A functional trait approach for understanding woody species assemblage in tropical deciduous forest

Abstract

Patterns of species distribution can be explained by functional traits of the dominant species and a few key environmental parameters which act as filters on the available pool of species. We performed principal component analysis (PCA) to determine which combination of functional traits best summarizes the grouping of the woody species of tropical deciduous forest located in Vindhyan highlands, India. In PCA ordination, the first three axes together explained 98.9% of the between species variation (89.5%, 6.4% and 3.1% for axis 1, 2 and 3, respectively). The woody species exhibited assemblage in the ordination space on the basis of their functional traits. We observed higher leaf area index (LAI), leaf relative water content (RWC) and specific leaf area (SLA) for plant species present at moist sites, whereas, leaf dry matter content (LDMC), mass–based photosynthetic rate (A\textsuperscript{max}) and leaf water use efficiency (WUEi) were found greater for the species present at dry sites. We suggest extensive investigation for functional traits and their ecological significance in grouping of plant communities in tropical deciduous forest.

Keywords: tropical deciduous forest, soil moisture content, woody species, functional traits, Vindhyan highlands

Introduction

Understanding plant species assemblage requires insight into the mechanisms which determine species richness, and also needs proper investigation of the mechanisms that determine composition of the local species. As compared to species richness, species assemblage is more difficult to assess, because it requires more detailed information about the constituent species. Species assemblage involves not only the total number of species and their abundance, but also the characteristic feature of the species. The Local species assemblage arises partly from stochastic phenomenon such as local species extinctions due to demographic drift and rare occurrence of long distance dispersal events, and partly resulting from deterministic processes associating habitat characteristics with species specific niches. The common approach for the prediction of spatial and temporal patterns of species distribution could be defined by certain “community assembly rules” in terms of a set of “filters” which are responsible for removal of some species from the total pool of species according to their functional traits.\textsuperscript{1,2} According to the “niche assembly view” of the plant community, the species assemblage in a community is determined by the physiological processes and biological interactions.\textsuperscript{3} Therefore, patterns of species assemblage can be mainly explained by a few key environmental parameters which act as filters on the available pool of species.

We performed principal component analysis (PCA) to determine which combination of functional traits best summarizes the grouping of the woody species of tropical deciduous forest located in Vindhyan highlands, India (24°18′07″N and 83°05′57″E to 25°00′17″N and 82°37′38″E). The study was conducted at five sites, exhibiting variable soil moisture content (SMC), and representing mature, naturally established and unmanaged tropical dry forest (TDF) of India.\textsuperscript{4,5} The functional traits analysed for the study were: bark thickness (BT), wood specific gravity (WSG), leaf area index (LAI), leaf relative water content (RWC), leaf dry matter content (LDMC), specific leaf area (SLA), leaf carbon concentration (LCC), leaf nitrogen concentration (LNC), leaf phosphorus concentration (LPC), chlorophyll concentration (Chl), mass based stomatal conductance (Gs\textsubscript{max}), mass base photosynthetic rate (A\textsuperscript{max}), leaf water use efficiency (WUEi), biomass increment (Bio Incr), and relative growth rate (RGR). We also measured as the environmental variable. PCA was done with the help of PC–ORD 5.\textsuperscript{6} For detail information about the study sites, study design and sampling protocol, see Chaturvedi\textsuperscript{7}, and Chaturvedi & Raghubanshi\textsuperscript{8} In PCA ordination, the first three axes together explained 98.9% of the between species variation (89.5%, 6.4% and 3.1% for axis 1, 2 and 3, respectively) (Figure 1). SLA was most strongly and negatively associated with axis 1 (R = –0.99), WUEi showed negative correlation with axis 2 (R = –0.96), RWC was positively associated with axis 3 (R = 0.96), positive correlation was also observed for LAI with axis 4 (R = 0.94), A\textsuperscript{max} showed negative association with axis 5 (R = –0.91) and LDMC was positively associated with axis 6 (R = 0.96) (Table 1). The environmental variable, SMC showed strong negative correlation with axis 1 (R = –0.66).

Table 1 Loading of traits that better explain between species variation in the PCA ordination of the woody species of Vindhyan highlands, India

<table>
<thead>
<tr>
<th>Trait</th>
<th>Ordination axes</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAI</td>
<td></td>
<td>–0.05</td>
<td>0.1</td>
<td>–0.06</td>
<td>0.94*</td>
<td>0.3</td>
<td>–0.02</td>
</tr>
<tr>
<td>RWC</td>
<td></td>
<td>–0.1</td>
<td>0.26</td>
<td>0.96*</td>
<td>0.01</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>LDMC</td>
<td></td>
<td>0</td>
<td>–0.07</td>
<td>–0.06</td>
<td>–0.04</td>
<td>0.22</td>
<td>0.96*</td>
</tr>
<tr>
<td>SLA</td>
<td></td>
<td>–0.99*</td>
<td>–0.01</td>
<td>–0.01</td>
<td>–0.06</td>
<td>0.02</td>
<td>–0.01</td>
</tr>
<tr>
<td>A\textsuperscript{max}</td>
<td></td>
<td>–0.05</td>
<td>–0.05</td>
<td>0.06</td>
<td>0.29</td>
<td>–0.91*</td>
<td>0.24</td>
</tr>
<tr>
<td>WUEi</td>
<td></td>
<td>–0.02</td>
<td>–0.96*</td>
<td>0.25</td>
<td>0.09</td>
<td>0.08</td>
<td>–0.07</td>
</tr>
</tbody>
</table>

*P < 0.001.

Source: Chaturvedi\textsuperscript{8}
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Pterocarpus marsupium, Shorea robusta, Terminalia tomentosa antidysenterica, Lantana camara, Lagerstroemia parviflora, M. glaberrima, Retz.

greater for the species present at dry sites, and some important species

LAI ranged from 10.0 to 12.1; RWC, 98.1 to 98.8%; SLA, 142 to 164

Source: Chaturvedi

We observed higher LAI, RWC and SLA for plant species present at moist sites, and in the PCA ordination space, some of the important species which were present in this group were: Acacia auriculiformis A.Cunn. ex Benth, A. catechu (L.) Willd., Azadirachta indica A. Juss., Bauhinia racemosa Lam., Bridelia retusa (L.) A. Juss, Cassia fistula L., Senna siamea (Lam.) HS Irwin & Barneby, Elaeodendron glaucum (Rottb.) Pers., Gardenia latifolia Ait., Holarrhena pubescens Wall ex G. Don, Lantana camara L., Lagerstroemia parviflora Roxb., Mitragyna parvifolia Wall ex G. Don, Grewia hirsuta (L.) Kurz., Kavalama urens (Roxb.) Raf., Terminalia chebula Retz., T. tomentosa, Woodfordia fruticosa (L.), Kurz, Ziziphus glaberrima and Z. oenoplia (L.) Mill. (their LDMC ranged from 10.0 to 12.1; RWC, 98.1 to 98.8%; SLA, 142 to 164 cm² g⁻¹).

The remaining three traits (i.e., LDMC, Aₘₜₐₓ and WUEi) were found greater for the species present at dry sites, and some important species were: Acacia catechu, Anogeissus latifolia (Roxb. ex DC.) Wall. ex Guillen. & Perr., Bridelia retusa, Buchanania cochinichensis (Lour.) Almeida MR. Carissa spinarum L., Diospyros melanoxylon Roxb., Elaeodendron glaucum, Phyllanthus emblica L., Ficus racemosa L., Grewia hirsute Vahl., Gardenia latifolia Aiton, Hardwickia binata Roxb., Holarrhena antidysenterica Wall, Lantana camara L., Lannea coromandelica (Houtt.) Merr., Lagerstroemia parviflora, Madhuca longifolia (J König ex L.) Macbr JF, Nyctanthes arbor–tristis L., Pterocarpus marsupium Roxb., Semecarpus anacardium L.f., Shorea robusta Gaertn., Kavalama urens (Roxb.) Raf., Terminalia chebula Retz., T. tomentosa, Woodfordia fruticosa (L.), Kurz, Ziziphus glaberrima and Z. oenoplia (L.) Mill. (their LDMC ranged from 35.5 to 37.1%; Aₘₜₐₓ 12.5 to 14.3 μmol m⁻² s⁻¹; WUEi, 54.1 to 58.8 μmol mol⁻¹).

Some of the species such as: Acacia catechu, Bridelia retusa, Elaeodendron glaucum, Gardenia latifolia, Holarrhena antidysenterica, Lantana camara, Lagerstroemia parviflora, Pterocarpus marsupium, Shorea robusta, Terminalia tomentosa and Ziziphus glaberrima were present in both the groups. Most of these species have been found in all study sites.10

Asynchrony, intra–species variability or plasticity in a species denotes the existence of individuals showing differing morphological, physiological and behavioral responses to environmental conditions.11–14 The woody species investigated in this study show asynchrony and intra–specific variability at different study sites and in different seasons.12,15 They have high adaptive ability and plasticity according to variations in soil moisture ability.14,15 Therefore, they are generally dominant and present at all the sites.

Dominant plant species have been reported to strongly influence the size as well as turnover rate of the aboveground carbon stocks.16–18 They are also a important determinant of the size as well as turnover rate of soil carbon stocks, for at least in the short to medium term. The effects of these dominant species are determined particularly by the quantity and quality of resources which they return back to the soil, which is in turn influenced by their functional traits.16–17 Within a specified envelope of a given climate and substrate, these functional traits influence the rates of carbon accumulation and carbon loss, as well as the density and longevity of the carbon stocks in equilibrium condition. Therefore, major importance should be given on the protection of the dominant plant species, especially the tree species which are abundant in the forest. These species have high adaptability as well as plasticity according to variations in soil moisture availability.16–18 Therefore, they can help in mitigating the ecological impacts of global climate change by enhancing carbon sequestration.

Conclusion

Our study highlights the importance of functional traits for understanding woody species assemblage in tropical deciduous forest. Moreover, functional traits of the dominant plants over large areas can also influence water and heat biophysical feedbacks from earth surface to the atmosphere, and thus impact climate directly. For example, leaf stomatal conductance and root depth of dominant plant species affect ecosystem evapotranspiration; canopy architecture, and leaf morphology, and lifespan affect albedo, sensible heat, roughness, and the balance between infiltration and runoff. All these processes feedback onto the atmosphere and have the potential to influence climate at the local, regional, or larger scales, depending on the size of the vegetation patches. Therefore, we suggest extensive investigation for functional traits of their ecological significance in grouping of plant communities in tropical deciduous forest.

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Conflict of interest

The author declares there is no conflict of interest.

References


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