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Neutral theory and the functional diversity in the semiarid area of District Karak, Pakistan

Zulqarnain[*1,2], Ayaz Malook[1], Zain Ullah[1], Rehman Ullah[1], Laiq Zaman[1], Asghar Ali[3]

[1]*Government Post Graduate College, Department of Botany, Karak, Pakistan*

[2]*Government College, Department of Botany, Peshawar, Pakistan*

[3]*Government Post Graduate College Matta, Swat, Pakistan*

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Abstract

Environmental gradients and human perturbations greatly involved in community assembly, stability and dynamics of habitat and the exploration of functional diversity support in an understanding communities and ecosystems. Present study is based on trait-based approach to know how species assemble in a random and non-random ways and what is the role of stochastic (random) and deterministic (nonrandom) processes in community assembly of species. This study aimed at advancing understanding about the functional diversity of the area to assess the plant species community assembly of District Karak. Twelve plots of 100 m × 100m, were randomly placed in five different monitoring sites of District Karak. Species were sampled by applying DBH method (Diameter at Breast Height) ≥ 1 cm. In addition to this leaf size and wood density were also calculated. The use of such characters depicts stability of the species in the habitat. CWMs (Community Weighted Mean) were used because these are measurements that account for trait values as well as abundance. Less variation was found among the traits in the species of all the communities. A non-random pattern of traits was recorded in the study area. Results suggest that limiting functional traits are the result of environmental factors prevailing in the area and non-random occurrence may the result of dispersal limitations of the species in the area.

***Corresponding Author:** Zulqarnain ✉ mezulqi@gmail.com

Introduction

Functional traits and environmental gradients enable leaves imprint into the effect on diversity and composition of plant communities (McGill *et al.,* 2006). For this purpose, we will use a trait-based approach to know how species may assemble in a random and non-random ways and what the role of stochastic (random) is and deterministic (nonrandom) processes in community assembly of species. Reich *et al.,* (2003) defines a plant functional trait as a notable characteristic of species that impress the ability of an individual to survive in a given environment. Floristic lists provide little information about the function of species (Swenson 2011), but the patterns of functional trait diversity illustrate stronger inferences about community structure.

A wide range of important ecological questions can be addressed in terms of functional diversity. There are questions about the evolutionary diversity can also address questions about determination of ecosystem level processes (Dı´az and Cabido 2001; Tilman 2001 and Chapin *et al.,* 2000) and is a concept that links species and ecosystems through mechanisms such as resource use complementarity and facilitation. It might thus also be a tool for predicting the functional consequences of biotic change caused by humans (Loreau *et al.,* 2002 and Chapin *et al.,* 2000).

Perhaps the importance of functional diversity influences ecosystem processes, the dynamics of ecosystems, and the stability of ecosystems. This study emphasizes on measuring functional diversity to know the functional differences in different areas of District Karak so that it can be rigorously applied to ecological problems that are concerned with habitat stability and dynamics. This research work describes leaf size that reflects leaf energy and water balance in plants which are impacted by variation in climate and geology (Cornelissen *et al.,* 2003). Reports are available that specific leaf area (SLA; leaf area per unit leaf mass) tends to be positively correlated with the rate of photosynthesis but negatively correlated with leaf life spans (Wright *et al.,* 2004 and Swenson 2012). Similarly, SLA is also a predictor of certain plants aspects such as behavior, performance, leaf economics spectrum traits, growth and survival rates (Swenson 2012). Second and third functional traits considered during this work were DBH (Diameter at Breast Height) and wood density respectively, which are related to the "wood economics spectrum" (Chave *et al.,* 2009). Maximum DBH represent maximum height, thereby giving us an insight into the size of individuals (Kraft *et al.,* 2008). Wood densities display the growth and survival of the plant species (Swenson 2012), because it is negatively correlated with both growth and mortality rates (Swenson 2012, Wright *et al.,* 2010 and Chave *et al.,* 2009). Dense wood shows resistant to stem breakage due to physical disturbance (Swenson 2012 and Zimmerman *et al.,* 1994). Dense wood resists insect invasion that use to bore through the woody stem (Swenson 2012). Therefore, based on "wood economics spectrum" (Chave *et al.,* 2009), it is expected that wood related traits will yield important insights into plant community assembly of District Karak. The general goal of the study was to advance our understanding about the functional diversity of the area to know the plant species community assembly of District Karak. This lead to questions; How much the communities are diverse in their functional traits? How much the traits are spread in the area? How much diversity of the functional traits is present in the community?

Material and methods

Introduction to the Area

The present study was centered on the exploration of functional diversity of District Karak. Extensive surveys were conducted at Tarkhun koi, Tangori chowk (Hereafter Community1), Dabli Lawagher, Sarachkhel (Hereafter Community 2), Amberi kala, Zarkhan Kala (Hereafter Community 3) in Southeastern part of District Karak. These monitoring sites fall in the South of Kohat and on the Western side of District Bannu and Laki Marwat about 123 km away from Peshawar on the main Indus Highway. These monitoring sites exist at 33 7'12N latitude and 71 5'41E longitude and cover an area of 3,372 square kilometers with a population of approximately 536000. The climate is hot during the summers, with temperature touching 40-45 degrees.

The average rainfall ranges from 30 to 110 inches in which the major precipitation time is summer monsoon.

Sampling

Twelve plots of 100m × 100m, were randomly placed in five monitoring sites of District Karak. Species were sampled with DBH method (diameter at of breast height) ≥ 1cm. Leaf size and wood density was also measured. Wood density was measured by volume displacement method (Osazuwa-Peters and Zanne 2011); all bark from the wood segment was removed and if the pith was large enough to affect wood density measurements, wood segments were sliced in half and to remove the pith. Wood segment was attacked to a needle and thread, which allowed immersion of the wood sample into water without contributing additional volume. Samples were submerged it in a beaker of distilled water located on a balance so that top of the wood segment was right below the meniscus. Mass of the water displaced was calculated, which equaled our fresh volume (assuming density of water at 1g/cm3). Wood samples were dried in an oven at 103^{o}C for 72 hours, wood density was calculated. To measure leaf size, three representative leaves were selected from the branch.

Analysis

Mean values for each trait were calculated for all species. These values were used to enumerate differences in trait values among the species. Community Weighted Means (CWMs) were taken into consideration because these account for trait values as well as abundance. The CWMs represent the mean value of a trait weighted by the quantity of the individuals with that trait in each 100 x 100m quadrat (Lavorel *et al.,* 2007). Statistical analyses was carried out by using 'FD' package (Laliberté and Legendre 2010, Laliberté and Shipley 2011) in the software R (Version 2.14.2, 2012). Moreover, standardized effect sizes of each diversity measure were also documented in order to compare values among different plots. Standardized effect sizes describe the difference between phylogenetic distances in the observed community versus null community generated by randomization. Standardized effect size of FD (SESFD) were calculated by using following formula as:

$$\text{Standardised Effect Size} = \frac{\text{Obs.value} - \text{Rnd.value}}{\text{Sd.Rnd.value}}$$

Where Obs. value is the observed value of the metric under analysis, Rnd. value is the mean metric value of null communities, and Sd. Rnd. value is the standard deviation of the 1,000 random values of the measure. Random values were generated by reshuffling traits labels across the tips of the cluster dendrogram of all traits species sampled. Positive values of the standardized effect indicate that the site has a diversity values higher than expected by chance, i.e. an over dispersion of the local traits community, whereas negative values indicate that the site has a diversity value lower than expected by chance (Pavoine and Bonsall 2011; Webb *et al.,* 2002). All the metrics were determined with the 'picante' package (Kembel *et al.,* 2010) for R environment (R Version 2.14.2, 2012).

Results

A total of 23 species in community 1, 20 species in community 2 and 29 species in community 3 were documented. Our results indicate less variation among the traits in the species of all the communities. It was observed that functional distance of community 1 was 1.25, community 2 was 1.64 and community 3 was 1.44 respectively. The results indicate the preservation of the functional traits and represent the similarity between community 2 and 3 (Table 1). Positive values of functional diversity (Z) were noticed in all the communities viz. 0.28 Z value of community 1, Z value of 1.67 in community 2 and 1.19 Z value in community 3 respectively. However, the *P* value observed for the traits distribution showed random pattern among all the three communities (Table 1). Six functional groups were observed in community 1 and 7 functional groups in community 2 and 3 respectively for different species present in these communities (Table 2). It was noticed that group 3 was mostly abundant in all communities (Table 3). All the species from group 3 belonged to different families but due to resemblance in functional traits, they were considered in the same group.

Table 1. Standardized effect of functional diversity measurments in the studied communities of the semi-arid area in District Karak.

Comm-unities	N taxa	FD obs	FD rand mean	FD rand sd	FD obs rank	FD obs Z	*P* Value
1	23	15.519	14.787	2.542	61	0.287	0.6
2	20	17.888	13.719	2.487	99	1.675	0.98
3	29	20.345	18.232	1.772	85	1.192	0.841

N Taxa = Number of species. FD obs = Functional diversity observed. FD rand mean = Functional diversity random mean matric value of null communities. FD rand sd = Functional diversity random standard deviation. FD obs rank = Functional diversity observed rank. FD obs Z = Functional diversity observed standardized effect value.

Table 2. Group wise distribution of different species in different communities.

Species	Group	Species	Group
Acacia-modesta(Wall.)P.J.Hurter	1	*Lactuca virosa* L.	3
Acacia-nilotica(L.)P.J.Hurter & Mabb	2	*Launaea procumbens*	3
Acacia-senegal(L.)Willd	1	*Medicago denticulata* Willd.	3
Alhagi maurorum Medik.	3	*Nannorrhops ritchieana* Griff.	6
Aloe vera(L.) Burm.	3	*Parthenium hysterophorus* L.	3
Astragalus adscendens Fisch.	3	*Peganum harmala* L.	3
Boerhaavia diffusa L.	3	*Phoenix dactylifera* L.	8
Borago officinalis L.	6	*Phoenix sylvestris*(L.) Roxb.	4
Calotropis procera(Aiton)W.T.Aiton	3	*Rhazya stricta* Decne.	3
Cenchrus ciliaris L.	3	*Ricinus communis* Linn.	3
Cenchrus spinifex Cav.	3	*Saccharum arundinaceae* Hook.	3
Cymbopogon jwarancusa(Jones)Schult	7	*Saccharum spontaneum* L.	3
Cynodon dactylon(L.) Pers.	3	*Solanum incanum* L.	3
Dalbergia sissoo Roxb.	1	*Solanum surattense* Burm.f.	3
Datura alba L.	4	*Tamarix aphylla*(L.) Karst.	4
Dodonaea viscosa L.	4	*Tribulus terrestris* L.	3
Eleusine tristachya(Lam.)Lam.	3	*Typha angustata* Bory.	3
Eucalyptus alba Reinw. Ex Blume.	5	*Withania coagulans*(Stocks) Dunals.	3
Fagonia cretica L.	3	*Withania somnifera*(L.) Dunal.	3
Heliotropium europaeum Linn.	3	*Xanthium strumarium* L.	3
Ziziphus jujuba Mill.	3	*Ziziphus nummularia*(Burm.f.)Wight	1

Table 3. Distribution of different groups among the three communities.

Communities	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Community 1	3	1	14	2	0	2	0
Community 2	3	1	12	1	1	0	1
Community 3	4	1	19	2	1	0	1

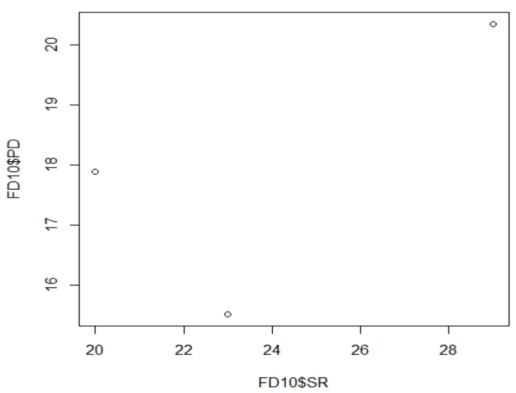

Fig. 1. Relationship between Species richness and Functional Diversity in the three communities of the studied sites. FD10$PD = Functional Diversity, FD10$SR = Species richness.

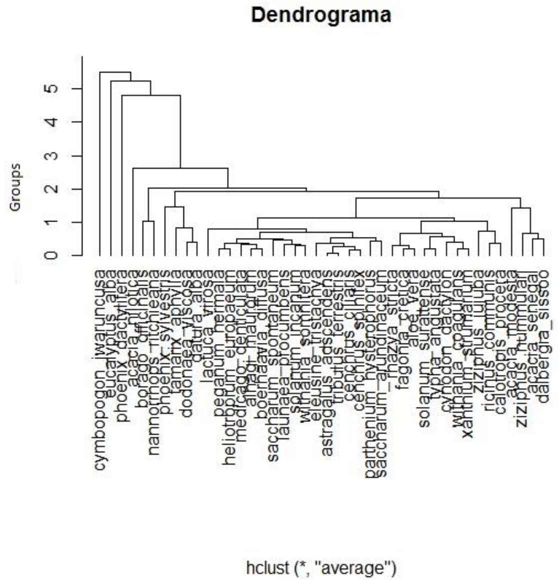

Fig. 2. Functional Groups in the three communities of the studied sites.

Discussion

In general, our results show less functional diversity in all the three communities. The results indicate functional conservatism in the area and show few functional groups for all the species and only one dominant group in all the three communities. The presence of one abundant group represents similarities and preservation in functional traits of these species even they belong to different families. It indicates that environmental factors may have some role in the limiting functional traits in all the three communities. However random distribution of the traits seems to be due to stochastic factors in all the studied communities. Lower traits variation is found in all the communities. The result is an assembly of species with similar characteristics (Pausas and Verdú 2010; Fukami *et al.*, 2005). Consequently, a restricted range of species trait values is viewed as evidence of environmental filtering (Pausas and Verdú 2008; Weiher *et al.*, 1998). Environmental filters are generally narrow the range of functional traits in a local community. Filtering can lead to stabilizing or directional natural selection over evolutionary time. The environmental factors such as climate, disturbance regime, some aspects of atmospheric composition, and biotic interactions are major (Woodward and Diament 1991; Keddy 1992, Díaz *et al.*, 1998, 1999), strongly determine which traits and functions can survive at any site. Since the environmental conditions of the area is semi-arid which represents dry conditions, therefore only those plants can grow better which can withstand the dry and harsh environment. Thus, functional traits of the species do not vary in all the communities. Nevertheless, random distribution of functional traits was seen in the local communities. Random distribution may be due to stochastic factors prevailing in the communities. The importance of these findings is that dispersal and recruitment limitation are sufficiently strong to prevent competitive exclusion among species whose traits exhibit the same or very similar adaptations for the most common environments (Hubbell, 2005). This notion backs findings of this study it was observed that most of the species in the three communities belong to family Poaceae which propagate by vegetative means and the seeds of most of the plants from family Fabaceae are dispersed near to the parent trees.

Conclusion and recommendations

Findings of this study suggest that random distributions of the functional traits are the result of dispersal limitations of the dominant species in the area. However less variations in the functional diversity among the communities is also indicating the role of prevailing environment in an area. Further study of the different functional traits and their relationship with environmental variables will elucidate the role of deterministic and in deterministic factors in community assembly.

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