

**PLANT SPECIES DIVERSITY AND TREE CARBON STOCK IN A
SHOREA ROBUSTA Gaertn. COMMUNITY FOREST, NAWALPARASI,
NEPAL**

**A Dissertation Submitted for the Partial Fulfillment of
Master of Science in Botany (Plant Ecology)**

Submitted by

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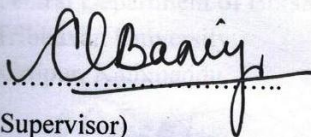
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RECOMMENDATION

This is to certify that the M.Sc. dissertation work entitled “ **Plant Species diversity and tree carbon stock in a *Shorea robusta* Gaertn. community forest, Nawalparasi, Nepal**” has been carried out by Mr. Ram Prasad Pathak under my supervision. The work is primarily based on the result of research work and has not been submitted for an 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), from Tribhuvan University, Nepal.



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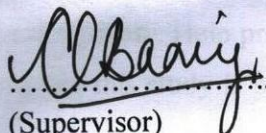


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LETTER OF APPROVAL

The M.Sc. dissertation entitled “**Plant Species diversity and tree carbon stock in a *Shorea robusta* Gaertn. community forest, Nawalparasi, Nepal**” submitted at the Central Department of Botany, Tribhuvan University by Mr. Ram Prasad Pathak, has been accepted for the partial fulfillment of requirements for Master’s of Science in Botany (Plant Ecology).

Expert Committee



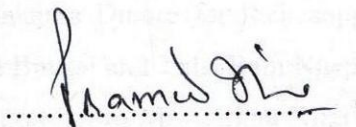
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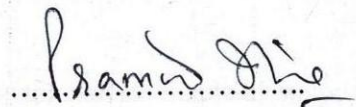
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ABSTRACT

Carbon trading and biodiversity conservation are hot issues at present global climate change. Carbon stock in tropical ecosystem is greater per hectare than elsewhere. *Shorea robusta* Gaertn. is one of the major forest components species in the tropical ecosystem of Nepal. Documentation of associated species in the tropical *Shorea robusta* community forest, their species richness and the carbon stock patterns are major objectives of this study. Thus, this present study has been initiated in the lowland (200 m asl), Bishnu Nagar Community Forest, Nawalparasi, Nepal. This forest has an area of 196.72 ha studied systematically after sampling it into 30 quadrates of 20 × 20 m² each encompassing all management blocks demarcated by Community Forest Users Groups (CFUGs). Species encountered inside each quadrat have been recorded and individual trees were tagged permanently for a year. Carbon stock for each tree calculated after using allometric equation. In addition, soil nitrogen, phosphorus, potash and pH were also measured. Detrended correspondence analysis (DCA), non metric multidimensional scaling (NMDS), correlations and regression methods were applied through R statistical packages. This study documented a total of 68 vascular plant species under 41 families and 61 genera. Fabaceae was the most dominant family (9 species) followed by Araceae (3 species). The first axis of DCA explained 7% of the total variance in the data set. Most species showed the significant linear relation to the major gradient (DCA Ist axis length = 1.4 unit). Abundance of *Indigofera decora* was highly correlated towards plots with the highest value of NMDS₁, may represent the grazing indicator. Likewise, *Albizia julibrissin* and *Typha angustifolia* significant on the NMDS₂ may represent the moisture loving species.

Soil nitrogen, phosphorus, organic matter and species richness were significantly correlated to the NMDS₁ but species richness is more significant to the NMDS₂. The average carbon stock value found to be 115 tons per hectare and tree stem volume was measured as 225.2 m³ per hectare.

Key words: Composition, detrended correspondence analysis (DCA), disturbance, Non-metric Multi Dimensional Scaling axis1 (NMDS₁), Non-metric Multi Dimensional Scaling axis 2 (NMDS₂), Silviculture.

TABLE OF CONTENTS

CONTENTS	PAGE NO.
1. INTRODUCTION	1
2. LITERATURE REVIEW	4
3. MATERIALS AND METHODS	7
3.1. Study area	7
3.2. Data Collection	9
3.3. Estimation of Carbon stock in biomass	11
3.4. Numerical Analysis	12
3.4.1. Pearson and correlation coefficient	12
3.4.2. Normality and regression	12
3.4.3. Nonmetric multidimensional scaling	13
3.4.4. Detrended Correspondence analysis (DCA) and Redundancy analysis (RDA)	13
4. RESULTS	14
4.1 Plant species diversity	14
4.2 Pearson correlation coefficient among the variables	15
4.3 DCA Summary	16
4.4 RDA Analysis	17
4.5 Tree carbon stock	22

5. DISCUSSION	24
5.1 Environmental variables in plain land	24
5.2 Species richness	24
5.3 Community forest and its management system	25
5.4 Tree carbon stock in the forest	25
6. CONCLUSION	27
REFERENCES	28
APPENDICES	36
Appendix 1: List of species encountered during this study their life form, short form and frequency.	36
Appendix 2: Plotwise Average Tree Biomass and Carbon stock for years 2013 and 2014.	38
Appendix 3: Regression table for variables.	40
Appendix 4: Soil Parameters Tests.	42
Appendix 5: Wood density of tree species used to estimate carbon stock using allometric Equation.	43
PHOTOPLATES	44

LIST OF TABLES

Table 1. Summary of variables used during this study.	15
Table 2. Pearson correlation coefficient matrix among variables.	16
Table 3. DCA summary.	16
Table 4: Total tree trunk volume and carbon stock by tree species per plot.	22

LIST OF FIGURES

Figure 1: Map of study area.	8
Figure 2: sampling plot design.	9
Figure 3. Species richness pattern with life form.	14
Figure 4. Species, environment and sample triplot after Redundancy analysis (RDA).	18
Figure 5: Relation between total species richness and carbon stock in 2013.	18
Figure 6: Relationship between total species richness and carbon stock in 2014.	18
Figure 7. Relationship between total species richness and NMDS1.	19
Figure 8: Relationship between total species richness and NMDS2.	19
Figure 9: Relation between total species richness and soil potassium.	19
Figure 10: Relation between herb richness and NMDS1.	19
Figure: 11 Relationship between tree richness and NMDS1.	20
Figure: 12 Relationship between tree richness and NMDS2.	20
Figure 13: Relationship between carbon stock and dbh (cm) of tree.	21
Figure 14: Relationship between height and dbh (cm) of tree.	21

ABBREVIATION AND ACRONYMS

°C	Degree Celsius
ABG	Above Ground Biomass
asl	above sea level
<i>et al.</i>	and others
C ₁₃	Carbon Stock in Year 2013
C ₁₄	Carbon Stock in Year 2014
CFUGs	Community Forest Users Groups
Climb	Climber
COP	Conferences of Parties
DBH	Diameter at Breast Height
DCA	Detrended Correspondence Analysis
DFO	District Forest Office
GAM	Generalized Additive Model
GHGs	Green House Gases
ha	Hectare
Hrb	Herb
IPCC	Intergovernmental Panel of Climate Change
K	Potassium
N	Nitrogen
NARC	Nepal Agricultural Research Council

NMDS	Nonmetric Multidimensional Scaling
OM	Organic matter
P	Phosphorous
RDA	Redundancy Analysis
REDD	Reducing Emissions from Deforestation and Degradation
SOM	Soil Organic Matter
Sppn	Total species richness
sqm	Square meter
UNFCCC	United Nations Framework Convention on Climate Change
VDC	Village Development Committee
yr	year

1. INTRODUCTION

Global forests store 4500 Gt carbon dioxide where as atmosphere store only 3000 Gt carbon dioxide (Prentice *et al.* 2001). Carbon trading and biodiversity conservation are two hot issues in the present global climate change. Carbon stock is valued as worth of each nation. Tropical ecosystem is believed to have greater amount of carbon storage per unit area than elsewhere (Garkoti and Singh 1995, Chave *et al.* 2005).

Tropical forests are characterized by high species richness, composition, standing biomass and productivity (Finegan, 2015, Baniya *et al.* 2010, O'Brien 1993, Jordan 1983) due to favorable climatic condition. Warm temperature, fast nutrient turnover rate, humid climate and long duration of precipitation throughout the year are some environmental factors for high species diversity, richness and biomass in the tropical lowland.

Nepal has tropical forests that lies in the low land between 100 to 1000 m above sea level (m asl). These forests are located in the Terai. *Shorea*, a single member of the family Dipterocarpaceae is the most successful and highly important timber species of this forest. Terai is rich in species diversity due the favorable climatic condition over long period. It is also the habitat for many endangered fauna species such as rhino. Terai is one of the highly disturbed landscapes due to over increasing human population in Nepal. Deforestation and destruction on the Sal forest is common here that directly and indirectly affect other ecosystems.

The distribution of *Sal* forest ranges from low land Terai ie., below 100 m above sea level (m asl) to 1500 m asl in the mid-hill (Gautam and Dovoie 2006). In the Terai the *Sal* is mainly associated with *Terminalia alata*, *Syzygium cumini*, *Carea arborea*, *Adina cardifolia*, *Lagerstroemia parviflora*. Lowland Sal forest is the suitable habitat for many kinds of unique species of trees, shrubs and herbs, climbers and ferns such as *Ampelocissus divaricata*, *Dephinium grandiflorum*, *Dioscorea alata*, *Dryopteris* sp., *Lygodium japonicum*, *Orisis wightina*, *Smilax spinosa*, *Clerodendrum viscosum*, *Curculigo capitulate*, *Chromolaena odorata*, *Indigofera decora*, *Osyris wightiana*, *Salvia officinalis*, *Stephania japonica*, *Zizyphus incurva*, mosses .

Terai refers to the southern low land belt of Nepal that ranges between east to west. Terai is characterized by rivers and valleys. Valleys are formed between the Siwalik and Mahabharat

ranges. Dense forest was located in the Terai before 1950's. After eradication of malaria, the condition changed a lot and there was a high migration in the Terai region from hilly regions and elsewhere of the country and new settlement started after deforestation (Schweik *et al.* 1997 and Mathews *et al.* 2000). Meantime an establishment of east-west highway also caused heavy destruction and fragmentation of the intact natural forest. Community forestry program is one of the highly successful programs for conservation and management of forest in Nepal (Subedi and Dhakal 2013, Shrestha and Jha 1997, Chakraborty, 2001). This program started relatively late in the country where dominance of the *Sal* forest was. Reason behind this would be a high value of this forest. Terai got community forest program not very long before than elsewhere in Nepal.

Before 1950s, about 75% of the central and western Terai, Nepal was covered by forest (Joshi, 2002). Now this has been reduced into 39.6 percent (Forest of Nepal 2012, Department of Forest). A total of 1793 community forest user groups are in Nepal, covering an area of 1.665 million hector of 5.5 million hector of total forest (DOF 2011, Subedi and Dhakal 2013). In community forest, user groups utilize the forest products in such a sustainable way that they get benefit from products without degrading the forest. Besides these successful activities on forest by community participation, there are some demerits of each community forest operation plan. Some common problems among community forests included are litter collections, tree species selection, and collection of dead plant parts and clearance of herbaceous and shrubby species during silviculture treatment. These treatments are one of the major causes of loss of biodiversity in community forests (Acharya *et al.* 2007). However, number of community forests is increasing day by day. This increasing number in community forests is a good contribution to reduce present day's global emission.

About 20% of total global green house gas emission occurs through deforestation and forest degradation (Gullison *et al.* 2007). There were very sophisticated modern techniques already invented and utilized to monitor amount of Carbon stored by each of the forest and its major species in developed countries. Methodological optimization and correctness are going on. However, developing counties as Nepal are far to reach that level. Initiatives have been taking place both by government and non-governmental organization. To address this issue, 13th Party of Conference (COP) in Bali 2007, a broader international agreement was made to pay for carbon accumulation by developing nation for reducing green house gases, (GHGs). This scheme

was initially named as REDD mechanism which later termed as REDD+ after COP 14 in Poland 2008 (Karky and Banskota, 2009).

The community forests of Terai region have potential power to reduce carbon emission and eligible to get compensation through REDD+. In spite of these extensive occurrence and importance from both economic and ecological aspects, lowland Terai Sal forest, its forest composition, amount of carbon stored at a semi-natural forest managed by community studied very less. Thus this present study has been undertaken in Bishnunagar Community Forest of Nawalparasi, Nepal to address these following objectives:

- i) to document the forest species occurred inside the Bishnunagar Community Forest
- ii) to find the species richness pattern inside the forest.
- iii) to estimate tree biomass, carbon stock and soil organic matter, soil nitrogen, phosphorus, potassium and pH.

Following are limitations of this study:

- the selected forest represented *Shorea robusta* only,
- there was a very little variation in altitude in the study area,
- only tree carbon stock was calculated excluding herb, shrub, litter, dead wood and soil carbon, and
- the tree height was considered as constant.

2. LITERATURE REVIEW

Globally, forest acts as a natural sink for carbon which contributes 80% and 40% of 4500 Gt terrestrial above and below ground storage respectively (Dixon et al 1994, Krischbaum, 1996, Prentice *et al.* 2001). About 1.41×10^{11} tons of global carbon equivalent to 37% of total is believed to be confined in the lowland latitudes (Dixon et al 1994, Prentice *et al.* 2001). However, lowland latitudinal forests are vanishing rapidly which trigger global warming, one of critical threats to climate change rapidly. It is also realized by the parties of Intergovernmental Panel of Climate Change (IPCC, 2007). Thus carbon storage in different lowland latitudes ecosystems should be documented strictly (IPCC, 2007).

Emission of green house gases played a vital role in climate change (IPCC 2007). Anthropogenic activities such as burning of fossil fuel, industrial effluents, forest degradation etc. increased green house gases (GHGs) tremendously (Vashum and Jayakumar, 2012). About 20% of total global green house gas emission occurs through deforestation and forest degradation (Stern, 2006, Gullison *et al.*, 2007 and Van der Werf *et al.* 2009).

The concept of REDD is based on governing the forest resources as long as the carbon reservoirs for the future by reducing the rate of deforestation and forest degradation ,Pokheral and Baral, 2009). The perspective of REDD+ regards co-benefits by biodiversity conservation, ecosystem protection, economic benefits, adaptation needs and community benefits (Chharre *et al.* 2012 and Joshi *et al.* 2013). Kyoto protocol was considered as the basis for reduction of carbon emission by providing the provision of carbon credit mechanism but failed to cover the reduction in deforestation, forest degradation and sustainable management of forests in developing countries (Karky and Banskota 2009). To address this issue, 13th Conference of Party (COP) of United Nations Framework Convention on Climate Change (UNFCCC) in Bali 2007, a broader international agreement was made to pay for carbon accumulation by developing nation for reducing green house gases (GHGs) Manandhar (2013). This scheme was initially named as REDD mechanism which later termed as REDD+ after COP 15 held in Poland 2008 (Karky and Banskota, 2009 and Manandhar 2013). Cop 18 was held in Doha in June 2013 with the aim of simplification and fastening the REDD+ performances (Manandhar ,2013).

In terrestrial ecosystems, functional diversity and relative abundance affect both the magnitude and variability of both above and below ground biomass. Aboveground biomass, in turn, considerably determines an ecosystem's capacity for carbon storage, which plays a chief role in the regulation of atmospheric carbon dioxide and global climate change. The potential for terrestrial carbon sequestration could be harshly changes by ensuring in composition of plant species (Bunker *et al.* 2005). The relationship between species diversity and aboveground biomass has been tested in herbaceous ecosystems (Bai *et al.* 2004). In tropical forests, conservative biodiversity manipulations are prohibitively expensive because of the large number of tree species as well as the size and long life of tropical trees (Bunker *et al.* 2005).

The history of Community forestry (CF) policy in Nepal starts from 1976, when the government launched the National Forest Plan, which acknowledged local people's rights to jointly manage the forest on which their livelihoods depended (Chettri *et al.* 2012). Moreover, the Forestry Master Plan of 1989 permitted the transfer of permanent status of all accessible forests in the hills to local people for control and ownership. Now there are 17,937 community forest user groups (CFUGs), consisting of 2.17 million households and managing 1.6 million ha of forests, a quarter of Nepal's total forestland (DOF, 2011 and Birendra *et al.* 2014).

Estimation of the stored biomass in the forest ecosystem is significant for assessing the productivity and sustainability of the plants. It also provides the knowledge about the amount of carbon that can be emitted in the form of carbon dioxide when forests are being burned (Vashum and Jayakumar 2012).

There are different models to estimate the above ground biomass given by different researchers. Mainly, forest biomass is estimated through field measurement, remote sensing and GIS methods (Lal 2005 and Lu 2006). Field measurements are divided into two methods that is harvesting or destructive method and non destructive method. Harvesting method is not suitable for large scale data and also not applicable for degraded forest and forest having threatened species (Montes *et al.* 2000). The way of estimating biomass by non-destructive method is simply measuring the diameter at breast height, height of the tree, volume of the tree and wood density (Ravindranath and Ostwald 2008) and biomass is calculated by using allometric equations (Brown *et al.* 1989

and Chave *et al.* 2005). Allometric regression model is very simple and scientific way to estimate the above ground biomass (Brown *et al.*1989 and Chave *et al.* 2005). Tree height, diameter at breast height (DBH) and specific wood density are parameters to estimate the above ground dry biomass (Mac Dicken 1997, IPCC2007). The best recommended models by IPCC (2007) were Chave *et al.* (2005) and Brown *et al.* (1989) equations.

3. MATERIALS AND METHODS

3.1 Study Area

3.11. Nawalparasi District:

Nawalparasi district is situated at the central Nepal in Terai region. Geographically the district is divided into three terrains i.e. southern Terai and gradual increasing altitudinal gradient (91m to 2136m) towards northern Bhitri Madhes and hilly region. The district covers an area of 2162 sq km and lies between 27°21” to 27°47”N and 83°36”to 84°25”E.

The district represents 154 community forests covering the area of 19515.39 hectare including 5470 households which is 3198134 population of the district (DFO, Nawalparasi, 2014). Besides this, there are 250 user groups of other community managed forests like religious forest, leasehold forest, and private forest. Forest covered 55.7 percentage of the total area in the district.

3.12. Study community forest

The study was conducted in Bishnunagar Community Forest lies in Shivamandir village development committee (VDC) now changed into Kawasoti Municipality, Nawalparasi, central Nepal (Figure 1). Nawalparasi is one of the districts of the Terai. This study area falls between 84°08.981’ E to 84°09.234’ E and 27°39.990’ N to 27°40.258’ N and altitude 195 m to 220 m above sea level (asl). The southern part of study area has buffer zone management forest which is separated by east-west highway where as the others three sides are bounded by other community forests. This study area covers an area of 196.72 ha.

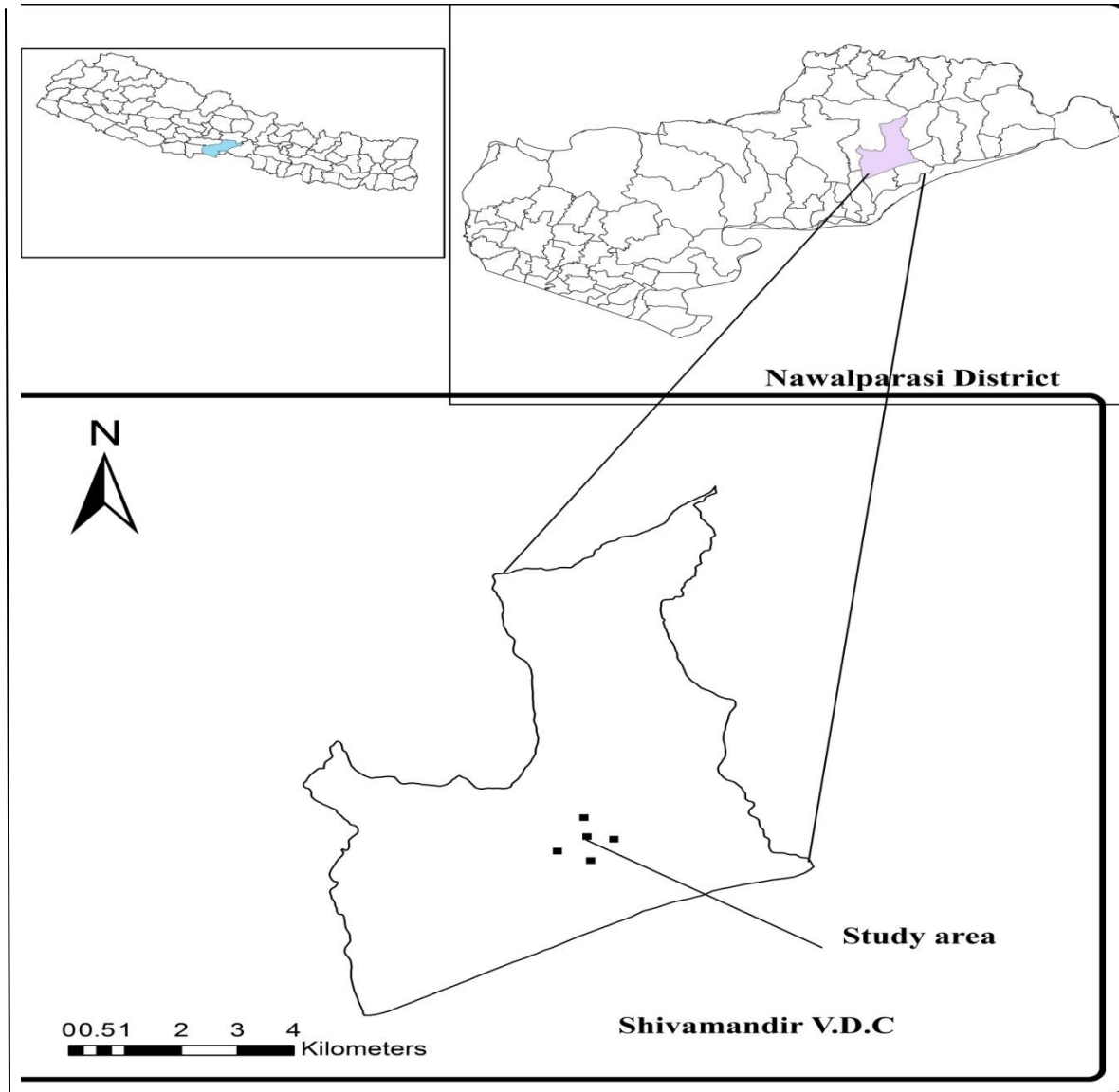


Figure 1: Map of study area

This study area represents the tropical forest dominated by the Sal (*Shorea robusta* Gaertn.) mixed with other tropical species such as *Lagerstroemia parviflora*, *Acacia catechu*, *Termenilia alata*, *Termenilia belerica*, *Syzcicum cumini*, *Premna integrifolia*, *Adina cordifolia*, *Bauhinia purpurea*, *careya arborea*, *Cassia fistula*, *Gmelina arborea*, *Lagrestroemia indica* , *Mallotus philippensis*, *Mariscus sumatrensis*, *Rhus wallichii*. Intact forest in the past has been fragmenting by the highway, human settlements and agricultural fields. The remaining small fraction is now regarded as the Bishnunagar Community Forest. This community forest is managing by 978 females and

1034 males of 364 households. This forest lies closer to the human settlement. Disturbances such as cattle grazing, timber cutting, forest fire, firewood and fodder collections are affecting the biodiversity of this forest.

The study area represents the tropical monsoon climate with summer, rainy and winter seasons. The maximum average temperature lies between 25.5°C to 36°C and average minimum temperature lies between 6°C to 8°C while recorded average annual rainfall is 2145 mm (<http://oneclicknepal.com/nawalparasi/>access on (08/31/2014).

3.2 Data collection

3.2.1 Locating the sampling plot and measurement.

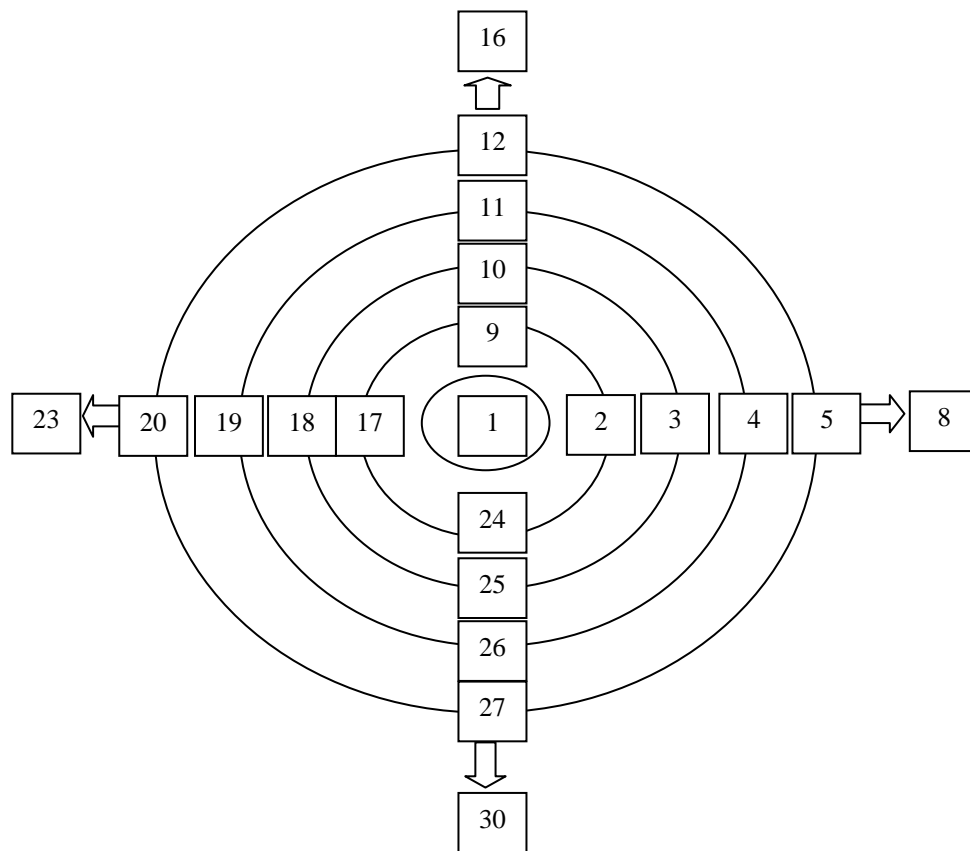


Figure 2: Sampling design

The field work was done for a complete year from July 2013 to 2014. A tentative mid-point for the community forest has been identified by the help of the local forest guard. That point was regarded

as the center of the first plot for this study. Other plots were placed at four directions in such a way that the minimum distance between two plots was 20 m and covering all three management blocks regulating by the community forest users. Altogether 30 plots of $20 \times 20 \text{ m}^2$ each were established (Baral *et al.* 2009). Every plot was divided into four subplots ($5 \times 5 \text{ m}^2$). Subplots were marked as A B, C, and D. Species enrooted in all subplots were recorded as 1 and unidentified species were collected, tagged and pressed safely for later identification. Absent of species within subplots were denoted by 0.

3.22 Plant collection, Herbarium Preparation and Identification

All plant species encountered inside each plot were identified with the help of the field guides (Siwakoti and Varma 1999) and local experts. Life-form of each species was recorded. Unidentified species were collected, tagged and pressed properly. Voucher specimens were made from properly dried specimens. Further confirmation of each plant specimen was done after consulting herbaria, relevant taxonomic literature and experts. Identified specimens were housed at Tribhuvan University Central Herbarium (TUCH). Nomenclature of angiosperms and pteridophytes were done by following Press *et al.* (2000) and Gurung (1985) respectively.

3.23 Soil collection:

Composite soil samples were collected from the four corners of each plot. Each soil sample was taken from 30 cm depth the ground (Wilbur and Christensen 1983). A mixture of 1 kg soil packed into the polythene bag for laboratory analysis. Each Soil sample was air dried first after bringing to the laboratory.

3.24 Laboratory Analysis:

Soil organic matter (SOM) was estimated by Walkley-Black method (Walkley and Black 1934). Soil pH was measured by suspension method. Soil Nitrogen by Kjeldahl digestion method, Phosphorous and Potassium were measured by Bingham and Ammonium acetate method respectively. All these methods were described in Black *et al.* (1965). These tests were carried out in the soil analysis laboratory of Nepal Agricultural Research Council (NARC), Khumaltar , Lalitpur, Nepal.

3.3 Estimation of Carbon Stock in Biomass

3.3.1 Estimation of Above ground Biomass:

A tree is defined as the species with a minimum diameter at breast height (dbh) of ≥ 5 cm at breast height (DBH) as Chave *et al.* (2005). Each tree was tagged and numbered permanently around 1.5 m above the ground. Height of each tree individual was calculated by clinometer and simple tape. Diameter of each tree at 137 cm above ground was measured by diameter tape. Diameter at breast height was re-measured exactly after one year from the same mark. Above ground biomass (ABG) was estimated by applying regression equation prepared by Chave *et al.* (2005).

$ABG = 0.0509 \times \rho D^2 H$. (As Chave *et al.* (2005), this equation might be suitable for this study as well as the moisture condition of this forest also lies between 1500 to 3500 mm).

Here,

ABG = above ground biomass (kg)

ρ = wood density (kg/m^3)

H = height of tree (m)

D = diameter of tree at breast height (cm)

Wood density differs as tree species. Zanne *et al.* (2009) prepared wood density index for global tree species. This standard wood density index value was also used for this study.

3.3.2 Estimation of Below Ground Biomass:

Generally 15% of above ground biomass believed to be the below ground biomass (Mac Dicken 1997).

3.3.3 Estimation of Carbon stock

Total carbon stock of individual living tree (above and below ground) species was calculated after multiplying its biomass by 0.47 (IPCC 2006). This constant value is taken as the default carbon fraction in dry biomass.

3.4 Numerical analyses

Information obtained from $5 \times 5 \text{ m}^2$ subplot was upscaled to $20 \times 20 \text{ m}^2$ plot. Thus each species encountered inside the plot ranged 0 to 4. All analyses were fully rely on the plot data not on the subplot. (Baral *et al.* 2009).

In this study, the total species richness, their functional derivatives and sequestered carbon per plot were response variables. Soil variables such as organic matter, nitrogen, phosphorus, potassium and pH were predictors.

3.4.1 Pearson correlation coefficient

Correlations among responses and predictors calculated after using Pearson Correlation method. Correlation Coefficient matrix was prepared with probability value (p) (Oksanen *et al.* 2013).

3.4.2 Normality and regression

Normality among variables was sought prior to statistical tests. Parametric method of regression such as Generalized Linear Model (GLM) and non parametric method of regression such as Generalized Additive Model (GAM) applied will be chosen after testing residual distribution. Most of the variables did not meet normal assumption of residual distribution. Thus the GAM (Hastie and Tibshirani, 1990) was applied. The smoother spline (s) was utilized via gam library (Hastie, 1992). Over dispersion in residuals was corrected after application of quasipoisson family of errors. Variance explained by each fitted gam model was accessed by the coefficient of determination (D^2) as Baniya *et al.* (2009).

$$D^2 = (\text{Null Deviance} - \text{Deviance}) / \text{Null Deviance}$$

Here D^2 is the coefficient of determination.

3.4.3 Nonmetric multidimensional scaling (NMDS)

It is an indirect gradient analysis in which samples were ordered in an ordination space based on various types of distances (Euclidean distance in this case) of species. Its axes were representative to underlying gradients. This gradient has been used to map samples in simplified, two dimensional ordination space (Shepard, 1966).

Allocation of plots as gradient was not feasible due to flatness of the landscape. Thus sample score values presented by NMDS axis1 and 2 utilized as environmental variables as Sahu *et al.* (2008).

3.4.4 Detrended correspondence analysis (DCA) and Redundancy analysis (RDA)

Zero inflation in the data matrix was first detected through change in axis length values during the DCA. This value was found higher in some of the higher axis. This error in the dataset may also cause multicollinearity. Thus these errors were corrected after removing only once and two times occurred species from the data set prior the multivariate analysis.

The Detrended correspondence analysis (DCA) resulted the first axis length value less than 1.5 sd units in the clean data set. This allowed us to choose Redundancy Analysis (RDA). During RDA the best fitted statistically significant environmental variables were chosen after regression, forward selection and permutations (Oksanen *et al.* 2013).

Statistically significant results from the RDA were shown by graphics. All analyses were done in R program (R Core Team 2014). Ordination and regression were done through *vegan* (Oksanen *et al.* 2013) and *gam* (Hastie, 1992) packages in R respectively.

4. RESULTS

4.1 Plant Species Diversity

This study recorded 68 plant species under 41 families and 61 genera (Appendix 1). Fabaceae was the richest family with nine species followed by Araceae, Euphorbiceae, Poaceae and Rubiceae with three species each.

These recorded species were categorized under four life forms (herb, shrub, climber and tree). Herb was the most dominant life form with 23 species followed by tree (22), shrub (16) (Figure 3).

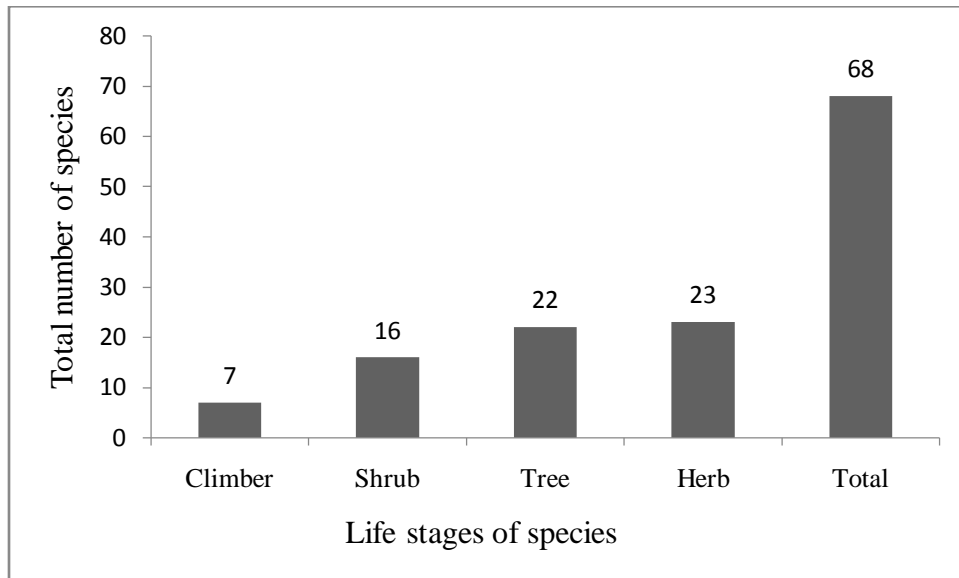


Figure 3. Species richness pattern with life stages.

This study included nine environmental and five species variables (Table 1). The total species richness per plot (sppn) was the counting response variable with value ranged between 21 to 40 and 28 species as the mean for this study. Similarly, climber species richness per plot (clmb) counted values from 4 to 7 with mean number 5.5. Soil pH is a ranked environmental variable recorded 4.7 to 5.4 (Table 1).

Table 1. Summary of variables used during this study.

S.No.	Variables	Short form	Unit	Minimum	1st Quartile	Median	Mean	Standard deviation	3rd Quartile	Maximum
1	Total species richness	Sppn	Number	21	25	26.5	27.9	4.5	29	40
2	Climber species richness	Clmb	Number	4	5	6	5.5	0.9	6	7
3	Herb species richness	Hrb	Number	0	0	1	0.8	0.9	1	3
4	Shrub species richness	Shrb	Number	0	0	1	0.8	0.9	1	3
5	Tree species richness	tree	Number	2	4	5	4.8	1.7	5	10
6	NMDS1	NMDS1	Score	0.9	6.5	7.6	8	3	9.4	14.6
7	NMDS2s	NMDS2	Score	2.3	6.8	8	8	2.4	9.4	12.6
8	Carbon stock 2013	C13	t/ha	5.4	62.9	115.15	114.9	67.62	153.32	289.7
9	Carbon stock 2014	C14	t/ha	5.6	63.5	116	115.7	67.47	153.5	290.2
10	Soil pH	pH	rank	4.7	5	5.1	5.1	0.18	5.2	5.4
11	Soil organic matter	Om	%	1	1.9	2	2.1	0.6	2.4	3.6
12	Soil Nitrogen	N	%	0.07	0.09	0.1	0.13	0.14	0.12	0.9
13	Soil Phosphorus	P	kg/400 sqm	0.64	1	3.4	3.2	2.3	4.4	8.1
14	Soil Potash	K	kg/400 sqm	4.7	6.9	8.4	8.6	2.8	10	16.2

4.2 Pearson correlation coefficient matrix among variables

The total species richness was found statistically significant positive correlation ($p \leq 0.05$) with herb richness, shrub species richness, tree species richness and soil potassium but statistically negative significant correlation ($p \leq 0.05$) to NMDS1 (Table 2). A positive correlation was found between total species richness and carbon 13 as well as carbon 14 but not statistically significant. Herb richness was found statistically positive significant correlation with soil potassium and phosphorus. Similarly, statistically positive significant relation was found between soil potassium and pH.

Table 2. Pearson correlation coefficient matrix among variables

	sppn	Clmb	hrb	shrb	tree	NMDS1	NMDS2	C13	C14	pH	Om	N	P
clmb	0.32	1											
hrb	0.68*	0	1										
shrb	0.61*	-0.09	0.27	1									
tree	0.77*	0.29	0.19	0.3	1								
NMDS1	- 0.51*	-0.31	-0.25	0.01	- 0.65*	1							
NMDS2	0.11	0.01	-0.1	0.07	0.25	-0.01	1						
C13	0.27	0.2	0.25	0.1	0.14	-0.17	-0.03	1					
C14	0.27	0.2	0.25	0.11	0.14	-0.17	-0.03	1	1				
pH	0.29	0.31	0.05	0.19	0.27	-0.2	-0.09	0.21	0.21	1			
om	0.22	-0.25	0.14	0.38*	0.13	0.05	-0.1	0.25	0.24	-0	1		
N	-0.07	-0.08	0.03	-0.25	0.04	-0.14	0.06	0.03	0.03	-0	-0.1	1	
P	0.29	-0.15	0.42*	0.25	0.06	0.38*	-0.19	0.17	0.17	0.1	0.34	-0.2	1
K	0.54*	0.29	0.38*	0.22	0.43*	-0.38*	-0.22	0.32	0.32	0.54*	0.35	0.05	0.11

Bold entry with '*' sign indicated statistical significant value(≤ 0.05).

4.3 DCA Summary

Table 3. DCA summary

Variables	DCA1	DCA2	DCA3	DCA4
Eigen value	0.09	0.08	0.08	0.07
Decorana value	0.13	0.10	0.07	0.05
Axis lengths	1.38	1.33	1.32	1.14
CA Total Inertia	1.34			

The sample by species data matrix resulted 1.4 standard deviation (sd) unit length of gradient value by the first axis of Detrended Correspondence Analysis (DCA) (Table 3). This length of gradient was found decreasing gradually with increasing axis. This first axis showed almost 7% of the total variance explained by the data set. This variance explained was found almost similar

(6%) of the total variance explained by the second and third axis. This DCA confirmed the linear pattern among species along samples and allowed to choose linear direct ordination method which is Redundancy Analysis (RDA).

4.4 RDA Analysis

Statistically significant axes were obtained by RDA. This redundancy analysis (RDA) gave four significant environmental variables viz. NMDS1, NMDS2 and soil Phosphorus (P) and pH after permutations with their species scores. The number of permutations was taken as default (199). The NMDS1 and P represented significantly the first axis of RDA (Figure 4). Similarly, NMDS2 and pH denoted statistically significant second axis of RDA. The abundance of *Shorea robusta* (*Shor robu*) in this study was found significantly explained by all four significant environmental variables. Abundance of *Indigofera decora* was highly correlated towards plots with the highest value of NMDS1 and P. The highest abundance of *Osyris wightiana*, *Mariscus sumatrensis* were supported the pots with significantly least value of NMDS1 (core of the forest). The abundance of *Murraya paniculata*, *Calotropis gigantea* was significantly correlated towards plots with the highest value of P. Similarly, *Ravolfia serpentine*, *Camelina sativa*, *Thyponium trilobatum* were supported by plots with significantly high value of pH. On the other hand, the highest abundance of *Borreria articularis* was found towards plots with significantly least value of pH. The abundance of *Albizia julibrissin* and *Typha angustifolia* were supported significantly towards the plots with higher value of NMDS2. The abundance of *Arisaema speciosum* supported the least value of NMDS2.

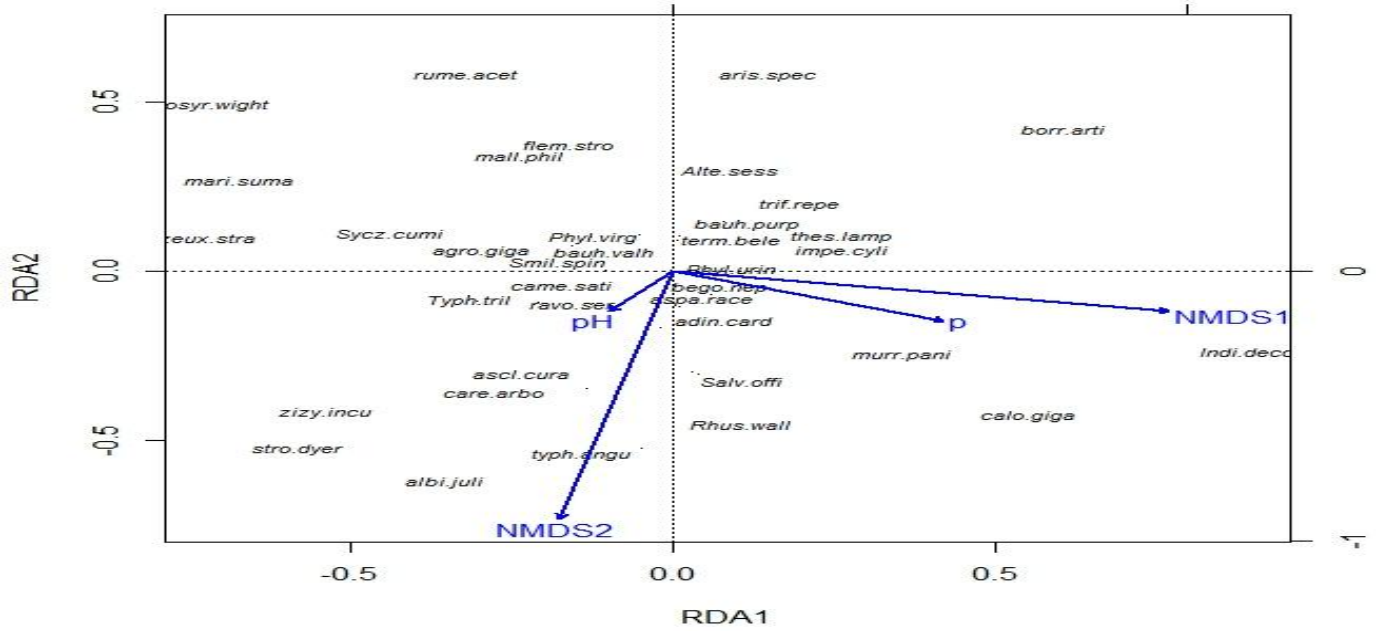


Figure 4. Species, environment and sample triplot after Redundancy analysis (RDA).

The total species richness showed statistically significant positive relationship with carbon stock in 2013 and 2014 (Figure 5, 6 and Appendix 3). The highest richness of 35 species obtained at maximum carbon stock.

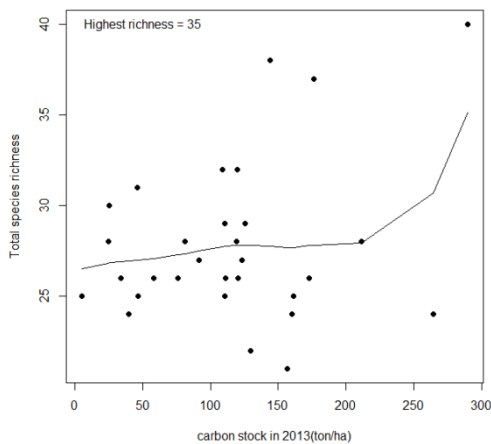


Figure 5: Relation between total species richness and carbon stock in 2013

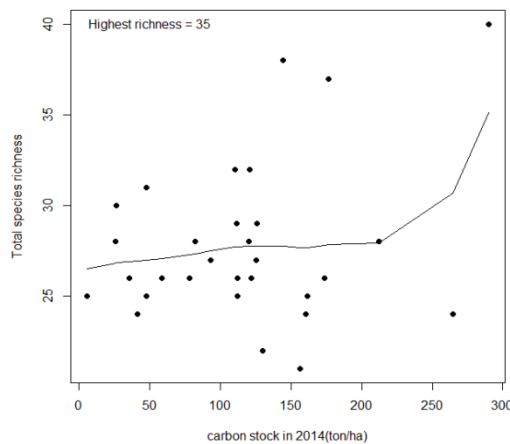


Figure 6: Relationship between total species richness and carbon stock in 2014

Total species richness was found significantly decreasing relationship with NMDS1 (Figure 7, Appendix 3). Similarly, there was significant non linear relationship between total species richness and NMDS2 (Figure 8, Appendix 3).

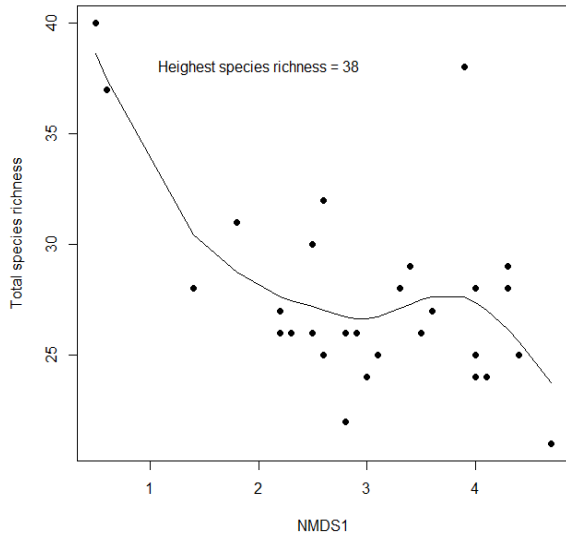


Figure 7. Relationship between total species richness and NMDS1

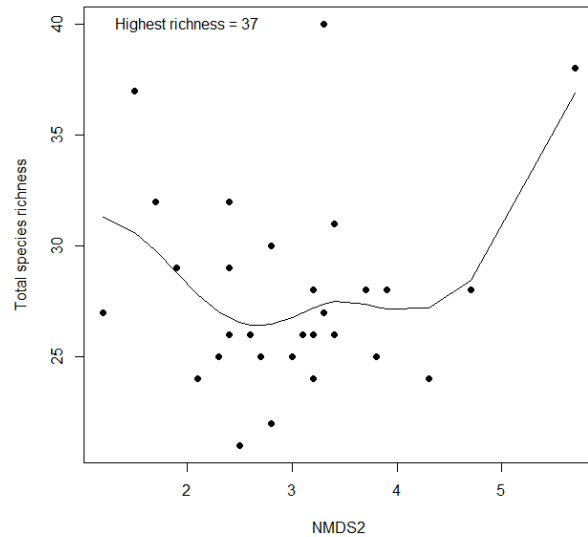


Figure 8: Relationship between total species richness and NMDS2

Similarly, there was a significant positive non linear relationship between total species richness and soil potassium, herb richness and NMDS1 (Figure 9, 10 and Appendix 3).

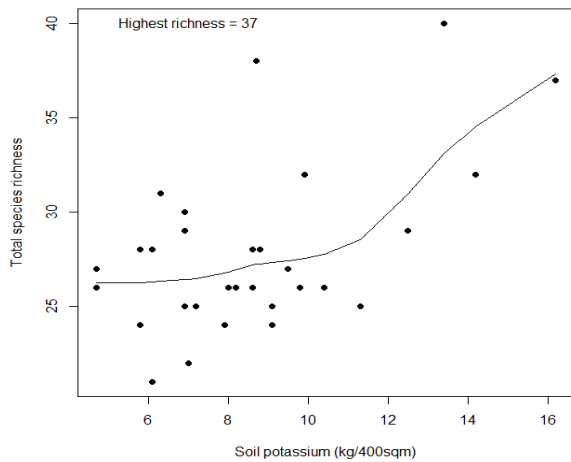


Figure 9: Relation between total species richness and soil potassium

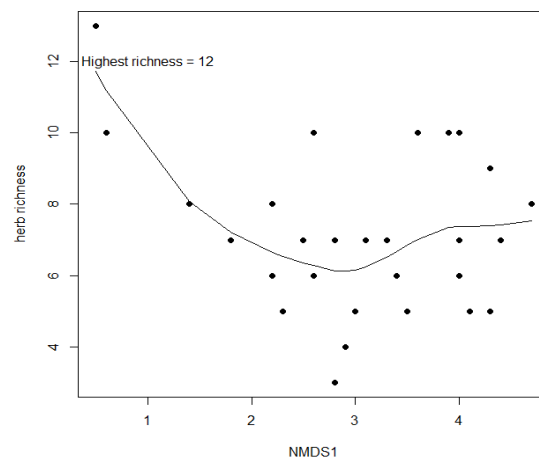


Figure 10: Relation between herb richness and NMDS1

Tree richness was found as statistically positive significant non linear relationship with NMDS1 and NMDS2.(Figure 11, 12 and appendix 3). The highest tree richness of 13 species was obtained at maximum values of NMDS axes.

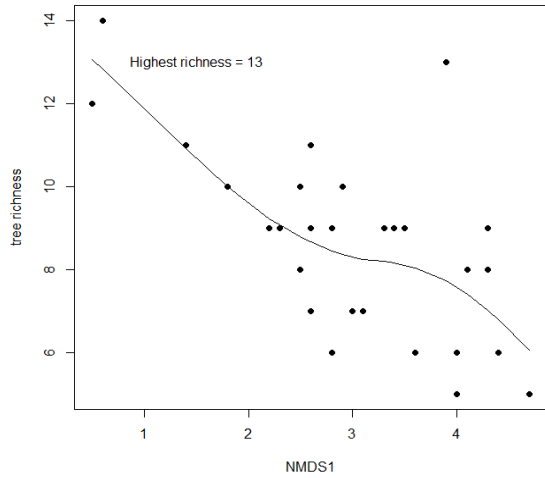


Figure: 11 Relationship between tree richness and NMDS1.

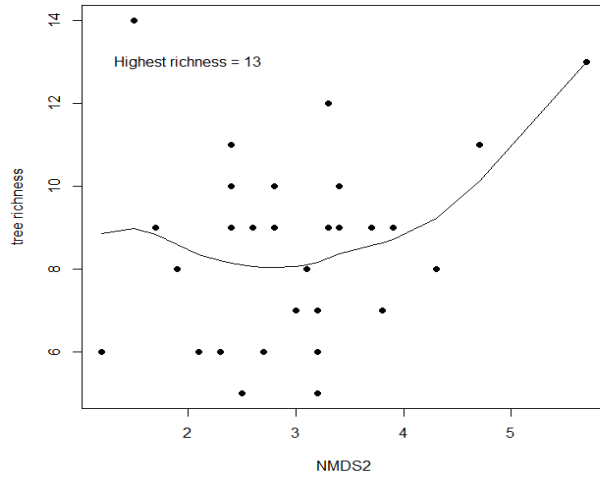


Figure: 12 Relationship between tree richness and NMDS2.

There is a statistical significant positive linear relationship between carbon stock and diameter at breast height (Figure 13).

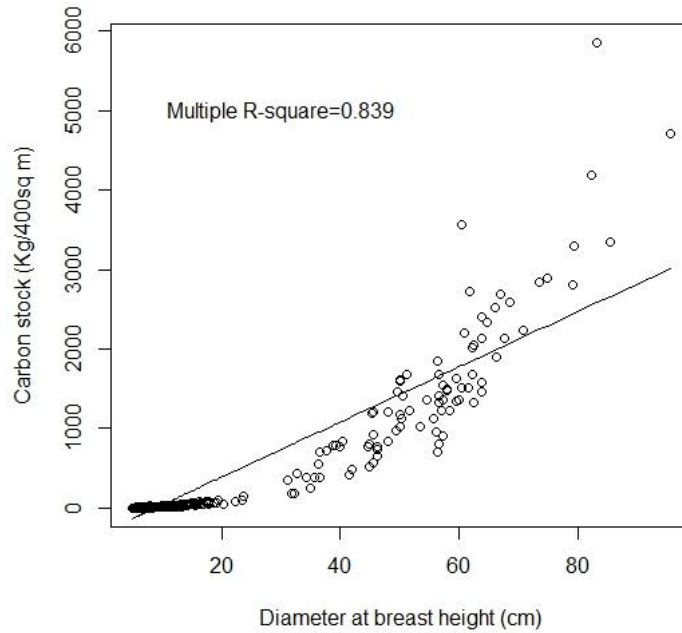


Figure 13: Relationship between carbon stock and dbh (cm) of tree.

There is also a statistical significant positive linear relationship between height and diameter at breast height (Figure 14).

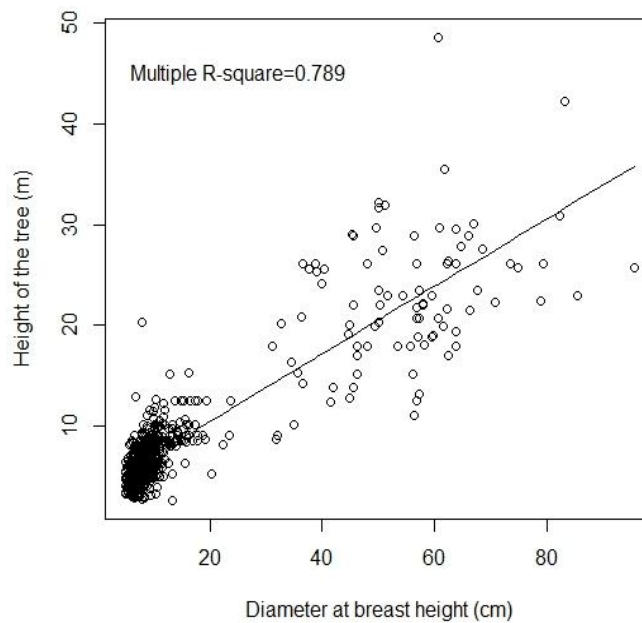


Figure 14: Relationship between height and dbh (cm) of tree.

4.5 Tree carbon stock.

The DBH of the total 651 tree individuals tagged ranged between 5.1 cm to 59 cm. Similarly, their height ranged from 3.84 m to 21 m. Average tree trunk volume for years 2013 and 2014 were 224.4 m³/ha and 226 m³/ha respectively that equivalent to 114.9 t/ha and 115.7 t/ha carbon stock respectively (Table 4). The rate of carbon stock increase was found 0.8 t/ha/yr.

Table 4: Total tree trunk volume and carbon stock by tree species per plot.

S. No.	Total TTV m ³ /400m ²		Total Carbon Stock kg/400 m ²		TTV m ³ /ha		Carbon Stock t/ha	
	Year2013	Year2014	Year2013	Year2014	Year2013	Year 2014	Year 2013	Year 2014
1	22.6	22.7	11587.9	11608.3	566.0	567.0	289.7	290.2
2	8.5	8.6	4359.7	4413.0	213.0	215.3	109.0	110.3
3	13.8	13.8	7050.0	7059.6	344.5	344.8	176.2	176.5
4	9.4	9.5	4804.7	4841.7	234.8	236.8	120.1	121.0
5	3.6	3.8	1862.6	1918.0	91.0	93.8	46.6	47.9
6	10.1	10.2	5187.3	5203.5	253.5	254.0	129.7	130.1
7	8.7	8.7	4424.0	4450.1	216.3	217.3	110.6	111.3
8	6.0	6.1	3054.1	3115.4	149.3	152.3	76.4	77.9
9	9.6	9.8	4932.0	5024.0	241.0	245.0	123.3	125.6
10	4.6	4.6	2339.3	2348.7	114.3	114.5	58.5	58.7
11	6.4	6.4	3255.4	3280.4	159.0	160.3	81.4	82.0
12	11.3	11.3	5752.7	5785.4	281.3	282.5	143.8	144.6
13	13.5	13.6	6917.9	6946.4	338.0	339.5	172.9	173.7
14	2.0	2.0	1001.0	1019.1	49.0	49.8	25.0	25.5
15	9.3	9.4	4770.6	4803.1	233.0	234.8	119.3	120.1
16	7.1	7.2	3659.0	3717.9	177.0	179.8	91.5	92.9
17	2.7	2.8	1367.9	1413.2	66.8	69.0	34.2	35.3
18	8.7	8.8	4438.9	4477.2	217.0	218.8	111.0	111.9
19	9.4	9.5	4807.1	4870.4	234.8	238.0	120.2	121.8
20	12.2	12.2	6259.0	6259.3	305.8	305.8	156.5	156.5
21	20.7	20.7	10577.1	10587.0	516.8	517.3	264.4	264.7
22	2.0	2.1	1020.2	1065.1	49.8	52.0	25.5	26.6
23	16.5	16.5	8450.3	8487.8	413.0	413.0	211.3	212.2
24	9.8	9.8	5026.4	5028.7	245.5	245.8	125.7	125.7
25	12.6	12.6	6458.7	6462.7	315.5	315.8	161.5	161.6

26	3.6	3.7	1842.6	1899.9	90.0	93.0	46.1	47.5
27	3.1	3.2	1591.4	1652.3	77.8	80.5	39.8	41.3
28	0.4	0.4	216.9	225.6	10.5	11.0	5.4	5.6
29	12.5	12.6	6401.4	6428.6	312.8	314.0	160.0	160.7
30	8.7	8.8	4431.0	4481.9	216.5	219.0	110.8	112.0

5. DISCUSSION

5.1 Environmental variables in plain land

Tropical lowland of Nepal distinguishes by almost plain land. A gentle gradient is a common phenomenon of the lowland. This study completely represents the part of it. Gradient analysis research is rather complicated here. This difficulty can overcome through an application of the NMDS first and second axis values as explanatory variables. The NMDS1 may act as a disturbance gradient for this study where the core of the forest has many grazing tolerant species which host much number of grazing sensitive species as refuges. As the value of NMDS1 increases number of palatable species for cattle are decreasing which may indicate high disturbance. The second axis may represent the soil moisture gradient as having higher abundance of moisture loving species, alluvial soil loving species towards centre of the community forest, are found growing towards greater value of Phosphorus. These two axes were taken as environmental variables to explain species richness and its derivatives.

All statistically significant results among soil variables (pH, N, OM, P and K), C13, C14, NMDS1 and NMDS2 with total species and its derivatives indicated a close relation among biotic and abiotic components in an ecosystem. Plant species diversity pattern depends on various biotic and abiotic factors (Ayappan and Parthasarathy 1999). Discrepancies among variables may indicate special peculiarity within this system.

5.2 Species richness

Total species richness by plot stood as the most strong response variable of this study that showed statistical significant relations to its functional group richness. Tree, shrub and climbers richness indicated their major significant share to the total species richness. Different herb species found confined from the mean to the highest end of the NMDS1 gradient. It can be articulated with disturbance related species richness pattern. High disturbance after clearing biomass towards the periphery of the community forest may facilitate more palatable herbaceous species towards periphery. Conversely, more diversity and richness were found towards the other end of the NMDS1 gradient. Grazing tolerant species specialized by thorny outgrowths may nucleate more specialist inside their habitat. The newly created safe habitats may attract more number of species which ultimately favor higher species richness. Thus decreasing pattern of

total species richness with NMDS1 is justified. This view is very much closer with many previous studies such as Grime (1973), Connell (1978), Mc Cabe and Gotelli (2000).

5.3 Community forest and its management system

Species preferences, selection and removal during silvicultural treatment and litter collection cause the loss of biodiversity in community managed forest (Shrestha *et al.* 2010). Community forest user groups (CFUGs) divided the forest into different blocks for better management plans. Every year the user groups clear the unwanted plants like pteridophytes, climbers, shrubs and other important herbs from their target block (Acharya *et al.* 2007). Due to such activities least plant species diversity was found and mixed *Sal* forest is gradually changing into monospecific forest stand. The positive correlation between climber and tree species indicates the dependency of tree species for climber also indicated. First axis length of DCA was 1.4 which indicated low turnover of new species and beta (β) diversity of the species in the study area.

5.4 Tree Carbon stock in the forest

Less increment of carbon stock in this study resembled matured forest. Measurement of the rate of carbon stock in community forests located at Kathmandu, Ilam and Manang (Banskota *et al.* 2007) were found to be 1.41 t/ha/yr, 3.1 t/ha/yr and 1.13 t/ha/yr respectively. All these values were higher than this study. Shrestha (2008) estimated the carbon stock by three different forest types in Palpa district and found as *Pinus rixburghi* forest (155.62 t/ha), *Shorea robusta* forest (105.3 t/ha) and *Schima-Castanopsis* forest (47.08 t/ha). Baral *et al.*(2009) found the total carbon stock of tropical riverine forest 80.47 t/ha and rate of carbon stock change 3.21 t/ha/yr. in chitwan district .similarly the carbon stock in foot hill was found 97.86 t/ha and sequestration was 1.3t/ha/yr. The carbon stock of the present study area showed greater than the same forest type in Palpa district. This may be due to different locations of similar forest type ie, Terai (Nawalparasi) and in mid- hill (Palpa). The carbon stock differs by vegetation type, their wood density, annual precipitation and age of the forest. The study site is a semi natural *Shorea robusta* (tropical) forest. More than 40% of trees crossed the aged more than 50 years. Such semi natural forests have high accumulation of biomass but low carbon stock increase rate. Older trees of *Sal* shows slow gain of carbon by year.

Global tropical lowland latitudes are considered as heterogeneous and contained 59 % of global forest vegetation (Dixon *et al.* 1994). Generally, tropical ecosystem has high species richness and diversity due to fast nutrients turnover rate. This finding justified this present study.

6. CONCLUSION

Latent environmental variables such as NMDS1 and NMDS2 explained significantly the species composition, carbon stock and species richness patterns in this study. *Shorea robusta* was favored moderately by all measured and observed environmental variables. *Indigofera decora* was significantly explained by the high value of NMDS1 and soil P whereas *Osyris wightiana*, *Mariscus sumatrensis* were supported by their least value. The total species and its derivatives such as herb richness and tree richness showed statistically significant linear decreasing relationship with NMDS1 but increasing pattern with carbon stock. Carbon stock for 2013 was measured as 114.9 t/ha and for 2014 was 115.7 t/ha.

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APPENDICES:

APPENDIX I: List of species encountered during this study their life form, short form and frequency.

S. No.	Name of Species	Family	Life form	Short form	Frequency
1	<i>Adina cordifolia</i> (wild. ex Roxb.)	Rubiaceae	Tree	Adin card	7
2	<i>Agrostis gigantea</i> Roth	Poaceae	Herb	Agro giga	2
3	<i>Albizia julibrissin</i> Durazz.	Fabaceae	Tree	Albi juli	9
4	<i>Alternanthera sessilis</i> (L.) DC	Amaranthaceae	Herb	Alte sess	10
5	<i>Ampelocissus divaricata</i> (Wall. ex M. A. Lawson) Planch	Vitaceae	climber	Ampe diva	30
6	<i>Ariopsis peltata</i> Nimmo	Araceae	Herb	Ario pelt	27
7	<i>Arisaema speciosum</i> (wall.) marlo.ex Schott	Araceae	Herb	Aris spec	15
8	<i>Asclepias curassavica</i> L.	Asclepiadaceae	Shrub	Ascl cura	8
9	<i>Asparagus racemosus</i> Wild	Liliaceae	Herb	Aspa race	1
10	<i>Bauhinia purpurea</i> L.	Fabaceae	Tree	Bauh purp	4
11	<i>Bauhinia valhii</i> Wight and Arn.	Fabaceae	climber	Bauh valh	7
12	<i>Begonia nepalensis</i> (A. DC.) Warb	Begoniaceae	Herb	Bego nepa	1
13	<i>Borreria articularis</i> (l.f.) F.N. will	Rubiaceae	Herb	Borr arti	8
14	<i>Calotropis gigantea</i> (L.) Dryand	Asclepiadaceae	Shrub	Calo giga	10
15	<i>Camelina sativa</i> L.	Brassicaceae	Herb	Came sati	1
16	<i>Careya arborea</i> Roxb.	Lecythidaceae	Tree	Care arbo	13
17	<i>Cassia fistula</i> L.	Fabaceae	Tree	Cass fist	9
18	<i>Chromolaena odorata</i>	Asteraceae	Shrub	Chro odor	7
19	<i>Clerodendrum viscosum</i> Vent.	Lamiaceae	Herb	Clero serr	30
20	<i>Conyza japonica</i> (Thunb.) Less.	Asteraceae	Herb	Coni japo	1
21	<i>Curculigo capitulata</i> (Lour.) Kuntze	Hypoxidaceae	Herb	Curc capi	30
22	<i>Curcuma aromatica</i> Salisb.	Zingiberaceae	Herb	Curc arom	6
23	<i>Cynodon dactylon</i>	Poaceae	Herb	Cyno dact	1
24	<i>Cyperus rotundus</i> L.	Cyperaceae	Herb	Cype rotu	5
25	<i>Delphinium grandiflorum</i> L.	Ranunculaceae	Tree	Deph gran	8
26	<i>Dioscorea alata</i> L.	Dioscoreaceae	climber	Dios alat	30
27	<i>Dioscorea bulbifera</i> L.	Dioscoreaceae	climber	Dios bulb	30
28	<i>Flemingia strobilifera</i> (L.) W. T. Aiton	Fabaceae	Shrub	Flem stro	15
29	<i>Floscopa scandens</i> Lour	Commelinaceae	Herb	Flos scan	22
30	<i>Gmelina arborea</i> Roxb.	Verbenaceae	Tree	Gmel arbo	2
31	Ground orchid (<i>zeuxine strateumatica</i>)(Lindl.)	Orchidaceae	Herb	zeux stra	17
32	<i>Imperata cylindrica</i> (L.) P. Beauv	Poaceae	Herb	Impe cyli	7

33	<i>Indigofera decora</i> Lindley	Fabaceae	Shrub	Indi deco	15
34	<i>Lagerstroemia parviflora</i> Roxb.	Lythraceae	Tree	Lage parv	30
35	<i>Lagerstroemia indica</i> L.	Lythraceae	Tree	Lage indi	4
36	<i>Leea asiatica</i> L.	Leeaceae	Shrub	Leea asit	11
37	<i>Lygodium japonicum</i> (Thunb.) Sw.	Lygodiceae	climber	Lygo japo	30
38	<i>Mallotus philippensis</i> (Lam.) Mull. Arg	Euphorbiaceae	Tree	Mall phil	12
39	<i>Mariscus sumatrensis</i> (Retz.) T. Koyama	Cyperaceae	Tree	Mari suma	14
40	<i>Millettia extensa</i> (Benth.) Baker	Fabaceae	Herb	Mill exte	1
41	<i>Murraya koenigii</i> (L.) Spreng.	Rutaceae	Tree	Murr koen	2
42	<i>Murraya paniculata</i> (L.) Jack	Rutaceae	Shrub	Murr pani	19
43	<i>Osyris wightiana</i> Wall. ex Wigh	Santalaceae	Tree	Osyr wight	19
44	<i>Phyllanthus urinaria</i> L.	Euphorbiaceae	Herb	Phyl urin	2
45	<i>Phyllanthus virgatus</i> G. Forst.	Euphorbiaceae	Shrub	Phyl virg	1
46	<i>Pogostemon benghalensis</i> (Burm.f.) Hassk.	Labiatae	Shrub	Pogo beng	26
47	<i>Premna integrifolia</i> L.	Verbenaceae	Tree	Prem inte	1
48	<i>Ravolfia serpentina</i> (L.) Benth	Apocynaceae	Shrub	Ravo serp	1
49	<i>Rhus wallichii</i> Hook. f.	Anacardiaceae	Tree	Rhus wall	2
50	<i>Rumex acetosa</i> L.	Polygonaceae	Shrub	Rume acet	16
51	<i>Salvia officinalis</i> L.	Lamiaceae	Herb	Salv offi	14
52	<i>Senna reticulata</i> (Willd.) H. S. Irwin & Barneby	Fabaceae	Shrub	Senn reti	1
53	<i>Shorea robusta</i> Gaertn.	Dipterocarpaceae	Tree	Shor robu	30
54	<i>sida cardifolia</i> L.	Malvaceae	Shrub	Sida card	1
55	<i>Smilax spinosa</i> Mill.	Smilacaceae	climber	Smil spin	13
56	<i>Stephania japonica</i> var. <i>discolor</i> (Thunb.) Miers S. Moore	Menispermaceae	climber	Step japo	24
57	<i>Strobilanthes divaricata</i> (Nees) T. Anderson	Acanthaceae	Shrub	Stro diva	12
58	<i>Syzygium cumini</i>	Myrtaceae	Tree	Sycz cumi	19
59	<i>Terminilia alata</i> Heyne ex. Roth	Combretaceae	Tree	Term alat	1
60	<i>Terminilia belerica</i> (Gaertn) Roxb	Combretaceae	Tree	Term bele	1
61	<i>Thespecia lampas</i> (cav.) Dalz	Malvaceae	Shrub	Thes lamp	28
62	<i>Trichilia connaroides</i> (Wight & Arn.) Bentv.	Meliaceae	Shrub	Tric conn	29
63	<i>Trifolium repens</i> L	Fabaceae	Herb	Trif repe	1
64	<i>Typha angustifolia</i> L.	Typhaceae	Herb	Typh angu	7
65	<i>Typhonium trilobatum</i> (L.) Schott	Araceae	Herb	Typh tril	5
66	<i>Wrightia antidysenterica</i> (L) R. Br	Apocynaceae	Tree	Wrig anti	30
67	<i>Xeromphis spinosa</i> (Thunb.) Keay	Rubiaceae	Tree	Xero spin	24
68	<i>Zizyphus incurve</i> Lam.	Rhamnaceae	Tree	Zizy incu	16

Appendix 2. Plotwise Average Tree Biomass and Carbon stock for two years 2013 and 2014.

			yr13	yr14		yr-13	yr-14	yr-13	yr-14
Plot No.	Name of species	No. of individuals	DBH(cm)	DBH(cm)	Height (m)	Average biomass(kg)		Average carbon-stock(kg)	
1	<i>Shorea robusta</i>	20	17.6	17.8	12.41	1232.7	1234.92	579.4	580.4
2	<i>Shorea robusta</i>	50	10.2	10.4	6.88	185.52	187.8	87.2	88.3
3	<i>Shorea robusta</i>	18	15.8	16	9.72	833.33	834.47	391.6	392.2
4	<i>Shorea robusta</i>	24	14	14.3	8.95	425.69	428.9	200.08	201.58
4	<i>Lagerstroemia parviflora</i>	1	5.1	6.2	5.5	6.1	8.07	2.87	3.8
5	<i>Shorea robusta</i>	27	11	11.3	7.42	146.77	151.14	68.98	71.04
6	<i>Shorea robusta</i>	43	11.7	11.9	7.23	256.67	257.47	120.63	121.01
7	<i>Shorea robusta</i>	9	24.4	24.7	14.04	1045.8	1052.04	491.55	494.5
8	<i>Shorea robusta</i>	26	12.3	12.6	7.6	249.92	254.94	117.46	119.89
9	<i>Shorea robusta</i>	20	17.9	18.2	11.55	524.68	534.47	246.6	251.2
10	<i>Shorea robusta</i>	22	13.3	13.6	7	225.79	227.03	106.12	106.54
10	<i>Lagerstroemia parviflora</i>	1	6	6.2	7	9.74	10.26	4.58	4.82
11	<i>Shorea robusta</i>	18	15.3	15.5	8.52	384.1	386.1	180.5	181.81
11	<i>Lagerstroemia parviflora</i>	2	7.1	7.1	3.84	6.23	8.23	2.93	3.87
12	<i>Shorea robusta</i>	27	15.6	15.9	8.1	452.48	454.85	212.67	213.78
12	<i>Lagerstroemia parviflora</i>	2	7.3	7.6	5.86	11.37	14.1	5.34	6.63
13	<i>Shorea robusta</i>	11	29.6	29.8	17.57	1238.25	1243.91	581.98	584.64
13	<i>Careya arborea</i>	1	44.9	44.9	12.74	1098.2	1098.2	516.16	516.16

14	<i>Shorea robusta</i>	29	10.2	10.4	6.62	73.44	74.77	34.52	35.14
15	<i>Shorea robusta</i>	22	15.6	16	9.9	460.92	463.9	216.6	218.03
15	<i>Lagerstroemia parviflora</i>	1	6.4	7	6.53	10.07	13.68	4.73	6.43
16	<i>Shorea robusta</i>	14	13.3	13.5	8.46	418.74	419.96	196.81	197.38
16	<i>Terminelia belerica</i>	1	57.3	58.9	13.17	1922.67	2030.97	903.65	954.56
17	<i>Shorea robusta</i>	28	11	11.3	7.28	100.6	104	47.28	48.88
17	<i>Careya arborea</i>	1	20.4	20.5	5.27	93.62	95.09	44	44.69
18	<i>Shorea robusta</i>	37	12.6	13	7.34	254.2	256.35	119.47	120.48
18	<i>Lagerstroemia parviflora</i>	1	12.7	13	6.36	39.24	41.22	18.44	19.37
19	<i>Shorea robusta</i>	16	17.7	18	10.94	639.2	647.7	300.44	304.4
20	<i>Shorea robusta</i>	5	36.5	36.5	13.53	2663.42	2663.55	1251.81	1251.87
21	<i>Shorea robusta</i>	9	46.5	46.5	21.04	2500.5	2502.84	1175.24	1176.34
22	<i>Shorea robusta</i>	29	12.7	13	8.71	74.85	78.14	35.18	36.73
23	<i>Shorea robusta</i>	23	16.8	17	9.5	778.7	811.51	366.02	367.32
23	<i>Lagerstroemia parviflora</i>	7	6.8	7.3	5.27	9.67	12.03	4.54	5.65
24	<i>Shorea robusta</i>	8	22.2	22.3	10.88	1336.8	1337.42	628.3	628.59
25	<i>Shorea robusta</i>	12	27.4	27.8	11.67	1145.15	1145.87	538.22	538.56
26	<i>Shorea robusta</i>	36	13.6	14	7.75	108.27	111.64	50.89	52.47
26	<i>Lagerstroemia parviflora</i>	1	11	11.1	4.95	22.73	23.39	10.68	10.99
27	<i>Shorea robusta</i>	11	11.5	12.1	6.85	302.23	313.75	142.05	147.46
27	<i>Lagerstroemia parviflora</i>	5	6.4	6.7	4.04	7.35	7.92	3.46	3.72

27	<i>Cassia fistula</i>	1	9.2	9.2	6.78	24.68	24.68	11.6	11.6
28	<i>Shorea robusta</i>	24	8.3	8.6	5.82	19.23	20.76	9.04	9.76
29	<i>Shorea robusta</i>	5	47.9	48.1	20.38	2723.99	2735.56	1280.27	1285.71
30	<i>Shorea robusta</i>	3	59	59.4	20.33	3142.55	3178.66	1477	1493.97

Appendix 3. Regression table for variables.

S. No.	Variable	Resid. Df	Resid. Dev	Deviance	D ²	F	Pr (>F)
1	sppn~C13	29	566.2				
		25	15.88	550.3	0.0280	211	< 2.2e-16***
2	sppn~NMDS1	29	566.2				
		25	9.66	556.51	0.0171	345	< 2.2e-16***
3	sppn~NMDS2	29	566.2				
		25	13.45	552.71	0.0238	245	< 2.2e-16***
3	sppn~ph	29	566.2				
		25	14.5	551.7	0.0256	227	< 2.2e-16***
4	sppn~om	29	566				
		25	14.2	552	0.0247	236	< 2.2e-16***
5	sppn~n	29	566				
		25	14	552	0.0247	236	< 2.2e-16***
6	sppn~p	29	566				
		25	14	552	0.0247	243	< 2.2e-16***
7	sppn~k	29	590.7				
		25	13.01	577.7	0.0220	266	< 2.2e-16***
8	clmb~NMDS1	29	23.5				
		25	3	20	0.1489	42	1.03e-10***
9	clmb~NMDS2	29	23.5				
		25	4	4	0.8298	32	1.5e-09***
10	clmb~ph	29	23.5				
		25	4	4	0.8298	34	8.0e-10***
11	clmb~om	29	23.5				
		25	3.3	20.2	0.1404	40	1.5e-10***

12	clmb~n	29	23.5				
		25	3.3	20	0.1489	40	1.40E-10
13	clmb~p	29	23.5				
		25	3.2	20	0.1489	39	1.9e-10****
14	clmb~k	29	23.5				
		25	3	20	0.1489	40	1.8e-10****
15	shrb~NMDS1	29	64.6				
		25	7.5	57	0.1176	48	2.2e-11****
16	shrb~NMDS2	29	64.6				
		25	8.1	56.5	0.1254	47	5.3e-11****
17	shrb~ph	29	65				
		25	8	56.7	0.1277	45	4.32e-11****
18	shrb~om	29	64.6				
		25	6	59	0.0867	61	1.4e-12****
19	shrb~n	29	64.5				
		25	6	59	0.0853	61	1.4e-12****
20	shrb~p	29	64.7				
		25	7.8	57	0.1190	46	3.5e-11****
21	shrb~k	29	65				
		25	8	56.7	0.1277	46	3.7e-11****
22	tree~NMDS1	29	147.4				
		25	9	88	0.4028	88	2.3e-09****
23	tree~NMDS2	29	147				
		25	14	133	0.0952	60	1.7e-12****
24	tree~ph	29	147				
		25	13	134	0.0884	63	1.09e-12****
25	tree~om	29	147				
		25	14.7	132	0.1020	57	3.2e-11****
26	tree~n	29	147				
		25	14	132	0.1020	57	3.2e-12****
27	tree~p	29	147				
		25	15	132	0.1020	56	3.9e-12****
28	tree~k	29	147				
		25	13	134	0.0884	65	6.95e-13****
29	tree~c14	29	147				
		25	15	132	0.1020	55	5.4e-12****
30	hrb~NMDS1	29	137				
		25	12	125	0.0876	65	7.86e-13****
31	hrb~NMDS2	29	137				

		25	13	124	0.0949	56	3.68e-12***
32	hrb~ph	29	137				
		25	17	120	0.1241	43	6.598e-11 ***
33	hrb~om	29	137				
		25	14	123	0.1022	55	5.032e-12 ***
34	hrb~n	29	137				
		25	14	123	0.1022	55	5.032e-12 ***
35	hrb~p	29	137				
		25	12	125	0.0876	65	7.448e-13 ***
36	hrb~k	29	137				
		25	14	123	0.1022	56	3.998e-12 ***
37	sppn`C14	29	566				
		25	16	550	0.0283	211	2.2e-16 ***

*indicates significant value.

Appendix 4. Soil Parameters Tests

SN	Plot no.	pH	Organic matter %	N %	P ₂ O ₅ kg/ha	K ₂ O kg/ha
1	P1	5.22	3.18	0.13	107	336
2	P2	5.31	2.65	0.12	115	355
3	P3	5.48	2.29	0.13	124	405
4	P4	5.33	2.11	0.11	110	312
5	P5	5.27	1.98	0.07	90	216
6	P6	5.23	1.92	0.09	83	145
7	P7	5.25	2.05	0.08	84	205
8	P8	5.28	1.85	0.09	88	219
9	P9	5.29	1.52	0.08	85	227
10	P10	5.22	2.45	0.12	94	247
11	P11	5.16	3.64	0.14	167	259

12	P12	5.12	2.5	0.11	190	217
13	P13	5.15	1.06	0.07	203	117
14	P14	4.85	1.98	0.1	187	153
15	P15	4.47	2.85	0.12	173	172
16	P16	4.95	3.11	0.12	111	180
17	P17	5.2	3.18	0.13	88	145
18	P18	5.02	2.38	0.11	20	282
19	P19	5.05	1.85	0.09	26	227
20	P20	5.08	1.97	0.9	22	237
21	P21	5.12	2.19	0.1	20	246
22	P22	5.05	2.13	0.12	30	216
23	P23	5.18	2.01	0.14	36	197
24	P24	4.94	1.99	0.1	46	172
25	P25	4.97	1.95	0.15	27	175
26	P26	4.94	2.19	0.1	16	117
27	P27	4.91	1.87	0.09	21	153
28	P28	5.01	1.39	0.08	20	199
29	P29	5.03	1.33	0.07	24	173
30	P30	5.07	1.39	0.08	29	158

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

SN	Name of Species	Wood density (gm/cm ³)
1	<i>Careya arborea</i> Roxb.	0.73
2	<i>Cassia fistula</i> L.	0.73
3	<i>Lagerstroemia parviflora</i> Roxb.	0.65
4	<i>Shorea robusta</i> Gaertn.	0.73
5	<i>Terminalia belerica</i> (Gaertn) Roxb	0.76

Some Photo Plates



Photo 1: collecting Fodder



Photo 2: Vegetable (Ophiglossum)



Photo 3: Orchid speceis



Photo 4: Sampling plot



Photo 5: Showing tag



Photo 6: A Permanent metallic tag



Photo 7: *Shorea robusta* forest



Photo 8: measuring DBH



Photo 8: Observing Orchid species



Photo 9: Forest Users women.