Determining Tree-habitat Associations at the Raghunandan Hill Reserve Forest in Bangladesh

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Abstract

The Raghunandan Hill Reserve (RHR) Forest is situated along the Indo-Burma Biodiversity Hotspot and comprises natural vegetation patches in the northeastern Bangladesh. Despite being a high conservation priority area, this is one of the least studied reserves in the tropics. In this paper, we classified the tree communities of the RHR and provided a first comprehensive investigation on tree-soil relationships. We collected vegetation and environmental data from 61 sample plots and recorded 40 tree species belonging to 22 families and 29 genera. Existing tree community types were determined using Hierarchical Agglomerative Cluster Analysis and Detrended Correspondence Analysis (DCA). Canonical Correspondence Analysis (CCA) was performed with associated Monte Carlo permutation tests to explore tree distributions in relation to the soil variables. Soil moisture and two macro-nutrients (phosphorus and potassium) were the most influential variables accounted for tree compositional variation in the reserve. Finally, we discuss the potential applications of these preliminary findings in vegetation management and biodiversity conservation of the RHR.

Keywords: Biodiversity; Hill forest; Species composition; Tree communities; Tropical forest.

1. Introduction

Understanding the mechanisms that influence tropical forest biodiversity has been a central topic in community ecology. Tropical forests have exceptional biogeochemical variation that allows for a suite of potential limiting nutrients that, in turn, have varied effects on vegetation structure and functions [1]. Numerous studies [2-8] have examined the influence of environmental variables on tropical plant species distribution. In the advent of multivariate methods ecologists are now able to describe the environment-species relationships in a quantitative way and thus the role of environmental variables especially soil variables in species distribution has become more specific [9-10]. Quantification and biological interpretation of the relationships between environmental variables and species composition are important to develop effective conservation plans, particularly in the remnant natural forests in the tropics that support many indigenous rare species [11].

Unfortunately, South-Asian tropical forests are still lagging behind in quantitative analysis of species distribution and their relation to habitat conditions (but see 12-13] which is a serious impediment to design and implement much needed conservation efforts. The scenario is even more degrading for Bangladesh where drastic changes in the forest composition and structure driven by human (e.g. deforestation, agricultural expansion, grazing etc.) and environmental (e.g., cyclones, fire etc.) perturbations have been reported [14 - 15]. In addition, large scale fragmentation of the primary forests has resulted in increased number of threatened species [16]. Recently, Bangladesh government has brought most of the natural forests under Protected Area Management to conserve and restore the remaining natural patches [17]. However, we have limited knowledge on plant distributions and habitat conditions in these reserves. The present study area, the Raghunandan Hill Reserve (henceforth, RHR), is located in the north-eastern tropical zone of Bangladesh. It was declared as a reserve forest in the early 19th century to protect the remaining natural vegetation patches.

The vegetation of the reserve still remains unclassified. Moreover, we are completely unaware of any study that examined the influence of soil in structuring the vegetation communities, although remarkable soil variation has been identified in different landforms of the reserve [16]. Here, the research hypothesis is that the spatial distribution of tree communities in the reserve is a function of a set of critical and measurable soil physio-chemical variables. Therefore, the study has two objectives; first, to identify tree communities in the reserve; second, to investigate the distribution of the communities in relation to soil variables.

2. Materials and methods

2.1 Study site

The Raghunandan Hill Reserve (91°20-91°30N latitude and 24°5-24°10E longitude; 4046.86 ha) is a part of the '9b-Sylhet hill' bio-ecological zone in Bangladesh and is surrounded (east and south) by India (Fig. 1.). The semi-evergreen vegetation of the reserve forms a part of transition zone between the Indian subcontinent and the Indo-Chinese ecological region [18]. A part of the reserve (243 ha) was declared as a national park (Satchari National Park) in 2005. The climate is moist tropical characterized by a period of high precipitation from April to September and five months (November to March) of relatively dry period. Soil varies from clay loam on level ground to sandy loam on hilly ground [19]. Mean annual temperature is $25.8^{o}C$ (range: 10.1^{o} - $33.3^{o}C$) and mean annual precipitation is 4162 mm year-1, most of which occur in July [20]. The reserve encompasses several moderately sloped hills of different elevations (10-50 m above ground level) with extended valleys. These valleys remain dry in winter and inundated during monsoon. Low lands occupy a reasonable portion of the reserve. These areas are situated around the internal channels and remain wet throughout the year. During monsoon these areas are also inundated by flood water [16].

2.2 Data collection

The species compositional data presented in this paper were collected (October - December, 2012) from 61 plots (0.04 ha size) taken at random from the Satchari Beat of the RHR which fairly represent the vegetation types of the reserve. Trees of diameter at breast height (d.b.h. at 1.3 m) ? 10 cm were identified to species level. We took count data of each species in each plot and measured their basal area. Total 40 tree species of 22 families and 29 genera were recorded (Appendix 1). Most of the tree species belong to Moraceae, Myrtaceae and Anacardiaceae families, and Artocarpus and Syzygium genera. We could not identify 8 trees to species level due to the lack of taxonomic documentation. However, based on local expert knowledge we are reasonably confident that these are the trees of distinct species. These species

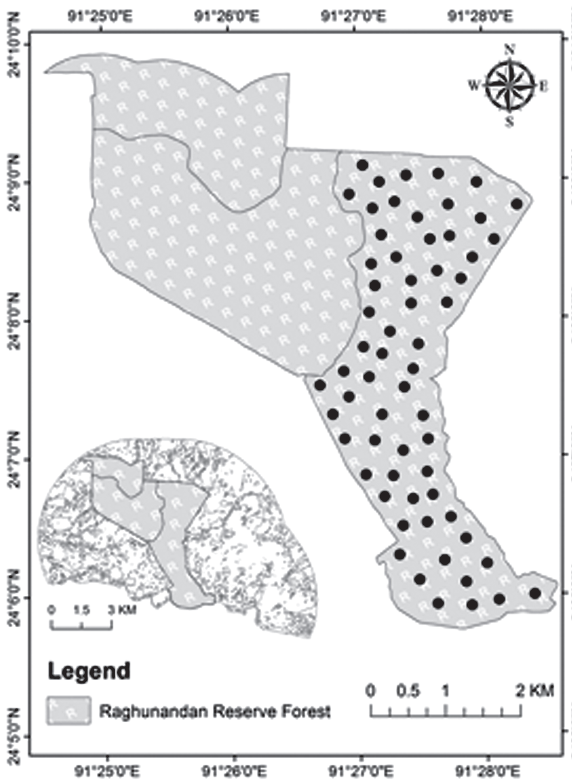

Figure 1. Map showing sample locations in the Raghunandan Hill Reserve (black circles).

are included in this study with their vernacular name.

Five soil samples were collected from each plot (soil depth = 10 cm), thoroughly mixed and then one quarter of the processed sample was transferred to the laboratory for chemical analysis. Infield readings of soil pH and moisture were taken. Soil organic matter, organic carbon, total nitrogen, magnesium, phosphorus, potassium and sulfur were measured in the laboratory.

2.3 Classification

Tree communities were identified by hierarchical agglomerative cluster analysis using BiodiversityR package [21] in R software version 3.2.2 [22] with Quantitative Sørensen (Bray-Curtis) distance. In community ecology, choosing a clustering method is not out of controversy [23]. In this paper, we did not select the clustering method a priory rather among the clustering methods (single, complete, ward's and average linkage) we selected the one with the highest cophenetic correlation coefficient value using Mantel test (99 permutations). Then, the importance value (IV) was used to explore the pattern of tree dominance in each tree community type. IV of each tree species was calculated using the formula [24]: (IV = RD + Rd + Rf) where RD = relative dominance, Rd = relative density and Rf = relative frequency. Each community type was named with the two tree species that achieved the highest IV.

Table 1. Correlation among the environmental variables. MC = soil moisture content, Mg = Magnesium, OC = Organic carbon, TN = Total nitrogen, OM = Soil organic matter, P = Phosphorus, S = Sulphur, K = Potassium. * P < 0.05, ** P < 0.01

	pH	MC	Mg	OC	TN	OM	P	S
MC	-0.38**							
Mg	-0.05	0.05						
OC	0.14	0.08	0.23					
TN	0.14	0.08	0.23	1.00**				
OM	0.13	0.07	0.22	0 .99**	0.99**			
P	0.21	0.13	0.11	0 .32*	0.32*	0.35*		
S	-0.08	-0.07	0.04	-0.19	-0.17	-0.19	-0.33**	
K	-0.11	0.05	0.32*	0.15	0.13	0.12	0.04	0.01

2.4 Numerical analyses

All statistical analyses were performed using CANOCO version 4.5 for Windows and CanoDraw for Windows [25]. Our dataset contained 61 sample plots, 48 tree species and 9 environmental variables. The square-root transformed species abundance data were used. Rare species were down weighted in proportion to their frequency in all ordinations as they may have an excessively large impact on the analysis when using unimodal methods [26]. Environmental variables were standardized to unit variance. In the ordination diagrams, species names are abbreviated using six letters from the scientific name of each plant by combining the three initial letters for the genus and species. For example, "Terbel" is an abbreviation for *Terminalia belerica.* Unidentified species are included in the ordination diagram by their local name. Full species names are given in the Appendix A.

Detrended correspondence analysis (DCA) [27] with detrending-by-segments and nonlinear re-scaling of axes was carried out to confirm the relevance of the plant communities defined by the cluster analysis. The first DCA axis had a gradient length of 4.67 standard deviation units and justified the use of canonical correspondence analysis (CCA) [28]. The nine environmental variables measured in this study were tested first for correlation using the Pearson correlation coefficient and strongly inter-correlated variables were removed because the inclusion of strongly inter-correlated variables may yield unreliable results in the ordination. For example, as soil organic matter content was highly correlated with total soil nitrogen content and carbon content (r = 0.99), only organic matter content was retained in the analysis (Table 1).

CCA was used to explore patterns of variation in tree species distribution explained by the measured environmental variables. Automatic forward selection of environmental variables with associated Monte Carlo permutation tests (499 permutations) in CANOCO was then used to identify the statistically significant soil variables reliable for tree compositional variation. Monte Carlo permutation tests were also performed to assess the significance of the eigenvalue of the first canonical axis and of all axes [26]. The variables were selected in order of the variance each explained without considering other environmental variables (marginal effects, I1), and in order of their inclusion in the model after successively selecting the most important variables (conditional effects, I A). This analysis shows the additional variance each variable explained, significance of the variable, the P-value and the test statistic (F-value) at inclusion in the model.

3. Results

3.1 Tree communities

In cluster analysis, Ward's linkage method (r = 0.52, P<0.009, Mantel test) with Bray-Curtis distance represented the actual ecological distances among the sample plots better than the single, complete and average linkage methods. The method classified the sample plots into three tree communities (TCs) (Fig. 2.): (I) TCI: Hill forest community (*Lannea coromandelica - Artocarpus chama* association); (II) TCII: Low land community (Grewia microcos - *Artocarpus chama* association); and (III) TCIII: Valley community (*Artocarpus chama - Ficus pyrifomis* association). DCA also confirmed this classification (Fig. 3.).

The DCA axes showed a clear separation among the samples of low lands (on the upper right side of the axis 1) and hill slope (at the top axis 2). Plain land samples are distributed widely in the middle of the DCA biplot. The floristic composition and diversity patterns of these three communities and environmental data summary is presented in (Table 2).

TCI *Lannea coromandelica - Artocarpus chama* association

Table 2. Summary of the tree communities and environmental variables.

Tree communities	*Lannea coromandelica – Artocarpus chaplasha* association (TCI)	*Grewia microcos – Artocarpus chaplasha* association (TCII)	*Artocarpus chaplasha – Ficus pyrifomis* association (TCIII)
Dominant Species (IV)	1st: *Lannea coromandelica* (66) 2nd: *Artocarpus chaplasha* (39)	1st: *Grewia microcos* (65) 2nd: *Artocarpus chaplasha* (64)	1st: *Artocarpus chaplasha* (85) 2nd: *Ficus pyrifomis* (33)
Plot nos.	15	8	38
Habitat	Hill land	Low land	Valley land
Family nos.	19	16	17
Genus nos.	24	18	24
Species richness	32	24	40
Mean values and standard deviation (±) of the soil variables			
Soil acidity (pH)	5.29±0.19	5.06±0.20	5.19±0.19
Soil moisture (MC, %)	15.33±2.33	19.23±3.50	17.22±3.45
Magnesium (Mg, mgl^{-1})	1.79±2.77	3.15±3.84	2.20±2.86
Organic carbon (OC, %)	1.25±0.49	1.26±0.20	1.18±0.18
Total nitrogen (TN, %)	0.12±0.04	0.12±0.02	0.11±0.018
Organic matter (OM, %)	2.16±0.84	2.17±0.35	2.02±0.30
Phosphorus (P, ugg^{-1})	2.45±1.05	2.53±0.76	2.00±0.93
Sulphur (S, $mg.kg^{-1}$))	13.44±3.07	15.61±3.04	13.96±3.64
Potassium (K, $meq.100g^{-1}$)	0.15±0.04	0.14±0.03	0.15±0.04

This community is distributed on the hill slopes and supports 32 species. Here, *L. coromandelica and A. chama* are the dominant species. Soil is medium acidic with lowest Mg content and relatively drier than the other communities. Other common species of this community include: Pichli, *Stereospermum personatum, Tarenna campaniflora, Garcinia cowa, Engelhardtia spicata,* and *Ficus lepidosa.*

TCII Grewia microcos - Artocarpus chama association

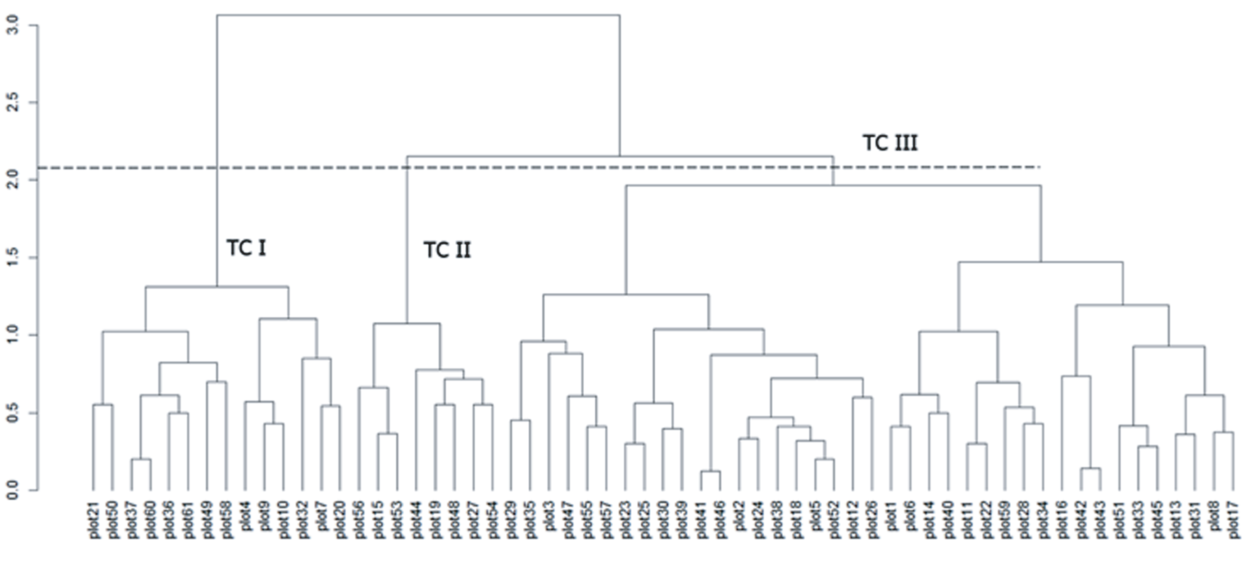

Figure 2: Dendrogram of the cluster analysis with 61 study plots and 48 tree species using Ward's linkage method and Bray-Curtis distance (Dendrogram pruned at distance 2.1). TC I, TC II, and TC III represents the hill, low land, and valley communities, respectively.

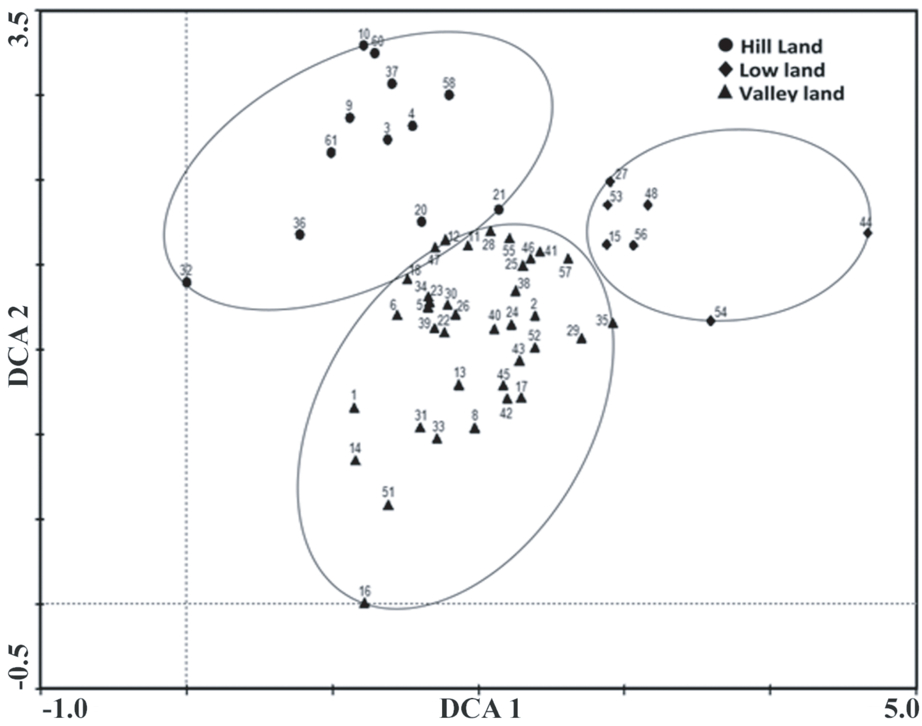

Figure 3. Bi-plot of the DCA ordination diagram using species composition for 61 plots.

This is the species-poor (24 species) community and occurs predominantly in the low-laying areas of the reserve. Here, *G. microcos* is the most dominant species and contributed mostly to raise the higher value of Simpson Dominance index. The forest floor in this community remains more or less wet throughout the year. The soil is more acidic and contains higher level of soil moisture, soil organic matter S, Mg, and P than the hill slopes and plain land tree communities. Other common species of this community include: *F. lepidosa, Aphanamixis polystachya, Elaeocarpus robusta, Sapium baccatum, T. belerica and F. pyrifomis.*

TCIII *Artocarpus chama - Ficus pyrifomis* association

This is the most species rich (40 species) tree community and is widely distributed across the extended valleys in the reserve. *A. chama* and *F. pyrifomis* are the most abundant species here. The moderately acidic soil is characterized by low soil P concentration and organic matter content. Other common species of this community include: *F. lepidosa, L. coromandelica, T. campaniflora, S. personatum, E. robusta,* and *G. microcos.*

3.2 Tree-soil relationships

The eigenvalues of the successive first four axes of the CCA decreased rapidly (Table 3), suggesting a well-structured dataset. These eigenvalues were somewhat lower than for the DCA axes, indicating that all important explanatory site variables were measured in the analysis.

Table 3. Ordination summary of DCA and CCA.

Axes	1	2	3	4	Total inertia
DCA					
Eigenvalues (λ)	0.42	0.35	0.26	0.21	5.92
Gradient length	4.67	3.30	3.02	1.99	
% (sum) variance of sp. data	7.0	13.0	17.3	20.8	
CCA					
Eigenvalues (λ)	0.36	0.21	0.15	0.10	
Species-environment correlations	0.67	0.66	0.67	0.65	
% (sum) var of sp. data	8.5	13.4	17.0	19.4	
% (sum) var of sp.-env. relation	25.6	45.3	62.1	76.9	
Sum of all λ					4.18
All canonical λ sum					1.20

The first four axes of CCA explained 19.4% of the cumulative variance in species data while DCA explained 20.8%. However, the species environment correlations were higher for the first four canonical axes, explaining 76.9% of the cumulative variance. From the intra-set correlations of the soil variables with the first four axes of CCA shown in Table 4, it can be inferred that the main correlates of the first CCA axis are moisture content (r = -0.63) and pH (r = 0.58), while P (r = 0.86) is the major correlate of Axis 2. On the other

Table 4. Canonical coefficients and intraset correlations between the site scores on the first four constrained axes and environmental variables generated by canonical correspondence analysis. **=p<0.01; *=p< 0.05.

	Correlation coefficients (Intraset)				Canonical coefficients (Standardized)			
Variables	axis 1	axis 2	axis3	axis 4	axis 1	axis 2	axis 3	axis 4
pH	0.59**	-0.04	-0.27*	0.35**	0.34	-0.26	-0.40	0.50
MC	-0.63**	0.20	-0.05	-0.10	-0.56	-0.01	-0.29	0.07
Mg	-0.28*	0.25	0.32*	0.79**	-0.32	0.25	-0.04	0.81
OM	-0.15	0.32*	0.62**	-0.12	-0.33	0.09	0.56	-0.35
P	0.38**	0.86**	0.21	0.03	0.43	0.91	0.13	0.02
S	-0.32*	-0.19	-0.07	0.33**	-0.24	0.10	0.03	0.29
K	0.17	-0.29*	0.78**	0.33**	0.38	-0.46	0.67	0.18

hand, K (r = 0.78) and organic matter (r = 0.62) are mainly correlated with axis 3.

Table 5. Variables explaining the tree species-environment relation selected by CCA using automatic forward selection.

Marginal effects		Conditional effects			
	λ_1		λ_A	P	F
P	0.10	P	0.10	0.006	1.7
K	0.08	MC	0.08	0.046	1.5
MC	0.08	K	0.08	0.046	1.5
pH	0.08	Mg	0.07	0.136	1.3
Mg	0.07	OM	0.06	0.366	1.1
OM	0.06	pH	0.06	0.324	1.1
S	0.06	S	0.04	0.69	0.9

Automatic forward selection of environmental variables by CANOCO (Table 5) showed that P explained the most variance (10%) while S explained the least (6%). Forward selection option in the CANOCO identified three significant variables: P, moisture content and K. The CCA model was significant for the first axis ($F = 2.05$, $p < 0.02$) and also for all axes ($F = 1.29$, $p < 0.001$) indicating that observed patterns did not arise by chance.

The CCA ordination biplot (Fig. 4) represents the species distribution patterns when constrained by soil variables. Species with high positive scores on axis 1 include *Spondius pinnata* and *Erythrina variegata.* These species of hill community are highly positively correlated with pH and negatively correlated with soil moisture content. Conversely, species with high negative score on axis 1-*Samanea saman* is positively correlated with soil moisture content and mostly found in the low laying areas. Species (e.g. *L. coromandelica, T. belerica, Vitex pubescens, G. microcos* and *A. chama*) placed in the middle of the Axis 1are the commonest in the reserve. Species with high positive scores on Axis 2 (*Protium serratum, Godamali, Vitex arborea* and *A. polystachya*) are positively correlated with P and occur mainly in the valleys and foothill sites. On the other hand, *Amoora spectabilis, Mangifera sylvantica,* Rana, and *Neolamarckia cadamba* (Kadam) are the species with low score along the Axis 2. These species are positively associated with K and S; and negatively correlated with organic matter, Mg and P. Importantly, all these species occur only in the valley land. Thus, distribution of tree species on the CCA ordination space (axis 1 and axis 2) suggests that species distribution patterns do not follow a single environmental gradient, rather several soil factors such as pH, moisture content, P and K are mainly responsible for species compositional variation in the reserve.

4. Discussion

4.1 Tree communities

Both cluster analysis and DCA confirm the presence of three tree communities namely *L. coromandelica- A. chama; G. microcos - A. chama* and *A. chama - F. pyrifomis* in the Raghunandan hill reserve. *L. coromandelica - A. chama* (TCI) community type that occurs in the hilly areas of the reserve is dominated by *L. coromandelica.* This is a fast-growing deciduous species and grows well in the other northeastern hill reserves in Bangladesh [16, 29]. This community also comprises a number of unique species (only occur in this community) namely *P. serratum, E. variegata* and *S. pinnata.* G. microcos - A. chama (TCII) community type dominates the low laying areas that experience flush flood during the monsoon and generally remain wet throughout the year. This community is comparatively species poor and harbors a number of unique species such as *S. saman, Bombax insigne* and Godamali. *A. chama - F. pyrifomis* (TCIII) community type forms the largest association in

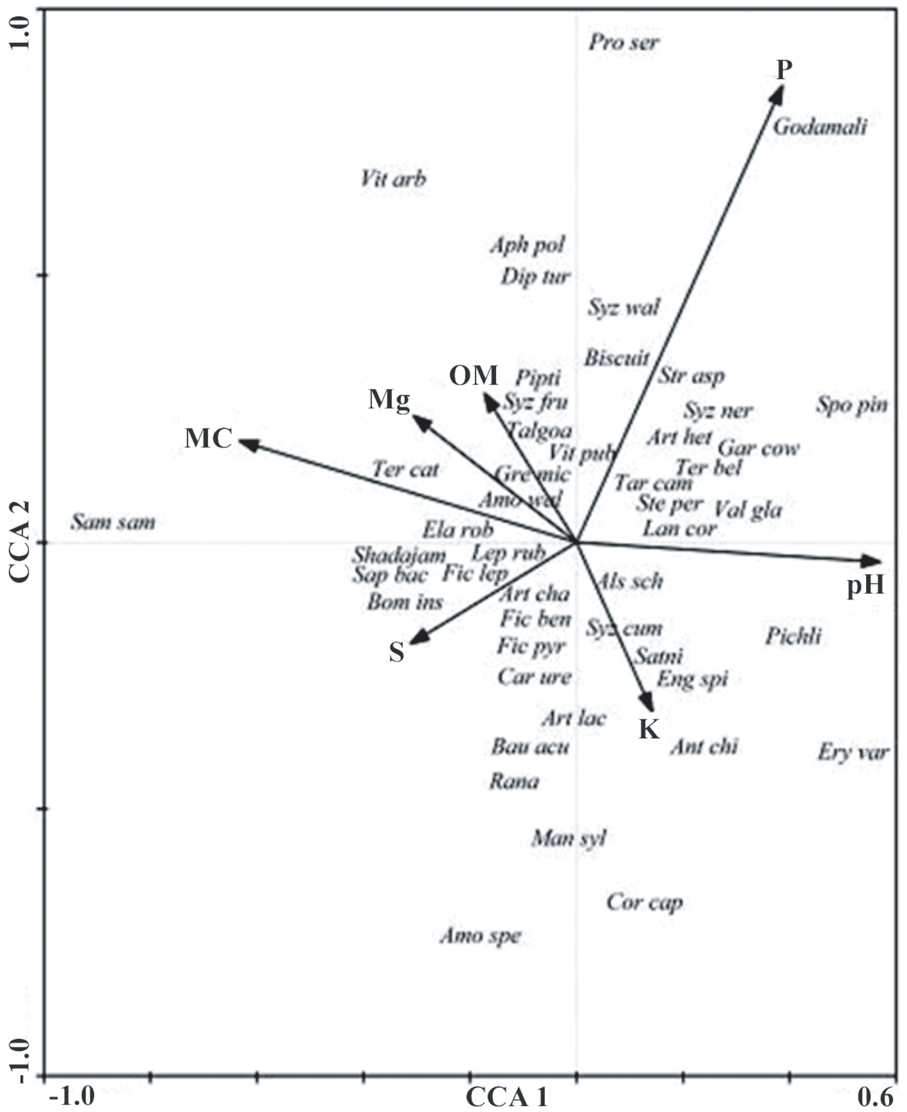

Figure 4: CCA ordination using species composition of 61 plots and the environmental variables. Each vector represents environmental variables, length is proportional to its importance and the angle between two vectors reflects the degree of correlation between them. For species abbreviations, see Appendix A.

the valley lands of the reserve. This is the most species rich community having maximum number (10) of unique species (e.g., *Alstonia scholaris, Artocarpus heterophyllus, N. cadamba, M. sylvantica, A. spectabilis* and *Ficus bengalensis*).

4.2 Determinants of tree distribution

The low value of explained variation (19.4%) can be attributed to high noise levels typical of species-abundance data (see Table 4) [30]. However, the first four CCA axes cumulatively explained 76.9% variance of species-environment relation. The first axis of CCA is strongly related with soil moisture and pH, and the second axis with only soil P. This result supports the idea that CCA as an explanatory technique led to a reasonable interpretation of important gradients in a few dimensions [31].

We observed that the overall species compositional variation in the reserve is well influenced by soil P, moisture level and K. This indicates that species in this reserve respond to multiple environmental gradients simultaneously and different combinations of gradients produce divergently shaped responses to the set of gradients.

A number of studies have demonstrated the influence of soil P, K, and moisture content on tree species distribution in tropical forests [32-35]. Soil P is frequently the nutrient that limits tree growth, maturity, and productivity in Oxisols and Ultisols, the most common soil types in the tropics [36]. Forest soils in Bangladesh are also poor in P [37]. We observed low concentration of P in the hilly and valley areas of the reserve. Soil moisture levels strongly regulate nutrient availability and uptake by roots and directly influence tropical forest structure and composition [38]. In the Raghunandan reserve, soil moisture level varies from season to season and site to site. This variation has direct link with plant regeneration and growth. Water-table of the reserve area is generally low and during the prolonged dry period (October-March), it further goes down [16]. However, very high soil moisture in the valley areas is not surprising because in the rainy season these sites are frequently inundated and soil pores become saturated. As inundation of water creates anaerobic conditions [38] which constrain existence of tree species, only inundation tolerating plants (e.g. S. saman, B. insigne etc.) can survive under flooding. Soil K also has direct influence upon spatial distribution of trees in the tropical forests having acidic soil [39]. In these forests, low soil pH is responsible for K leaching from the soil substrate [35] which has negative impact on plants water use [40]. Soil is mostly acidic in all the community sites in our study reserve (see Table 1). This could be the reason behind the role of K as a constraining soil nutrient on the distribution of trees in the reserve.

4.3 Conservation implications

This baseline study has several important implications for preparing and implementing management strategies, conservation techniques and restoration of degraded habitats in the Raghunandan reserve. Results of this study indicate significant influence of the phosphorous and potassium of the soil as well as the soil moisture on the distribution of tree species in the reserve. Hence, future tree conservation strategies and restoration projects should take the variations in these soil nutrients and the water availability into account. Furthermore, the study confirms the presence of three tree communities with considerable difference in species composition, diversity and environmental conditions. The valley communities are comparatively more species rich than hilly and low-lying communities and these three community types also contained many of the unique species. Hence, the findings could help management of the forest, for instance, to take habitat specific restoration and conservation strategies. Again, this study could assist forest managers to facilitate the conservation of wildlife and their associated habitat management. For example, few of the endangered and critically endangered primates (*Trachypithecus phayrei, T. pileatus, Hoolock hoolock* etc.) are found in the study site and many species of *Ficus genera* are regarded as importance source of their food. So, protection of these tree species from illegal logging and planting new seedlings in the denuded hills could be an effective strategy to support wildlife conservation in RHR. Most importantly, the findings may help the conservation agencies and Bangladesh Forest Department to assess the relative conservation value of different sites and also to focus their forest protection and conservation activities at the appropriate (i.e. highly disturbed and degraded sites) forest sites.

5. Conclusions

This primary study successfully identified the existing tree communities and explored their distributions in relation to critical environmental factors in the Raghunandan reserve. A considerable number of tree species form unique assemblages in different habitats which has direct conservation implications. Despite the low variance in the data explained, the accounted variables provide useful insight on tree community distribution. We recommend for future research with extended sample size and environmental variables, particularly human disturbance. Finally, we suggest that future conservation efforts (e.g. ex-situ, in-situ, reforestation and restoration) in the reserve should consider unique species diversity and community-centric spatial variations in environmental conditions (i.e. soil P, K and moisture content).

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Appendix A. Tree species recorded during the fieldwork at of Raghunandan hill reserve, Bangladesh.

Family	Genus	Scientific name	Code	Communities
Anacardiaceae	Lannea	*Lannea coromandelica* (Moutt.) Merr.	Lan cor	TCI,TCII,TCIII
	Mangifera	*Mangifera sylvatica* Roxb.	Man syl	TCIII
	Spondius	*Spondius pinnata* (L.f) Kunz. T	Spo pin	TCI
Apocynaceae	Alstonia	*Alstonia scholaris* R.Br.	Als sch	TCIII
	Vallaris	*Vallaris glabarta* (L.) O. Ktze.	Val gla	TCI,TCII,TCIII
Bignoniaceae	Stereospermum	*Stereospermum personatum* (Hassk.) Chatt.	Ste per	TCI,TCII,TCIII
Bombacaceae	Bombax	*Bombax insigne* Wall.	Bom ins	TCII
Burseraceae	Protium	*Protium serratum* Engl.	Pro ser	TCI
Caesalpiniaceae	Bauhinia	*Bauhinia acuminata* L. - St	Bau acu	TCI,TCII
Combretaceae	Terminalia	*Terminalia belerica* (Gaertn.) Roxb.	Terbel	TCI,TCII,TCIII
		Terminalia catappa L.	Ter cat	TCI,TCII,TCIII
Dipterocarpaceae	Dipterocarpus	*Dipterocarpus turbinatus*C.F.Gaertn.	Dip tur	TCIII
Elaeocarpaceae	Elaeocarpus	*Elaeocarpus robusta* Roxb.	Ela rob	TCI,TCII,TCIII
Euphorbiaceae	Sapium	*Sapium baccatum* Roxb.	Sap bac	TCI,TCII,TCIII
Fabaceae	Erythrina	*Erythrina variegata* L.	Ery var	TCI
Guttiferae	Garcinia	*Garcinia cowa* Roxb.	Gar cow	TCI,TCII,TCIII
Juglandaceae	Engelhardtia	*Engelhardtia spicata* Bl.	Eng spi	TCI,TCIII
Meliaceae	Amoora	*Amoora spectabilis*Miquel	Amo spe	TCIII
		Amoora wallichii King.	Amo wal	TCI,TCIII
	Aphanamixis	*Aphanamixis polystachya*(Wall.) R. Parker	Aph pol	TCII,TCIII
Mimosaceae	Samanea	*Samania saman* (Jacquin) Merrill.	Sam sam	TCII
Moraceae	Artocarpus	*Artocarpus chaplasha* Roxb.	Art cha	TCI,TCII,TCIII
		Artocarpus heterophyllus Lam.	Art het	TCIII
		Artocarpus lacucha Buch.-Ham.	Art lac	TCI,TCIII
	Ficus	*Ficus lepidosa* Wall.	Fic lep	TCI,TCII,TCIII
		Ficus bengalensis L.	Fic ben	TCIII
		Ficus pyrifomis var. hirtinervis S.S.Chang	Fic pyr	TCI,TCII,TCIII
	Streblus	*Streblus asper* Lour.	Str asp	TCI,TCII,TCIII

Myrtaceae	Syzygium	*Syzygium wallichi* Weight	Syz wal	TCI,TCIII
		Syzygium cumini (L.) Skeels.	Syz cum	TCI,TCIII
		Syzygium fruticosum (Roxb.) DC.	Syz fru	TCII,TCIII
		Syzygium nervosum DC.	Syz ner	TCI,TCII,TCIII
		-	Shada jam	TCII,TCIII
Palmae	Caryota	*Caryotaurens William* J.	Car ure	TCI,TCII,TCIII
Rubiaceae	Anthosephalus	*Neolamarckia cadamba*	Ant chi	TCIII
	Tarenna	*Tarenna campaniflora* (Hook.f.) *N.P.Balakr.*	Tar cam	TCI,TCIII
Sapindaceae	Lepisanthes	*Lepisanthes rubiginosa* (Roxb.) Leenh.	Lep rub	TCI,TCIII
	Tarenna	*Tarenna campaniflora* (Hook.f.) N.P.Balakr.	Tar cam	TCI,TCIII
Sapindaceae	Lepisanthes	*Lepisanthes rubiginosa* (Roxb.) Leenh.	Lep rub	TCI,TCIII
Tiliaceae	Grewia	*Grewia microcos* Linn.	Gre mic	TCI,TCII,TCIII
Verbenaceae	Vitex	*Vitex arborea* Roxb.	Vit arb	TCI,TCIII
		Vitex pubescens Vahl	Vit pub	TCI,TCII,TCIII
-	-	-	Biscuit	TCI,TCIII
-	-	-	Godamali	TCII
-	-	-	Talgoa	TCIII
-	-	-	Pichli	TCI,TCIII
-	-	-	Pipty	TCI,TCII,TCIII
-	-	-	Rana	TCIII
-	-	-	Satni	TCIII