Original Research Article

Vegetation Structure and Diversity of Wadi Wasaa, Jazan, Saudi Arabia

Abstract

This study was the first report conducted on Wadi Wasaa of Jazan area in Saudi Arabia. A total of 95 species belonging to 75 genera and 31 families were recorded, both Poaceae and Euphorbiaceae were the dominant families constituted 23% of the total species of the study area. The next dominant families were Apocynaceae and Malvaceae. Chamaephytes and therophytes were the prevailed life forms, indicating a typical desert life-form spectrum (chameo-therophytic) type, followed by phanerophytes. The chorological analysis revealed a total of 26 species representing 27% were falls under monoregional, 56 species (60.0%) as bioregional area and four species were detected under pluriregional region. Cover abundance values were visually estimated and used to form ten clusters of plant community types by statistical methods with Euclidian Distance and Ward method using SPSS program (ver.20). The Shannon-Wiener diversity index was used to estimate diversity, richness and evenness of the recorded species where it revealed the highest diversity index (H) was detected in *Tamarindus indica* community, followed by the community of *Acacia asak* whereas the lowest one calculated in *Lawsonia inermis*. At the same time, Sorensen's Index of Similarity (ISs) confirmed some different affinities among these communities.

Key words: Floristic composition, Diversity, Chorology, Community type Analysis

Introduction

The diversity of wild plants is an important aspect of our earthly environments and plays a major role in protecting the ecological consistency and balance of the region

(Abd El-Khalik *et al*., 2017). The flora of Saudi Arabia is one of the richest biodiversity in the Arabian Peninsula and comprises very important genetic resources of crops and medicinal plants (Atiqur *et al*., 2004). In the dry lands, wadis represent one of the most prominent desert landforms, which exhibit physiographic irregularities that lead to parallel variations in plant species distribution (Kassas and Girgis, 1964). Life-form distribution is significantly related to the topography and landform. (Zohary, 1973 and Orshan, 1986). Jazan province is situated in the southwestern part of Saudi Arabia characterized by rocky slopes, cliffs and crevices with granite, sandy soil whereas the hilly areas are generally formed of rocky cliffs, rocky ridges, granite boulders, granite outcrops, granite sand stones and crevices(Al-Farhan *et al*, 2005). Jazan region can be broadly divided into Tihama, the Escarpments and the Farasan Islands. The first two regions are part of the oldest agricultural centers of the Arabian Peninsula and composed of wadis, mountains and plateaus (Al-Farhan *et al*, 2005 and Masrahi, 2012) Several studies om the floristic diversity and vegetation analysis in Tihama plains of Saudi Arabia were performed by El-Demerdash *et al*, (1994), Masrahi, (2012) and Marei *et al*, (2014). Wadi vegetation of Saudi Arabia were studied by many authors such as Wadi Al Ammaria (El Ghenam 2006, Al Yemeni 2001), Wadi Al Jufair (Al Atar *et al*. 2012), Wadi Al Argy (Farrag 2012), Wadi Al Noman (Abdel Khalik *et al.* 2013), Wadi El Ghayl (Fahmy and Hassan 2005), Wadi Al Rummah (El Ghazali *et al* 2013) Wadi Talha (Al Wadie 2002), Wadi Khulab (Kasem and Marei, 2017) and Wadi Tashar (El-Shabasy and Kasem, 2018). Evenness Index (E) and Shannon-Wiener Diversity Index (H) methods are of the most widely used approaches in measuring the diversity of species (Siraj *et*

al., 2016). The present study aimed to investigate the floristic composition, life-form and chorotype to classify, document and assess the species diversity between the different community types of the Wadi Wasaa of Jazan region in Saudi Arabia.

Study Area

Wadi Wasaa located in the southeast of Jazan. It located between the AL-Dabha Mountain in the east and AL-Hague in the west, it around 60 km^2; altitude ranges from 480-680m above sea level (a.s.l.). It lies between 17°482' N latitude and 42° 894' E longitude (Figure 1). According to Al-Farhan *et al* (2005) and Masrahi (2012) the study area lies within the subtropical dry zone and has very hot summers and mild winters; the topography is mostly mountainous with steep to moderately steep slopes gradually tapering off to a relatively flat mountain plateau. December and January are the coldest months (20°C) while the hottest month is, July (39°C). The maximum precipitation (20.0 mm) falls during June, while the minimum precipitation of about 6.0 mm falls during November (Figure 2).

Materials and methods

A total of 46 sites located in a randomly stratified manner were selected along the wadi Wasaa and conducted from January to October 2017, this period in Jazan Region represents the optimum growing and flowering seasons for most plant species. Locations and sample plots (25 m × 25 m) were selected randomly using the methods of Muller-Dombois and Ellenberg (1974) and Barbour *et al.* (1987). The collected specimens were identified and named according to Chaudhary (2001), Al-Farhan *et al* (2005), Migahid (1996) and updated according to the Plant List database (2013). Plant specimens deposited at Jazan University Herbarium, KSA (JAZUH). Life-forms

were determined according to Raunkier (1937). A chorological analysis of the recoded species was made to assign to world geographical groups, according to Wickens (1978) and Zohary (1973). Altitude and geographical coordinates were measured using GPS for each quadrate (Geographical Position System). Cover abundance were calculated by the equation: Total number of individuals of the species/ total number of quadrates in which species has occurred. Cover abundance were converted to 1-9 according to Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974) and modified later by Maarel (1979). The computer program (SPSS, ver.20) was used to analyze the vegetation structure and perform hierarchical clustering dendrogram constructed from ten plant community types (Fig. 6), these communities named by the highest mean cover abundance in each community. The species diversity of each cluster was calculated using Shannon-Weiner diversity index (1949) based on cover/abundance value of the species as input source.

$$H = -\sum Pi \ln Pi$$

Where, H: Shannon-Wiener Index and; Pi: proportion of individual species; ln: log basin. The relative equitability (evenness) of the species in each cluster was also calculated.

$$\text{Equitability } J = \frac{H'}{Hmax} = \sum_{i=1}^{S} \frac{Pi \ln Pi}{\ln S}$$

Where, S: the number of species; Pi: the proportion of individuals of the species or the abundance of the species expressed as a proportion of total cover; ln: log base. Sorenson's Similarity ratio was used to evaluate the phytogeographical similarity

between the plant community types. It was described using the following formula (Kent and Cooker, 1992)

$$Ss = \frac{2a}{2a + b + c}$$

Where Ss: Sorensen's similarity coefficient; a: number of species common to both sites; b: species number in site one; c: species number in site two.

Results

Floristic analysis

The floristic data on the study area, occurring between altitudinal gradients of 480-680 m (a.s.l), indicates a total of 95 species belonging to 75 genera and 31 families. According to species richness, the majority of plants in the study area are perennials (66 species, 69.5% of the total recorded species), the second most frequent growth type was the annuals which revealed by 27 species (28.5% of the total species) also two species of *Chenopodium fasciculosum* and *Asphodelus tenuifolius* were estimated as biennial life span. Four species of *Leptadenia arborea, Merremia aturensis, Dalechampia scandens* and *Cissus rotundifolia* were estimated as climber species. Poaceae and Euphorbiaceae were the most dominant families represented by 14 and 8 species, respectively (Table 1). The next abundant families were Apocynaceae and Malvaceae which represented by 6 species. Acanthaceae, Astraceae, Amaranthaceae, Papilionaceae have five species constituted a total of 21%. Four species were recorded in Mimosaceae while Caesalpiniaceae, Boraginaceae, Solanaceae and Zygophyllaceae were finding out by three species each. Asphodalaceae, Cleomaceae, Lamiaceae, Moraceae, Nyctaginaceae, Plantagonaceae and Salvadoraceae were represented by

two species. The remainder (11 families) contributed 12.0% of the total species represented by single species each (Figure 3).

Life form spectrum

According to the life form classification of Raunkiaer (1937) and as shown in Table 2 and Figure 4, the chamaephytes were the most dominant life form, constituted by 33 species representing 35% of the total recorded species followed by the therophytes represented by 28 species (29%). On the other hand, 17 species of the phanerophytes estimated 18 % were conducted. Also Hemicryptopyte were occurred by 11 species (12%) of the total recorded taxa. Cryptophytes have the lowest contribution by six species of *Asphodelus tenuifolius, Cyperus conglomeratus, Corchorus depressus*, *Cenchrus ciliaris, Panicum turgidum* and *Sorghum bicolor* with a percentages of 6%.

Phytogeographical data

Regarding the global floristic regions, monoregional, biregional and pluriregional are constructed as phytochorial regions (Table 2). A total of 26 species representing 27% were falls under monoregional region. In this area the highest number of 15 species was recorded in Saharo-Arabian (16%) whereas the lowest one which estimated by five species of *Abutilon bidentatum, Boerhavia elegans. Echinochloa colona, Opuntia dillenii* and *Ricinus communis* recoded in Tropical region. Biregional area included the highest number of species, i.e. 56 species with 60%, 32 species occurred in the area shared by Saharo-Arabian and Sudano-Zambezian regions (34%) followed by area of Saharo-Arabian shared with tropical represented by 14 species (16%). Both Saharo-Arabian and Mediterranean has four species (4%). Both Mediterranean-Irano-Turanian and Mediterranean-Tropical regions are represented by two species (2%).

The lowest one was recorded in Saharo-Zambezian and tropical regions has only one species of *Cyanthillium cinereum*. The pluriregional area (4%) has four species of *Euphorbia inarticulata, Dichanthium foveolatum , Ziziphus spina-christi* and *Corchorus tridens* falls under one main phytochoria of Mediterranean, Saharo-Arabian and Sudano-Zambezian. The remainder nine recorded taxa were distributed as follows: three species are cosmopolitan and four species pantropical and only two species of *Lawsonia inermis* and *Sorghum bicolor* are cultivated plants (Table 2 and Figure 5).

Dominant Community Types (DCT)

Distribution of the plant community types among their altitudinal ranges was given in Table 4. Based on the mean cover abundance values, the description of the ten plant community types (Table 3, 4 and Figure 7) can be summarized as follow: **I-*Ziziphus spina-christi,*** this community type consists of 5 quadrats with 35species distributed between altitudinal ranges of 500m and 570m a.s.l., this community types found at fine calcareous soils in the wadi bed associated with *Adenium obesum, Anisotes trisulcus, Argemone ochroleuca, Barleria trispinosa, Caralluma retrospiciens, Heliotropium longiflorum, Lavandula coronopifolia, Trianthema crystallina* and *Tribulus terestris,* their abundance cover is 10.4%. **II-*Salvadora persica***, this community type widespread in the wadi terrace, consists of three stands in which 18 species distributed between altitudinal ranges of 520m and 586m a.s.l. Associated with *Aloe officinalis, Anisotes trisulcus, Blepharis edulis, Calotropis procera, Corchorus depressus, Euphorbia triaculeata, Indigofera colutea, Ocimum forsskaolii, Ziziphus spina-christi, Pluchea dioscoridis* and *Senra incana;* the

abundance plant cover is about 5.7%. **III-** ***Anisotes trisulcus,*** located as finely-calcarous soils on wadi slopes and bed associated it contain four stands with 29 species distributed between altitudinal ranges of 450m and 510m a.s.l. This community types associated with *Abutilon hirttum*, *Acacia asak, Acacia tortilis, Adenium obesum, Aerva javanica, Cleome scaposa, Euphorbia triaculeata, Forsskaolea tenacissima, Indigofera spinosa, Leptadenia arborea, Lavandula coronopifolia* and *Maytenus senegalensis*; cover abundance is 9.53%. **IV-*Adenium obesum*** community, found at the wadi plateau and fissures it comprised of four sites with 32 species distributed between altitudinal ranges of 550m and 640m a.s.l associated with *Anisotes trisulcus*, *Cenchrus ciliaris, Eragrostis papposa, Eclipta prostrate, Panicum turgidum*, and seedling of *Lawsonia inermis* located at sandy-calcareous soils, cover abundance about 8.15%. **V-*Ricinus communis*** community type, found at fine sandy soils it consists of four stands with 27 species distributed between altitudinal ranges of 450m and 510m a.s.l associated with *Acalypha, fruticosa, Asphodelus tenuifolius***,** *Catharanthus roseus, Cenchrus ciliaris, Chenopodium murale, Chloris barbata, Cyperus conglomeratus, Dobera glabra, Pluchea dioscoridis* and *Acacia tortilis* seedlings, the plant cover abundance about 9.20%. **VI-*Acacia asak*** community type, occupies a large parts of the wadi, located on slopes at sandy soils, it consists of seven plots with 42 species distributed between altitudinal ranges of 550m and 580m a.s.l, associated with *Abutilon hirttum, Aerva javanica, Anisotes trisulcus, Argemone ochroleuca, Catharanthus roseu* and *Fagonia indica;* their cover abundance are 13.10 %. **VII-*Lawsonia inermis*** community, located at sandy soils, it represents a large amount in the plateau, consists of two

quadrates with 15 species distributed between altitudinal ranges of 630m and 690 m a.s.l associated with *Asphodelus tenuifolius, Aristida adscensionis, Cleome viscosa*, *Cyperus conglomerates, Malva parviflora, Paspalidium desertorum,* and *Senna alexandrina;* cover abundance about 2.71%. **VIII-*Dobera glabra*** community type inhabits the wadi bed; it consists of three stands with 22 species distributed between altitudinal of 460m and 570m a.s.l, associated with *Acacia asak* branches*, A. ehrenbergiana, Acacia tortillis, Adenium obesum, Aristida adscensionis, Asphodelus tenuifolius, Catharanthus roseus, Cissus rotundifolia, Chenopodium murale, Chloris barbata, Cyperus conglomeratus, Delonix elata, Ricinus communis* seedling*, Senra incana* and *Tephrosia subtriflora;* cover abundance about 7.11%. **IX-*Tamarindus indica*** community type, widespread at sandy soils it consists of eight quadrates with 50 species distributed between altitudinal ranges of 650m and 740m a.s.l, associated with *Abutilon bidentatum*, *Aerva javonica, Catharanthus roseus, Calotropis procera, Cissus rotundifolia, Lawsonia inermis*seedling*, Panicum turgidum,* and *Tephrosia subtriflora* at rough-sandy soils; their cover abundance about 16.2%. **X-*Leptadenia arborea*** community type represents a large area in the wadi it found in a dry state in most sites. It consists of six stands with 38 species distributed between altitudinal ranges of 520m-620m a.s.l, associated with *Adenium obesum, Calotropis procera, Cissus rotundifolia*, *Echinochloa colona, Indigofera colutea* and *Tamarindus indica* (sub-shrub); their cover abundance are 10.2%.

The Shannon-Wiener diversity index (H') was computed between the ten community types (Table 5). Community of *Tamarindus indica* (IX) had the highest diversity value (H=1.51) followed by *Leptadenia arborea* community (H=1.37). The next dominant

community types were *Acacia asak* (H=1.32) and *Ziziphus spina-christ* (H=1.27). *Adenium obesum* and *Anisotes trisulcus* communities had H=1.162 and H=0.880 respectively. The lowest diversity index appeared in *Lawsonia inermis* community type being H=0.570 (Table 5). The equitability (evenness) which measures the relative abundance between the different species demonstrated the highest evenness values in community type (VI) *Acacia asak* followed by community type (IX) *Tamarindus indica*. The next evenness values were community types of *Leptadenia arborea* (X) and *Dobera glabra* (VIII). The lowest value was for (VII) *Lawsonia inermis* community (Table 5).

Similarity and dissimilarity between the different sites calculated by Sorensen's Index coefficient (Table 6) detected the highest values appeared between *Ricinus communis* and *Dobera glabra* (ISs=41.66%) followed by *Adenium obesum* community types and *Tamarindus indica* communities (ISs=36.36%). The lowest similarity estimated between *Ziziphus spina-christi* community types and *Lawsonia inermis* community types (9.09%) followed by community types of *Ricinus communis* and *Tamarindus indica* (8.33%).

Discussion

A total of 95 species belonging to 75 genera and 31 families were recorded from wadi Wasaa, Jazan. The floristic analysis revealed four most families of Poaceae, Euphorbiaceae, Malvaceae and Apocynaceae abundant in the wadi. These floristic findings were in accordance with those of Marei *et al*. (2014) on Tihama Hill Slopes and Kasem and Marei (2017) on wadi Khulab, Jazan of Saudi Arabia. The abundance of the Poaceae might be due to water availability, including annual precipitation and

soil properties (Osman *et al*., 2014 and Abdel Abd El-Khalik *et al*. 2017). Life forms were diverse and the vegetation is sparse; chameophytes and therophyte are the dominant, referring to the permanent vegetation that can be accompanied by ephemeral (or annual) plant growth depending on the amount of precipitation in a given year in accordance with finding of E1-Demerdash *et al*. (1994). Moderate of cover abundance in the study area is may be due to the soil is mobile which in accordance to Al-Gifri and Husse (1993) on their studies along the road from Aden to Sheikh Salem (Abyan), Yemen. The intermediate diversity in the wadi was due to the temperate of the rainfall sources and soil fertility which considered as a biotic factor, accordingly the phytoclimate of the wadi was a chameo-therophytic type. The dominance of chaemophytes-therophytes over other life forms is seen to be a response to the hot dry climate, topographic variation and human and animal interference (Abd El-Ghani and Abd El-Khalik, 2006). The high contributions of therophytes lead to adjustment of the flora to water balance. These results are in accordance with several studies in different regions of Saudi Arabia such as: Mosallam (2007) on Sudera, Taif; Al-Turki and Al-Olayan (2003) In Hail Region; Al-Atar, *et al*. (2012) on wadi Al-Jufair; Abd El-Ghani (1993) on Aseer regions and Kasem and Maeri (2017) on wadi Khulab. Biregional area of the Saharo-Arabian, Sudano-Zambezian chorotype were dominated with higher percentage than mono- and pluriregional area, this was in accordance with Kasem and Marei (2017), El-Shabasy and Kasem (2017) and Osman *et al*. (2014), it represented more than one third of the total species (33 %) because this area mainly deserted and located within the belt of Saharo-Sindian, at the same time it is a part of that belt between Saharo and Sindian. This result was confirmed by

the evidence: The ratio of Saharo-Arabian, Sudano-Zambezian chorotypes decrease while moving to the north and are replaced by Mediterranean and Irano-Turanian chorotypes (Danin and Plitman 1987; Abd El-Ghani and Amer 2003). The studied 46 plots were grouped into clusters with the aid of computer program SPSS, ver.20. Ten plant communities were identified and described with varying degrees of species richness, evenness and diversity. The ninth plant community (*Tamarindus indica*) exhibited the highest richness (50 species). Since it is known that the increase in the number samples will increase the species encountered (Mcnaughton and Wolf, 1973); the community types *Salvadora persica* (II) and *Lawsonia inermis* (VII) appeared with the lowest species richness compared to the other community types because they represented species from only two and three sample plots respectively, and could be attributed to variations in their environmental gradients that can limit the ecological distributions of plant species (Lulekal, 2014), it could also be related to the effects of environmental factors such as altitude aspect, soil contents and moisture, human impacts and grazing intensity (Bekele, 1993). Moreover, the area covered by these plants were large in size and occupies vast area of the quadrates. According to Kent and Coker (1992), the Shannon is the most frequently index used for the combination of species richness and relative abundance measurements; the index normally varies between 1.5 and 3.5 and rarely exceeds 4.5. In the present study, the index is between 0.57-1.51, showing less even representation of individuals of all species in the sampled quadrats. Sorensen's Index of Similarity (ISs) gives greatest weight to the species that occurred in the two test areas than to those that are unique to either area (Mueller-Dombois and Ellenberg, 1974). According to Sorensen's Index of Similarity

(ISs), the highest values calculated within the adjacent sites were in accordance with results of Tadesse & Bekele (2017). On their studied on the vegetation in Ilu Gelan district, West Shewa Zone of Oromia region, Central Ethiopia. On the other hand, Psamophytic species, such as *Senna alexandrina, Catharanthus roseus, Echinochloa colona, Datura stramonium, Heliotropium lasiocarpum, Cleome viscosa*, *Malva parviflora*, *Cyperus conglomeratus* and *Boerhavia elegans* were recorded from the sample plots of the wadi bed, this result matches that of Marei *et al*.2014, as well as, the association of various species in plant communities (III) *Anisotes trisulcus* and (VI) *Acacia asak* is in agreement with Masrahi (2012).

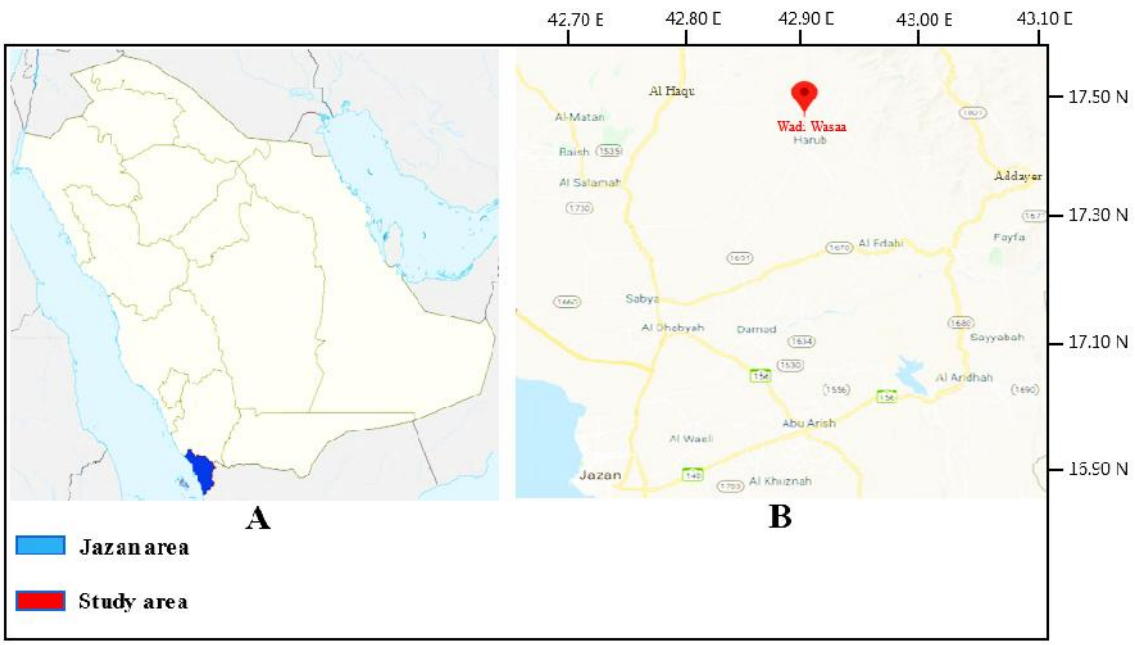

Figure 1: A. Location of Jazan in Saudi Arabia, B. Study area in Jazan region

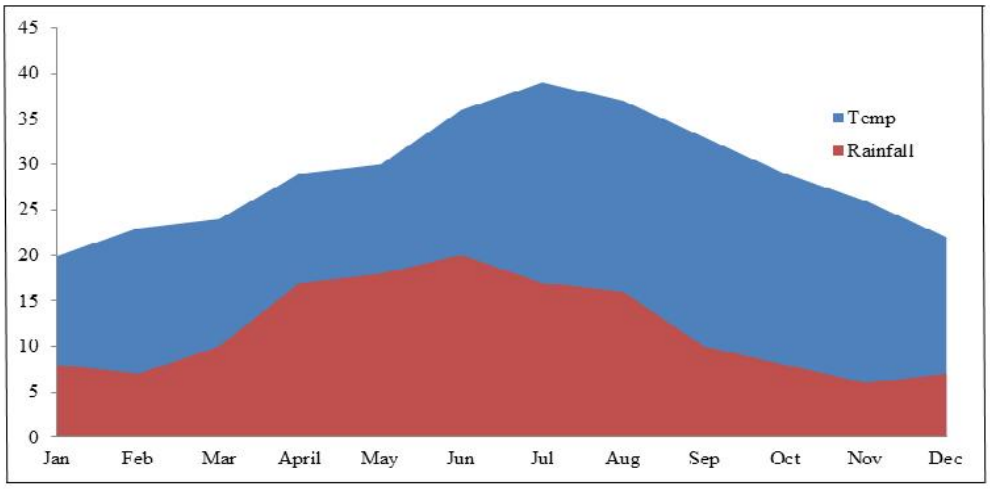

Figure 2: Monthly average temperature and rainfall percentages in the study area

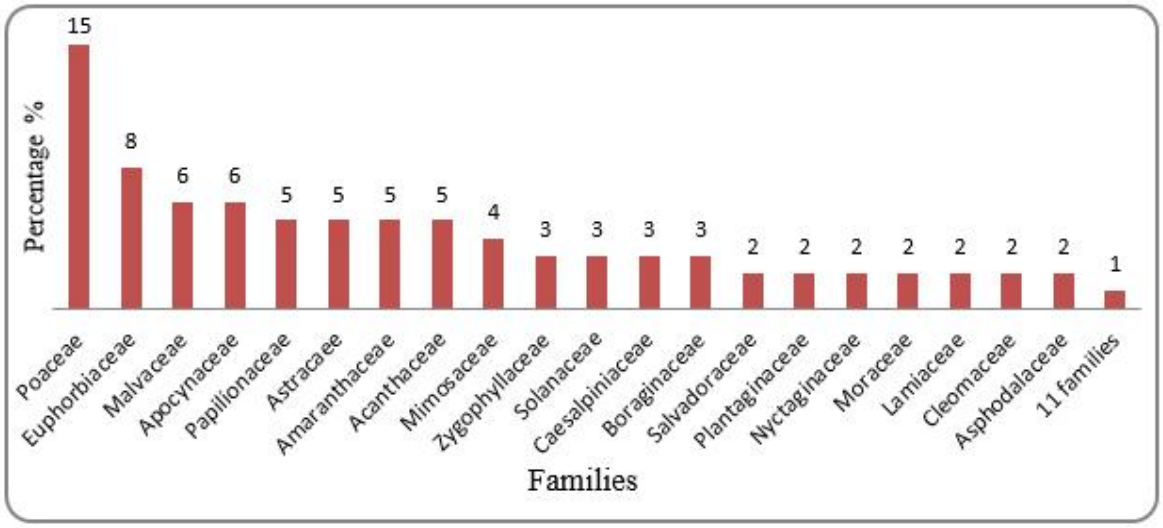

Figure 3. Species percentages in the recorded families

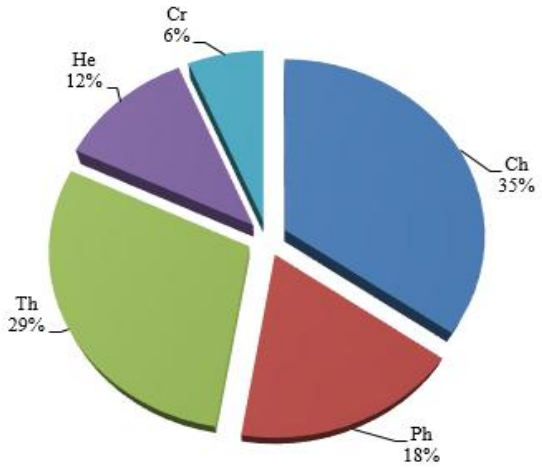

Figure 4. Life-form relative spectrum of Wadi Wasaa vegetation. Ch = Chamaephyte, Th= Therophyte, Ph= Phanerophyte, He= Hemi-cryptophyte and Cr= Cryptophyte.

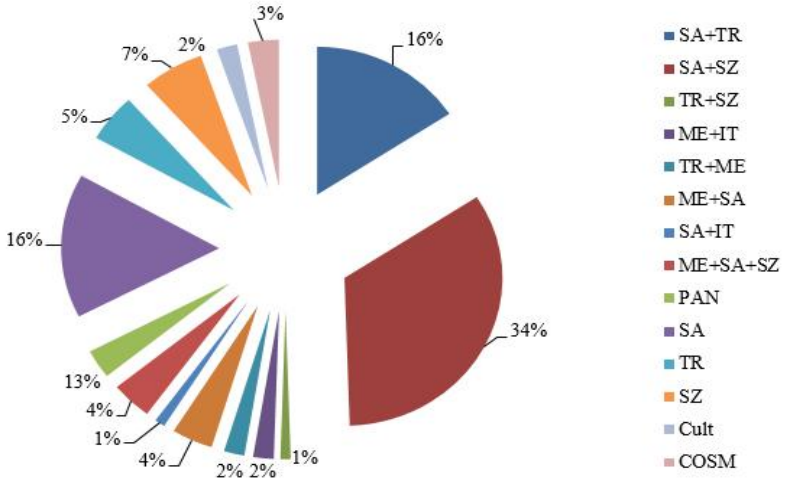

Figure 5. Floristic category spectrum of Wadi Wasaa. COSM= Cosmopolitan, TR= Tropical, PAN= Pantropical, SA= Saharo-Arabian, SZ = Sudano-Zambezian, ME= Mediterranean and IT= Irano-Turanian.

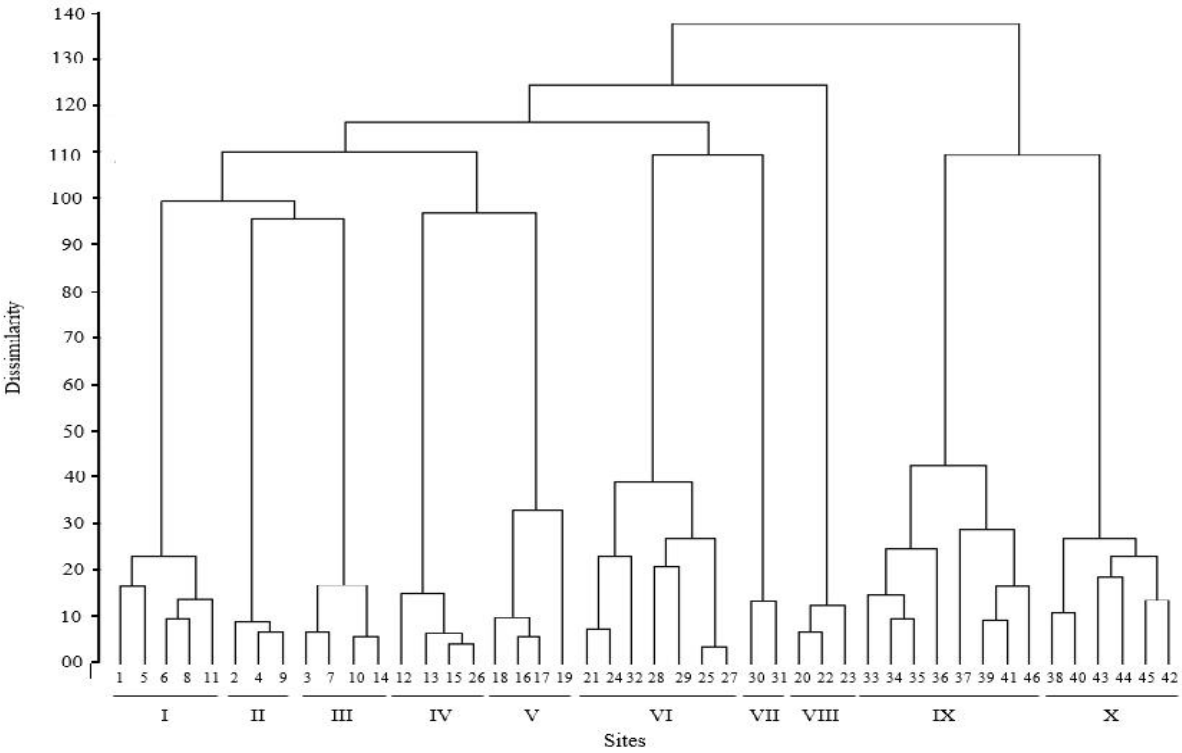

Figure 6. Dendrogram showing different plant community types in the study area

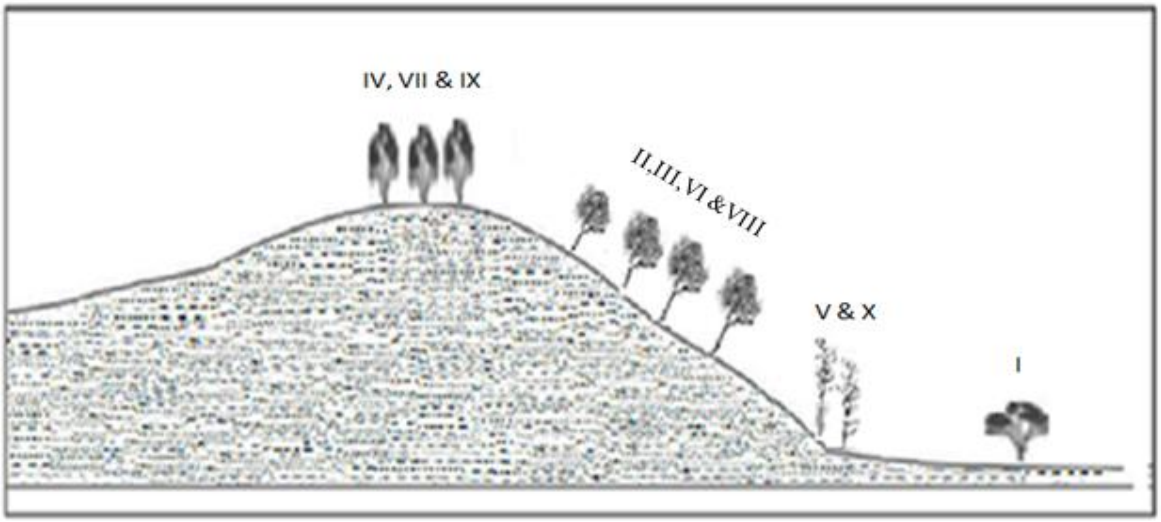

Figure 7. Diagram showing the abundance of ten plant community types in the wadi. I-*Ziziphus spina-christi,* II- *Salvadora persica* III- *Anisotes trisulcus,* IV- *Adenium obesum,* V- *Ricinus communis.* VI-*Acacia asak,* VII- *Lawsonia inermis,* VIII- *Dobera glabra,* IX-*Tamarindus indica* and X- *Leptadenia arborea*

333 **Table 1:** Collected plant species from Wadi Wasaa with their families, life forms and
334 chorotypes. Ph, phanerophytes; Ch, chamaephytes; Cr, cryptophyte; H, hemi-
335 cryptophytes and Th, therophytes, Per=perennial, Ann=Annual,
336 COSM=Cosmopolitan, IT=Irano-Turanian, ME=Mediterranean, PAN=Panatropical,
337 SA= Saharo-Arabian, SZ=Sudano-Zambezian and TR=Tropical
338

Family	Species	Life form	Habit	Life span	Chorotype
Acanthaceae	*Anisotes trisulcus* (Forssk.) Nees	Ch	Shrub	Per	SA+TR
	Barleria trispinosa (Forssk.) Vahl.	Ch	Sub-shrub	Per	SA
	Blepharis edulis (Forssk.) Pers.	Ch	Sub-shrub	Per	SA+SZ
	Ecbolium viride (Forssk.) Alston.	Ph	Sub-shrub	Per	SA
	Ruellia patula Jacq.	Ch	Sub-shrub	Per	SA+TR
Aizoaceae	*Trianthema crystalline* -Vahl	Th	Herb	Ann	SA
Amaranthaceae	*Aerva javanica* (Burm.f.) Juss ex Schult.	Ch	Sub-shrub	Ann	SA+ TR
	Amaranthus hybridus L.	Th	Herb	Ann	PAN
	A. viridis L.	Ch	Herb	Ann	ME + TR
	Chenopodium fasciculosum Aellen	He	Herb	Biennial	SA+TR
	C. carinatum R. Br.	Th	Herb	Ann	SA+SZ
Apocynaceae	*Adenium obesum* (Forssk.) Roem. & Schult.	Ph	tree	Ann	SA
	Calotropis procera (Aiton) Dryand.	Ch	shrub	Per	SA+SZ
	Caralluma retrospiciens (Ehrenb.) N.E.Br.	Ch	Succulent	Per	SA+SZ
	Catharanthus roseus(L.) G.Don.	Ch	Herb	Ann	ME + TR
	Kanahia laniflora (Forssk.) R. Br.	Ch	Sub-shrub	Per	SA+SZ
	Leptadenia arborea (Forssk.) Schweinf	Ch	Climber	Per	SA+ SZ
Asphodelaceae	*Aloe officinalis* Forssk.	He	Succulent	Per	ME+SA
	Asphodelus tenuifolius Cav.	Cr	Herb	Biennial	SA+ SZ
Astracaee	*Conyza steudelii* Sch.Bip. ex A.Rich.	Ph	Sub-shrub	Per	SA+TR
	Cyanthillium cinereum (L.) H.Rob.	Th	Herb	Ann	SZ +TR
	Eclipta prostrata(L) L.	Th	Herb	Per	ME+ SA
	Pluchea dioscoridis (L.) DC.	Ch	Sub-shrub	Per	SA+SZ
	Pulicaria schimperi DC.	Ch	Herb	Ann	SA+TR
Boraginaceae	*Heliotropium longiflorum* (A.DC.) Jaub. & Spach	He	Herb	Per	SA+TR
	H. pterocarpum (DC.&A.DC.) Hochst. & Steud. ex Bunge	He	Herb	Per	SA+SZ
	H. strigosum Willd.	He	Herb	Per	SA+SZ
Capparaceae	*Capparis cartilaginea* Decne.	Ch	Sub-shrub	Per	SA+SZ
Cactaceae	*Opuntia dillenii* (Ker Gawl.) Haw.	Ch	Shrub	Per	TR
Caesalpiniaceae	*Senna alexandrina* Mill.	Ch	Sub-shrub	Per	SA+SZ
	S. italica Mill.	Ch	Sub-shrub	Per	SZ
	Tamarindus indica L.	Ph	Tree	Per	SA+TR
Cleomaceae	*Cleome scaposa* DC.	He	Herb	Ann	SA+TR
	C. viscosa L.	Th	Herb	Ann	PAN
Clesteraceae	*Gymnosporia senegalensis* (Lam.) Loes.	Ph	Tree	Per	SA
Convolvulaceae	*Merremia aturensis* (Kunth) Hallier f	He	Climber	Per	SA+SZ
Cyperaceae	*Cyperus conglomeratus* Rottb.	Cr	Herb	Per	SA
Euphorbiaceae	*Acalypha fruticosa* Forssk.	Ch	Sub-shrub	Per	SA
	Chrozophora oblongifolia (Del.) A. Juss. ex Spreng.	Ph	Sub-shrub	Per	SA+SZ
	Dalechampia scandens L.	Ph	Climber	Per	SA+TR

	Euphorbia inarticulata Schlecht.	Ch	Succulent	Per	ME+SA+SZ
	E. hirta L.	Th	Herb	Ann	COSM
	E. prostrata Aiton.	Th	Herb	Per	COSM
	E. triaculeata Forssk	Ch	Succulent	Per	SZ
	Ricinus communis L.	Ph	Tree	Per	TR
Lamiaceae	*Lavandula coronopifolia* Poir.	Ch	Sub-shrub	Ann	ME+SA
	Ocimum forsskaolii Benth.	Ch	Sub-shrub	Ann	SA+TR
Lythraceae	*Lawsonia inermis* L.	Ph	Tree	Per	Cultivated
Malvaceae	*Abutilon bidentatum* Hochst. ex A.Rich	Ch	Sub-shrub	Per	TR
	A. hirtum (Lamk.) Sweet	Ch	Sub-shrub	Per	PAN
	Corchorus depressus (L.) Stocks	Cr	Herb	Per	ME+IT
	C. tridens L.	Th	Herb	Ann	ME+SA+SZ
	Malva parviflora L.	He	Herb	Ann	ME+ IT
	Senra incana Cav.	Ch	Sub-shrub	Per	SA+SZ
Mimosaceae	*Acacia asak* (Forssk.) Willd	Ph	Tree	Per	SA+SZ
	A. ehrenbergiana Hayne	Ph	Tree	Per	SA+SZ
	A. tortilis (Forssk.) Hayne	Ph	Tree	Per	SA+SZ
	Delonix elata (L.) Gamble	Ph	Tree	Per	SA+TR
Moraceae	*Ficus cordata* ssp. *salicifolia* (Vahl) Berg.	Ph	Shrub	Per	SA
	F. ingens (Miq.) Miq.	Ph	Tree	Per	SA+SZ
Nyctaginaceae	*Boerhavia elegans* Choisy	He	Herb	Ann	TR
	Commicarpus grandiflorus (Rich.) Standley	He	Herb	Per	SA+TR
Papavaraceae	*Argemone ochroleuca* Sweet	Th	Herb	Per	PAN
Papilionaceae	*Crotalaria microphylla* M.Vahl.	Th	Herb	Per	SA+SZ
	Indigofera colutea (Burm.f.) Merr.	Ch	Sub-shrub	Per	SZ
	I. hochstetteri Bak.	Ch	Sub-shrub	Ann	SZ
	I. spinosa Boiss.	Ch	Sub-shrub	Per	SA+SZ
	Tephrosia subtriflora Baker	Ch	Sub-shrub	Per	SA
Plantaginaceae	*Scoparia dulcis* L.	Ch	Herb	Per	SA
	Schweinfurthia pterosperma A. Braun	Th	Herb	Ann	SA
Poaceae	*Aristida adscensionis* L.	Th	Herb	Ann	ME+SA
	Cenchrus ciliaris L.	Cr	Herb	Per	SA+ SZ
	Chloris barbata Sw.	Th	Herb	Per	SZ
	C. gayana Kunth	Th	Herb	Per	SA+SZ
	Dichanthium foveolatum (Del.) Roberty	Th	Herb	Per	ME+SA+SZ
	Echinochloa colona (L.) Link.	Th	Herb	Ann	TR
	Eragrostis japonica (Thunb.) Trin.	Th	Herb	Ann	SA+ SZ
	E. papposa (Roem & Schult) Steud.	Th	Herb	Per	SZ
	Hyparrhenia hirta (L.) Stapf	Th	Herb	Per	SA
	Panicum turgidum Forssk.	Cr	Herb	Per	SA+SZ
	Paspalidium desertorum (Rich.) Stapf.	Th	Herb	Per	SA
	Sorghum bicolor (L.) Moench	Cr	Herb	Ann	Cultivated
	Sporobolus nervosus Hochst.	Th	Herb	Per	SA+SZ
	Tetrapogon cenchriformis (Rich.) Clayton	Th	Herb	Ann	SA+SZ
Rhamnaceae	*Ziziphus spina-christi* (L.) Desf.	Ph	Tree	Per	ME+SA+SZ
Salvadoraceae	*Dobera glabra* (Forssk.) Juss. ex Poir	Ph	Tree	Per	SA+TR
	Salvadora persica L.	Ch	shrub	Per	SA+SZ
Solanaceae	*Datura innoxia* Mill.	Ch	Sub-shrub	Ann	SA
	D. stramonium L.	Th	Sub-shrub	Ann	COSM
	Solanum surattense Burm. F.	Th	Herb	Per	SA+TR
Urticaceae	*Forsskaolea tenacissima* L.	Th	Herb	Per	SA+SZ
Vitaceae	*Cissus rotundifolia* Vahl	Ch	Climber	Per	SA
Zygophyllaceae	*Fagonia indica* Burm.F.	He	Herb	Per	SA+IT

	F. paulayana J.Wagner & Vierh.	Th	Herb	Per	SA+SZ
	Tribulus parvispinus C. Presl	Th	Herb	Ann	SA+SZ

Table 2: Species number related to main floristic categories and their phytochoria percentage.

Growth type		**Phytochoria**				**Life Form**		
Type	%	**Category**	**Type**	**No.**	%	Form	**No.**	%
Annual	27	Monoregional	SA	15	16	Ch	33	35
Biennial	02		TR	5	5	Th	28	29
Perennial	66		SZ	6	6	Ph	17	18
		Biregional	SA+SZ	31	33	He	11	12
			SA +TR	16	16	Cr	6	6
			ME + IT	2	2	--	--	
			SZ+TR	1	1	--	--	
			ME+TR	2	2	--	--	
			ME+SA	4	4	--	--	
			SA +IT	1	1	--	--	
		Pleuriregional	ME+ SA +SZ	4	4	--	--	
			PAN	4	4	--	--	
			COSM	3	3	--	--	
			Cult	2	2	--	--	
		Total	**14**	**95**	**100**	**5**	**95**	**100**

Table 3: Plant species and their cover abundance in all quadrates among the dominant communities. I-*Ziziphus spina-christi,* II- *Salvadora persica* III- *Anisotes trisulcus,* IV- *Adenium obesum,* V- *Ricinus communis.* VI-*Acacia asak,* VII- *Lawsonia inermis,* VIII- *Dobera glabra,* IX-*Tamarindus indica* and X- *Leptadenia arborea*

Species	Community Types										Cover abundance
	I	II	III	IV	V	VI	VII	VIII	IX	X	
Abutilon hirtum	-	-	+	-	-	+	-	-	-	-	0.008
Abutilon bidentatum	-	-	-	-	-	-	-	-	+	-	0.060
Acalypha fruticosa	-	-	-	-	+	-	-	-	-	-	0.050
Acacia asak	-	-	+	-	-	-	-	+	-	-	13.10
A. ehrenbergiana	-	-	-	-	-	-	-	+	-	-	0.708
A. tortilis	-	-	+	-	+	-	-	+	-	-	0.300
Adenium obesum	+	-	-	-	-	-	-	+	-	+	8.150
Aerva javanica	-	-	+	-	-	+	-	-	+	-	0.045
Aloe officinalis	-	+	-	-	-	-	-	-	-	-	0.030
Anisotes trisulcus	+	+	-	+	-	+	-	-	-	-	9.530
Aristida adscensionis	-	-	-	-	-	-	+	+	-	-	0.007
Argemone ochroleuca	+	-	-	-	-	+	-	-	-	-	0.027
Asphodelus tenuifolius	-	-	-	-	+	-	+	+	-	-	0.005
Barleria trispinosa	+	-	-	-	-	-	-	-	-	-	0.077
Blepharis edulis	-	+	-	-	-	-	-	-	-	-	0.047
Catharanthus roseus	-	-	-	-	+	+	-	+	+	-	0.004
Calotropis procera	-	+	-	-	-	-	-	-	+	+	0.024

Caralluma retrospiciens	+	-	-	-	-	-	-	-	-	-	0.069
Cenchrus ciliaris	-	-	-	+	+	-	-	-	-	-	0.054
Cissus rotundifolius	-	-	-	-	-	-	-	+	+	+	0.008
Chenopodium murale	-	-	-	-	+	-	-	+	-	-	0.023
Chloris barbata	-	-	-	-	+	-	-	+	-	-	0.025
Cleome viscosa	-	-	-	-	-	-	+	-	-	-	0.006
Cleome scaposa	-	-	+	-	-	-	-	-	-	-	0.004
Corchorus depressus	-	+	-	-	-	-	-	-	-	-	0.054
Cyperus conglomeratus	-	-	-	-	+	-	+	-	-	-	0.005
Delonix elata	-	-	-	-	-	-	-	+	-	-	0.070
Dobera glabra	-	-	-	-	+	-	-	-	-	-	7.110
Eragrostis papposa	-	-	-	+	-	-	-	-	-	-	0.011
Eclipta prostrate	-	-	-	+	-	-	-	-	-	-	0.004
Euphorbia triaculeata	-	+	+	-	-	-	-	-	-	-	0.008
Echinochloa colona	-	-	-	-	-	-	-	-	-	+	0.003
Fagonia indica	-	-	-	-	-	+	-	-	-	-	0.007
Forsskaolea tenacissima	-	-	+	-	-	-	-	-	-	-	0.004
Heliotropium longiflorum	+	-	-	-	-	-	-	-	-	-	0.004
Indigofera colutea	-	+	-	-	-	-	-	-	-	+	0.005
Indigofera spinosa	-	-	+	-	-	-	-	-	-	-	0.006
Leptadenia arborea	-	-	+	-	-	-	-	-	-	-	10.20
Lavandula coronopifolia	+	-	+	-	-	-	-	-	-	-	0.005
Lawsonia inermis	-	-	-	+	-	-	-	-	+	-	2.710
Maytenus senegalensis	-	-	+	-	-	-	-	-	-	-	0.080
Malva parviflora	-	-	-	-	-	-	+	-	-	-	0.002
Ocimum forsskaolii	-	+	-	-	-	-	-	-	-	-	0.025
Panicum turgidum	-	-	-	+	-	-	-	-	+	-	0.028
Pluchea dioscoridis	-	-	-	-	+	-	-	-	-	-	0.010
Paspalidium desertorum	-	-	-	-	-	-	+	-	-	-	0.011
Ricinus communis	-	-	-	-	-	-	-	+	-	-	9.200
Senna alexandrina	-	-	-	-	-	-	+	-	-	-	0.007
Senra incana	-	-	-	-	-	-	-	+	-	-	0.026
Tamarindus indica	-	-	-	-	-	-	-	-	-	+	16.02
Tephrosia subtriflora	-	-	-	-	-	-	-	+	+	-	0,050
Trianthema crystallina	+	-	-	-	-	-	-	-	-	-	0.004
Tribulus parvispinus	+	-	-	-	-	-	-	-	-	-	0.005
Ziziphus spina-christi	-	+	-	-	-	-	-	-	-	-	10.40

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Table 4: Distribution of the ten plant communities with their altitudinal ranges.

Name	Altitude		Plot Number	Plot list
	Ranges (m a.s.l.)	Means (m a.s.l.)		
I-*Ziziphus spina-christi*	500-570	616.13	5	1, 5, 6, 8 &11
II-*Salvadora persica*	520-586	552.66	3	2, 4 & 9
III- *Anisotes trisulcus*	450-510	498.24	4	3, 7, 10 & 14
IV-*Adenium obesum,*	550-640	585.43	4	12, 13, 15 & 26
V-*Ricinus communis*	450-510	482.53	4	16, 17, 18 &19
VI-*Acacia asak*	550-580	564.60	7	21, 24, 25, 27, 28, 29 & 23
VII-*Lawsonia inermis*	630-690	650.65	2	30 & 31
VIII-*Dobera glabra*	460-570	503.30	3	20, 22 & 23
IX-*Tamarindus indica*	650-740	685.32	8	33, 24, 35, 36, 37, 39, 41 & 46
X-*Leptadenia arborea*	520-620	576.66	6	38, 40, 43, 44, 45 &42

Table 5: Shannon-Wiener diversity index for ten plant community types

Communities	**Species richness (S)**	**Diversity index (H')**	**H max**	**Species evenness (J)**
I- *Ziziphus spina-christi*	35	1.271	1.382	0.060
II- *Salvadora persica*	18	0.692	0,761	0.040
III- *Anisotes trisulcus*	29	0.880	0,940	0.040
IV- *Adenium obesum*	32	1.162	1.260	0.052
V- *Ricinus communis*	27	0.781	0.850	0.043
VI- *Acacia asak*	42	1.322	1.461	0.084
VII- *Lawsonia inermis*	15	0.570	0.631	0.032
VIII -*Dobera glabra*	22	0.742	0,811	0.061
IX- *Tamarindus indica*	50	1.513	1.652	0.080
X- *Leptadenia arborea*	38	1.370	1.493	0.071

Table 6: Similarity and dissimilarity between the 10 community types calculated by Sorensen's similarity coefficient (ISs)

Communities	*Ziziphus spina.*	*Salvadora persica*	*Aniso. trisulcus*	*Adenium obesum*	*Ricinus communis*	*Acacia asak*	*Lawsonia inermis*	*Dobera glabra*	*Tamarindus indica*
Ziziphus spina-christi	0.00								
Salvadora persica	30.7	0.00							
Anisotes trisulcus	24.3	30.10	0.00						
Adenium obesum,	27.2	15.60	28.5	0.00					
Ricinus communis	29.1	33.30	32.8	27.27	0.00				
Acacia asak	28,5	28.50	33.0	30.7	18.8	0.00			
Lawsonia inermis	**9.09**	18.50	16.6	29.0	16.6	19. 0	0.00		
Dobera glabra	21.42	23.01	24.2	17.91	**41.66**	13.0	9.51	0.00	
Tamarindus indica	23.07	15.38	16.4	**36.36**	**8.33**	12.8.	29.1	14.2	0.00
Leptadenia arborea	16.66	13.04	18.18	19. 4	12.6	10.2	18.18	20.0	20.0

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