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Vegetation analysis in the Rawdhat Om Al-Khefas, Central Saudi Arabia

Abdulaziz A. Al-Qarawi

Department of Plant Production, College of Food & Agricultural Sciences, King Saud University, P.O. Box 2460, 11451 Riyadh, Saudi Arabia

Abstract: Rawdhats are unique habitats in the hyper-arid region of Central Saudi Arabia. However, its vegetation is under constant threat of heavy anthropogenic activities. The present study identifies the major plant communities and gradients of plant compositional change within the Rawdhat Om Al-Khefas. Classification and of vegetation data by TWINSPAN displayed seven clear vegetation groups, each with specific indicator species. The seven vegetation groups were confirmed by detrended correspondence analysis (DCA). The direct canonical correspondence analysis (CCA) was used to assess the vegetation–soil relationships. The main soil variables controlling the separation of the vegetation groups on the first two axes of CCA are soil texture, pH and $CaCO_3$. However, these factors contributed not more than 30.5% of total species data variances along the three axes of CCA. The tree layer represented by *Acacia tortilis* subsp. *tortilis* and *Ziziphus nummularia* is positively correlated with the proportion of soil silt and clay, while the communities characterized by *Rhazya stricta, Lasiurus scindicus* and *Lycium shawii* are positively correlated with the proportion of soil sand. The findings of this study suggests that the further research are needed to evaluate the human impact on the vegetation dynamics within the rawdhats.

Key words: Central Saudi Arabia; classification; desert vegetation; ordination; rawdhats

INTRODUCTION

The flora of the central Saudi Arabia is impoverished and meager, due to its location within the hyper-arid hinterland location, and its associated very dry climate (Vesey-Fitzgerald, 1957). In contrast to the whole arid and hyper-arid central region, the rawdhats possess a rich variety of mesophytic vegetation during the rainy seasons (Al-Farhan, 2001). Rawdhat means a closed basin with a firm, flat vegetation covered mud surface, occasionally rocky and sandy (Vesey-Fitzgerald, 1957; Bramkamp and Ramirez, 1978).

The flora and the vegetation of rawdhats are not only comparatively rich in plant species but also distinctive. They have many taxonomically and geographically isolated taxa, including *Ziziphus nummularia, Acacia gerrardi* and the rather isolated extinct and rare species, *Capparis decidua,* and *Delphinum orientales.* However, little consideration has been given to its ecological implications (Shaltout and Mady, 1993, 1996). Most of the available studies were concerned with floristic lists and qualitative description of the vegetation (Tag El-Din *et al*., 1994; Al-Farraj *et al*., 1997; Al-Hemaid, 1998; Al-Farhan, 2001; Al-Nafie, 2007). Furthermore, most of these studies were concentrated in the king's spring camp "Rawdhat Khuraim" (e.g. Tag El-Din *et al*., 1994; Al-Farraj *et al*., 1997; Al-Farhan, 2001). Accordingly, Rawdhat Khuraim has been regarded as an important component in the natural conservation network of the country, and actively protected from human disturbances. However, other rawdhats are subjected to camping, off-road driving, heavy grazing, firewood cutting, harvesting of medicinal plants, etc., which led to an eradication of many plant species (Assaeed and Al-Doss 2002; Al-Nafie, 2007).

The present study aims to identify the major plant communities and gradients of plant compositional change within the Rawdhat Om Al-Khefas, Central Saudi Arabia, and to identify which environmental variables have the main role in establishing different plant communities. Such studies are essential if we are to understand the ecological factors accounting for the survival and dynamics of rawdhat dependent species.

MATERIAL AND METHODS

The Study Area:

The study site is located at the Rawdat Om Al-Khefas (24^0 48/N, 45^0 50/E), located about 120 km

Corresponding Author: Abdulaziz A. Al-Qarawi, Department of Plant Production, College of Food & Agricultural Sciences, King Saud University, P.O. Box 2460, 11451 Riyadh, Saudi Arabia
E-mail: alqarawi@ksu.edu.sa

northwest Riyadh, Saudi Arabia. The region has a hyper arid climate. The lowest and highest absolute temperatures are 6.5^{0}C and 45^{0}C, respectively. The annual average temperature is about 29^{0}C. The average annual rainfall is ca. 85 mm, most of which is received during January to March. The growing season starts in late November and ends in late April. The area is under heavy grazing by camels, sheep and goats. In addition to over-grazing, the site is allowed for picnic but not for camping.

Methods:

All quantitative field data were collected between April 2008 and May 2009. A total of 130 vegetation sampling plots (each of 10 m x 10 m, based on the minimal area) were selected to represent the main plant communities in the study area. The cover values of plant species within each plot were recorded using the Braun-Blanquet scale (Westhoff and van der Maarel, 1973). Plant nomenclature was according to Migahid 1988-1990; Chaudhary 1989, 1999 and Collenette, 1999.

In a subsample of 15 randomly selected plots from different plant communities, three soil cores per plot were randomly collected at profiles 0-50 cm and pooled together to form one composite sample. Measured soil variables included physical and chemical properties. Soil texture (the proportions of sand, silt and clay) were determined by the hydrometer method (Bouyoucos, 1951). Soil–water extracts (1:5) were prepared for the estimation of electrical conductivity (E.C.) using an electric conductivity meter and soil reaction (pH) using a pH meter and glass electrode (Anonymous, 1980); organic matter was estimated by the Walkley-Black's method (Nelson and Sommers, 1996); total carbon was estimated by the method of Allison (1965) and the proportion of $CaCO_3$ was measured by the Calsimeter method (Allison and Moode, 1965).

Data analysis

Vegetation and soil data were entered into PC-ORD, V. 4.17 package (McCune and Mefford, 1999), allowing analysis of species-in-site by classification and ordination. Two-way indicator species analysis (TWINSPAN) was performed to classify the vegetation data (Kent and Cooker, 1992). Ordination was carried out by unconstrained ordination (detrended correspondence analysis, DCA) to find major gradients in species composition and thus describe the general pattern in species distribution along the gradients (ter Braak, 1987). In addition, constrained ordination (canonical correspondence analysis, CCA) was applied to assess the relative importance of first and second major gradients of environmental variables in explaining the species distribution patterns (Lepš and Šmilauer, 2003).

Results:

Seven vegetational groups were recognized by TWINSPAN for the studied stands (Figure 1). These vegetation groups are named after the first two dominant species (Table 1). The second level of TWINSPAN division separated group A that characterized by the indicator species *Acacia tortilis* subsp. *tortilis* and *Ziziphus nummularia.* At the same level of division, group G was generated with *Zygophyllum coccineum* and *Zilla spinosa* as the indicator species. Group B was generated by the third level of division of TWINSPAN with presence of the indicator species *Z. nummularia* and *Lycium shawii*. In addition, the two groups C and D were also generated at the third division of TWINSPAN (Figure 1). Group C was indicated by *L. shawii* and *Pennisetum divisum*, while group D by *Artemisia sieberi* and *Rhanterium epapposum*. Groups E and F were separated at the fourth level of the classification. These two groups were mostly confined to the overgrazed and degradable stands. Group E was characterized by the dominance of *Rhazya stricta* and *Z. spinosa*, while group F was indicated by dominated *R. stricta* and *Lasiurus scindicus*.

The results of applications of DCA-ordination indicated a reasonable separation of the TWINSPAN groups along the first and second axes (Figure 2). Sample quadrats containing *A. tortilis* subsp. *tortilis* and *Z. nummularia* displayed high scores on axis 1 and were typical for the tree layer, while samples with species such as *R. stricta, L. scindicus* and *Z. spinosa* had low scores on this axis and were characteristic of degraded habitats. DCA axis-2 separated quadrats with *A. sieberi* and *R. epapposum* (high scores) from quadrats rich in *R. stricta* and *L. scindicus* (low scores). The lengths of the first two axes of the DCA were 2.74 and 1.95, respectively. This length of the gradient is reasonable to perform a constrained analysis with CCA (Lepš and Šmilauer, 2003).

The CCA-axes 1 and 2 were considered as the most important axes because their eigenvalues were 0.531 and 0.354, respectively (explaining 24.3% of total species data variances) (Table 2). The values of the correlation coefficients between the soil factors and the axes for the CCA ordination were shown in Table 3. CCA-axis 1 was positively correlated with sand, pH and $CaCO_3$, and negatively with silt and clay, while the second axis was correlated negatively with pH and $CaCO_3$. The proportion of soil sand was positively correlated with vegetation groups (E and F) dominated by *R. stricta, Z. spinosa* and *L. scindicus* (Figure 3). Two groups, A and B (indicated by *A. tortilis* subsp. *tortilis, L. shawii* and *Z. nummularia)* were positioned in the centre of the CCA diagram and can be separated on the first axis of the diagram. The proportion of soil silt together with the proportion of clay, $CaCO_3$ and pH were correlated with these two groups.

Table 1: Presence percentage of the dominant and common species in the seven vegetation groups derived after the application of TWINSPAN classification.

Plant Species	TWINSPAN vegetation groups						
	A	B	C	D	E	F	G
Acacia tortilis subsp *tortilis*	100	10.2	0	0	0	0	0
Artemisia sieberi	0	0	0	100	0	0	0
Convolvulus oxyphyllus	0	8.6	4.3	0	22.3	10.4	0
Cynodon dactylon	33.3	22.3	0	0	0	0	10.6
Echium arabicum	0	0	8.6	7.5	8.6	0	0
Fagonia indica	0	12.4	4.3	33.4	0	12.3	45.8
Farsetia aegyptia	0	12.4	8.6	45.6	0	22.3	22.3
Helianthemum lippii	0	0	22.3	0	0	10.3	0
Heliotropium digynum	0	12.4	33.4	3.4	8.6	22.1	5.5
Lasiurus scindicus	0	8.6	45.6	0	36.4	95.6	0
Lycium shawii	0	92.4	100	0	0	0	0
Panicum turgidum	0	12.2	8.6	0	4.3	8.6	3.9
Pennisetum divisum	0	33.4	89.8	0	0	0	0
Pulicaria	0	0	2.4	8.6	0	0	0
Reseda	5.5	0	0	3.4	0	10.2	0
Rhanterium epapposum	0	0	6.3	100	0	0	0
Rhazya stricta	2.4	8.6	8.6	0	100	0	0
Teucrium polium	0	0	0	3.4	2.4	3.3	0
Zilla spinosa	0	0	12.4	22.1	100	66.8	100
Ziziphus nummularia	67.8	100	32.5	0	0	0	0
Zygophyllum coccineum	0	0	0	8.6	22.3	15.4	100

Table 2: The extracted and cumulative variance of CCA-ordination

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.531	0.354	0.221
% of variance explained	14.1	10.2	6.2
Cumulative % explained	14.1	24.3	30.5
Pearson Correlation, Spp-,Soil	0.872	0.766	0.701
Kendall (Rank) Corr., Spp-Soil	0.731	0.642	0.621

Table 3: Correlation coefficients between soil variables and CCA-ordination axes (Bold indicates statistical significance at $p<0.05$, Tukey's test).

Soil variable	Axis 1	Axis 2	Axis 3
pH	0.505	-0.757	0.036
EC	0.341	-0.404	-0.217
Organic matter	0.249	-0.230	-0.079
Clay	-0.753	-0.031	0.032
Silt	-0.781	-0.149	-0.301
Sand	0.832	0.107	0.203
$CaCO_3$	-0.336	-0.672	0.085

Discussion:

Rawdhats vegetation composed of psammophytes and nonpsammophytes distributed in rocky and/or sandy habitats. The species composition revealed for Rawdhat Om Al-Khefas using classification and ordination supported, in general, the community types previously described for other rawdhats (Tag El-Din *et al*., 1994; Shaltout and Mady, 1996). Some groups are dominated by prominent component of native flora such as those dominated by *Z. nummularia* and *A. tortilis* subsp. *tortilis.* The community dominated by *A. tortilis* subsp. *tortilis* is exposed to heavy grazing by camels in the study area. It grows in pure community or mixed with *Z. nummularia*. Abulfatih (1992) recognized *A. tortilis* subsp. *tortilis* in all the shrublands of Saudi Arabia.

The groups characterized by *R. stricta, L. scindicus* and *Z. spinosa* covers thousands of square kilometers of the degraded rangelands in central Saudi Arabia (Tag El-Din *et al*., 1994; Assaeed and Al-Doss, 2001, 2002). *R. stricta* is a perennial dwarf shrub widely distributed in the different habitats of the Arabian Gulf rangelands (Chaudary and Al-Jowaid 1999). It has been considered as a recurrent and ubiquitous threat to both biodiversity and livestock grazing in arid regions (Assaeed 1996; Assaeed and Al-Doss 1996, 1997; Adam *et* *al*., 2002). In the study area, *R. stricta* dominates the disturbed ground and usually colonizes clean-graded sites. *L. scindicus* is an important livestock grazing plant, and sometimes it may be very abundant and virtually the only available forage in many rangelands of the country (Assaeed, 1997).

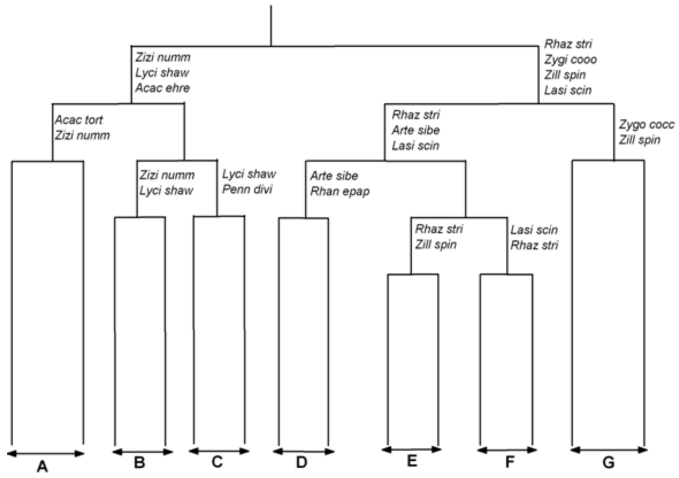

Fig. 1: Dendrogram of the TWINSPAN classification of the study quadrats. Indicator species of each group are abbreviated to four letters of the genus and species.

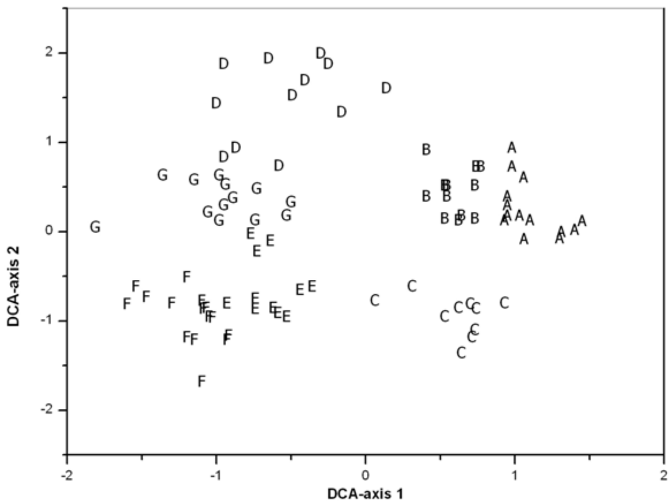

Fig. 2: Distribution of vegetation samples in DCA ordination space with superimposed of TWINSPAN groups.

The communities indicated by *L. shawii* and *Z. nummularia* are characterized by the formation of huge sand hillocks (nebkhas). The nebkhas formed by *L. shawii* has large sand accumulation between its ramets and branches, while the nebkhas built by *Z. nummularia* are around its trunks. The formation of such phytogenic hillocks has great implications for increasing plant abundance and diversity in arid regions (El-Bana *et al*., 2002, 2007). The two species have been recognized as distinctive communities in the different regions of the country (Abd El-Ghani, 1996; Böer, 1996; Barth, 1999; Al-Nafie, 2007). The vegetation groups dominated by *Z. coccineum*, *Z. spinosa, A. sieberi* and *R. epapposum* resemble to those recognized in the sandy habitats of the neighboring wadis and rawdhats (Alyemeni, 2001; Shaltout and Mady, 1996).

The soil factors of rawdhats influence greatly the distribution and abundance of plant species. Tag El-Din *et al*. (1994) found that soil texture, EC, exchangeable cations and anions, and surface organic matter are the main factors affecting the vegetation distribution in Rawdhat Khuraim. Among the soil variables measured in the present rawhdat, soil texture, pH and CaCO3 are the factors that have significance with CCA-ordination. However, these factors contributed not more than 30.5% of total species data variances along the three axes of CCA. This means that other factors, not included in this analysis, are more effective. No doubt, some physical factors of anthropogenic activities (e.g. overgrazing, overcutting, off-road driving and picnic) contribute largely for the vegetation dynamics in the rawhdats. Therefore, further studies are needed to evaluate such activities and to manage the biodiversity in the Rawdhat Om Al-khefas.

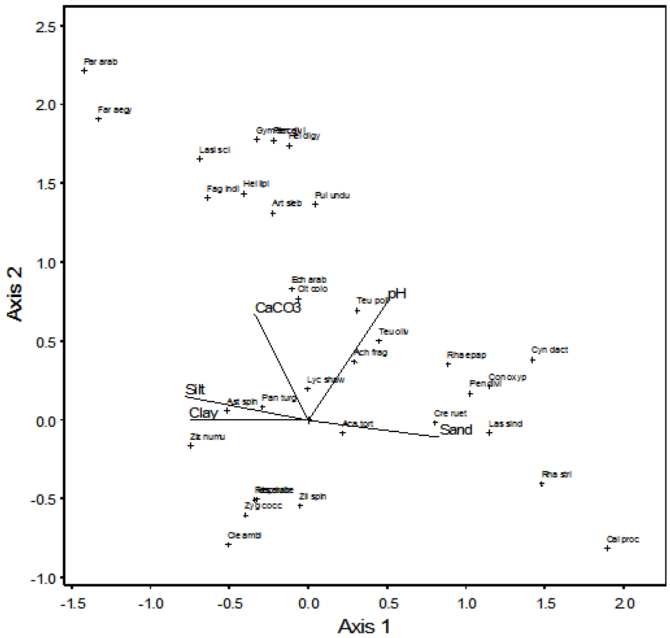

Fig. 3: CCA biplot of species and the selected soil variables. Only the most important species have been given. (full names of species in Table 1).

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