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Full Length Research Paper

Floristic composition and vegetation-soil relationships in Wadi Al-Argy of Taif region, Saudi Arabia

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Abstract

Little is known about the effects of soil variables on vegetation composition of many Wadis in Taif region. Wadi Al-Argy is one of the important wadis of Taif region (Saudi Arabia) sheltering a rich diversity of higher plants. In this study, three sites representing different habitats in Wadi Al-Argy were regularly visited during summer and winter growing seasons for one year; in each site 4 stands were selected for studying floristic composition and vegetation types in the area. Composition and diversity of vegetation were studied in relation to soil variables. A total of 75 species representing 27 families were recorded. The classification of vegetation using Two Way Indicator Species Analysis (TWINSPAN) resulted in the recognition of three vegetation groups representing Wadi bed, rocky slope and fallow land habitats. The application of Canonical Correspondence Analysis (CCA) indicated the recognition of three vegetation groups which aggregated along the ordination plane of the first and second axes. The TWINSPAN classification indicated considerable variation in the edaphic factors among stands of the different vegetation groups. The percentage of organic carbon attained maximum value of 2.61 % in the Wadi bed, while the minimum value of 0.88% was recorded in the fallow land. Electric conductivity greatly varied from a minimum (5.9 mmhos/cm) recorded in the Wadi bed habitat and this value was tripled (15.5 mmhos/cm) in the fallow land habitat.

Keywords: Floristic composition; Vegetation analysis; Soil characteristics; Wadi Al-Argy; Saudi Arabia

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INTRODUCTION

Saudi Arabia (Lat. 25° 0' 0" N, Long. 45° 0' 0" E) is a vast arid desert with an area of about 2250,000 sq kms covering the major part of the Arabian Peninsula. Accordingly, xerophytic vegetation makes up the prominent features of the plant life in the kingdom (Zahran, 1982). Several reports have been published on the Flora of the country, the most comprehensive are two Floras (the first was written by Mighaid in 1974 published four times the last in 1996, and the other is the three volume Flora written by Chaudhary 1999, 2000, 2001). Other publications on the Flora of Saudi Arabia include the illustrated flowers of Saudi Arabia by Collenette (1999) and a number of reports on regional on certain parts of the Kingdom (El-Ghanim et al., 2010).

Several ecological studies have been published on the vegetation of Saudi Arabia; Batanouny (1979) described the vegetation types in the Jeddah-Makkah road, Zahran (1982, 1983) wrote an introduction to the plant ecology and vegetation types in Saudi Arabia, Batanouny and Baeshain (1983) described vegetation types in the Al-Madinah-Badr road across the Hijaz Mountains and Fayed and Zayed (1999). reported on the vegetation along Makkah-Taif road. Some other reports have dealt with the vegetation types in certain regions of the kingdom (De Marco and Dinelli, 1974; Migahid, 1978; Chaudhary, 1983; Mandaville, 1986; Shaltout and Madi, 1996; Al-Turki and Al- Olayan, 2003; Al-Huquial and Al-Turki, 2006; Sharawy and Alshammari, 2008; El-Ghanim et al., 2010; Alatar et al., 2012). However, to our knowledge few studies have dealt with vegetation analysis in relation to floristic composition and habitat variation in Taif region and the only study was carried on the mountainous Taif area by Abdel-Faffah and Ali, 2005. In addition, vegetation-soil relationships in wadi ecosystems in Taif region is still under worked area. The aim of the present work is to study the vegetation in

Wadi Al-Argy at Taif region in terms of species composition, life form and diversity in relation to habitat change in the study area. Multivariate techniques and species diversity indices have been used to differentiate vegetation groups and to assess the relation between the vegetation types in the study area.

Study Area

Taif region lies south east of Jiddah and the Holy City of Makkah and is situated in the mountains above Makkah and Jeddah at one thousand and eight hundred meters above sea-level (M asl) on the eastern slopes of the Al-Sarawat Mountains (Figure. 1, a). Taif now covers a total area of about eight hundred hectares, whereas the area of the city did not exceed two and half square kilometers in 1951, which indicates the great expansion which the city of more than three hundred and fifty thousand population has witnessed. Wadi Al-Argy (21º 17´ N and 40º 29´ E and altitude of 1595m) is one of the important wadis of Taif region sheltering a rich diversity of higher plants (Figure. 1, b).

Topography and geomorphology

Taif constitutes an extended part of the western Arabian Shield, which is covered by Neoproterozoic rocks consisting of various types of volcanics and volcaniclastics, together with several varieties of intrusive (diorites, granodiorites and granites). These rocks are covered by Tertiary and Quaternary lavas and sediments. Three distinct geologic units could be distinguished in the concerned area, these are from oldest to youngest, the Neoproterozoic basement, the Tertiary sediments and lavas, and the Holocene sediments and sabkhas (Moore and Al-Rehaili, 1989).

Climate

The climate of Saudi Arabia is generally hot and dry (Shaltout and Mady, 1996). It is affected by two climate types, namely: Monsoon and Mediterranean. The weather system in Taif region is general arid. According to the records of Taif meteorological station for the period 1998-2008, the study area is characterized by a mean minimum temperature of 8.4 ºC in January and a mean maximum temperature of 34.4 ºC in July with an annual mean temperature of 19.8 ºC. The rainfall in the region is erratic and irregular, the high precipitation occurs in May (30.6 mm/day) and in November (21.5mm/day), however precipitation is scarce throughout the other months. The average annual rainfall is 102.4mm/day. The mean monthly relative humidity ranges between 23% in June and 60% in January. The average annual wind speed is 59.6 km/h.

MATERIALS AND METHODS

Vegetation sampling

A total of 3 sites were selected in the study region, representing three different habitats namely; Wadi bed, rocky slope and fallow land habitats (Figure. 1, b). The study region was regularly visited from September 2011 to May 2012. In each site, four stands were randomly selected for the present investigation at different growing seasons. The area of the stand was 20 x 20 m. In each stand, the present species were recorded and their cover was evaluated visually as percentage of the ground surface in 10 randomly sampled quadrats of area (5 x 5m each). The vegetation parameters included listing of all species and life forms. Species identification and nomenclature followed Chaudhary and Akram (1987), Chaudhary (1999, 2000 and 2001) and Al-Hassan (2006). Plant cover was estimated and the importance value (Importance value = relative density + relative frequency + relative cover) of each species was calculated using the line intercept method followed Muller and Ellenberg (1974) and Hegazy *et al.* (2008). Voucher specimens of each species were collected, identified in Taif University Herbarium (TUH).

Soil analysis

Five soil samples were collected from profile (0-50 cm depth) of each sampled stand, and then mixed well to form a composite soil sample. Soil texture was determined by Bouyoucos hydrometer method. Soil porosity was determined as described by Zahran (1987). Calcium carbonate was estimated gravimetrically according to Jackson (1962), while organic carbon (as indication of the total organic matter, where % organic matter = % organic carbon x 1.724) was determined using Walkely and Black rapid titration method described by Piper (1947). Soil water extracts of 1:5 were prepared for determinations of soil reaction using pH meter Model HI 8519, and soil salinity (EC) using CMD 830 WPA conductivity meter. Soluble chlorides were determined by direct titration against silver nitrate solution (N/ 35.5) using 5% potassium chromate indicator (Jackson 1962). Sulphates were obtained by the difference between cations and anions of soil extract according to Jackson (1962). Soluble carbonates and bicarbonates were determined by titration method using H_2SO_4 (0.1N), phenol phthalein and methyl orange as indicators for carbonates and bicarbonates, respectively (Richard, 1954). The extractable sodium and potassium cations

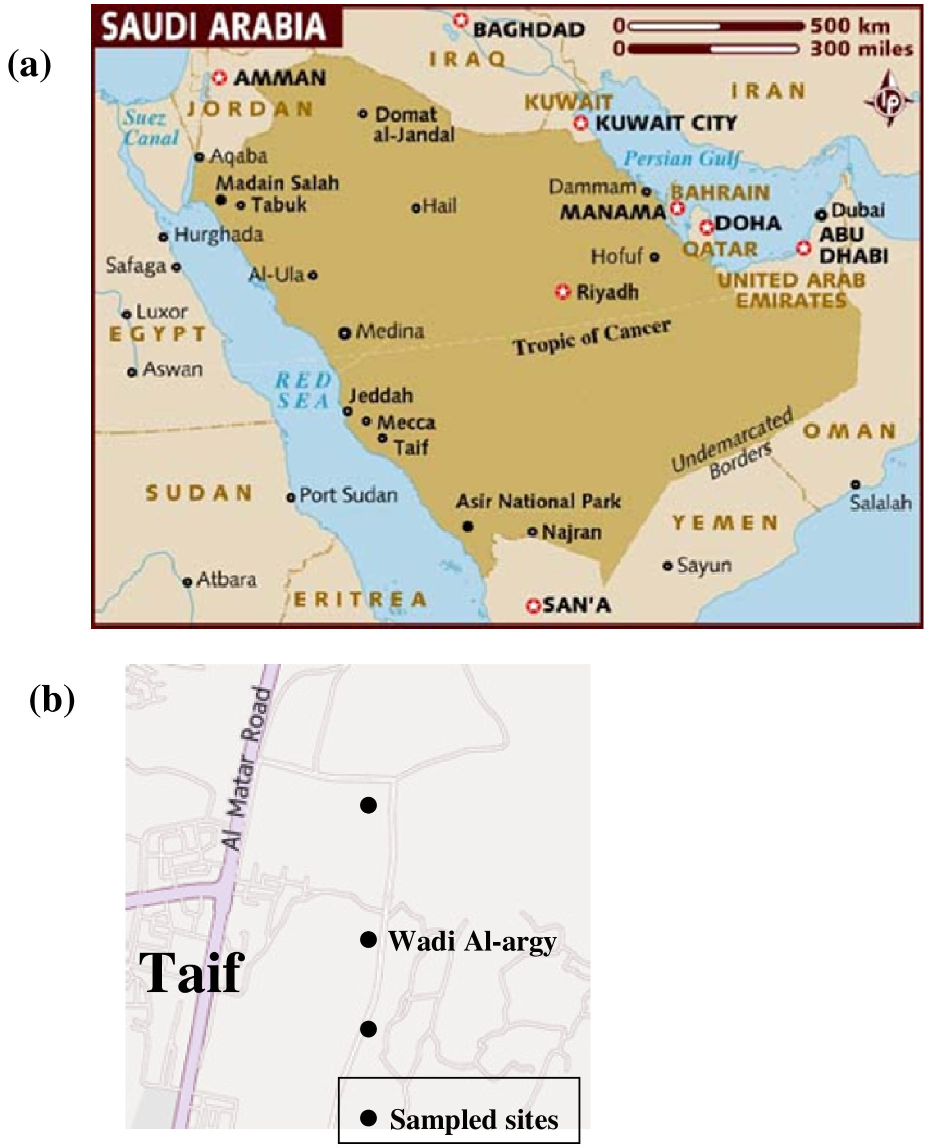

Figure 1. Map of Saudi Arabia (a) and the sampled sites in the study area of Wadi Al-argy (b). *(Map downloaded from http://www.google.com.sa/imgres?imgurl)*.

were estimated using flame photometer (Allen et al.1986). While, extractable calcium and magnesium cations were determined using EDTA (0.01N) as described by Jackson (1962).

Data analyses and statistical testing

Vegetation classification and ordination techniques were employed. The stand-species data matrix was classified into groups using the importance values (IV) of species by means of the Two Way Indicator Species Analysis (TWINSPAN) computer program (Hill, 1979). The ordination techniques applied were the Canonical Correspondence Analysis (CCA) that was used to examine the using the CANOCO software version 3.12 (Ter Braak, 2002). The following soil variables were included: % organic carbon, % calcium carbonate, % chlorides, % sulphates, % soluble carbonates, % bicarbonates, sodium (meq./L.), potasium (meq./L.), calcium (meq./L.), magnesium (meq./L.), pH value, electric conductivity (mmhos/cm), % coarse sand, % fine sand, % silt, % clay and % porosity. Data of the soil variables of the vegetation groups identified by TWINSPAN were compared by one-way ANOVA followed by Tukey's post hoc test. The same analysis was used to compare between the diversity indices of the vegetation groups. Linear correlations of soil variables

Table 1. List of 75 species recorded in the study area with their families, life form and importance values in the three vegetation groups resulted from TWINSPAN classification. (Th= Therophytes; H= Hemicryptophytes; G= Geophytes; Ch= Chaemophytes; Ph= Phanerophytes; A= Wadi Bed; B= Rocky Slope and C= Fallow Land).

Species	Family	Life form	Vegetation group		
			A	B	C
Acacia asak (Forssk.) Willd	Fabaceae	Ph	0.00	0.00	88.82
Acacia gerrardii Benth	Fabaceae	Ph	0.00	71.05	0.00
Acacia ehrenbergiana Hayne	Fabaceae	Ph	69.84	0.00	0.00
Acacia mellifera(Vahl) Benth.	Fabaceae	Ph	0.00	64.79	0.00
Acacia tortilis (Forssk.) Hayne	Fabaceae	Ph	31.54	0.00	46.04
Aerva javanica(Burm.f.) J.E. Schult.	Amaranthaceae	Ch	23.18	28.30	15.35
Aerva lanata (L.) J.E. Schult	Amaranthaceae	Ch	0.00	7.38	0.00
Alternanthera pungens Kunth	Amaranthaceae	Th	0.00	7.34	0.00
Argemone mexicana L.	Papaveraceae	Ch	24.44	33.22	23.44
Atriplex leucoclada Boiss.	Chenopodiaceae	Th	0.00	25.10	0.00
Atriplex suberecta Verd.	Chenopodiaceae	Th	9.17	0.00	19.29
Bidens biternata L.	Asteraceae	Ch	0.00	0.00	13.82
Blepharis ciliaris (L.) B.L. Burtt	Acanthaceae	Th	5.56	0.00	0.00
Caralluma subulata (Decne) A. Berger	Asclepiadaceae	Ch	11.80	0.00	0.00
Chenopodium album L.	Chenopodiaceae	Th	5.38	0.00	27.19
Chenopodium ambrosioides L.	Chenopodiaceae	Th	30.60	8.56	0.00
Chenopodium murale L.	Chenopodiaceae	Th	38.60	10.71	0.00
Chenopodium opulifolium L.	Chenopodiaceae	Th	0.00	25.90	0.00
Cichorium bottae L.	Asteraceae	Th	5.48	0.00	0.00
Commicarpus grandiflorus (A. Rich.) Standl.	Nyctaginaceae	Ph	0.00	7.53	0.00
Convolvulus arvensis L.	Convolvulaceae	Th	0.00	10.05	0.00
Conyza bonariensis (L.) Cronquist.	Asteraceae	Th	0.00	0.00	7.70
Cynodon dactylon (L.) Pers.	Poaceae	G	44.33	0.00	16.34
Cyperus laevigatus (L)	Cyperaceae	H	0.00	5.10	18.94
Datura innoxia L.	Solanaceae	Th	30.56	3.94	15.19
Ephedra foliate Boiss. ex. C. A. Mey	Ephedraceae	Ph	0.00	11.09	0.00
Euphorbia hirta L.	Euphorbiaceae	Th	10.85	3.62	0.00
Euphorbia lathyris L.	Euphorbiaceae	Th	0.00	3.59	0.00
Fagonia boveana (Hadidi) Hadidi & Garf	Zygophyllaceae	Ch	0.00	0.00	7.82
Fagonia indica Burm. f.	Zygophyllaceae	Ch	6.24	0.00	0.00
Farsetia longisiliqua Decne	Brassicaceae	Ch	0.00	21.09	0.00
Forsskaolea tenacissima L.	Urticaceae	Ch	0.00	7.38	0.00
Glinus lotoides L.	Molluginaceae	Ch	8.01	0.00	0.00
Heliotropium arbainense Frense.	Boraginaceae	Ch	0.00	3.57	0.00
Heliotropium bacciferum Forssk.	Boraginaceae	Ch	9.05	0.00	0.00
Heliotropium curassavicum L.	Boraginaceae	Ch	13.72	0.00	4.61
Heliotropium longiflorum L.	Boraginaceae	Ch	10.93	0.00	6.62
Imperata cylindrical (L.) Raeusch.	Poaceae	H	16.63	10.04	19.151
Indigofera spinosa Forssk.	Fabaceae	Ph	8.19	10.80	0.00
Juncus rigidus Desf.	Juncaceae	H	0.00	3.67	54.02
Kedrostis foetidissima (Jacq.) Cogn.	Cucurbitaceae	H	0.00	3.70	15.24
Lactuca serriola L.	Asteraceae	Th	0.00	0.00	8.24
Launaea spinosa (Forssk.) Sch.Bip. ex Kuntze	Asteraceae	Th	0.00	22.94	0.00
Leptochloa fusca (L.) Kunth.	Poaceae	Th	0.00	0.00	13.21
Leptadenia pyrotechnica (Forssk.) Decne.	Brassicaceae	Ph	0.00	22.16	0.00
Lycium shawii Roem. & Schult.	Solanaceae	Ph	10.22	13.82	0.00
Mentha longifolia (L.) Huds.	Labiatae	Ch	0.00	7.24	0.00
Ochradenus baccatus Delile	Resedaceae	Ph	17.30	3.63	0.00
Otostegia fruticosa (Forssk.) Penz.	Labiatae	Ch	0.00	0.00	6.60
Panicum coloratum L.	Poaceae	Ch	0.00	9.01	0.00
Peganum harmala L.	Zygophyllaceae	Ch	6.28	0.00	0.00
Pennisetum divisum (J. F. Gmel) Henrard	Poaceae	Ch	12.40	8.88	0.00
Pennisetum setaceum (Forssk.) Chiov.	Poaceae	Ch	6.23	0.00	0.00
Pluchea dioscoridis (L.) DC.	Asteraceae	Th	0.00	0.00	4.58
Polygonum equisetiform Sm.	Polygonaceae	H	5.61	0.00	0.00

Table 1. Continue

Polypogon monspielensis (L.) Desf.	Poaceae	H	19.57	0.00	25.46
Portulaca oleracea L.	Portulacaceae	Ch	0.00	0.00	21.10
Pulicaria crispa (Forssk.) Oliv.	Asteraceae	Ch	6.38	0.00	56.11
Pupalia lappaceae (L.) Juss.	Amaranthaceae	Ch	0.00	3.64	14.51
Ricinus communis L.	Euphorbiaceae	Ph	13.92	0.00	0.00
Salsola imbricata Forssk.	Chenopodiaceae	Ch	11.68	0.00	0.00
Salsola spinescens Moq.	Chenopodiaceae	Ch	0.00	0.00	23.14
Senna italica Miller	Fabaceae	Ch	0.00	5.17	24.44
Sisymbrium irio L.	Brassicaceae	Th	9.71	0.00	15.30
Silybum marianum (L.) Gaertn.	Asteraceae	Ch	0.00	0.00	36.13
Sonchus oleraceus L.	Asteraceae	Ch	23.09	3.64	0.00
Spergularia marina (L.) Griseb.	Caryophyllaceae	Th	0.00	0.00	55.83
Suaeda monoica Forssk. ex. J.F. Gmel.	Chenopodiaceae	Ph	2.86	0.00	17.88
Tamarix nilotica (Ehrenb.) Bunge	Tamaricaceae	Ph	14.16	11.57	48.36
Tagetes minuta L.	Asteraceae	Ch	0.00	0.00	13.88
Tribulus parvispinus Presl	Zygophyllaceae	Ch	0.00	0.00	17.70
Tribulus terrestris L.	Zygophyllaceae	Ch	0.00	0.00	13.82
Withania somnifera (L.) Dunal.	Solanaceae	Ch	0.00	0.00	15.16
Xanthium strumarium L.	Asteraceae	Ch	0.00	3.72	0.00
Zygophyllum simplex L.	Zygophyllaceae	Th	13.21	0.00	0.00

with diversity indices and CCA axes were made to relate the vegetation diversity to edaphic factors. The one-way ANOVA and correlation analyses were conducted using SPSS version 13 for Windows. The Shannon-Wiener index H' and Shannon-evenness index E_1 were determined as follows:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

Where $p_i = n_i / N$ = proportional abundance of species i in a habitat made up of s species, n_i = the number of stands containing species i and $N = \Sigma n_i$. The Shannon-evenness index was applied to quantify the evenness component of diversity and was calculated as:

$$E_1 = H' / \ln s$$

Species richness, Shannon index and relative eveness were applied for measurement of vegetation diversity in each stand (Pielou 1975, Magurran 1988).

RESULTS

Floristic composition

A total of 75 species representing 27 families were recorded. Family Asteraceae is represented by the highest number of species (11 species) followed by Chenopodiaceae (9 species), Fabaceae and Poaceae (7 species), Zygophyllaceae (6 species), Amaranthaceae (4 species), Solanaceae, Euphorbiaceae, Brassicaceae and Boraginaceae (3 species), Labiatae (2 species) whereas, 16 families including Papaveraceae, Acanthaceae, Asclepiadaceae, Nyctaginaceae, Convolvulaceae, Cyperaceae, Ephedraceae, Urticaceae, Molluginaceae, Juncaceae, Cucurbitaceae, Resedaceae, Polygonaceae, Portulacaceae, Caryophyllaceae and Tamaricaceae, are represented by a single species each (Table 1). The life form spectrum exhibited a wide range of variation. chaemophytes were the predominant life form and constituted 44% of the total flora, followed by therophytes (28%), phanerophytes (18.66%), hemicryptophytes (8%), and geophytes (1.3%). The most common recorded species in the wadi bed of the study area were; *Acacia ehrenbergiana, Acacia tortilis, Aerva javanic, Argemone mexicana, Chenopodium murale, Cynodon dactylon* and *Datura innoxia* while the common species in the rocky slope were; *Acacia gerrardii, Acacia mellifera, Aerva javanica, Argemone mexicana, Atriplex leucoclada, Chenopodium opulifolium* and *Farsetia longisiliqua*. The most common species recorded the fallow land were; *Acacia asak, Acacia tortilis, Argemone mexicana, Chenopodium album* and *Juncus rigidus*. Each of these species attained maximum importance value (IV) greater than 20 (Table 1).

Vegetation classification

The application of TWINSPAN based on the importance value of the 75 species, recorded in the 12 sampled stands produced three vegetation groups represent and coincide with the three habitat types of the study area. These three vegetation groups are labeled A, B and C (Figure 2). Each group comprises a set of stands, which are similar in their vegetation and are characterized by specific indicator species.

Group A

This group comprises five stands; four stands were sampled in the wadi bed habitat (stand numbers 1, 2, 4

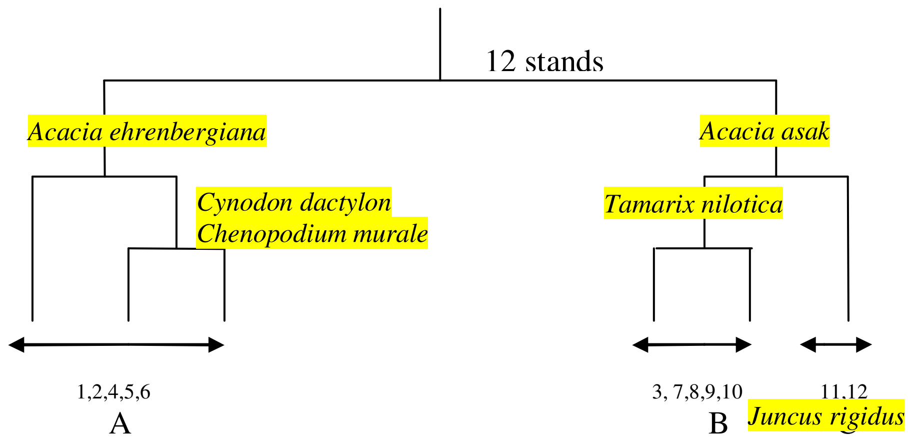

Figure 2. TWINSPAN dendrogram of the 12 stands based on the importance value of species. Indicator species names provided for each vegetation group.

and 5) while one stand was sampled in the rocky slope habitat of the study area (number 6). This vegetation group contains 36 species. The dominant species were *Acacia ehrenbergiana*, *Cynodon dactylon* and *Chenopodium murale* (IV values ranged between 38.6 and 69.8) while the common species were *Acacia tortilis, Aerva javanic, Argemone mexicana,* and *Datura innoxia* (IV values ranged between 23.18 and 31.54). Indicator species of this vegetation group was *Acacia ehrenbergiana*.

Group B

This vegetation group comprises the five stands numbers 3, 7, 8 and 9, all stands representing the rocky slope habitat type except stand number 3 which represents the wadi bed habitat. Thirty six species were recorded in this group including *Tamarix nilotica* as indicator species, while *Acacia gerrardii* and *Acacia mellifera* were the dominant species recording maximum IV values of 71.05 and 64.79; respectively. *Aerva javanica, Argemone mexicana, Atriplex leucoclada, Chenopodium opulifolium* and *Farsetia longisiliqua* were common species with IVs ranged from 21.09 to 33.22. The remaining species of this group representing the associated species (Table 1).

Group C

This vegetation group includes two stands; 11 and 12, and occurs in the fallow land habitat. Total number of species of this group was 36 including *Juncus rigidus* as an indicator species. *Acacia asak, Acacia tortilis* and *Juncus rigidus* were the dominant species of this vegetation group while *Argemone mexicana* and *Chenopodium album* were common species with IV-values ranged between 23.44 and 88.82 (Table 1).

Ordination of stands

The application of CCA on the IV- values of the 75 species, recorded in the 12 sampled stands in the study area indicated the recognition of three vegetation groups which aggregated along the ordination plane of the first and second axes (Figure. 3, a).

Species of group C representing the fallow land are located at the top right of the diagram, while species of group A represent the wadi bed habitat types and are arranged nearly at the upper left side of the diagram in between the two CCA axes. Species of groups B which represent the rocky slope, are arranged at the lower left of axis 1 of the ordination diagram (Figure. 3, a).

Vegetation – soil relationships

Edaphic characteristics of the soil containing the three vegetation groups are summarized in Table 2. The TWINSPAN classification indicates considerable variation in the edaphic factors among stands of the different vegetation groups. The percentage of organic carbon is significantly different (*p=0.017*) among habitat types; it attains maximum value of 2.61 % in group A (wadi bed) while the minimum value of 0.88% was recorded in group C (fallow land). There was no significance difference concerning the soil reaction which is slightly alkaline in all groups; pH ranges between 7.7 in group A to 8.0 in group C. Electric conductivity greatly varied from a minimum (5.9 mmhos/cm) recorded in vegetation group A, and this value was tripled (15.5 mmhos/cm) in vegetation group

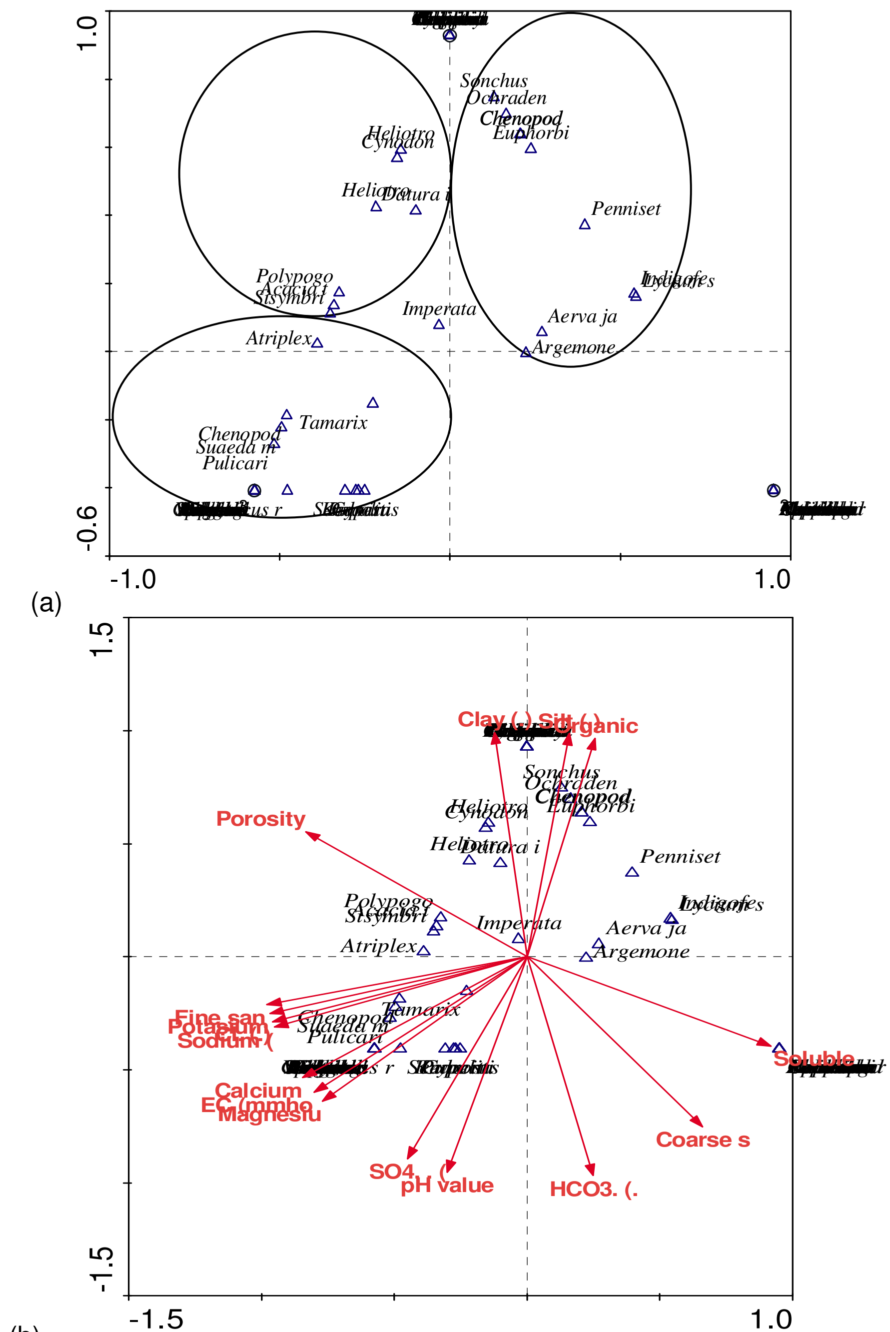

Figure 3. CCA biplot with environmental variables (arrows), the stands (a) and the recorded species by the first 8 letters (b). (For complete names of species, see Table 1)

C. Concerning the following soil variables; chlorides, soluble carbonates, bicarbonates, sodium, potassium, calcium, magnesium, coarse sand, silt, clay and porosity, there was a significant differences (p= 0.015, p=0.133, p=0.019, p=0.078, p=0.065, p=0.007, p=0.011, p=0.077, p=0.063, p=0.084 and p=0.015; respectively) throughout the soil of the three vegetation groups (Table 2). There were significant differences in values of species indices among the three vegetation groups; group C has the highest value of species richness (13.4) as well as the highest value of relative evenness (0.94) while group A recorded the highest value of Shannon index (1.64). On the other hand, group B has lower species richness (9.7) and relative evenness (0.51) as compared to the other two vegetation groups (Table 2).

The correlation between vegetation and soil

Table 2. Mean ± standard deviation of soil variable and diversity indices of the different vegetation groups. (A= Wadi Bed; B= Rocky Slope, C= Fallow Land and EC= Electric Conductivity).

	Vegetation group		
Variable	**A**	**B**	**C**
Species richness spp/stand	11.5^{a}±1.4	9.7^{b}±1.1	13.4^{a}±1.3
Shannon index	1.64^{a} ±0.14	1.52^{a} ±0.27	1.47^{a} ±0.23
Relative evenness	0.69^{a} ±18.5	0.51^{a} ±13.5	0.94^{b} ±16.7
Organic carbon (%)	2.61^{a} ±0.13	1.35^{b} ±0.12	0.88^{c}±0.05
pH value	7.70^{a} ±0.25	7.90^{a} ±0.17	8.00^{a} ±0.31
EC (mmhos/cm)	5.90^{a} ±0.39	6.21^{a} ±0.31	15.50^{b} ±1.33
Cl^{-} (%)	21.60^{a} ±0.85	18.7^{a} ±1.31	26.72^{b} ±1.77
SO_4^{--} (%)	45.23^{a} ±1.53	51.5^{a} ±1.54	57.13^{a} ±2.56
Soluble CO_3^{--} (%)	0.10^{a} ±0.02	0.22^{b} ±0.02	0.06^{a} ±0.01
HCO_3^{-} (%)	0.48^{a} ±0.04	1.57^{b} ±0.06	1.30^{b} ±0.16
Sodium (meq./L.)	21.21^{b} ±0.89	14.33^{a} ±1.06	34.80^{c} ±1.44
Potasium (meq./L.)	5.62^{a} ±0.24	4.43^{a} ±0.11	7.43^{b} ±1.13
Calcium (meq./L.)	34.22^{a} ±1.63	32.82^{a} ±0.56	53.30^{b} ±1.43
Magnesium (meq./L.)	6.28^{a} ±0.02	7.43^{a} ±0.35	18.55^{b} ±0.79
Coarse sand (%)	12.6^{a} ±1.29	23.3^{b} ±2.86	16.7^{a} ±0.52
Fine sand (%)	62.4^{a} ±2.42	59.4^{a} ±0.17	66.3^{a} ±1.43
Silt (%)	12.3^{b} ±0.08	8.5^{a} ±0.12	7.7^{a} ±0.22
Clay (%)	12.7^{b} ±0.15	8.80^{a} ±0.42	9.3^{a} ±0.65
Porosity (%)	66.45^{b} ±2.75	54.15^{a} ±3.23	64.33^{b} ±1.42
Soil texture	Sandy loam	sandy	Sandy loam

Values in a row sharing the same letter are not significantly different at the 0.05 level of probability.

Variables, is seen in the Canonical Correspondence Analysis (CCA) ordination biplot (Figure 3, b) in which the soil variables are represented by arrows. The edaphic variables that have long arrows are more important influence on community variation and species distribution. The angle between an arrow and each axis is a reflection of its degree of correlation with that axis. Species in group A (wadi bed) exhibit a close relationship with the soil porosity and clay content while species in group B (rocky slope), strongly correlated with values of electric conductivity, pH, fine sand, sulphates, potassium, sodium and calcium. On the contrary, species in group C (fallow land) affected by silt and organic carbon (Figure 3, b).

The species richness was positively correlated with organic carbon ($r = 0.56, p<0.01$), electric conductivity ($r = 0.39, p<0.01$), fine sand ($r = 0.23, p<0.05$), silt ($r = 0.65, p<0.01$) and porosity ($r = 0.65, p<0.05$), and negatively with pH, potassium and coarse sand ($r = -0.46, p<0.05$), ($r = -0.34, p<0.05$) and ($r = -0.43, p<0.01$); respectively (Table 3). Shannon index was positively correlated with electric conductivity ($r = 0.04, p<0.05$), sulphates ($r = 0.44, p<0.05$), bicarbonate ($r = 0.37, p<0.05$) and coarse sand ($r = 0.03, p<0.05$), and negatively with organic carbon ($r = -0.34, p<0.05$). Relative evenness was positively correlated with pH ($r = 0.04, p<0.05$), and negatively with chlorides, magnesium and clay ($r = -0.11, p<0.05$), ($r = -0.22, p<0.05$) and ($r = -0.13, p<0.05$); respectively. CCA axis 1, is positively correlated with electric conductivity, sulphates and coarse sand while it is negatively with organic carbon, potassium, calcium and silt. On the other side, CCA axis 2, is positively correlated with clay and porosity while it is negatively with pH, chlorides and coarse sand (Table 3).

DISCUSSION

Floristic composition

The floristic composition of the present study showed the dominance of members of Asteraceae, Chenopodiaceae, Fabaceae and Poaceae which coincides with the findings reported by many authors; Turki and Al-Olayan (2003), El-Ghanim et al., (2010) and Alatar et al., (2012). The life form spectrum of the present study exhibited predominant of chaemophytes and constituted 44% of the total flora, followed by therophytes. These results coincide with the findings of Al-Turki and Al-Olayan ,2003; Orshan, 1986 and Shaltout et al., 2010. The domination of chaemophytes and therophytes in the vegetation spectra of Taif region in the present study also

Table 3. Linear correlations of soil variable with diversity indices and the first two CCA axes.

Soil variable	Species richness	Shannon index	Relative evenness	CCA axis1	CCA axis2
Organic carbon (%)	0.56**	-0.34*	-0.22	-0.85**	0.16
pH value	-0.46*	-0.12	0.04**	0.28	-0.42*
EC (mmhos/cm)	0.39**	0.04*	-0.21	0.29*	-0.16
Cl^- (%)	-0.34	0.31	-0.11*	-0.44	-0.40*
SO_4^{--} (%)	-0.54	0.44*	0.32	0.39*	-0.23
Soluble CO_3^{--} (%)	-0.50	0.11	-0,31	-0.02	0.06
HCO_3^- (%)	0.43	0.37*	-0.12	-0.55	0.14
Sodium (meq./L.)	-0.12	0.05	-0.02	-.013	0.11
Potasium (meq./L.)	-0.34*	-0.28	-0.05	-0.51*	0.32
Calcium (meq./L.)	-0.65	0.32	-0.43	-0.54**	-0.17
Magnesium (meq./L.)	-0.44	0.31	-0.22*	-0.43	-0.21
Coarse sand (%)	-0.43**	0.03*	-0.19	0.89**	-0.35*
Fine sand (%)	0.23*	-0.06	-.03	-0.87	0.22
Silt (%)	0.65**	0.07	-0.09	-0.76*	0.54
Clay (%)	-0.39	0.03	-0.13*	-0.65	0.35*
Porosity (%)	0.65*	-0.02	-0.31	-0.73	0.13*

* p≤0.05, ** p≤0.01, *** p≤0.001

agrees with the spectra of vegetation in deserts and semi-desert habitats in other parts of Saudi Arabia as described by some other authors (e.g. El-Demerdash et al., 1995; Fahmy and Hassan, 2005; El-Ghanem et al., 2010; Alatar et al., 2012). This picture is also congruent with the vegetation spectra in other parts of the Middle East (Zahran and Willis, 1992; El-Bana and Al-Mathnani, 2009). Moreover, life forms of desert plants are also closely related with topography (Kassas and Girgis, 1964; Zohary, 1973; Migahid, 1978; Orshan, 1986; Hosni and Hegazy, 1996; Hegazy et al., 1998; Shaltout et al., 2010; Alatar et al., 2012).

Vegetation classification

The application of TWINSPAN classification techniques to the vegetation data produced three vegetation groups; A, B and C, which are coincide with the three habitat types of the study area. Vegetation groups (A and B represent Wadi bed and slope; respectively), dominated mainly by tree species (e.g. *Acacia ehrenbergiana, Acacia gerrardii* and *Acacia mellifera*) while vegetation group (C, fallow land) dominated mainly by weed species (e.g. *Juncus rigidus, Argemone mexicana* and *Chenopodium album*). That may be explained as the habitat type has direct effect on the dominance relations among different vegetation groups (Hegazy et al.., 2008).

Ordination of stands

The application of CCA on the studied species, demonstrate the relative positions of species and studied sites along the most important ecological gradients. In this respect, species of group C are located at one side of the diagram (right), while species of the other two group located to the left side of the diagram. These results agree with the reports of Chaudhary (1983) and (Hegazy et al., 2008).

Vegetation – soil relationships

The vegetation-soil relationships as assessed by CCA – biplot, indicated that organic carbon and Electric conductivity are important ecological gradients affecting vegetation distribution. Moreover, Electric conductivity recorded in the Wadi bed habitat was tripled in the fallow land. This can be attributed to the high salt content in the fallow land as compared to the other studied habitat types. This was reported in other studies (e.g. Hegazy et al., 2004; Härdtle et al., 2006). The variations in species richness, Shannon index and relative evenness among the different habitat types may be attributed to the difference in soil characteristics, substrate discontinuities and the relative dominance of certain species among other associated species (Shaltout et al., 2010). This is in accordance with the findings of Hegazy et al., 2008, who provide evidence that the high level of species diversity would be brought about by a local differentiation in soil properties around individual plants, since heterogeneity of environments allows satisfaction of the requirements of many species within a community. The positive correlation between species richness and organic carbon of the studied habitat types is in accordance with many studies (e.g. Yang et al., 2006; Hegazy et al., 2008). Consequently, the vegetational groups in the Wadi bed habitats of the present study are more diverse than those of the other two vegetational groups. Moreover, this may also attributed to the fact that Wadi Al-Argy is a mature Wadi characterized by its narrow Wadi bed, deep valley-fill deposits, and older rocky slope of limestone formations. Therefore, the Wadi ecosystem divided into a number of habitats is discernible on the ground of the soil thickness and plant cover. The vegetation is featured into associations where the dominant perennial species give the permanent character of plant cover in each habitat. In addition, the rather scanty rainfall which is not adequate for the appearance of many annuals. On the other hand, the rainy season provides better chance for the appearance of a considerable number of annuals, which give a characteristic physiognomy to their vegetation (Shaltout and Mady, 1996; Hosni and Hegazy, 1996; Shaltout et al., 2010; Alatar et al., 2012). In Saudi Arabia, Shaltout and Mady (1996), Al-Yemeni and Zayed (1999), Al-Yemeni (2001), Al-Wadie (2002), El-Ghanim et al., (2010) and Alatar et al., (2012), recognized several plant associations, some of which are comparable to those of the present study (e.g. *Acacia ehrenbergiana-Heliotropium bacciferm* which is comparable to that identified by Alatar et al., 2012). On the contrary, communities in the rocky slope, in Wadi Talha at Asir, as recognized by Al-Wadie (2002) and that of Wadi Al-Jufair which studied by Alatar et al., (2012), are, however, less comparable in Wadi Al-Argy, which may attributed to the variation in climate and topography. Moreover, the dominance of *Juncus rigidus* in the fallow land vegetation group, where this plant germinate opportunistically upon irregular, but season-related moisture availability. Moisture conditions and salinity in the soil represent favorable micro-sites for *J.rigidus* and that in accordance with many studies (e.g. El-Sheikh et al., 2006).

CONCLUSION

Taif region comprises diverse ecosystems and presents very interesting aspects for vegetation studies. Vegetation of present work revealed the dominance of members of Asteraceae, Chenopodiaceae, Fabaceae and Poaceae in the different habitat types. The life form spectrum of the present study exhibited predominant of chaemophytes and therophytes. Species diversity and dominance is related to soil physical characteristics and variation of habitat types. Vegetational groups in the Wadi bed habitats are more diverse than those of slope and fallow land habitats.

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