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Environmental Correlates of Vegetation Distribution in Rajkandi Hill Reserve of Bangladesh †

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Abstract: The present study deals with the primary assessment of the relationship between plant species and environmental variables of Rajkandi Hill Reserve of Bangladesh. Total 50 circular plots (13 m radius) were taken for the collection of functional and vegetation data. Cluster analysis was done to determine the communities, DCA and CCA analyses were performed to determine the species distribution pattern and relationship with environmental variables. By the Cluster analysis, 3 different communities were identified. DCA analysis clarified 18.4% of the variance in species data, and CCA ordination clarified 67.2% of the variance of species-environmental relation.

Keywords: plant species; environmental variables; cluster analysis; correlation; reserve forest

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1. Introduction

In ecological studies, understanding the relationship between biotic and abiotic components of an ecosystem has been a major research focus. Realizing the interactions of different plants and their relationships with various soil variables could provide essential guidance in forest improvement and forest ecosystems [1]. Species diversity in forests is important in conservation management and is frequently used as an indicator of the stability of community systems [2]. The relationship of community structure, composition, and species diversity of forest with environmental factors have been considered as a central issue in ecological and environmental sciences [3]. The variation in species diversity can be linked to several ecological gradients [4]. The most ecologically important environmental factors affecting species composition and distribution are topography and soil [1]. Tropical forests represent one of the most biologically diverse ecosystems in the world, which are experiencing high rates of deforestation, and as a result, day by day, the concentration of CO_2 is increasing [5,6]. So, it is necessary to identify the vegetation patterns and structures of the forest and to determine the key environmental variables responsible for their distribution for future conservation purposes. North-eastern forests of Bangladesh cover an area of 40,000 ha, only a small part of the area (118.46 ha) comprises freshwater swamp forest [7], and the rest are hill forests having a mixture of tropical evergreen and deciduous vegetations. Some north-eastern reserve forests, namely Patharia Hill Reserves, Tarap Hill Reserves, Raghunandan Hill Reserves, etc., represent the latitudinal gradient of the north-eastern hill system.

Already ecologists have been studied the species composition and distribution pattern, community classification, soil and plant species correlation, comparison of natural fragmentation, etc., in these reserve forests. They found good species and distribution patterns; plant species are aggregated and form significantly distinct groups in these forests. But natural fragmentation and deforestation are the main causes for species

extinction. The location of the present study was Rajkandi Reserve Forest which is one of the hill reserves of Bangladesh. This forest is the most biologically diverse and ecologically least explored reserve and is comprised of several natural fragments. An extensive bibliographic search showed that the study on the interaction between species and environmental variables has been poorly studied or in many cases absent in this forest. Hence, the present study focuses on determining the relationship between plant species and environmental variables, and in detail, to classify plant species based on their abundance value, to identify the plant species composition along with distribution pattern and to find out the relationship between soil variables and plant species.

2. Materials and Methods

2.1. Study Site

The Rajkandi Hill Reserve (24°15′0″ N latitude and 91°55′0″ E longitude, 5295.55 ha) is a natural forest in north-eastern Bangladesh (Sylhet forest division), located at an elevation of 70 m above sea level [8]. The topography of the area varies from medium to steep slopes and water streams. Several channels with many tributaries spread over the forest. The soils of the forests are brown, sandy clay loam to clay loam. The climate is generally warm and humid, but the weather is cool and pleasant during winter. The temperature varies on average from nearly 27 °C in February to almost 36 °C in June. The humidity is high throughout the forest, with monthly average humidity ranging from 74% in March to 89% in July. There is heavy dew during winter when rainfall is low. The area covered under forest is one of the wettest in the country, so the rainfall is relatively high with an annual average of 4000 mm approx., with maximum rainfall during June to September for South-West monsoon [9].

2.2. Methods

The fieldwork was conducted in April–May, 2013. During an early reconnaissance survey, it was documented that tree species are generally aggregated in different habitats. Rajkandi reserve forest has been considered as a continuous forest patch. Thus the entire forest was counted as a single stand for sample plot collection. Total 50 circular plots were taken through a 13 m radius to collect functional and vegetation data. Cluster analysis using the software PC-ORD, ver. 6.0 has been used to determine the communities. DCA (Detrended correspondence analysis) and CCA (Canonical correspondence analysis) using the software CANOCO 4.5 has been used to determine the species distribution pattern and relationship with environmental variables. The correlation between species and environmental variables was performed by SPSS Statistics 17.0 software.

3. Result and Discussion

Vegetation survey yielded in total 90 plant species (53 trees and 37 herb/shrub) belonging to 50 families (27 trees and 23 herb/shrub). Family Moreceae and Verbenaceae comprise higher species numbers in comparison to other families. Cluster analysis identified 3 plant community types (Figure 1). These 3 communities of this forest are considered with (A) *Amomum corynostachyum-Mallotus roxburghianus*, (B) *Lippia alba-Clerodendrum viscosum,* (C) *Euryale ferox-Achyranthes aspera* dominant species. The relationship between species and sample plots can be easily seen in the Cluster analysis results, and the summary of the communities is presented in Table 1.

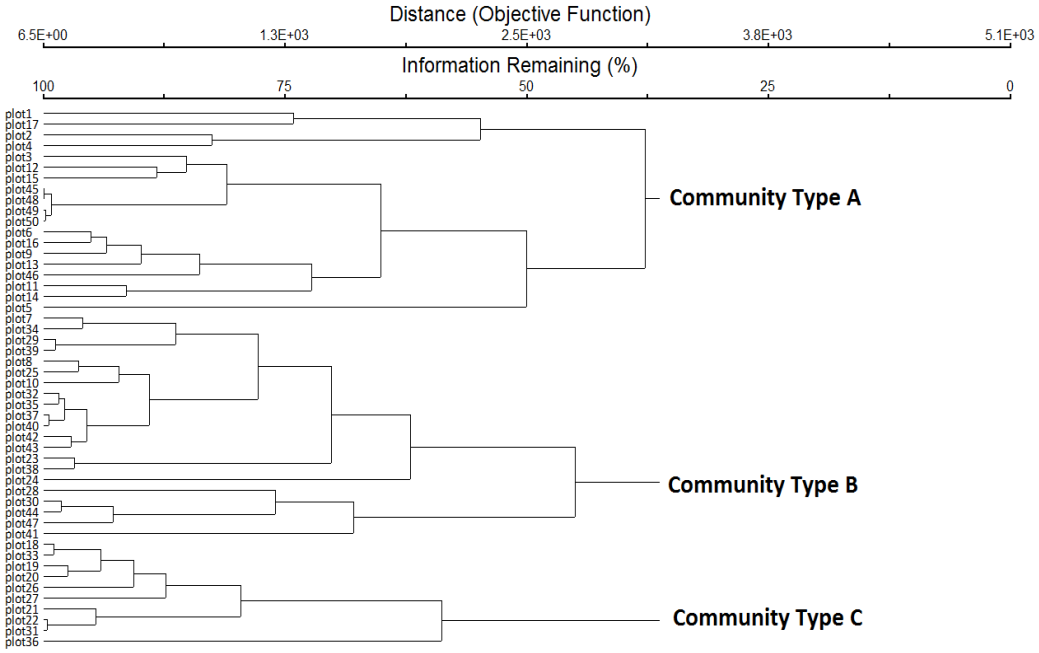

Figure 1. Dendrogram of the cluster analysis with 50 study plots and 90 plants species using Ward`s linkage method and Euclidian distance.

Table 1. Summary of community types and environmental conditions.

Community Types	**A**	**B**	**C**
Community name	*Amomum corynostachyum-Mallotusrox-burghianus*	*Lippia alba-Clerodendrumviscosum*	*Euryale ferox-Achyranthes aspera*
Plot Num.	19	21	10
Habitat	Hill ridge	Valley land	Mid slope
No. of species	64	67	33
No. of unique species	24	8	7
No. of family	38	34	21
Density (ha^{-1})	427.72	408.04	627.12
Mean value of environmental data with standard deviation			
pH	5.13 ± 0.34	5.17 ± 0.24	5.53 ± 0.42
OM (%)	1.72 ± 0.46	1.83 ± 0.23	1.88 ± 0.57
OC (%)	0.99 ± 0.27	1.07 ± 0.14	1.09 ± 0.33
P (mg/kg)	0.87 ± 0.28	0.95 ± 0.48	0.64 ± 0.18
K (mg/kg)	1.16 ± 0.65	1.53 ± 0.58	1.52 ± 0.54
Fe (mg/kg)	7.52 ± 3.36	8.68 ± 4.26	9.56 ± 5.47
Mn (mg/kg)	0.03 ± 0.02	0.02 ± 0.02	0.06 ± 0.08
Dis. (%)	54.15 ± 9.76	63.17 ± 5.44	64.23 ± 3.14
Ele. (m)	57.74 ± 24.42	50.76 ± 22.69	56.7 ± 27.59

Detrended correspondence analysis revealed a zone of rapid transition separating one distinct forest community from another, as shown in Table 2 and Figure 2a. CCA uses a site-by-species matrix and a site-by-environment matrix to extract orthogonal ordination axes representing linear combinations of environmental variables, as shown in Table 3 and Figure 2b.

Table 2. Summary statistical table for DCA ordination of Rajkandi forest.

Axes	1	2	3	4	Total Inertia
Eigenvalues	0.732	0.467	0.374	0.264	10.001
Length of gradient	6.347	3.952	4.473	3.145	
Cumulative percentage variance of species data	7.3	12.0	15.7	18.4	
Sum of all eigenvalues					10.001

Table 3. Summary statistical table for CCA ordination of Rajkandi forest.

Axes	1	2	3	4	Total Inertia
Eigenvalues	0.555	0.357	0.344	0.316	10.001
Species-environment correlations	0.901	0.925	0.924	0.948	
Cumulative percentage variance of species data	5.6	9.1	12.6	15.7	
Cumulative percentage variance of species-environment relation	23.7	39	53.7	67.2	
Sum of all eigenvalues					10.001
Sum of all canonical eigenvalues					2.34

Table 4 shows the intraset correlation coefficient between sample scores on the first two axes and environmental gradients using canonical correspondence analysis. Table 5 shows the marginal and conditional effect obtained from the summary of the forward section of CANOCO software.

Table 4. Intraset correlation coefficient between sample scores on first two axes and environmental gradients using canonical correspondence analysis.

Variables	Correlation Coefficients (Intraset)	
	Axis 1	Axis 2
pH	−0.435 **	0.431 **
OM	−0.175	0.416 **
P	0.026	0.572 **
K	−0.586 **	−0.014
Fe	−0.165	0.029
Mn	−0.142	0.066
Dis.	−0.92 **	−0.058
Elv.	−0.231	−0.573 **

** $p < 0.01$.

Table 5. Marginal and conditional effect obtained from the summary of forward section of CANOCO software.

Marginal Effects		Conditional Effects			
Variable	λ_1	Variable	λ_A	p	F
Dis.	0.51	Dis.	0.51	0.002	2.58
P	0.32	P	0.31	0.038	1.6
K	0.32	K	0.25	0.136	1.26
pH	0.29	pH	0.25	0.056	1.3
Elv.	0.25	Elv.	0.24	0.086	1.25
OM	0.24	OM	0.17	0.664	0.89
Fe	0.2	Fe	0.16	0.78	0.85
Mn	0.15	Mn	0.15	0.812	0.75

Variables are arranged in descending order of variance explained by each variable. λ_1 shows variance explained without considering other variables; λ_A shows variance explained after successively selecting the most important variables.

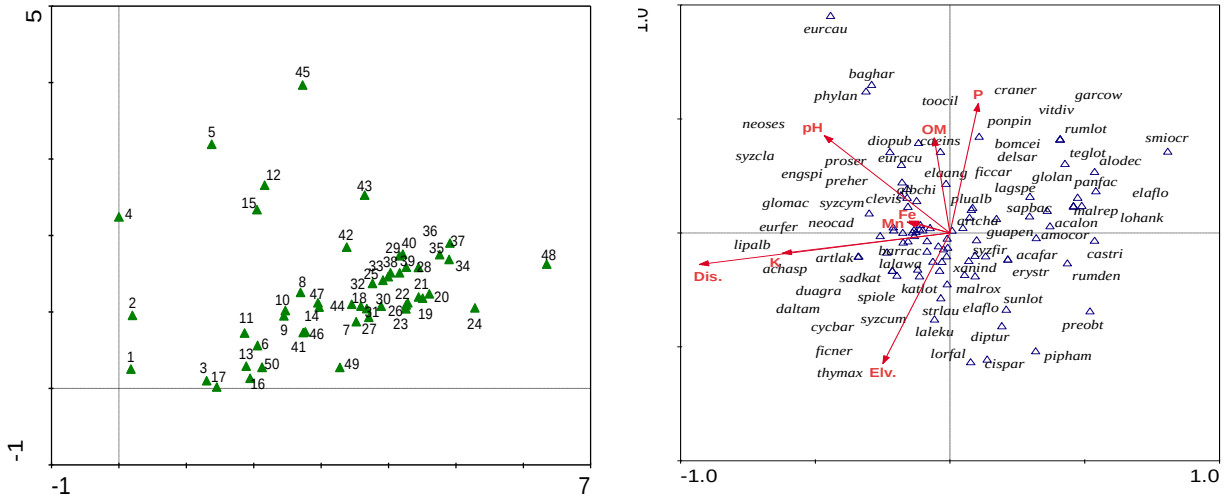

Figure 2. (**a**) Representation of DCA ordination diagram comprises 50 samples; (**b**) Bi-plot representation of CCA ordination diagram comprises 90 species of 50 samples.

In this study, the community types were defined for the Natural Forest of Rajkandi Hill Reserve. Three plant community types were generated after applying hierarchical agglomerative cluster analysis to the cover estimates of 90 species in 50 plots. These three communities of this forest are considered with (A) *Amomum corynostachyum-Mallotus roxburghianus*, (B) *Lippia alba-Clerodendrum viscosum*, (C) *Euryale ferox-Achyranthes aspera* dominant species. Community Type A is the characteristic community of the ridge hill and harbors the maximum number (24) of unique species. Examples include- *Acacia longifolia, Acacia farnesiana, Syzygium cymosum, Elaeocarpus floribundus, Vitex diversifolia, Garcinia cowa* etc. It also comprises higher elevation than the other two communities. Community Type B represents the highest number of species (67) belonging to 34 families. Among the 9 environmental variables that were measured for this study P and K are the most important variables to this community which influence to grow the abundant and unique species. The most abundant species are- *Lippia alba, Clerodendrum viscosum, Euryale ferox*, etc., which occur in the valley land. Community Type C comprises the lowest number of sample plot (10) which has 7 unique species- *Ficus semicordata, Engelhardtia spicata, Protium serratum, Duabanga grandiflora, Vitex pinnata* etc. Species occur in the mid slope of the hill where soil is moderately acidic. Soil OM, OC, Fe, Mn, and Disturbance are the highly influenced variable for the species occurrence to this community. DCA analysis performed well in describing the compositional change of vegetation. Cumulatively, the first four axes of DCA ordination clarified 18.4% of the variance in species data. It also confirms the result of cluster analysis that suggests a grouping of sites based on distance from the continental divide. Three easily distinguishable groups were formed, and a smaller group of points represented a transitional zone. Within these three clusters, distinct groupings of points were not apparent. These complementary statistical approaches independently reinforce the conclusion that distinct community types are identifiable, arrayed along with environmental gradients corresponding to distance from the continental divide. The first four CCA axes explained 15.7 and 67.2% variance of the species data and species-environment relation, respectively. These low values can be attributed to high noise levels typical of species–abundance data [10]. However, the eigenvalues of the CCA axes were lower than the eigenvalues of the DCA axes, indicating that important explanatory site variables were included in the analysis. The automatic forward selection in CANOCO identified

that the disturbance, soil P, and K are the significant variables that govern species compositional variation in the Rajkandi Hill Reserve. CCA ordination graph shows that the abundance of certain species was related to the particular soil variables. Disturbance is the most important factor for compositional variation of the species followed by P, K, pH, Ele., Fe, Mn concentration. The abundance of *Toona ciliate, Bombyx ceiba, Pongamia pinnata* have occurred in sites with a high concentration of P, *Lal ekush, Ficus caria,* and *Palaquium polyanthum* were found in sites with higher elevation. In addition, the abundance of *Artocarpus lakucha, Lippia alba, Duabanga, Sada kath,* etc. are growing spuriously in the sites with high concentrations of K. Distribution of *Rumex dentatus, Castanopsis tribuloids* are not dependent on these environmental variables, they can survive in anywhere irrespective of K and Fe and Mn.

4. Conclusions

The studied forest shows the high structural complexity, and it also seeks high degree of conservation technique. The floristic composition is quite good and helps to create significantly distinct groups. Cluster analysis revealed 3 plant community types: (i) *Amomum corynostachyum-Mallotusroxburghianus*, (ii) *Lippia alba-Clerodendrumviscosum*, (iii) *Euryale ferox-Achyranthes aspera* with their dominant species. DCA analysis proves that the plant species of this forest form distinct plant group based on similarities. On the other hand, CCA analysis demonstrates the biotic and abiotic relationship, and it also describes the plant distribution pattern and significant correlation with environmental variables. Though the vegetation of the forest of Bangladesh is under threat, this study can be helpful for the conservation of the remaining natural patches of the Rajkandi Hill Reserve forest by providing information on habitats and plant-environmental variable relations.

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