86	85	85	80	15
59	441	$29^{0}07'789''$	$80^{0}23'373''$	360^{0}N	1	0.85	45	85	70	8
60	455	$29^{0}07'771''$	$80^{0}23'489''$	10^{0}NE	1	0.77	55	30	75	13
61	482	$29^{0}07'742''$	$80^{0}23'524''$	30^{0}NE	3	0.77	40	75	85	11
62	649	$29^{0}07'238''$	$80^{0}23'588''$	30^{0}NE	12	0.75	65	20	65	16
63	766	$29^{0}07'236''$	$80^{0}23'605''$	360^{0}N	10	0.8	60	75	60	17
64	680	$29^{0}07'184''$	$80^{0}23'576''$	360^{0}N	12	0.8	70	70	80	20
65	726	$29^{0}07'091''$	$80^{0}23'598''$	360^{0}N	12	0.65	65	55	80	16
66	735	$29^{0}07'066''$	$80^{0}23'595''$	344^{0}NW	8	0.8	75	80	95	12
67	707	$29^{0}07'098''$	$80^{0}23'581''$	254^{0}SW	34	0.84	60	30	70	25
68	671	$29^{0}07'118''$	$80^{0}23'529''$	360^{0}N	20	0.69	55	60	55	16
69	678	$29^{0}07'136''$	$80^{0}23'485''$	50^{0}NE	10	0.66	95	40	65	20
70	649	$29^{0}07'222''$	$80^{0}23'414''$	360^{0}N	4	0.76	75	70	75	15
71	660	$29^{0}07'243''$	$80^{0}23'374''$	60^{0}NE	25	0.79	45	70	70	15
72	640	$29^{0}07'263''$	$80^{0}23'361''$	38^{0}NE	22	0.78	65	85	95	16
73	826	$29^{0}06'637''$	$80^{0}23'825''$	100^{0}SE	35	0.83	75	65	70	15
74	893	$29^{0}06'542''$	$80^{0}23'748''$	310^{0}NW	12	0.9	90	60	80	19
75	838	$29^{0}06'563''$	$80^{0}23'722''$	284^{0}NW	20	0.86	55	40	95	25
76	783	$29^{0}06'536''$	$80^{0}23'564''$	348^{0}NW	5	0.89	60	80	90	28
77	884	$29^{0}06'571''$	$80^{0}23'754''$	174^{0}SE	4	0.96	65	75	95	24
78	746	$29^{0}06'556''$	$80^{0}23'406''$	294^{0}NW	2	0.6	50	60	85	24
79	675	$29^{0}06'529''$	$80^{0}23'318''$	244^{0}SW	10	0.77	85	65	80	25
80	655	$29^{0}06'611''$	$80^{0}23'053''$	212^{0}SW	20	0.85	15	60	90	22
81	587	$29^{0}06'690''$	$80^{0}23'876''$	286^{0}NW	38	0.86	90	50	60	21
82	581	$29^{0}07'437''$	$80^{0}23'973''$	360^{0}N	10	0.86	50	80	70	17
83	570	$29^{0}07'392''$	$80^{0}23'963''$	88^{0}NE	10	0.79	90	80	90	20
84	584	$29^{0}07'350''$	$80^{0}23'966''$	64^{0}NE	3	0.85	50	70	70	20
85	618	$29^{0}07'295''$	$80^{0}23'395''$	326^{0}NW	1	0.84	70	20	55	19
86	625	$29^{0}07'222''$	$80^{0}23'878''$	40^{0}SE	10	0.84	50	85	35	20
87	659	$29^{0}07'207''$	$80^{0}23'821''$	60^{0}NE	5	0.81	50	80	35	21
88	677	$29^{0}07'118''$	$80^{0}23'849''$	80^{0}NE	12	0.84	55	60	55	25

89	727	$29^{0}07'031''$	$80^{0}23'863''$	28^{0}NE	4	0.86	50	70	60	20
90	802	$29^{0}07'772''$	$80^{0}23'857''$	52^{0}NE	10	0.87	80	30	95	15
91	591	$29^{0}07'389''$	$80^{0}23'591''$	310^{0}NW	5	0.86	80	90	75	14
92	590	$29^{0}07'359''$	$80^{0}23'633''$	314^{0}NW	2	0.86	85	45	80	15
93	602	$29^{0}07'323''$	$80^{0}23'651''$	270^{0}NW	2	0.82	65	70	35	15
94	598	$29^{0}07'308''$	$80^{0}23'685''$	300^{0}NW	2	0.86	55	70	90	19
95	608	$29^{0}07'292''$	$80^{0}23'710''$	342^{0}NW	2	0.85	60	85	85	23
96	620	$29^{0}07'265''$	$80^{0}23'738''$	342^{0}NW	6	0.84	70	65	40	24
97	633	$29^{0}07'227''$	$80^{0}23'780''$	300^{0}NW	3	0.86	60	75	35	18
98	638	$29^{0}07'206''$	$80^{0}23'797''$	50^{0}NE	4	0.85	85	90	55	21
99	648	$29^{0}07'186''$	$80^{0}23'812''$	60^{0}NE	6	0.85	50	50	85	26
100	621	$29^{0}07'246''$	$80^{0}23'781''$	300^{0}NW	2	0.84	60	65	50	20
101	617	$29^{0}07'276''$	$80^{0}23'775''$	10^{0}NE	3	0.84	40	60	50	21
102	688	$29^{0}07'144''$	$80^{0}23'835''$	12^{0}NE	7	0.86	95	80	50	16
103	606	$29^{0}07'318''$	$80^{0}23'768''$	324^{0}NW	8	0.82	35	90	60	22
104	584	$29^{0}07'383''$	$80^{0}23'752''$	347^{0}NW	14	0.73	50	30	70	21
105	556	$29^{0}07'449''$	$80^{0}23'754''$	354^{0}NW	14	0.73	75	35	60	12

Annex 3. Total number of individuals of tree taller than 137 cm in two categories of community managed forests of Dadeldhura district, Nepal.

(Where, 1 = 10-15, 2 = 15-20, 3 = 20-25, 4 = 25-30, 5 = 30-35, 6 = 35-40, 7 = 40-45, 8 = 45-50, 9 = 50-55, 10 = 55-60, 11 = 60-65, 12 = 65-70, 13 = 70-75, 14 = 75-80 & 15 = ≥ 80).

Management duration	DBH classes (cm)															
	0-5	5-10	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
≥ 20 Years	1456	573	126	30	21	13	13	9	12	20	7	3	6	5	2	2	7
≤ 11Years	527	282	62	25	23	17	25	15	9	10	5	5	5	5	1	1	1

Annex 4. Regeneration status of major tree species in two categories of community managed sal forests.

Species	**Seedlings (pls/ha)**		**Saplings (pls/ha)**		**Trees (pls/ha)**	
	≥ 20 Yrs	**≤ 11 Yrs**	**≥ 20 Yrs**	**≤ 11 Yrs**	**≥ 20 Yrs**	**≤ 11 Yrs**
Shorea robusta	11,655	6,366	1304	398	896	620
Terminalia alata	126	30	145	60	67	46
Semecarpus anacardium	145	110	152	40	124	42
Mallotus philippensis	130	103	187	66	120	14
Casearia glomerata	168	103	160	84	60	40
Miscellaneous species	263	328	697	406	277	220
Total	**12,487**	**7,040**	**2,645**	**1,054**	**1,544**	**982**
Mean	**9,763.5**		**1,849.5**		**1,263**	

Annex 5. Wood density of tree species used to estimate carbons stock using allometric equation Chave *et al.* (2005).

Species name (with author citation)	**Family**	**Wood density ($g\ cm^{-3}$), oven dry mass/fresh volume**
Adina cordifolia (Willd. ex Roxb.) Benth. & Hook. ex Brandis.	*Rubiaceae*	0.590
Bauhinia purpurea L.	*Fabaceae*	0.720
Bauhinia variegata L.	*Fabaceae*	0.653
Careya arborea Roxb.	*Lecythidaceae*	0.731
Casearia glomerata Roxb.	*Flacourtiaceae*	0.627
Cassia sp.	*Fabaceae*	0.739
Celtis sp.	*Ulmaceae*	0.520
Cleistocalyx operculatus (Roxb.) Merr. & Perry	*Myrtaceae*	0.661
Dalbergia sissoo Roxb. ex DC.	*Fabaceae*	0.676
Desmodium oojeinense (Roxb.) H. Ohashi	*Fabaceae*	0.640
Dysoxylum binectariferum (Roxb.) Hook.f. ex Bedd.	*Meliaceae*	0.606
Ficus bengalensis L.	*Moraceae*	0.494
Ficus neriifolia Sm.	*Moraceae*	0.412
Garuga pinnata Roxb.	*Burseraceae*	0.640
Grewia optiva J.R.Drumm. ex Burret.	*Tiliaceae*	0.646
Grewia sp.	*Tiliaceae*	0.557
Holoptelea integrifolia (Roxb.) Planch.	*Ulmaceae*	0.563
Lagerstroemia parviflora Roxb.	*Lythraceae*	0.658
Lindera pulcherrima (Nees) Benth. ex Hook.	*Lauraceae*	0.515
Macropanax undulatus (Wall. ex G. Don) Seem.	*Araliaceae*	0.31
Mallotus philippensis (Lam.) Mull. Arg.	*Euphorbiaceae*	0.637
Phyllanthus emblica L.	*Euphorbiaceae*	0.636
Pinus roxburghii Sarg.	*Pinaceae*	0.327
Psidium guajava L.	*Myrtaceae*	0.589
Schleichera oleosa (Lour.) Merr.	*Sapindaceae*	0.897
Semecarpus anacardium L.	*Anacardiaceae*	0.425
Shorea robusta Gaertn.	*Dipterocarpaceae*	0.730
Spatholobus parviflorus (DC.) Kuntze	*Fabaceae*	0.465
Syzygium cumini (L.) Skeels	*Myrtaceae*	0.673
Tectona grandis L.	*Verbenaceae*	0.720
Terminalia alata (Heyne.) ex Roth.	*Combretaceae*	0.750
Terminalia bellirica (Gaertn.) Roxb.	*Combretaceae*	0.760
Terminalia chebula Retz.	*Combretaceae*	0.880
Toona ciliata M. Roem.	*Meliaceae*	0.376
Xeromphis spinosa (Thunb.) Keay	*Rubiaceae*	0.584
Bhaira*		0.584
Chiplopate*		0.584
Dheudi*		0.584
Kaubhala*		0.584
Kharsha*		0.584
Pulayo*		0.584
Unidentified 1		0.584

Source: Zanne *et al*. (2009). * represents the local name of species

Annex 6. Soil physico-chemical parameters, stand properties and carbon stock in plots sampled at community managed forests of Dadeldhura district, Nepal.

(Where, SOC = Soil organic carbon, DBH = Diameter at breast height, No of plants = Trees only).

Plot No	pH	SOC	Nitrogen (%)	Potassium (kg ha^{-1})	Phosphorus (kg ha^{-1})	No of plants	DBH (cm)			Height (m)			Carbon stock (Mg ha^{-1})		
							Min	Max	Mean	Min	Max	Mean	Tree	Shrub	Total
1	4.8	2.950	0.200	292.08	110	11	1.5	31.5	8.2	1.5	34	6	62.042	22.126	84.168
2	4.7	1.302	0.136	315.888	92	19	1.4	39	7.2	1.7	18	4.4	88.222	86.497	174.718
3	4.8	3.238	0.168	250.416	156	10	1.6	60	26.1	1.7	30	14.3	226.914	61.927	288.842
4	4.9	2.332	0.176	184.944	128	13	1.5	37	9.6	1.5	29.9	6.8	76.039	55.906	131.945
5	4.6	2.332	0.176	309.936	37	18	1.5	49.7	8.6	1.8	30	6.4	178.698	39.016	217.715
6	4.5	2.332	0.176	143.28	183	48	1.4	51.9	3.9	1.9	29.6	2.9	127.204	43.978	171.183
7	4.5	3.238	0.211	226.608	110	55	1.4	33.2	5.3	1.6	28	4.9	85.968	47.937	133.905
8	4.7	5.216	0.287	548.016	183	26	1.4	28.8	8.3	1.5	40	8.9	125.185	37.350	162.535
9	4.4	1.366	0.089	321.84	219	54	1.5	76.5	5.9	1.7	31.3	3.9	257.365	35.529	292.894
10	4.6	3.980	0.239	250.416	146	39	1.5	61.5	4.4	2	26.8	3	155.905	64.987	220.892
11	5	0.684	0.113	565.872	183	47	1	64.3	5.2	2.3	34	3.9	249.183	38.075	287.258
12	4.6	3.156	0.208	369.456	92	46	1	93	5.8	1.6	50	4.3	271.84	31.196	303.036
13	4.8	2.126	0.168	238.512	220	38	1	23.4	4.8	1.9	60	5.5	65.65	40.715	106.365
14	4.9	3.362	0.215	381.36	146	26	1	69.2	7.9	1.5	41	5.8	165.705	33.837	199.543
15	5	4.392	0.255	184.944	146	22	1	102	12.6	1.5	40	8.6	273.156	34.589	307.745
16	4.5	4.186	0.247	244.464	110	38	1	32.4	3.8	2.1	19	3.4	38.665	57.601	96.266
17	5	3.980	0.239	274.224	73	53	1	18	3.5	1.5	19	3.5	168.901	32.521	201.423
18	4.4	3.156	0.207	244.464	73	43	1	52.8	6.5	2.3	32.8	6.1	165.778	41.920	207.699
19	4.9	3.342	0.296	326.879	178	56	1	20	4.8	1.4	28.5	3.5	46.304	50.439	96.743
20	4.6	4.186	0.247	428.976	55	24	1	47.4	9.9	1.5	29	6.9	243.822	28.118	271.941
21	4.7	3.156	0.208	351.6	92	47	1	46.5	5.2	1.5	24.5	3.8	121.289	36.281	157.57
22	5.2	2.044	0.227	298.456	132	54	1	71.3	6.1	1.6	36	4.4	225.28	64.363	289.644
23	4.4	1.096	0.128	220.656	110	36	2	31.3	4.7	1.5	14	3.6	67.497	40.981	108.478
24	4.7	0.684	0.113	387.312	128	22	1.3	70.5	10.3	1.5	36	7.7	237.923	26.294	264.217
25	4.6	2.744	0.192	238.512	110	26	1.4	96	9.8	2	32	6.4	252.511	36.458	288.969
26	5	5.010	0.279	292.08	37	23	1	37.5	7.1	2.4	21	5	101.553	39.907	141.461

27	5.5	1.656	0.247	246.931	178	12	1.3	46.5	12.7	1.5	29.6	7	228.218	25.933	254.152
28	4.8	2.145	0.186	220.638	212	35	1	9.5	3.3	1.7	15	3	5.717	23.732	29.449
29	5	1.219	0.221	374.276	184	62	1	47	5.4	1.5	40	5.6	45.273	39.359	84.632
30	5.4	2.332	0.176	482.544	37	73	1.2	90	6.8	1.5	37	5.3	329.582	57.893	387.475
31	4.5	1.219	0.133	232.56	36	42	1.3	46	7.6	1.5	32	6.5	340.455	36.645	377.101
32	4.7	2.538	0.184	244.464	110	47	1.3	10.6	4.2	1.5	15.5	3.4	13.361	50.698	64.06
33	4.8	4.186	0.247	303.984	73	96	1.3	21.2	4.7	1.8	16	4.8	47.991	42.129	90.12
34	4.8	4.186	0.247	250.416	73	57	1	54.7	4.2	1.5	24	3.2	144.232	73.313	217.545
35	5.2	2.950	0.200	232.56	274	91	1	51.9	4.4	1.4	35.5	3.8	162.679	64.160	226.84
36	4.6	3.362	0.215	250.416	128	62	1.3	88	5.1	1.5	36.5	4.1	321.746	71.237	392.983
37	4.6	1.096	0.128	363.504	37	69	1	53.4	7	1.8	32.5	4.9	234.293	84.286	318.579
38	5.5	1.508	0.144	268.272	37	77	1.2	69	6	1.5	32.5	4.5	262.772	44.804	307.577
39	4.8	3.444	0.219	250.416	36	33	1	48.3	5.7	2.2	32.5	3.9	124.938	37.368	162.307
40	4.8	2.661	0.189	309.936	36	29	1.4	59.3	9.8	1.5	34.5	7.2	152.512	32.520	185.032
41	5.1	2.538	0.184	274.224	37	34	1	65	8.6	1.9	13	5.6	95.235	41.159	136.394
42	4.9	1.225	0.033	214.704	18	50	1	22.5	8.7	2	17	7.4	109.074	52.503	161.578
43	4.9	3.376	0.193	161.136	128	34	2	45.4	10.1	1.5	28	7.3	137.096	54.372	191.469
44	5.2	4.927	0.276	482.544	37	73	1.2	67	5.3	1.6	34.2	3.3	235.679	85.864	321.544
45	4.3	1.796	0.155	375.408	18	23	1.4	49.6	12.9	1.5	24.5	7.1	306.477	74.788	381.266
46	5.5	4.598	0.263	155.184	109	35	1	89.5	9.4	1.5	36.8	5.9	217.466	61.987	279.453
47	5.4	3.362	0.312	327.078	183	30	1.2	23	4.5	1.5	13	3.9	19.142	48.189	67.332
48	4.3	3.856	0.279	324.184	74	43	1.4	18.2	5.5	2	13	4.4	30.558	37.622	68.181
49	4.7	2.703	0.190	292.08	36	49	1.2	14	5.1	2.2	12	4.2	26.777	43.984	70.761
50	5.3	0.225	0.035	161.136	37	40	1.5	47.2	8	1.5	32.5	5	162.618	56.261	218.88
51	5.1	2.868	0.259	278.567	220	54	1.7	68	5.1	1.5	32.8	3.9	143.314	52.129	195.443
52	4.7	4.519	0.196	101.616	189	88	1.4	15.5	4.6	1.5	8	3.9	25.184	31.568	56.753
53	5.6	3.980	0.239	196.848	73	22	1.4	11.5	4.1	1.5	7.5	3	5.314	39.762	45.077
54	4.9	3.362	0.215	292.08	146	38	1	49	4.3	1.4	17	3	66.027	47.562	113.59
55	4.2	4.144	0.176	328.216	204	13	1.4	77.5	19.1	1.5	27.6	12	313.796	41.462	355.259
56	5.2	0.478	0.105	59.952	165	10	1.8	47.5	13.7	1.9	24	8.6	131.323	24.673	155.997
57	4.4	5.916	0.314	571.824	146	32	1.3	57.4	5	1.4	36.9	3.7	183.308	51.763	235.072
58	4.6	2.950	0.2	143.28	110	37	2	33.5	3.2	1.9	20	2.5	39.677	49.352	89.029
59	4.3	0.643	0.111	119.472	183	15	1.7	37.4	5.9	1.8	25.2	4.9	73.676	56.679	130.355
60	4.1	4.639	0.265	137.328	73	21	1.3	29.2	3.3	2.3	10	2.1	16.181	62.537	78.718

61	4.9	4.598	0.263	214.704	146	12	1.5	33	7.3	2.1	20	4.1	45.105	31.548	76.653
62	4.9	2.867	0.196	101.616	220	11	1.5	52	16.9	1.7	25	11.3	125.998	36.764	162.762
63	5	5.834	0.311	351.6	110	16	1.2	66	9.7	1.5	39.2	6.5	284.488	39.651	324.139
64	4.9	5.834	0.311	440.88	183	12	1.7	45.5	11.4	1.5	25	8.2	119.664	33.237	152.901
65	5.1	4.392	0.255	476.592	73	18	1.2	57	7.6	1.5	35	5.7	208.928	37.863	246.791
66	5.3	3.362	0.215	190.896	37	34	1.7	11.5	5	1.5	16	4.6	19.778	46.398	66.176
67	4.9	4.309	0.252	268.272	37	26	1.3	31.5	8.1	1.5	19	5.6	80.278	52.634	132.912
68	4.9	5.628	0.303	161.136	238	28	1.2	38.1	6.1	1.9	12	4.1	20.113	34.520	54.633
69	5.1	5.916	0.314	315.888	55	38	1.5	34	6	1.5	28	4.1	80.676	26.631	107.307
70	5.4	5.133	0.284	387.312	183	12	1.2	52	11.7	1.5	34	8.9	129.052	49.395	178.447
71	5.2	2.332	0.176	345.648	73	27	1.6	66	8.8	1.5	28	5.5	167.569	43.968	211.537
72	5.6	3.406	0.217	298.032	165	16	1.5	36	11	1.5	35	8.7	158.867	30.793	189.66
73	4.9	1.099	0.025	196.848	110	18	1.3	49	10.7	1.5	26	7.1	213.672	32.291	245.963
74	5.5	3.856	0.235	268.272	73	60	1.7	14.2	6.6	1.7	15	5.1	56.124	25.094	81.218
75	4.8	1.096	0.128	244.464	201	22	1.5	57	12.7	1.8	28	8	120.022	35.092	155.114
76	5.1	5.010	0.279	214.704	72	36	1.2	66	6.8	2.4	29.9	5.2	131.809	41.952	173.761
77	5.1	4.927	0.276	565.872	128	42	1.4	9.2	5.5	2.2	10	4.5	19.577	20.719	40.296
78	4.4	2.744	0.192	232.56	165	26	1.4	64	7.7	1.5	35.9	5.5	157.142	36.669	193.811
79	4.6	1.310	0.252	196.848	37	26	1.5	34.6	7.1	1.5	32	5.6	88.541	47.289	135.83
80	5	4.557	0.261	244.464	37	19	1.3	46.5	10.3	1.5	27	6.9	137.551	42.940	180.491
81	5.6	3.362	0.215	405.168	73	30	1.6	13.9	6.7	1.5	13.5	5.7	30.609	31.075	61.684
82	4.7	4.680	0.266	399.216	18	11	1.4	81.5	15	1.5	30	6.3	207.561	33.196	240.757
83	4.9	1.942	0.217	264.832	67	16	1.4	34	8.6	1.5	26.5	5.3	95.862	56.926	152.788
84	5	0.256	0.081	232.56	165	14	1.3	33.5	5.3	1.5	28	4.1	56.377	42.435	98.812
85	4.7	0.224	0.065	369.456	165	10	1.5	51.5	19	1.8	32.2	12.8	233.873	32.079	265.952
86	4.7	0.684	0.113	244.464	55	13	1.6	78.5	21.8	1.6	37.5	12.9	86.352	76.982	163.334
87	4.8	4.721	0.268	309.936	275	26	1.8	15.4	7.6	1.5	15	6.2	32.339	44.155	76.494
88	5.3	2.006	0.292	286.138	58	44	1.6	11.5	5.6	1.8	12	4.5	22.545	34.176	56.721
89	4.7	3.238	0.211	488.496	37	15	1.2	67.5	10.9	2	24.5	5.3	83.629	35.097	118.726
90	5	2.249	0.261	321.564	128	8	1.6	46.5	16.5	1.9	27	11.2	199.646	29.762	229.408
91	4.8	3.234	0.193	193.456	68	7	1.5	51.5	18.1	1.5	31.8	11.3	45.26	38.371	83.631
92	5.3	5.339	0.292	381.36	65	9	1.2	61.5	18.6	1.5	27	10	236.145	41.649	290.814
93	5.1	2.678	0.324	328.491	127	8	1.8	38.3	11.8	2.2	29.6	7	93.736	27.292	121.028
94	4.3	2.249	0.173	178.992	110	8	1.3	62.5	14.4	1.7	37.5	10.7	72.913	47.826	120.739

95	4.7	2.532	0.214	156.934	65	13	1.5	43.3	14.3	1.5	23.3	8.7	160.868	41.372	202.24
96	5.1	2.332	0.176	190.896	37	20	1	71	9.4	1.5	32.5	5.7	249.477	34.982	34.459
97	4.9	3.977	0.168	243.112	58	25	1.5	17.5	6.9	1.5	12	5	24.097	43.236	67.333
98	5.2	3.567	0.324	328.478	73	17	2.6	65	13.9	1.5	15	6	104.229	33.762	137.991
99	4.9	2.148	0.251	298.364	65	27	1.2	19.5	7.3	1.5	12	5.2	25.534	38.456	63.99
100	5.4	2.744	0.192	542.064	55	14	1.6	50.7	21.2	1.9	35.9	12.9	78.277	56.839	135.116
101	5	4.598	0.189	268.419	146	16	1.2	44.2	12.2	1.5	29	9.6	198.26	46.761	245.021
102	5.2	3.376	0.324	220.596	128	6	2.5	60.3	24.4	2	32.9	13.6	69.982	39.472	109.454
103	5	3.568	0.223	321.84	73	15	1.3	49.5	10	1.5	33	7	144.706	28.972	173.678
104	5.5	2.332	0.176	286.128	37	19	1.3	62.7	16	1.5	38.6	9.5	89.801	32.576	122.377
105	5.3	0.684	0.184	256.197	55	13	1.5	43.2	10.2	1.4	32.9	5.6	127.466	35.567	163.033

Annex 7. Importance Value Index (IVI) of tree species in two different categories of community managed forests and when combining both categories of forests.

Where, F = Frequency, RF = Relative Frequency, D = Density, RD = Relative Density, BA = Basal area, RBA = Relative Basal Area, pls = plants, ha = hectare, ≥ 20 = forest category managed for ≥ 20 years & ≤ 11 = forest category managed for ≤ 11 years.

Species	**F (%)**		**RF (%)**		**D (pls/ha)**		**RD (%)**		**BA (%)**		**RBA (%)**		**IVI (%)**	
	≥ 20	**≤ 11**	**≥ 20**	**≤ 11**	**≥ 20**	**≤ 11**	**≥ 20**	**≤ 11**	**≥ 20**	**≤ 11**	**≥ 20**	**≤ 11**	**≥ 20**	**≤ 11**
Shorea robusta	100	100	11.0	14.3	2200	1018	52.5	50	0.387	0.301	81.78	82.8	145	147
Semecarpus anacardium	67	48	7.4	6.9	276	82	6.6	4.03	0.0098	0.007	2.078	1.8	16.0	12.7
Terminalia alata	65	50	7.2	7.1	212	106	5.1	5.21	0.0047	0.0082	0.987	2.26	13.2	14.6
Mallotus philippensis	71	46	7.8	6.6	307.3	80	7.3	3.93	0.0178	0.0012	3.765	0.32	18.9	10.8
Lagerstroemia parviflora	56	52	6.2	7.4	138.2	86	3.3	4.22	0.0152	0.0077	3.215	2.12	12.7	13.8
Cleistocalyx operculatus	47	22	5.2	3.1	118.2	38	2.8	1.87	0.0092	0.0044	1.955	1.21	9.9	6.2
Syzygium cumini	47	38	5.2	5.4	101.8	54	2.4	2.65	0.0053	0.002	1.122	0.55	8.7	8.6
Desmodium oojeinense	35	38	3.9	5.4	56	60	1.3	2.95	0.0039	0.0014	0.841	0.39	6.0	8.8
Lindera pulcherrima	2	6	0.2	0.9	4	8	0.1	0.39	0.000005	0.0002	0.001	0.07	0.3	1.3
Spatholobus parviflorus	22	32	2.4	4.6	36	56	0.9	2.75	0.0005	0.0021	0.111	0.59	3.4	7.9
Xeromphis spinosa	5	36	0.6	5.1	19	50	0.5	2.46	0.00004	0.0006	0.008	0.16	1.0	7.8
Adina cordifolia	24	10	2.6	1.4	38.2	28	0.9	1.38	0.000436	0.0003	0.092	0.07	3.6	2.9

Terminalia bellirica	25	6	2.8	0.9	36.4	8	0.9	0.39	0.000309	0.0033	0.065	0.91	3.7	2.2
Terminalia chebula	27	8	3.0	1.1	40	8	1.0	0.39	0.000472	0.0003	0.100	0.09	4.0	1.6
Grewia sp.	9	24	1.0	3.4	18.6	46	0.4	2.26	0.00029	0.0008	0.061	0.23	1.5	5.9
Phyllanthus emblica	9	22	1.0	3.1	18.5	38	0.4	1.87	0.000109	0.0017	0.023	0.48	1.5	5.5
Pinus roxburghii	7	2	0.8	0.3	3.6	6	0.1	0.29	0.002	0.0121	0.423	3.33	1.3	3.9
Grewia optiva	7	10	0.8	1.4	12.8	2	0.3	0.1	0.000018	0.00004	0.004	0.01	1.1	1.5
Dysoxylum binectariferum	13	2	1.4	0.3	19.7	2	0.5	0.1	0.000436	0.0004	0.092	0.11	2.0	0.5
Careya arborea	0	10	0.0	1.4	8	18	0.2	0.88	0	0.0032	0.000	0.87	0.2	3.2
Cassia sp.	7	8	0.8	1.1	9.1	4	0.2	0.2	0.000072	0.0001	0.015	0.03	1.0	1.4
Bauhinia purpurea	11	0	1.2	0.0	16.4	0	0.4	0	0.000036	0	0.008	0.00	1.6	0.0
Bauhinia variegata	5	2	0.6	0.3	11	2	0.3	0.1	0.000818	0.000004	0.173	0.001	1.0	0.4
Garuga pinnata	5	2	0.6	0.3	9.1	2	0.2	0.1	0.0002	0.000004	0.042	0.001	0.8	0.4
Toona ciliata	5	2	0.6	0.3	7.3	2	0.2	0.1	0.000109	0.000004	0.023	0.001	0.7	0.4
Ficus neriifolia	5	0	0.6	0.0	7.3	0	0.2	0	0.000054	0	0.012	0.000	0.7	0.0
Celtis sp.	4	2	0.4	0.3	5.5	2	0.1	0.1	0.000018	0.000004	0.004	0.001	0.6	0.4
Tectona grandis	0	6	0.0	0.9	0	6	0.0	0.29	0	0.000016	0.000	0.004	0.0	1.2
Schleichera oleosa	4	0	0.4	0.0	3.6	0	0.1	0	0.000036	0	0.008	0.000	0.5	0.0
Holoptelea integrifolia	0	4	0.0	0.6	0	6	0.0	0.29	0	0.00014	0.000	0.038	0.0	0.9
Dalbergia sissoo	0	2	0.0	0.3	0	4	0.0	0.2	0	0.0001	0.000	0.027	0.0	0.5
Ficus benghalensis	2	0	0.2	0.0	1.8	0	0.0	0	0.0002	0	0.035	0.000	0.3	0.0
Psidium guajava	0	2	0.0	0.3	0	2	0.0	0.1	0	0.000004	0.000	0.001	0.0	0.4
Casearia glomerata	78	52	8.6	7.4	220	124	5.3	6.09	0.007	0.00312	1.387	0.858	15.2	14.4
Macropanax undulatus	5	0	0.6	0.0	7.3	0	0.2	0	0	0.00008	0.012	0.000	0.7	0.0
Kharsha*	0	2	0.0	0.3	0	4	0.0	0.2	0.0028	0.00062	0.000	0.022	0.0	0.5
Pulayo*	31	24	3.4	3.4	34.5	38	0.8	1.87	0.00419	0.0026	0.592	0.170	4.8	5.5
Bhaira*	45	24	5.0	3.4	130.3	40	3.1	1.96	0.00027	0.000004	0.886	0.715	8.9	6.1
Dheudi*	42	2	4.6	0.3	32.3	2	0.8	0.1	0.00004	0	0.058	0.001	5.4	0.4
Kaubhala*	13	0	1.4	0.0	16.4	0	0.4	0	0.00005	0	0.008	0.000	1.8	0.0
Chiplopate*	4	2	0.4	0.3	5.5	2	0.1	0.1	0.00002	0.000004	0.004	0.001	0.6	0.4
Unidentified 1	5	2	0.6	0.3	7.3	2	0.2	0.1	0.00005	0.000004	0.012	0.001	0.7	0.4
Total	**909**	**700**	**100**	**100**	**4189**	**2036**	**100**	**100**	**0.473**	**0.364**	**100**	**100**	**300**	**300**

* represents the local name of species.

PHOTO PLATES

1. Collecting information from DFO Dadeldhura

2. Setting plot for sampling

3. Recording the plot characteristics

4. Measuring slope of plot

5. Measuring DBH of tree

6. Collecting the soil

7. Collecting information about CF during rest

8. On the way for locating the plot in CF

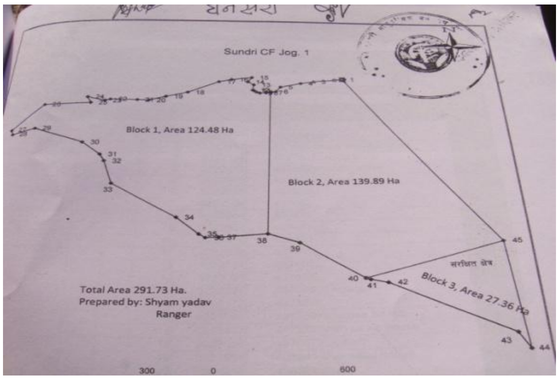
9. Counting seedling in Sundari CF

10. Ground vegetation in Khajurani CF

11. Soil samples in air tight plastic bags

12. Preparation of herbarium

13. Dansera CF



14. Map of Sundari CF