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Species Diversity and Tree Carbon Stock Pattern in a Community-Managed Tropical *Shorea* Forest in Nawalparasi, Nepal.

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ABSTRACT

Carbon stocks are a major topic in discussions on climate change and are valued as reserved cash by various nations. Carbon stock in tropical ecosystems is greater than in other ecosystems. *Shorea robusta* Garten. is one of the major forest components of the tropical ecosystems in Nepal where community forestry is successfully practised. In this study, we document the species diversity in a community-managed semi-natural tropical *Shorea* forest and its carbon storage. The study was made in the lowland (200 m altitude), Bishnu Nagar Community Forest in Nawalparasi, Nepal. The 197 ha forest was studied by sampling 30 quadrats of 20 × 20 m each, including all management block by Community Forest User Groups (CFUGs). All species encountered in each quadrat were recorded and trees were tagged permanently for a year. Carbon stock for each tree was estimated using allometric formulae. Soil nitrogen, phosphorus, potash and pH were also determined. Detrended correspondence analysis (DCA), non metric multidimensional scaling (NMDS), correlation and regression methods were applied. A total of 68 vascular plant species belonging to 42 families and 61 genera was recorded. Fabaceae was the most dominant family (6 species). The first axis of DCA explained10% of the total variance in the present study. *Strobilanthus dyeriana*, *Agrostis gigantea* and *Gmelina arborea* were species significant to the $NMDS_1$ representing the grazing indicators. *Rhus wallichii* and *Chromolaena odorata* were significant to the $NMDS_2$ representing the openness of the habitat. Soil nitrogen, phosphorus, organic matter and species richness were significantly correlated to the $NMDS_1$ but species richness was more significant to the $NMDS_2$. The carbon stock was estimated at 115 Mg ha^{-1} and tree trunk volume at 225.2 m^3 ha^{-1}.

Key Words: Detrended Correspondence Analysis (DCA); Disturbance; Non-metric Multi Dimensional Scaling; Silviculture.

INTRODUCTION

Tropical forests are characterized by high species richness, composition, standing biomass and productivity (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 in tropical lowland.

The distribution of *Shorea* forest ranges from low land Terai, i.e., below 100 m above sea level (m asl) to 1500 m asl in the mid-hills (Gautam and Dovoe 2006). In the Terai, *Shorea* is mainly associated with *Terminalia alata*, *Syzgium cumini*, *Carea arborea*, *Adina cordifolia*, *Lagerstroemia parviflora*, etc.

Terai refers to the southern lowland 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 conditions changed a lot and there was a large migration in the terai region from hilly regions and elsewhere in the country and new settlements started after deforestation (Schweiket al.1997, Mathews et al. 2000). Meanwhile, the establishment of an east-west highway also caused heavy destruction and fragmentation of the intact natural forests.

Lowland Sal forest is the suitable habitat for many unique species of trees, shrubs, herbs, climbers and ferns and mosses. It is also the habitat for many faunal species. Deforestation and destruction of the Sal forest directly and indirectly affects the other dependent plant and animal species.

The concept of community forest and its implementation have played significant role in the most successful conservation of forest and biodiversity in Nepal (Subedi and Dhakal 2013, Shrestha and Jha 1997, Chakraborty 2001). Now, 17809 community forest user groups cover an area of 1.665 million ha of community forest out of 5.5 million ha forest area in Nepal (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 in each of the community forest's plan. Some common problems among community forests include litter collection, tree species selection, collection of all dead plant parts and clearance of herbaceous and shrubby species during silviculture activities. These activities are one of the major causes of loss of biodiversity in community forests (Acharya et al. 2007).

Globally, forests have 3.82×10^{11} Mg carbon of which 1.41×10^{11} Mg (37%) is confined in the lowland latitudes (Dixon et al. 1994). 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 ecosystems are believed to have greater amount of carbon store per unit area than others (Garkoti and Singh 1995, Chave et al. 2005). Before 1950s, about 75% of the central and western Terai, Nepal was covered by forest (Joshi 2002).

About 20% of total global green house gas emission occurs through deforestation and forest degradation (Gullison et al. 2007). At the 13th COP of UNFCC 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 was later termed as REDD+ after COP14 in Poland 2008. Thus, the community forests of terai region have the potential to reduce carbon emission and are eligible to get compensation through REDD+.

In spite of their extent and importance from both economic and ecological viewpoint, lowland Terai Sal forest, its composition and the amount of carbon stored in it have not been investigated. Hence, the present study focused on the species diversity and richness pattern and tree carbon stock in a semi-natural Terai Sal forest located at Bishnu Nagar, Nawalparasi, Nepal with the following objectives:

i) to document of the forest species occurring inside the Bishnunagar Community Forest,

i) to describe the species richness pattern in the forest,

iii) to estimate tree biomass, carbon stock and soil organic matter, soil nitrogen, phosphorus, potassium and pH.

MATERIALS AND METHODS

Study Area

The Bishnunagar Community Forest lies in Shivamandir Village Development Committee (VDC), Nawalparasi, central Nepal (Figure 1). Nawalparasi is one of the districts of the Terai, Nepal. 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 at195m to 220m above sea level. The southern part of the study area forms the buffer zone management forest which is separated by east-west highway where as the other three sides are bounded by other community forests. This study area covers an area of 196.72 ha.

This study area represents the tropical forest dominated by the Sal (*Shorea robusta* Garten.) mixed with other tropical species such as *Lagerstroemia parviflora, Acacia catechu*, *Terminalia alata, Terminalia belerica, Syzigium cumini* etc. Intact forest in the past has been fragmented by the highway, human settlements and agricultural fields. The remaining small fraction is now regarded as the Bishnunagar Community Forest. This community forest is managed by 978 female and 1034 males of 364 households. The forest lies close to the human settlement. Disturbances such as cattle grazing, timber cutting, forest fire, firewood and fodder collections affect the biodiversity of this forest.

The climate of the study area is tropical monsoonal with three distinct seasons: summer, rainy and winter. The maximum temperature lies between 25.5˚C and 36˚C while recorded average annual rainfall is 2145 mm (http://oneclicknepal.com/nawalparasi/accessed 08/31/2014).

Data Collection

The field work was done for a complete year from July

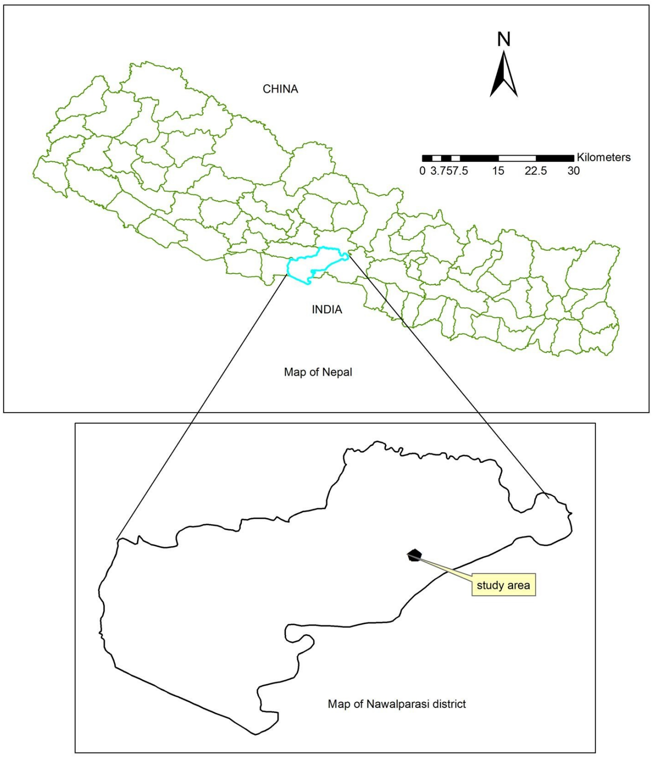

Figure 1. Map of the study area.

2013 to July 2014. A tentative mid-point for the community forest was identified with the help of the local forest guard. This point was regarded as the center of the first plot for this study. Other plots were placed in four directions in such a way that the minimum distance between two plots was 20 m and covered all the three management blocks regulated by the community forest users. A total of thirty 20 × 20 m plots were established. Each plot was divided into four subplots (5×5m) marked as A B, C, and D. Species rooted in all subplots were recorded as 1. Absent species within subplots were denoted by 0.

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 safely for later identification. Each plant specimen was confirmed after consulting herbaria, relevant taxonomic literature and experts. Identified specimens were housed atTribhuvan University Central Herbarium (TUCH). Nomenclature of angiosperms and pteridophytes followed Press et al. (2000) and Gurung (1985) respectively.

Information obtained from 5×5 m subplots was upscaled to 20×20 m plot. Thus each species encountered inside the plot ranged 0 to 4. All analyses were made on the plot data, not on the subplot.

A tree is defined as the species with a minimum diameter of ≥5 cm at breast height (DBH; 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 meter tape. Diameter of each tree at 137 cm above ground was measured by a tape, and re-measured exactly after one year from the same mark. Aboveground biomass (ABG) was estimated by applying regression equation prepared by Chave et al. (2005).

$$ABG = 0.0509 \times \rho D^2 H.$$

where, 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 with 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. Generally 15% of aboveground biomass is believed to be the belowground biomass (Mac Dicken 1997). We acknowledge this view into our study.

Total carbon sequestration 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.

Soil

Composite soil samples were collected from the four corners of each plot. Each soil sample was taken from 30 cm below the ground. A mixture of 1 kg soil was packed into the polythene bag for laboratory analysis. Each soil sample was air dried after bringing to the laboratory. Soil organic matter (OM) was estimated by Walkley-Black method (Walkley and Black 1934).

Soil pH was measured by suspension method. Soil nitrogen was estimated 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). The soils were analysed in the laboratory of Nepal Agricultural Research Council (NARC), Khumaltar, Lalitpur, Nepal.

Data Analyses

Total species richness, their functional derivatives and sequestered carbon per plot were considered as response variables whereas soil variables such as organic matter, nitrogen, phosphorus, potassium and pH were predictors. Correlations among responses and predictors were calculated using Pearson's Correlation method (R-Core Team 2014). Correlation Coefficient matrix was prepared with probability value (*p*).

Normality and Regression

Normality among variables was sought prior to statistical tests. Sequestered carbon showed normality in distribution but not by the total species richness. Normality did not meet even after log and square root transformation separately. Thus, the Generalized Additive Model (*GAM*, Hastie and Tibshirani 1990) was applied. This is a non-parametric regression. The smoother *spline* (*s*) was utilized via *gam* library (Hastie 1992). Over dispersion in residuals was corrected through application of quasipoisson family of errors. Variance explained by each fitted *gam* model was accessed by the coefficient of determination as in Baniya et al. (2009).

D^2 = (Null Deviance – Deviance)/ Null Deviance
where D^2 is the coefficient of determination.

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 of underlying gradients. This gradient is 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 were utilized as environmental variables (see Sahu et al. 2008).

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 multi-collinearity. These errors were corrected after removing one and two times occurrence species from the data set before the multivariate analysis.

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. Statistically significant results from the RDA were shown by graphics. All analyses were made 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.

RESULTS

We recorded 68 plant species representing 42 families and 61 genera (Appendix 1). Fabaceae was the richest family with nine species followed by Araceae, Euphorbiaceae, Poaceae and Rubiaceae with three species each.

Our study included nine environmental and five species variables (Table 1). The total species richness per plot (tospn) was the counting response variable with value ranging between 21 to 40 and 28 species as the mean. The 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) and shrub (16) (Figure 2). Similarly, climber species richness per plot (clmb) varied from 4 to 7 with a mean of 5.5. Soil pH is a ranked environmental variable, recorded at 4.7 to 5.4 (Table 1).

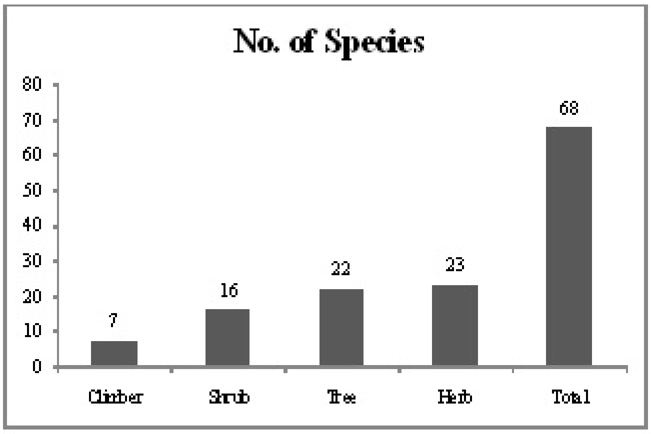

Figure 2.Species richness pattern with life form.

A total of 651 tree individuals were tagged to estimate the tree biomass and carbon sequestration. The DBH of individual trees ranged from 5.1 cm to 59 cm,

Table 1.Name and summary of variables used during this study.

S.N.	Variables	Abbrev.	Unit	Minimum	1st Quartile	Median	Mean	SD	3rd Quartile	Maximum
1	Total species richness	tospn	Count	21	25	26.5	27.9	4.5	29	40
2	Climber species richness	clmb	Count	4	5	6	5.5	0.9	6	7
3	Herb species richness	hrb	Count	0	0	1	0.8	0.9	1	3
4	Shrub species richness	shrb	Count	0	0	1	0.8	0.9	1	3
5	Tree species richness	tree	Count	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	NMDS2	NMDS2	Score	2.3	6.8	8	8	2.4	9.4	12.6
8	Carbon stock 2013	c13	kg (400 $m^2)^{-1}$	217	2518	4605	4595	2705	6132	11590
9	Carbon stock 2014	c14	kg (400 $m^2)^{-1}$	226	2540	4642	4629	2698.3	6141	11610
10	Soil pH	pH	rank	4.7	5	5.1	5.1	0.18	5.2	5.4
11	Soil organic matter	om	%	1	1.8	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 $m^2)^{-1}$	0.64	1	3.4	3.2	2.3	4.4	8.1
14	Soil Potash	K	kg (400 $m^2)^{-1}$	4.7	6.9	8.4	8.6	2.8	10	16.2

Table 2. Total tree trunk volume and carbon sequestration by tree species per plot.

S. No.	Total TTV, m^3 (400 $m^2)^{-1}$		Total Carbon Stock, kg (400 $m^2)^{-1}$		TTV, m^3 ha^{-1}		Carbon Stock, Mg ha^{-1}	
	Yr 2013	Yr 2014	Yr 2013	Yr 2014	Yr 2013	Yr 2014	Yr 2013	Yr 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	8.7	8.7	4424.0	4450.1	216.3	217.3	110.6	111.3
5	6.4	6.4	3255.4	3280.4	159.0	160.3	81.4	82.0
6	9.3	9.4	4770.6	4803.1	233.0	234.8	119.3	120.1
7	9.4	9.5	4807.1	4870.4	234.8	238.0	120.2	121.8
8	16.5	16.5	8450.3	8487.8	413.0	413.0	211.3	212.2
9	3.1	3.2	1591.4	1652.3	77.8	80.5	39.8	41.3
10	9.4	9.5	4804.7	4841.7	234.8	236.8	120.1	121.0
11	6.0	6.1	3054.1	3115.4	149.3	152.3	76.4	77.9
12	11.3	11.3	5752.7	5785.4	281.3	282.5	143.8	144.6
13	7.1	7.2	3659.0	3717.9	177.0	179.8	91.5	92.9
14	12.2	12.2	6259.0	6259.3	305.8	305.8	156.5	156.5
15	9.8	9.8	5026.4	5028.7	245.5	245.8	125.7	125.7
16	0.4	0.4	216.9	225.6	10.5	11.0	5.4	5.6
17	12.5	12.6	6401.4	6428.6	312.8	314.0	160.0	160.7
18	8.7	8.8	4431.0	4481.9	216.5	219.0	110.8	112.0
19	3.6	3.8	1862.6	1918.0	91.0	93.8	46.6	47.9
20	9.6	9.8	4932.0	5024.0	241.0	245.0	123.3	125.6
21	13.5	13.6	6917.9	6946.4	338.0	339.5	172.9	173.7
22	2.7	2.8	1367.9	1413.2	66.8	69.0	34.2	35.3
23	20.7	20.7	10577.1	10587.0	516.8	517.3	264.4	264.7
24	12.6	12.6	6458.7	6462.7	315.5	315.8	161.5	161.6
25	10.1	10.2	5187.3	5203.5	253.5	254.0	129.7	130.1
26	4.6	4.6	2339.3	2348.7	114.3	114.5	58.5	58.7
27	2.0	2.0	1001.0	1019.1	49.0	49.8	25.0	25.5
28	8.7	8.8	4438.9	4477.2	217.0	218.8	111.0	111.9
29	2.0	2.1	1020.2	1065.1	49.8	52.0	25.5	26.6
30	3.6	3.7	1842.6	1899.9	90.0	93.0	46.1	47.5

Table 3. Pearson correlation coefficient matrix among variables.

	tospn	clmb	hrb	shrb	tree	NMDS1	NMDS2	c13	c14	ph	om	n	p
clmb	0.35*												
hrb	-0.05	-0.2											
shrb	0.63*	-0.07	0.09										
tree	0.74*	0.29	-0.14	0.4*									
NMDS1	-0.6*	-0.57*	0.43*	-0.21	-0.34								
NMDS2	-0.03	-0.01	-0.53*	-0.16	0.07	0							
c13	0.23	0.15	0.03	0.05	0.1	-0.2	-0.09						
c14	0.23	0.15	0.03	0.05	0.1	-0.2	-0.09	1					
ph	0.3	0.3	-0.24	0.24	0.25	-0.43*	0.07	0.2	0.2				
om	0.19	-0.3	0.2	0.34	0.16	0.03	-0.04	0.2	0.2	-0			
n	-0.02	-0.1	-0.16	-0.21	0.05	-0.07	0.04	0.1	0.1	-0	0.1		
p	0.25	-0.19	0.5*	0.22	0.21	0.2	-0.51	0.2	0.2	0.1	0.3	-0.2	
k	0.5*	0.31	-0.18	0.16	0.43*	-0.46*	0.12	0.3	0.3	0.56*	0.4	0.1	0.1

and their height ranged from 3.84 m to 21 m. Average tree trunk volumes for years 2013 and 2014 were 224.4 m^3 ha^{-1} and 226 m^3 ha^{-1} which equalled to 114.9 Mg ha^{-1} and 115.7 Mg ha^{-1} carbon sequestrated respectively (Table 2). The rate of carbon sequestration was therefore 0.8 Mg ha^{-1} yr^{-1}.

The total species richness was statistically significant with positive correlation ($p \leq 0.05$) between climber species richness, shrub species richness, tree species richness and soil potassium but statistically negative significant correlation ($p \leq 0.05$) to NMDS1 (Table 3). A positive correlation was found between total species richness and carbon measured for 2013 and 2014 but not statistically significant. Herb richness has statistically positive significant correlation with NMdS1 and negative with NMDS2. Similarly, statistically positive significant relation was found between soil potassium and pH.

The sample by species data matrix resulted 1.2 standard deviation (*sd*) unit length of gradient value by the first axis of Detrendent Correspondence Analysis (DCA) (Table 4). This length of gradient was found decreasing gradually with increasing axis. This first axis showed almost 10% of the total variance explained by the data set that is almost similar (5%) to 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).

Statistically significant axes were obtained by RDA. The redundancy analysis (RDA) gave three significant environmental variables viz. NMDS1, NMDS2 and soil phosphorus (P) after permutations with species score. The number of permutations was taken as default. The NMDS1 represented significantly the first axis of RDA (Figure 3). Similarly NMDS2 and P denoted statistically significant second axis of RDA. The abundance of *Shorea robusta* (Shorrobu) was significantly explained by all three significant environmental variables. Abundance of *Leea asiatica* was highly correlated towards plots with the highest value of NMDS1. The highest abundance of *Mariscus sumatrensis* was supported by the pots with significantly least value of NMDS1. The abundance of *Trichilia connaroides*, *Floscopa scandens* and *Thespesia lampas* were significantly correlated towards plots with the highest value of potassium. On the other hand, the highest abundance of *Osyris wightiana* was towards plots with significantly least value of potassium but with the highest value of NMDS2.

Table 4. DCA summary

	DCA1	DCA2	DCA3	DCA4
Eigenvalues	0.08	0.05	0.05	0.04
Decorana values	0.09	0.05	0.04	0.03
Axis lengths	1.23	0.97	0.96	0.68

There were no statistical significant relation among sequestrated carbon in 2013 and 2014 and total species richness but total species richness showed significant linear relationship with carbon sequestrated in 2013 (Figure 4, Appendix 3) but statistically significant non-linear relationship with carbon sequestered in 2014 (Figure 5, Appendix 3). Total species richness had significantly decreasing non-linear relationship with NMDS1 (Figure 6, Appendix 3). Similarly, there was significant non-linear relationship between total species richness and NMDS2 (Figure 7, Appendix 3) and a significantly positive non-linear relationship between total species richness and soil potash (Figure 8, Appendix 3).

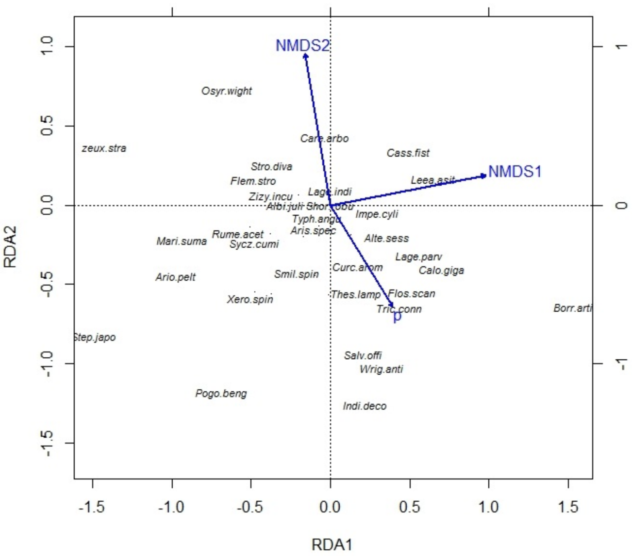

Figure 3. Species, environment and sample triplot after Redundancy Analysis (RDA).

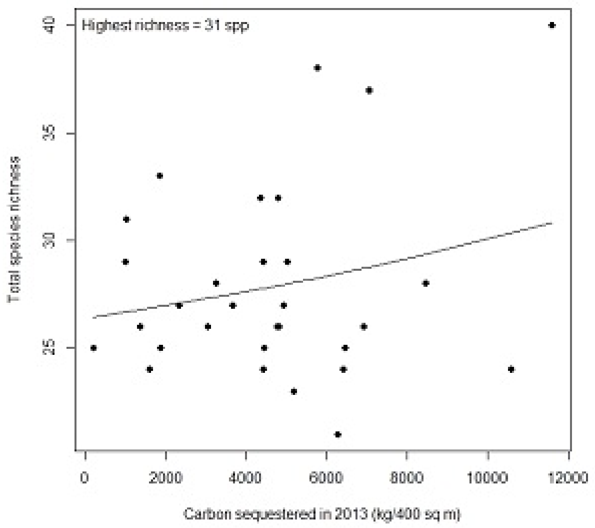

Figure 4.Relationship between total species richness and carbon sequestered in 2013.

DISCUSSION

Tropical lowland of Nepal is distinguished by almost plain land with a gentle gradient. Gradient analysis research is rather complicated here. This difficulty has been overcome through an application of the NMDS first and second axis values as explanatory variables. The

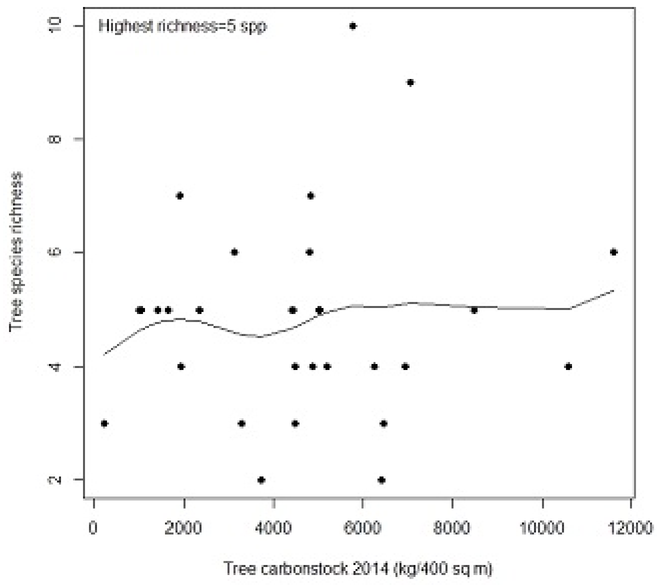

Figure 5. Relationship between total species richness and carbon

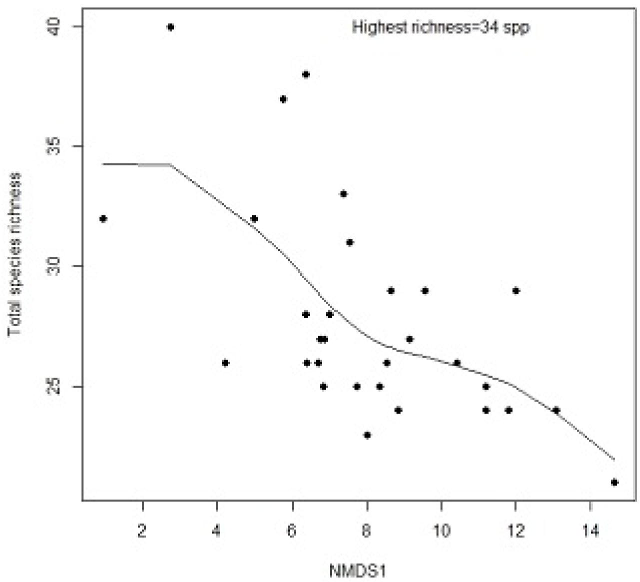

Figure 6.Relationship between total species richness and NMDS1.

where core of the forest has many grazing tolerant species and hosts several species as refugees. As value of NMDS1 increases, number of palatable species for cattle increase that may indicate high disturbance. The second axis represented the soil moisture gradient with higher abundance of moisture loving species, alluvial soil loving species and greater value of phosphorus. These two axes were taken as environmental variables to

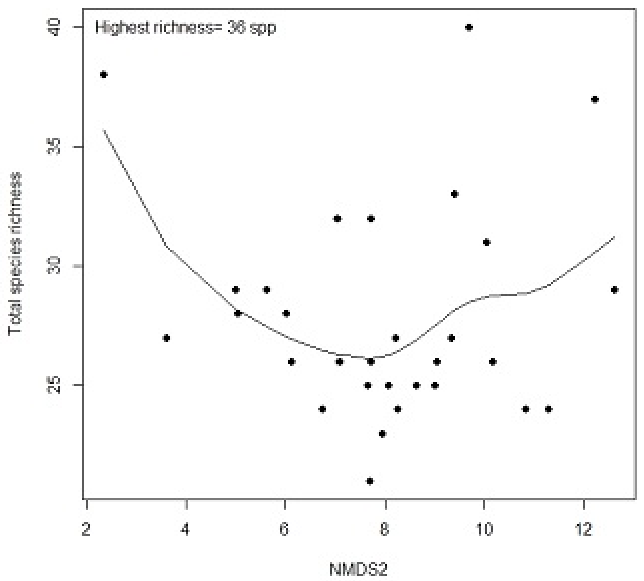

Figure 7.Relationship between total species richness and NMDS2.

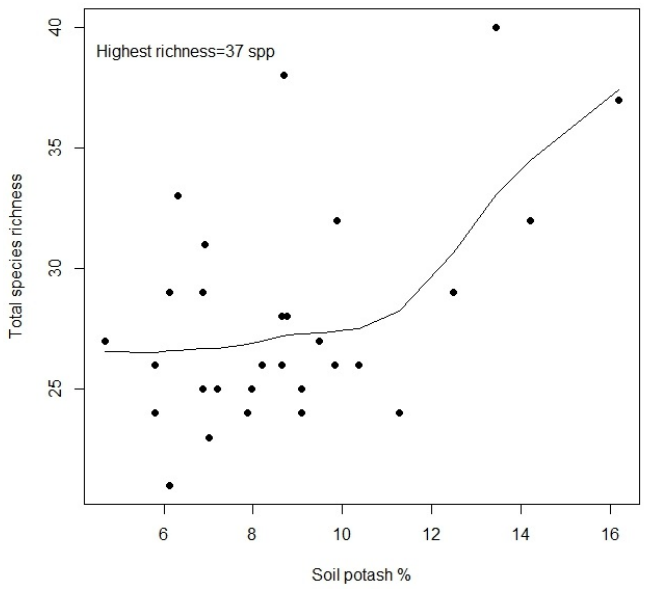

Figure 8. Relationship between total species richness and soil potash

All statistically significant results among soil variables (pH, N, OM, P and K), C13, C14, NMDS1 and NMDS2 with total species and its derivatives except herb richness indicated a close relationship between biotic and abiotic components of 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.

Species Richness

Total species richness by plot stood as the most strong response variable in this study, had statistical significant relations to all its derivatives richness except herbs. Tree, shrub and climbers richness indicated their major significant share in the total species richness but not herbs richness. Different herb species were confined from the middle to the highest end of the NMDS1 variable. It can be articulated with high 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 variable. Grazing tolerant species specialized by thorny outgrowths may nucleate more specialist inside their habitat. The newly created safe habitats may attract more species which ultimately favor higher species richness. Thus decreasing pattern of total species richness with NMDS1 is justified. This view is very much closer to that of many previous studies (Grime 1973, Connell 1978 and McCabe and Gotelli 2000).

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 rapid nutrients turnover rate.

Species preferences, selection and removal during silvicultural activities 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 we found least plant species diversity and mixed *Shorea* 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 1.23 which indicated low turnover of new species and beta (β) diversity of the species in the study area.

We recorded a low increment rate of carbon sequestration. Banskota et al. (2007) reported the rate of carbon sequestration in community forests located at Kathmandu, Ilam and Manang to be 1.41 Mg ha^{-1} yr^{-1}, 3.1 Mg ha^{-1} yr^{-1} and 1.13 Mg ha^{-1} yr^{-1}, respectively. All these values were higher than tree carbon in our study. Shrestha (2008) estimated the carbon sequestration by three different forest types in Palpa districts: *Pinus roxburghii* forest (155.62 Mg ha^{-1}), *Shorea robusta* forest (105.3 Mg ha^{-1}) and *Schima-Castanopsis* forest (47.08 Mg ha^{-1}). The carbon sequestration rate of our study area was greater than in similar forest types elsewhere such as in Palpa district, Nepal. This may be due to different locations of similar forest type, i.e, Terai (Nawalparasi) and in Mid-hill (Palpa). Carbon sequestration differs by vegetation type, their wood density, annual precipitation and age of the forest. Our study site is a semi-natural *Shorea robusta* (tropical) forest. More than 40% of trees crossed the age of more than 50 years. Such semi-natural forests have high accumulation of biomass but low carbon sequestration rate. Older trees of *Shorea* show slow gain of carbon each year.

CONCLUSION

Latent environmental variables such as NMDS1 and NMDS2 explained significantly the species richness as well as composition pattern in this study. High disturbance may favor more palatable species whereas non palatable species nucleated or shield more sensitive specialists. Carbon accumulation rate is slower than higher altitudes. Although community managed forest has great role in biodiversity conservation and its sustainable development but less preferred species in local community peoples' prospective are ignored and cleared during silvicultural operation. The rate of mature tropical forest carbon sequestration is slow but sequestrated carbon is higher than in the regenerating forest. Our study showed slow carbon sequestration rate but high accumulation of biomass.

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Appendix 1. List of species encountered during this study their life form, short form and frequency.

S. N.	Family	Name of Species	Life form	Short form	Frequency
1	Acanthaceae	*Strobilanthes divaricata* (Nees) T. Anderson	shrub	Stro diva	12
2	Amaranthaceae	*Alternanthera sessilis* (L.) DC	herb	Alte sess	10
3	Anacardiaceae	*Rhus wallichii* Hook. f.	tree	Rhus wall	2
4	Apocynaceae	*Wrightia antidysenterica* (L) R. Br.	tree	Wrig anti	30
5	Apocynaceae	*Rauwolfia serpentina* (L.) Benth	shrub	Ravo serp	1
6	Araceae	*Ariopsis peltata* Nimmo	herb	Ario pelt	27
7	Araceae	*Arisaema speciosum* (Wall.) Marlo.ex Schott	herb	Aris spec	15
8	Araceae	*Typhonium trilobatum* (L.) Schott	herb	Typh tril	5
9	Asclepiadaceae	*Asclepias curassavica* L.	shrub	Ascl cura	8
10	Asclepiadaceae	*Calotropis gigantea* (L.) Dryand	shrub	Calo giga	10
11	Asteraceae	*Conyza japonica* (Thunb.) Less.	herb	Coni japo	1
12	Asteraceae	*Chromolaena odorata* (L.) R.M.King & H. Rob.	shrub	Chro odor	7
13	Begoniaceae	*Begonia nepalensis* (A. DC.) Warb	herb	Bego nepa	1
14	Brassicaceae	*Camelina sativa* L.	herb	Came sati	1
15	Combretaceae	*Terminilia alata* Heyne ex. Roth	tree	Term alat	1
16	Combretaceae	*Terminalia belerica* (Gaertn) Roxb	tree	Term bele	1
17	Commelinaceae	*Floscopa scandens* Lour	herb	Flos scan	22
18	Cyperaceae	*Cyperus rotundus* L.	herb	Cype rotu	5
19	Cyperaceae	*Mariscus sumatrensis* (Retz.) T. Koyama	tree	Mari suma	14
20	Dioscoreaceae	*Dioscorea bulbifera* L.	climber	Dios bulb	30
21	Dioscoreaceae	*Dioscorea alata* L.	climber	Dios alat	30
22	Dipterocarpaceae	*Shorea robusta* Gaertn.f.	tree	Shor robu	30
23	Euphorbiaceae	*Mallotus philippensis* (Lam.) Mull. Arg	tree	Mall phil	12
24	Euphorbiaceae	*Phyllanthus urinaria* L.	herb	Phyl urin	2
25	Euphorbiaceae	*Phyllanthus virgatus* G. Forst.	shrub	Phyl virg	1
26	Fabaceae	*Flemingia strobilifera* (L.) W. T. Aiton	shrub	Flem stro	15
27	Fabaceae	*Millettia extensa* (Benth.) Baker	herb	Mill exte	1
28	Fabaceae	*Trifolium repens* L.	herb	Trif repe	1
29	Fabaceae	*Indigofera decora* Lindley	shrub	Indi deco	15
30	Fabaceae	*Senna reticulata* (Willd.) H. S. Irwin and Barneby	shrub	Senn reti	1
31	Fabaceae	*Albizia julibrissin* Durazz.	tree	Albi juli	9
32	Fabaceae	*Cassia fistula* L.	tree	Cass fist	9
33	Fabaceae	*Bauhinia purpurea* L.	tree	Bauh purp	4
34	Fabaceae	*Bauhinia vahlii* Wight and Arn.	climber	Bauh valh	7
35	Hypoxidaceae	*Curculigo capitulata* (Lour.) Kuntze	herb	Curc capi	30
36	Labiatae	*Pogostemon benghalensis* (Burm.f.) Hassk.	shrub	Pogo beng	26
37	Lamiaceae	*Clerodendrum serratum* (L.) Moon	herb	Clero serr	30
38	Lamiaceae	*Salvia officinalis* L.	herb	Salv offi	14
39	Lecythidaceae	*Careya arborea* Roxb.	tree	Care arbo	13
40	Leeaceae	*Leea asiatica* L.	shrub	Leea asit	11
41	Liliaceae	*Asparagus racemosus* Wild	herb	Aspa race	1
42	Lygodiceae	*Lygodium japonicum* (Thunb.) Sw.	climber	Lygo japo	30
43	Lythraceae	*Lagerstroemia parviflora* Roxb.	tree	Lage parv	30
44	Lythraceae	*Lagrestroemia indica* L.	tree	Lage indi	4
45	Malvaceae	*Thespecia lampas* (Cav.) Dalz	shrub	Thes lamp	28
46	Malvaceae	*Sida cardifolia* L.	shrub	Sida card	1
47	Meliaceae	*Trichilia connaroides* (Wight and Arn.) Bentv.	shrub	Tric conn	29
48	Menispermaceae	*Stephania japonica* var. *discolor* (Thunb.) Miers S. Moore	climber	Step japo	24
49	Myrtaceae	*Syzygium cumini* (L.) Skeels	tree	Syzy cumi	19
50	Orchidaceae	*Zeuxine strateumatica* (Lindl.)	herb	zeux stra	17
51	Poaceae	*Agrostis gigantea* Roth	herb	Agro giga	2

Appendix 1. Continued

S. N.	Family	Name of Species	Life form	Short form	Frequency
52	Poaceae	*Imperata cylindrica* (L.) P. Beauv	herb	Impe cyli	7
53	Poaceae	*Cynodon dactylon* (L.) Pers.	herb	Cyno dact	1
54	Polygonaceae	*Rumex acetosa* L.	shrub	Rume acet	16
55	Ranunculaceae	*Delphinium grandiflorum* L.	tree	Delp gran	8
56	Rhamnaceae	*Zizyphus incurva* Roxb.	tree	Zizy incu	16
57	Rubiaceae	*Xeromphis spinosa* (Thunb.) Keay	tree	Xero spin	24
58	Rubiaceae	*Adina cordifolia* (wild. ex Roxb.)	tree	Adin card	7
59	Rubiaceae	*Borreria articularis* (l.f.) F.N. will	herb	Borr arti	8
60	Rutaceae	*Murraya paniculata* (L.) Jack	shrub	Murr pani	19
61	Rutaceae	*Murraya koenigii* (L.) Spreng.	tree	Murr koen	2
62	Santalaceae	*Osyris wightiana* Wall. ex Wigh	tree	Osyr wight	19
63	Smilacaceae	*Smilax spinosa* Mill.	climber	Smil spin	13
64	Typhaceae	*Typha angustifolia* L.	herb	Typh angu	7
65	Verbenaceae	*Gmelina arborea* Roxb.	tree	Gmel arbo	2
66	Verbenaceae	*Premna integrifolia* L.	tree	Prem inte	1
67	Vitaceae	*Ampelocissus divaricata* (Wall. ex M. A. Lawson) Planch	climber	Ampe diva	30
68	Zingiberaceae	*Curcuma aromatica* Salisb.	herb	Curca rom	6

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

Plot No.	Species	No. of indiv	DBH (cm)	Height (m)	Biomass-13	Biomass-14	C stock-13	C stock-14
1	*Shorea robusta*	20	17.6	12.41	1232.7	1234.92	579.4	580.4
2	*Shorea robusta*	50	10.2	6.88	185.52	187.8	87.2	88.3
3	*Shorea robusta*	18	15.8	9.72	833.33	834.47	391.6	392.2
4	*Shorea robusta*	9	24.4	14.04	1045.8	1052.04	491.55	494.5
5	*Shorea robusta*	18	15.3	8.52	384.1	386.1	180.5	181.81
	Lagerstroemia parviflora	2	7.1	3.84	6.23	8.23	2.93	3.87
6	*Shorea robusta*	22	15.6	9.9	460.92	463.9	216.6	218.03
	Lagerstroemia parviflora	1	6.4	6.53	10.07	13.68	4.73	6.43
7	*Shorea robusta*	16	17.7	10.94	639.2	647.7	300.44	304.4
8	*Shorea robusta*	23	16.8	9.5	778.7	811.51	366.02	367.32
	Lagerstroemia parviflora	7	6.8	5.27	9.67	12.03	4.54	5.65
9	*Shorea robusta*	11	11.5	6.85	302.23	313.75	142.05	147.46
	Lagerstroemia parviflora	5	6.4	4.04	7.35	7.92	3.46	3.72
	Cassia fistula	1	9.2	6.78	24.68	24.68	11.6	11.6
10	*Shorea robusta*	24	14	8.95	425.69	428.9	200.08	201.58
	Lagerstroemia parviflora	1	5.1	5.5	6.1	8.07	2.87	3.8
11	*Shorea robusta*	26	12.3	7.6	249.92	254.94	117.46	119.89
12	*Shorea robusta*	27	15.6	8.1	452.48	454.85	212.67	213.78
	Lagerstroemia parviflora	2	7.3	5.86	11.37	14.1	5.34	6.63
13	*Shorea robusta*	14	13.3	8.46	418.74	419.96	196.81	197.38
	Termineliabelerica	1	57.3	13.17	1922.67	2030.97	903.65	954.56
14	*Shorea robusta*	5	36.5	13.53	2663.42	2663.55	1251.81	1251.87
15	*Shorea robusta*	8	22.2	10.88	1336.8	1337.42	628.3	628.59
16	*Shorea robusta*	24	8.3	5.82	19.23	20.76	9.04	9.76
17	*Shorea robusta*	5	47.9	20.38	2723.99	2735.56	1280.27	1285.71
18	*Shorea robusta*	3	59	20.33	3142.55	3178.66	1477	1493.97
19	*Shorea robusta*	27	11	7.42	146.77	151.14	68.98	71.04
20	*Shorea robusta*	20	17.9	11.55	524.68	534.47	246.6	251.2
21	*Shorea robusta*	11	29.6	17.57	1238.25	1243.91	581.98	584.64
	Careyaarborea	1	44.9	12.74	1098.2	1098.2	516.16	516.16
22	*Shorea robusta*	28	11	7.28	100.6	104	47.28	48.88
	Careyaarborea	1	20.4	5.27	93.62	95.09	44	44.69
23	*Shorea robusta*	9	46.5	21.04	2500.5	2502.84	1175.24	1176.34
24	*Shorea robusta*	12	27.4	11.67	1145.15	1145.87	538.22	538.56
25	*Shorea robusta*	43	11.7	7.23	256.67	257.47	120.63	121.01
26	*Shorea robusta*	22	13.3	7	225.79	227.03	106.12	106.54
	Lagerstroemia parviflora	1	6	7	9.74	10.26	4.58	4.82
27	*Shorea robusta*	29	10.2	6.62	73.44	74.77	34.52	35.14
28	*Shorea robusta*	37	12.6	7.34	254.2	256.35	119.47	120.48
	Lagerstroemia parviflora	1	12.7	6.36	39.24	41.22	18.44	19.37
29	*Shorea robusta*	29	12.7	8.71	74.85	78.14	35.18	36.73
30	*Shorea robusta*	36	13.6	7.75	108.27	111.64	50.89	52.47
	Lagerstroemia parviflora	1	11	4.95	22.73	23.39	10.68	10.99

Appendix 3.Regression table for variables.*ns* represents statistically non-significant value.

S. N.	Variable	Resid.Df	Resid.Dev	Deviance	D^2	F	Pr (>F)
1	tospn~c13	29	590.7				
		28	18.9	571.8	0.0320	748.8	<0***
1	tospn~NMDS1	29	590.7				
		25	11.4	579.3	0.0193	311	<0***
2	tospn~NMDS2	29	590.7				
		25	14.4	576.3	0.0244	240.4	<0***
3	totspn~ph	29	590.7				
		25	15	575.7	0.0254	228.2	<0***
4	totspn~om	29	590.7				
		25	15.2	576	0.0249	231.5	<0***
5	totspn~n	29	590.7				
		25	15.1	575.6	0.0256	234	<0***
6	totspn~p	29	590.7				
		25	15	575.6	0.0256	233	<0***
7	tospn~k	29	590.7				
		25	13.01	577.7	0.0220	266.2	<0***
8	clmb~NMDS1	29	23.5				
		25	2.1	21.3	0.0936	62.5	<0***
9	clmb~NMDS2	29	23.5				
		25	4.2	4	0.8298	29	<0***
10	clmb~ph	29	23.5				
		25	4	4	0.8298	37.3	<0***
11	clmb~om	29	23.5				
		25	3.3	20.2	0.1404	40.1	<0***
12	clmb~n	29	23.5				
		25	4.2	19.2	0.1830	28.8	<0***
13	clmb~p	29	23.5				
		25	3.3	20.2	0.1404	38.8	<0***
14	clmb~k	29	23.5				
		25	3.03	20.4	0.1319	42.4	<0***
15	shrb~NMDS1	29	64.3				
		25	7.5	56.8	0.1166	47.3	<0***
16	shrb~NMDS2	29	64.3				
		25	7.8	56.5	0.1213	46.6	<0***
17	shrb~ph	29	64.3				
		25	7.5	56.8	0.1166	48	<0***
18	shrb~om	29	64.3				
		25	6.2	58.1	0.0964	58.6	<0***
19	shrb~n	29	64.3				
		25	7.3	57	0.1135	48.7	<0***
20	shrb~p	29	64.3				
		25	7.8	56.5	0.1213	45	<0***
21	shrb~k	29	64.3				
		25	8.2	56.1	0.1275	43.8	<0***
22	tree~NMDS1	29	92.2				
		25	14.5	77.7	0.1573	33.3	<0***
23	tree~NMDS2	29	92.2				
		25	12.4	80	0.1323	42.1	<0***
24	tree~ph	29	92.2				
		25	14.1	78.1	0.1529	34.2	<0***

Appendix 3. Continued

S. N.	Variable	Resid.Df	Resid.Dev	Deviance	D^2	F	Pr (>F)
25	tree~om	29	92.2				
		25	12.8	79.4	0.1388	38	<0***
26	tree~n	29	92.2				
		25	16.1	76.1	0.1746	29	<0***
27	tree~p	29	92.2				
		25	15	77.3	0.1616	32	<0***
28	tree~k	29	92.2				
		25	13.7	78.5	0.1486	33.6	<0***
29	tree~c14	29	92.2				
		25	16.9	75.3	0.1833	27	<0***
30	hrb~NMDS1						NS
31	hrb~NMDS2						NS
32	hrb~ph						NS
33	hrb~om						NS
34	hrb~n						NS
35	hrb~p						NS
36	hrb~k						NS

Resid.Df = Residual degree of freedom; Resid.Dev =Residual deviance; D^2 = coefficient of determination, F = Fischer's value, Pr (>F) = Probability at Confidence interval. NS represents non significant.

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