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

A. N. Al-Gifri[1,2], W. T. Kasem[1,3] and Lamiaa F. Shalabi[1,4*]

[1]Department of Biology, Faculty of Science, Jazan University, Jazan, Saudi Arabia.
[2]Department of Biology, Faculty of Science, University of Aden, Yemen.
[3]Department of Botany and Microbiology, Faculty of Science, Al-Azhar University, Cairo, Egypt.
[4]Department of Biological and Geological Sciences, Faculty of Education, Ain Shams University, Cairo, Egypt.

Original Research Article

ABSTRACT

This study is the first report conducted on Wadi Wasaa of Jazan area in Saudi Arabia. Total of 95 species belonging to 75 genera and 31 families were recorded from the study area, Poaceae and Euphorbiaceae both are the dominant families constituted 23% of the total species of the study area followed by Apocynaceae , 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% fell under monoregional, 56 species (59.0%) as biregional 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

**Corresponding author: E-mail: Flora_lamiaa@yahoo.com;*

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.

Keywords: Floristic composition; diversity; chorology; community type analysis.

1. INTRODUCTION

Diversity of wild plants is an important feature of the healthy environments and plays a major role in protecting the ecological stability 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 includes very significant genetic resources of crops and medical plants (Atiqur *et al*., 2004). In arid lands, wadis represent one of the most conspicuous desert landforms, which reveal physiographic abnormalities which 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; Orshan, 1986). Jazan region is situated in the southwestern part of Saudi Arabia characterised 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 Slopes and the Farasan Islands. The first two regions are parts of the oldest agricultural centers of the Arabian Peninsula and collected of wadis, mountains and plateaus (Al-Farhan *et al*., 2005; Masrahi, 2012). Several studies on the floristic diversity and vegetation analysis in Tihama plains of Saudi Arabia were achieved by El-Demerdash *et al*. (1994), Masrahi (2012) and Marei *et al*. (2014).

Wadi vegetation of Saudi Arabia were studied extensively such as Wadi Talha (Al Wadie, 2002), Wadi El Ghayl (Fahmy and Hassan 2005), Wadi Al Ammaria (El Ghenam, 2006), Wadi Al Jufair (Al Atar *et al*., 2012), Wadi Al Argy (Farrag, 2012), Wadi Al Noman (Abdel Khalik *et al.,* 2013), Wadi Al Rummah (El Ghazali *et al*., 2013), Wadi Khulab (Kasem and Marei, 2017) and Wadi Tashar (El-Shabasy and Kasem, 2018).

Evenness Index (E) and Shannon-Wiener Diversity Index (H) are most standard methods in the diversity of species measuring (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.

1.1 Study Area

The Jazan city is situated in the south-western part of Saudi Arabia at 16°20`N to 17°40` N and 41°55`E to 43°20`E, about 260 km long coastal area on the western side, stretching from Al-Muwassam in the south to Al Shuqaiq in the north Al-Farhan *et al.* (2005). Wadi Wasaa located in the southeast of Jazan, It located between the Al-Dabha Mountain in the east and Al-Hague in the west of Jazan region, it extends between 17°482' N latitude and 42°894' E longitude (Fig. 1). It covers an area around 60 km^2; altitude ranges from 480-680 m above sea level (a.s.l.). 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 (Fig. 2).

2. MATERIALS AND METHODS

A total of 46 sites along Wadi Wasaa, Jazan were randomly selected for surveying the plant vegetation and diversity. The study was conducted from January to October 2017, that this period represents the optimum growing and flowering seasons for most plant species in Jazan. 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 in Jazan University Herbarium, KSA (JAZUH) 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 Zohary (1973) and Wickens (1978). Altitude and geographical coordinates were measured using GPS (Geographical Position System) for each quadrate. Cover abundance were calculated by the equation: total number of individuals of the species/ total number of stands in which species has occurred. Cover abundance were estimated according to Braun-Blanquet scale (Mueller-Dombois and Ellenberg, 1974) and modified later by Maarel (1979).

The computer program (SPSS, ver. 20) was used to analyse 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 base n. 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.

3. RESULTS

3.1 Floristic Analysis

The floristic data on the study area, occurring between altitudinal gradients of 480-680 m (a.s.l.), indicated a total of 95 species belonging to 75 genera and 31 families. According to species richness, the majority of plants in the study area were perennials with estimated 58 species (61.05% of the total recorded species), the second most frequent growth type were annuals; which was revealed by 35 species (36.8% 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 were represented by 6 species each. Acanthaceae, Astreaceae, Amaranthaceae, Papilionaceae have five species each constituted a total of 5.0%. 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% of the total species represented by single species each (Fig. 3).

3.2 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 Hemicryptophyte 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 percentage of 6.

3.3 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% fell 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 larger number of species (56 species with 59%). Also in this region, 31 species (33%) shared by Saharo-Arabian and Sudano-Zambezian whereas the lowest one represented in Saharo-Zambezian and tropical regions by only one species (*Cyanthillium cinereum*), Saharo-Arabian shared with tropical by 15 species (16%). Both Saharo-Arabian and Mediterranean has four species (4%). 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 Fig. 5).

3.4 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 summarised as follows:

I-*Ziziphus spina-christi,* this community type was represented through five quadrats with 35 species distributed between altitudinal ranges of 500 m and 570 m 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 520 m and 586 m 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-calcareous soils on wadi slopes and bed associated it contain four stands with 29 species distributed between altitudinal ranges of 450 m and 510 m 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 550 m and 640 m a.s.l. associated with *Anisotes trisulcus*, *Cenchrus ciliaris, Eragrostis papposa, Eclipta prostrata, 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 consisted of four stands with 27 species distributed between altitudinal ranges of 450 m and 510 m 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 on sandy soils. It consisted of seven plots with 42 species distributed between altitudinal ranges of 550 m and 580 m a.s.l, associated with *Abutilon hirttum, Aerva javanica, Anisotes trisulcus, Argemone ochroleuca, Catharanthus roseus* and *Fagonia indica;* their cover abundance are 13.10%.

VII-*Lawsonia inermis* community, located at sandy soils, represents a large amount in the plateau. It consisted of two stands with 15 species distributed between altitudinal ranges of 630 m 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; consisted of three stands with 22 species distributed between altitudinal of 460 m

and 570 m 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* seedlings*, Senra incana* and *Tephrosia subtriflora;* cover abundance about 7.11%.

IX-*Tamarindus indica* community type, widespread on sandy soils it consisted of eight stands with 50 species distributed between altitudinal ranges of 650 m and 740 m a.s.l., associated with *Abutilon bidentatum*, *Aerva javonica, Catharanthus roseus, Calotropis procera, Cissus rotundifolia, Lawsonia inermis* seedlings*, Panicum turgidum,* and *Tephrosia subtriflora* on 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 consisted of six stands with 38 species distributed between altitudinal ranges of 520 m-620 m 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%.

3.5 Species Diversity of Communities

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=0.57 (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%).

4. 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 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; Abd El-Khalik *et al*., 2017). Life forms were diverse and the vegetation is sparse; chameophytes and therophyte were 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 as indicated with the finding of E1-Demerdash *et al*. (1994). Moderate cover abundance in the study area may be due to the soil mobility, as indicated by Al-Gifri and Husse (1993) in their studies along the roadside from Aden to Sheikh Salem (Abyan), Yemen. The intermediate diversity in the wadi appears to be due to abiotic factors (temperate rainfall and soil fertility), so the phytoclimate of the wadi was classified as chameo-therophytic type.

The dominance of chaemophytes-therophytes over other life forms is seen to be an outcome of hot dry climate, topographic variation, 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 reports proceeded in different regions of Saudi Arabia by Abd El-Ghani (1993) on Aseer regions, Al-Turki and Al-Olayan (2003) in Hail Region; Mosallam (2007) on Sudera, Taif; Al-Atar *et al*. (2012) on wadi Al-Jufair and Kasem and Maeri (2017) on wadi Khulab.

Biregional area of the Saharo-Arabian,Sudano-Zambezian chorotype were dominated than monoregional and pluriregional area, which is 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 is mainly deserted and located within the Saharo-Sindian belt. This result was confirmed by the evidence: Saharo-Arabian, Sudano-Zambezian chorotypes percentages reduced due to moving to the north area and are replaced by Mediterranean and Irano-Turanian area (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 community types 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). The increase in the number of samples increased the species encountered (Mcnaughton and Wolf, 1973). The community types *Salvadora persica* (II) and *Lawsonia inermis* (VII) appeared with the lowest species richness, that they represented species from only two and three sample plots respectively. This result could be attributed to variations in their environmental gradients that can limit the ecological distributions of plant species (Lulekal, 2014). Moreover, the area covered by these plants was large in size and occupied vast area of the quadrates.

According to Kent and Coker (1992), the Shannon is the most frequent 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 the 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 Tadese and Bekele (2017) on their vegetation study in Ilu Gelan district, Central Ethiopia.

On the other hand, *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).

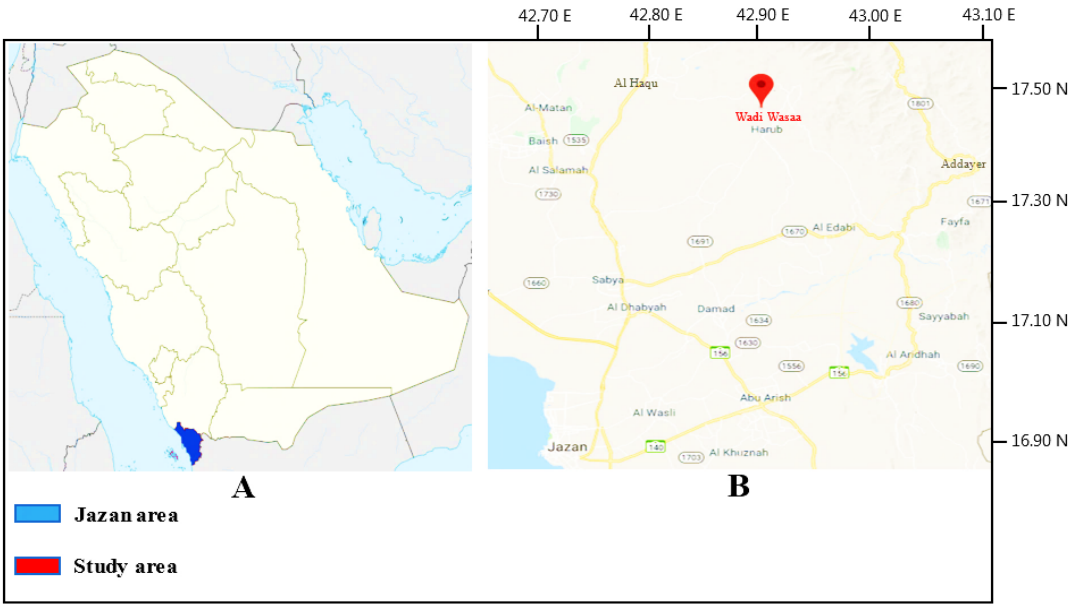

Fig. 1. (A), Map of Saudi Arabia in which Jazan region (blue point in overview map), (B) location of study area (red point in overview map) in Jazan region (B)

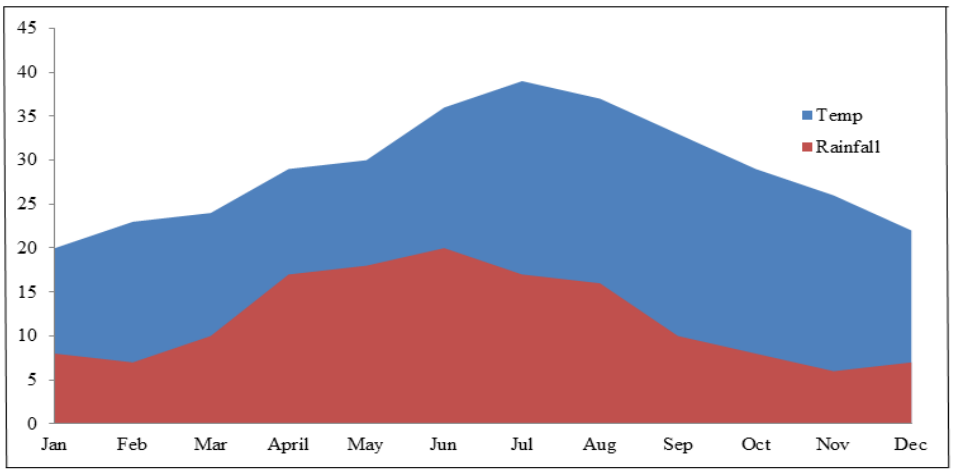

Fig. 2. Monthly average temperature and rainfall percentages in the study area

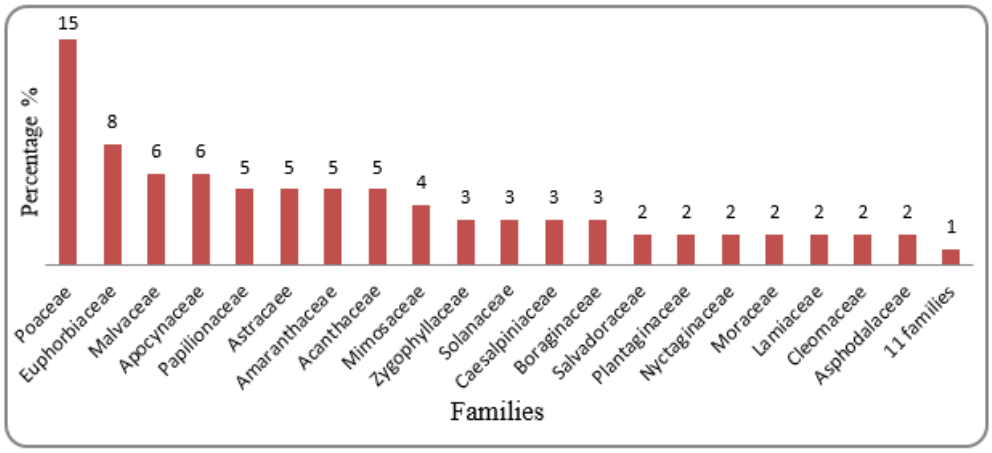

Fig. 3. Species percentages in the recorded families

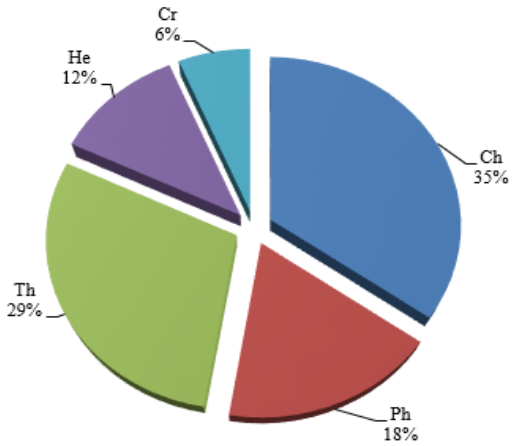

Fig. 4. Life-form relative spectrum of Wadi Wasaa vegetation. Ch = Chamaephyte, Th= Therophyte, Ph= Phanerophyte, He= Hemi-cryptophyte and Cr= Cryptophyte

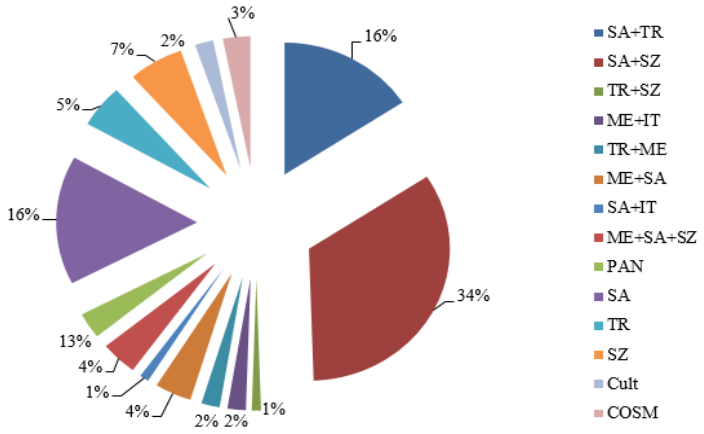

Fig. 5. Floristic category spectrum of Wadi Wasaa. COSM= Cosmopolitan, TR= Tropical, PAN= Pantropical, SA= Saharo-Arabian, SZ = Sudano-Zambezian, ME= Mediterranean and IT= Irano-Turanian

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

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	Per	SA+ TR
	Amaranthus hybridus L.	Th	Herb	Ann	PAN
	A. viridis L.	Th	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	Per	SA
	Calotropis procera (Aiton) Dryand.	Ch	Shrub	Per	SA+SZ
	Caralluma retrospiciens (Ehrenb.) N.E.Br.	Ch	Succulent	Per	SA+SZ
	Catharanthus	Ch	Herb	Ann	ME + TR

Family	Species	Life form	Habit	Life span	Chorotype
	roseus(L.) G.Don.				
	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	Ann	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	Ann	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	Ann	COSM
	E. triaculeata Forssk	Ch	Succulent	Per	SZ

Family	Species	Life form	Habit	Life span	Chorotype
	Ricinus communis L.	Ph	Tree	Per	TR
Lamiaceae	*Lavandula coronopifolia* Poir.	Ch	Sub-shrub	Per	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	Ann	PAN
Papilionaceae	*Crotalaria microphylla* M.Vahl.	Th	Herb	Ann	SA+SZ
	Indigofera colutea (Burm.f.) Merr.	Ch	Sub-shrub	Per	SZ
	I. hochstetteri Bak.	Ch	Sub-shrub	Per	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	Ann	SZ
	C. gayana Kunth	Th	Herb	Ann	SA+SZ

Family	Species	Life form	Habit	Life span	Chorotype
	Dichanthium foveolatum (Del.) Roberty	Th	Herb	Ann	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	Ann	SZ
	Hyparrhenia hirta (L.) Stapf	Th	Herb	Ann	SA
	Panicum turgidum Forssk.	Cr	Sub-shrub	Per	SA+SZ
	Paspalidium desertorum (Rich.) Stapf.	Th	Herb	Per	SA
	Sorghum bicolor (L.) Moench	Cr	Herb	Ann	Cultivated
	Sporobolus nervosus Hochst.	Th	Herb	Ann	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.	Th	Herb	Ann	SA
	D. stramonium L.	Th	Herb	Ann	COSM
	Solanum surattense Burm. F.	Th	Herb	Ann	SA+TR
Urticaceae	*Forsskaolea tenacissima* L.	Ch	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.	Ch	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	**No.**	**Category**	**Type**	**No.**	**%**	**Form**	**No.**	**%**
Annual	35	Monoregional	SA	15	16	Ch	33	35
Biennial	02		TR	5	5	Th	28	30
Perennial	58		SZ	6	6	Ph	17	18
		Biregional	SA+SZ	31	33	He	11	12
			SA +TR	15	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 satnds 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

Species	Community types										Cover
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

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

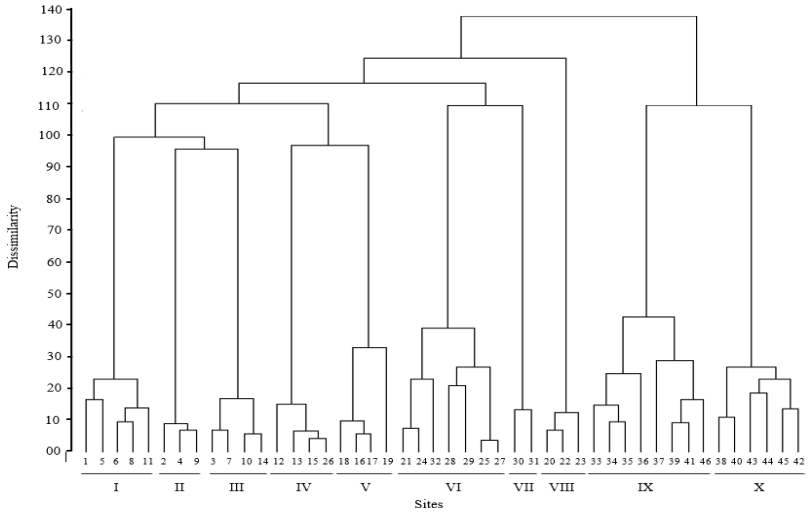

Fig. 6. Dendrogram showing different plant community types in the study area

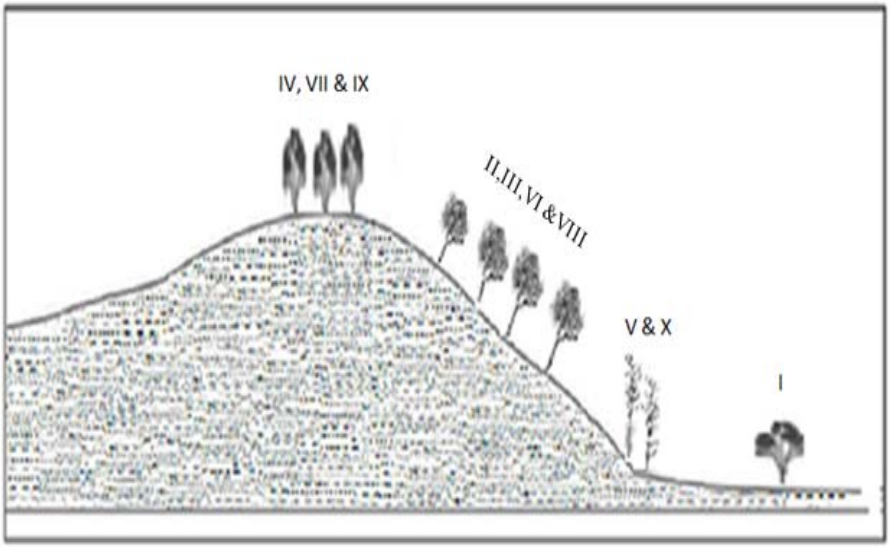

Fig. 7. Diagram showing the abundance of ten plant community types in the wadi. I-*Ziziphus spina-christi,* II- *Salvadora persica* III- *Anisotes trisulcus,* IV- *Adenium obesum,* V- *Ricinus communis.* VI-*Acacia asak,* VII- *Lawsonia inermis,* VIII- *Dobera glabra,* IX-*Tamarindus indica* and X- *Leptadenia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

5. CONCLUSION

Survey report of Wadi Wasaa of Jazan revealed out of 95 species belonging to 75 genera and 31 families. Poaceae and Euphorbiaceae were among the most abundant families covering about one quarter of the checklist record (studied area). Apocynaceae and Malvaceae stand next to most abundant families in a decreasing trend. Chamaephytes and therophytes, indicating typical desert life spectrum of the studied area (chameo-therophytic) type followed by phanerophytes. On the other hand, plants plurality are perenials (60 species) followed by annuals (27 species) including two species of biennial. According to chronological analysis 26 species represent monoregional, 56 species as bioregional and pluriregional region is represented by 4 species according to the conducted survey. In addition to these H index (Shannon-Wiener diversity index) of 10 plants showed that *Tamarindus indica* has highest values followed by the *Acacia asak,* whereas the lowest values were calculated in *Lawsonia inermis*. At the same time, Sorensen's Index of Similarity (ISs) confirmed some different affinities among these communities

ACKNOWLEDGEMENT

The author wish to thank the Biology Department, Faculty of Science, Jazan university, Jazan University Herbarium (JAZUH). We are also grateful for support and assistance Prof. Dr. Mahmoud Salah, Prof. Dr. Abd-Allah Tharwat, Dr. Diaa Radwan and Dr. Remesh Moochikka of Jazan University for their help and advices. Thanks to Mr. Mohamed Sahloli and Yahia Somily for helping me in sample collecting in the study area.

Competing interests

Authors have declared that no competing interests exist.

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