Opinion

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Application of ordination methods for determining influence of soil properties on woody species assemblage in tropical deciduous forest

Abstract

Local and regional processes have considerable impact on the tropical deciduous forest (TDF) vegetation dynamics. To determine association between the soil physico-chemical properties and woody species assemblage in TDF, we applied an indirect ordination method. We randomly selected five sites in TDF of Vindhyan highlands, India and established nine plots (50×20m) at each site, and measurement was done for woody species assemblage in each plot. The soil physico-chemical properties measured at each site include soil moisture content (SMC), soil depth, clay, silt, sand, rockiness, bulk density, pH, organic carbon, total nitrogen and total phosphorus. We observed considerable influence of soil physico-chemical properties on the woody species assemblage in TDFs. We observed that the DCA (detrended correspondence analysis*)* ordination divided woody species into three major communities, i.e., moist, semi-dry and dry. Our study suggests extensive investigation of vegetation parameters in TDFs, and their association with local and regional environmental processes with the application of advanced ordination techniques.

Keywords: tropical deciduous forest; woody species assembly; soil physico-chemical properties; detrended correspondence analysis

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Introduction

Recently, several modeling approaches have been started which integrate the influence of local as well as regional environmental processes on the local species assemblage and diversity.[1–4] Studies have reported that the local and regional processes have considerable impact on the tropical deciduous forest (TDF) vegetation dynamics.[5] The TDFs are characterized by severe climatic conditions and experience drought period of several months each year.[5] It has been emphasized that TDFs exhibit remarkable patchiness in the plant species assemblage as a result of small differences in the soil physico-chemical properties.[6] The diversity[7] and seasonal growth[8–10] of woody species in TDFs are highly influenced by soil physico-chemical properties,[5,11] therefore it is important to understand the effect of soil conditions on the woody species assemblage.

To determine association between the soil physico-chemical properties and woody species assemblage in TDF, we applied an indirect ordination method, which is considered a powerful tool for extracting hypothetical soil physico-chemical properties from the species assemblage data.[12–14] For this study, we identified five unmanaged forest fragments in Vindhyan highlands, Uttar Pradesh, India (24º18′07″ - 25º00′17″ N, 82º37′38″ - 83º23′05″ E). Forest area selected in our study experiences a typical monsoonal climate exhibiting three important seasons each year

i. Summer (April - mid June)
ii. Rainy (mid June - September)
iii. Winter (November - February)

Based on the meteorological data taken from the weather stations located in the regional forest department of Uttar Pradesh for the year 1980–2010, the average rainfall per year varies from 865mm to 1,196mm.[16] Generally, around 85% of the rainfall, each year is recorded in the monsoon season, especially from the monsoonal winds coming from south west direction, while the remaining rainfall is commonly registered in December as well as in May. The forest region experience a long dry period ranging from eight to nine months, which starts from November and ends in mid June.[5] The monthly rainfall in the forest region ranges from the lowest value of 6 mm in the month of April to highest value of 334 mm in August.[17] Soils of the study region have been reported as residual ultisols, with sandy-loam texture, light red to grayish color, and nutrient conditions very poor.[18] The recent estimation of physico-chemical soil properties of the forest region have been clearly described in Chaturvedi and Raghubanshi.[19] Based on the density-dbh woody species distributions investigated in the study region, the forest registered the dominance of low dbh stems, and the mean densities of seedling, sapling, and adult stems were 9,261±1,511, 799±154, and 297±62, respectively.[7,20,21]

The selected forest fragments in our study represented a range in soil water availability. At each selected site, we randomly established nine plots (50×20m) and measurement was done for woody species assemblage. The soil physico-chemical properties measured at each site include soil moisture content (SMC), soil depth, clay, silt, sand, rockiness, bulk density, pH, organic carbon, total nitrogen and total soil phosphorus. For detail protocol about the measurement of species assemblage and physico-chemical properties, see Chaturvedi,[15] Chaturvedi & Raghubanshi.[18] The ordination analyses were done by using the PC-ORD 5 program.[22] Generally, a unimodal (non-negative) species response curve (i.e., Gaussian response curve) is suggested for datasets which cover wide range of environmental gradients, therefore we applied the DCA (detrended correspondence analysis) ordination.[12,14] We performed DECORANA to explore relationship between the woody species assemblage from each habitat and the selected soil physico-chemical properties.[12] In this method, DCA develops a theoretical variable axis (DCA axis 1) which best describes the magnitude of variance in the woody species assemblage between different local communities, and also constructs second, third and further DCA axes by using the constraint which they need not to be correlated with the previous DCA axes.[14] In the ordination diagram, relative positions or distance of the plots distributed along the DCA axes provide an estimate of the floristic similarity among the plots. Here, we also emphasize that the relative position of our plots situated inside the multidimensional DCA ordination space is primarily on the basis of similarities in the woody species assemblage.

The DCA ordination which we developed for our plots indicated strong correlations between the plot positions along the DCA axes (on the basis of species assemblage) and soil physico-chemical properties (Figure 1). This suggests that the variations in the plot positions within the DCA ordination space may be explained majorly on the basis of the soil physico-chemical properties. Moreover, the first ordination axis had high eigenvalue, indicating a high resolution. Results showed that the first ordination axis have strong negative correlations with the mean SMC (R=-0.614), clay (R=-0.550), soil depth (R=-0.399) organic carbon (R =-0.288), total nitrogen (R=-0.390) and total phosphorus (R = -0.328), and positive correlations with soil pH (R= 0.637), sand (R=0.509) and rockiness (R=0.380) (Table 1), whereas the second DCA axis exhibited positive correlation with total phosphorus (R=0.457). The third DCA axis showed negative correlation with bulk density. It was also observed that soil pH (R=-0.74, P<0.001) and bulk density (R=-0.56, P<0.001) exhibited strong negative correlation and total phosphorus showed positive association (R=0.49, P<0.01) with SMC. We observed that the DCA ordination divided the woody species into three major communities, i.e., moist, semi-dry and dry. The species present in these communities are as follows:

Table 1 Summary of DCA ordination. SMC, soil moisture content; Number of plots: 45; number of species including adult, sapling and seedling: 53; number of occurrences: 853; total variance ("inertia") in the species data: 2.71. Source: Chaturvedi.[15]

Ordination axes	1	2	3
Eigenvalues	0.931	0.341	0.193
Lengths of gradient	3.700	2.289	2.013
Total (multiple correlation)			
SMC	-0.614	0.122	-0.068
Soil depth	-0.399	0.002	0.105
Clay	-0.550	0.170	0.033
Silt	-0.038	-0.241	0.207
Sand	0.590	0.073	-0.218
Rockiness	0.380	-0.049	-0.104
Bulk density	0.249	-0.098	-0.317
pH	0.637	0.080	0.119
Organic carbon	-0.288	-0.098	-0.032
Total nitrogen	-0.390	0.035	0.010
Total phosphorus	-0.328	0.457	0.000

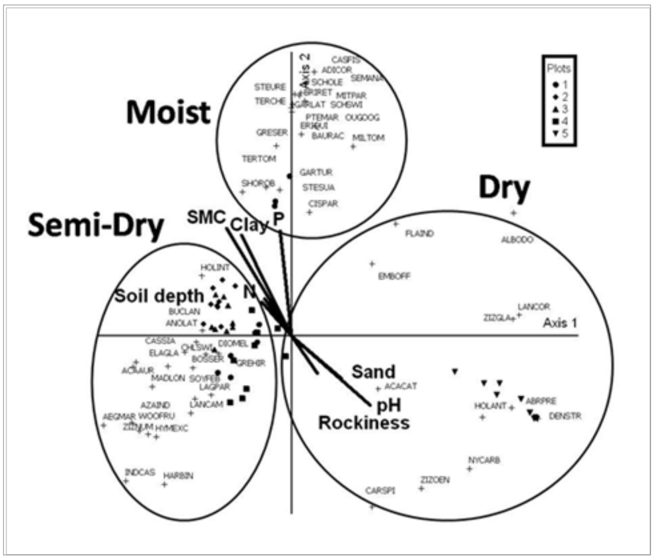

Figure 1 DCA ordination of the woody species on the basis of soil physico-chemical properties. SMC, soil moisture content; C, soil organic carbon; 1, Hathinala; 2, Gaighat; 3, Harnakachar; 4, Ranitali; 5, Kotwa. Species abbreviations are given in Chaturvedi.[15] Source: Chaturvedi.[15]

Moist

Adina cordifolia, Bauhinia racemosa, Bridelia retusa, Cassia fistula, Cissampelos pareira, Elaeodendron quinquelocularis, Gardenia latifolia, Gardenia turgida, Grewia serrulata, Miliusa tomentosa, Mitragyna parvifolia, Pterocarpus marsupium, Schleichera oleosa, Schrebera swietenioides, Semecarpus anacardium, Shorea robusta, Sterculia urens, Stereospermum suaveolens, Terminalia chebula and *Terminalia tomentosa.*

Semi-dry

Acacia auriculiformis, Aegle marmelos, Anogeissus latifolia, Azadirachta indica, Boswellia serrata, Buchanania lanzan, Cassia siamea, Chloroxylon swietenia, Diospyros melanoxylon, Elaeodendron glaucum, Grewia hirsuta, Hardwickia binata, Holarrhena integrifolia, Hymenodictyon excelsum, Indigofera cassioides, Lagerstroemia parviflora, Lantana camara, Madhuca longifolia, Soymeda febrifuga, Woodfordia fruticosa and *Ziziphus nummularia.*

Dry

Abrus precatorius, Acacia catechu, Albizia odoratissima, Carissa spinarum, Dendrocalamus strictus, Emblica officinalis, Flacourtia indica, Holarrhena antidysenterica, Lannea coromandelica, Nyctanthis arbortristis, Ziziphus glaberrima and *Ziziphus oenoplea.*

These communities differ from each other on the basis of variations in effects of different soil physico-chemical properties on them. On one hand, there were effects of SMC, clay, nitrogen and phosphorus on moist and semi-dry communities, while on the other side, dry community was strongly affected by pH, sand and rockiness.

Conclusion

We observed considerable influence of soil physico-chemical properties on the woody species assemblage in TDFs. With the application of ordination methods, we categorized woody species of TDF on the basis of their association with soil physico-chemical properties. Our study suggests extensive investigation of vegetation parameters in TDFs, and their association with local and regional environmental processes with the application of advanced ordination techniques.

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Conflict of interest

The author declares there is no conflict of interest.

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