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Research Paper

Impact of waste water discharge on the plant diversity and community structure of Al-Marj Plain, Libya

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The present study aims at describing and analyzing the floristic composition and vegetation types, as well as evaluating the impact of waste water pollution on the plant diversity and community structure in Al-Marj plain, North Libya. Forty-two stands, distributed among polluted and non-polluted sites, were selected seasonally for this study. A total of 156 species were recorded (92 in the polluted and 121 in the non-polluted sites). Eight vegetation groups were resulted after the application of TWINSPAN and DCA as classification and ordination techniques: four represented the polluted sites, two for the non-polluted sites and other two were mixed groups. Group II (*Sarcopoterium spinosum* – *Pistacia lentiscus*), which represents the polluted sites, had the highest values of soil moisture, salinity, sulphate, calcium and potassium; while group VI (*Juniperus phoenicea* – *Olea europaea*) inhabiting the non-polluted site, had the lowest value of organic matter, salinity and magnesium. Group VII (*Foeniculum vulgare* – *Nicotiana glauca*), representing the non-polluted site, was the most diverse, while VG III (*Ricinus communis* – *Chrysanthemum coronarium*), characterizing the polluted one, was the least. Heavy metal analysis, in both soil and waste water, indicated that the concentrations of Pb, Cd, Cr, Cu and Ni in the polluted sites were significantly higher than that in the non-polluted ones. The diagram resulting from CCA showed effectiveness of most soil variables, except carbonates, sodium, magnesium and chlorides. The impact of waste water discharge led to the emergence of new invasive species, which may severely affects the plant diversity and community structure of this hot spot of biodiversity in Libya

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1 Introduction

Human survival and wellbeing depend on biodiversity and healthy ecosystems. Yet, in recent decades, the world has experienced unprecedented biodiversity loss and ecosystem degradation, undermining the very foundations of life on Earth (UNDP 2012). In recent years, increased urbanization and industrialization in many developing countries have led to corresponding increases of environmental pollutants (Chauhan and Joshi 2010; Mage et al. 1996). This very rapid urbanization, though contributed to economic development, had resulted in heavy losses to economic welfare in terms of effects on agricultural activities, human health and ecosystem. Over the years, there was a continuous increase in human population, high ways transportation, vehicular traffic and industries, which has resulted in further increase in the concentration of pollutants (Joshi et al. 2009). This type of pollution is among the most limiting factors to plant production and survivorship (Seyyednejad and Koochak 2011; Woo et al. 2007).

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In developing countries, fast-growing urban populations are demanding more fresh water and food, while generating greater volumes of wastewater. Due to the lack of comprehensive wastewater management, a major portion of these wastes pollutes natural water bodies (Scott et al. 2004). These polluted sources are used in and around the cities for agriculture and other purposes. In drier climates, farmers often use wastewater from drains and sewers because it is the most reliable source of water (WHO 2006). Soil pollution is a serious environmental problem that has been attracting considerable attention in the recent years (Garbisu and Alkorta, 2001; Marques et al. 2009). Deteriorating soil quality and decrease in vegetation abundance are grave consequences of open waste dumping which have resulted in growing public concern (Ali et al. 2013).

Al-Gabal Al-Akhdar (Green Mountain in English) area is a highland along the northern eastern Libya (Cyrenaica). It is a crescent-shaped ridge attaining a height of more than 850 m a.s.l. in its central part. The northern flank consists of step-like plateaus bordered by escarpments. The southern flank dips gently towards a depression extending from Ajdabiya to Al-Jaghbub, which is marked by several large sabkhas. To the east and mostly to the west, a coastal plain was well developed between the foot of the first escarpment and the sea (Pallas 1978). It comprises the richest vegetation and the highest number of species known from Libya (Boulos 1997, 1972). It is a hot spot of plant diversity that confines about 50% of the endemic plant species in Libya (Qaiser and El-Gadi 1984). Few studies were carried out on its ecology (Gimingham and Walton 1954; Drar, 1963; Boulos 1972, 1997; Le Houerou 1997, 1986; Al-Sodany et al. 2003; Hamad 2012; Hegazy et al., 2011; Abusaief and Dakhil 2013; Shaltout et al. 2014).

The impacts of waste water discharge on terrestrial ecosystems in arid and semiarid regions and the practice of using untreated wastewater for irrigation have hardly been studied. In the light of increased water scarcity, lack of water treatment and clear willingness by farmers in some places to use untreated wastewater, studies that look into these impacts are urgently needed. The present study aims at describing and analyzing the floristic composition and vegetation types as well as evaluating the impact of pollution with industrial and household sewage on the plant diversity, and vegetation structure of Al-Marj plain in North Libya.

2 Material and methods

2.1 Study area

Al-Marj plain is one of the most important regions in Al-Jabal Al-Khdar (the Green Mountain), which located at Cyrenaica Province along the southern coast of the Mediterranean Sea (Newport and Haddor, 1963). It is located between latitudes 33° and 31° N, and longitudes 20.30°–21.30° E, and depends on groundwater of 350–200 m as the chief source of the potable water. With population of more than 8000 inhabitants practicing different activities, the increment of the urban area caused several environmental problems such as leaking of sewage water. Sewage discharged passes over large areas with natural and agricultural plant coverage towards a depression known as Lake Om Almakhali, where waste water was discharged in effluents drained towards the depression (Alshamikh, 2009). The study area is about 28 km^2, which is characterized by two climatic regions: Mediterranean sea from rainlines 400 mm north to 200 mm south, and semi-desert region that extends from rainline 200 mm north to 50 mm south (Alfatih Agro-Project, 2001).

The distinctive feature of the climate of the study area is the heavy rainfall during winter, while summer is virtually dry with mean annual rainfall of 270.3 mm $year^{-1}$. The lowest mean minimum air temperature varies between 5.5 °C in January and 18.5 °C in August, while the highest varies between 20.5 °C in January and 38.3 °C in May. The relative humidity varies between 53% in June and 75.2% in January (El-Tantawy, 2005).

2.2 Sampling

Twelve field trips were carried out during the period from March (2010) to April (2013) in Al-Marj plain, west Al-Jabal Al-Akhdar. The flora and vegetation of this plain were studied seasonally in 14 sites: 7 in each of the polluted and non-polluted sites (Fig. 1). In each site 3 stands (each of 5 × 5 m), were selected to represent the apparent variation in the vegetation physiognomy and physiography. In each stand, the species was listed and their cover was estimated visually. Identification and nomenclature were according to Boulos (2009, 1999–2005) and Jafri and El-Gadi (1977–1993). Life forms of the recorded species were identified following the system of Raunkiaer (1937). The actual and relative number of species belonging to each life form (i.e. biological spectrum) was calculated, while endemic species were gathered from (Jafri and El-Gadi 1977–1993; Boulos 1997). Voucher specimens of the recorded species were deposited in Tanta University and Alexandria University Herbaria.

2.3 Soil analysis

Three composite soil samples were collected from each stand as profiles of 0–50 cm. Soil texture was analyzed by Bouyoucos hydrometer, while soil moisture content was determined by calculating the difference between

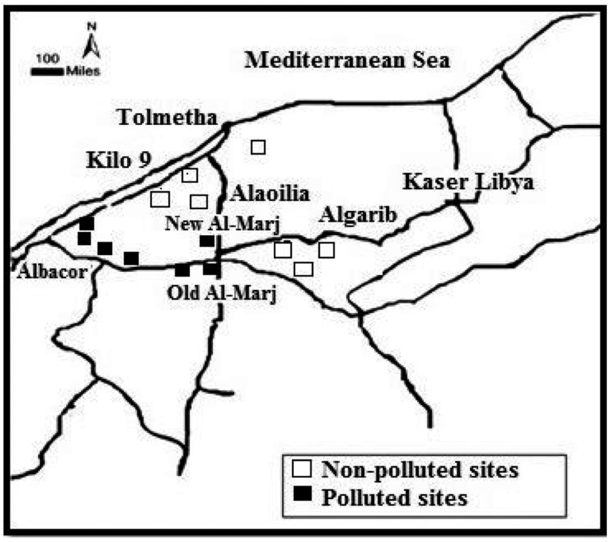

Figure 1. Map showing the 14 sampled sites in Al-Marj plain.

weight of soil before and after drying at 105 °C. Soil water extracts (1:5 w/v) were prepared for the determination of soil salinity (EC) using conductivity meter (60 Sensor Operating Instruction Corning) and soil reaction (pH) using pH meter (Model 9107 BNORION type). Chlorides were determined by direct titration against silver nitrate solution using 5% potassium chromate as an indicator, while carbonates were estimated by titration against 0.01 N HCl using phenolphthalein and methyl orange as indicators. Sulphates were determined turbidimetrically by barium sulphate using spectrophotometer (CECIL CE 1021) set at 500 nm. Calcium and Magnesium were determined by titration against 0.01 N versenate solution using meroxide and erichrome black T as indicators and ammonium hydroxide and ammonium chloride as buffers, while sodium and potassium were determined using flame photometer (Model 410). All these procedures are outlined by Allen et al. (1986).

Metal content in the collected samples were determined using the acid digestion method adopted by Wade et al. (1993). Half gram soil samples were digested with 8 ml concentrated nitric acid (HNO_3) in a closed Teflon vessel designed for this purpose, at a temperature of 130 °C for 24 h, 2 ml hydrofluoric acid was added to the mixture and returned to the oven at 130 °C for 24 h, then 17 ml of boric acid 5% was added to the mixture and put again in the oven at 130 °C for 24 h. Digestion was continued until the solution became clear. The resultant liquid was diluted up to 25 ml with distilled water then stored for analysis. Concentrations of Cr, Ni, Cd, Cu, and Pb in soil samples were determined by Perkin-Elmer 2380 atomic absorption spectrophotometer, which calibrated with standard solutions containing known concentrations of each element. Standard solutions were prepared by diluting available high purity stock solutions (BDH).

2.4 Waste water analysis

Waste water samples were collected from the effluents discharge in polluted and non-polluted sites; three water samples were collected from each sampling stand. The water samples were collected in plastic bottles and were acidified immediately in the field with nitric acid (1 ml HNO_3/l) for determination of Pb, Cr, Cu, Cd and Ni (Allen et al. 1986; APHA 1998).

2.5 Data analysis

Two trends of multivariate analysis were applied in the present study: two-way indicator species analysis (TWINSPAN) and detrended correspondence analysis (DCA) as classification and ordination techniques, respectively (Hill 1979a and b). The relationship between the vegetation and soil characteristics was determined by Canonical Correspondence Analysis (CCA) (ter Braak 1987). Species richness (alpha-diversity) for vegetation groups was calculated as the average number of species per stand, while species turnover (beta-diversity) was calculated as the ratio between the total number of species recorded in certain vegetation group and its alpha-diversity (Whittaker 1972). The significance of variation in water and soil heavy metals contents were assessed using one-way analysis of variance (ANOVA-1) (SPSS 2006).

3 Results

One hundred and fifty-six species (92 annuals and 64 perennials) belonging to 115 genera and 46 families were recorded along the polluted and non-polluted sites (Table 1). A total of 121 species (77.6% of the total species) were recorded in the non-polluted sites, while 95 species (60.9%) were recorded in the polluted sites; five of them were recently recorded in the study area: *Datura innoxia, Nicotiana glauca, Nerium oleander*, *Juncus rigidus*, and *Phragmites australis* (Appendix 1). Asteraceae had the highest contribution (14.7% of the total species), followed by poaceae (11.5%), fabaceae (8.3%) and labiatae (7.7%).

The life form spectrum of the recorded species showed the predominance of therophytes (80 species = 51.3% of the total species), followed by chamaephytes (40 species = 25.6% of the total species) and phanerophytes (20 species = 12.8%). Six endemic species (3.8% of the total recorded species) were recorded in the non-polluted sites: *Arum cyrenaicum*, *Anthemis cyrenaica* var. *cyrenaica*, *Centaurea cyrenaica*, *Echinops*

Table 1. Floristic analysis of the recorded species in the polluted and non-polluted sites in Al-Marj plain

Site	Polluted	Non-polluted	Total
Families	28	33	46
Genera	81	94	115
Species	95	121	156
Unique species	35	46	81

cyrenaicus, *Linaria tarhunensis* and *Scabiosa libyca* Alavi.

The application of TWINSPAN on the matrix of 156 species and 42 stands resulted in 8 vegetation groups at the third level. These groups were segregated along the ordination plane of the first and second axes of DCA (Fig. 2a and b). Vegetation groups were named after the first and occasionally the second dominant species (Table 2). Four groups represented the polluted site (I: *Cynara scolymus – Centaurea alexandrina*, II: *Sarcopoterium spinosum – Pistacia lentiscus*, III: *Sarcopoterium spinosum – Juniperus phoenicea* and IV: *Juniperus phoenicea – Ceratonia siliqua*), 2 represented the non-polluted site (VI: *Juniperus phoenicea – Olea europaea* and VII: *Foeniculum vulgare – Nicotiana glauca*), and other 2 inhabited both sites (V: *Juniperus phoenicea – Olea europaea* and VIII: *Ricinus communis – Chrysanthemum coronarium*). Group VII, inhabiting the non-polluted site, was the most diverse, which had 32 species and the highest species richness (39.7 species stand^{-1}), but the lowest species turnover (1.4), while VG III, representing both polluted and non-polluted sites, was the least diverse with 23 species, 10.3 species stand^{-1} species richness, and 2.2 species turnover (Table 2).

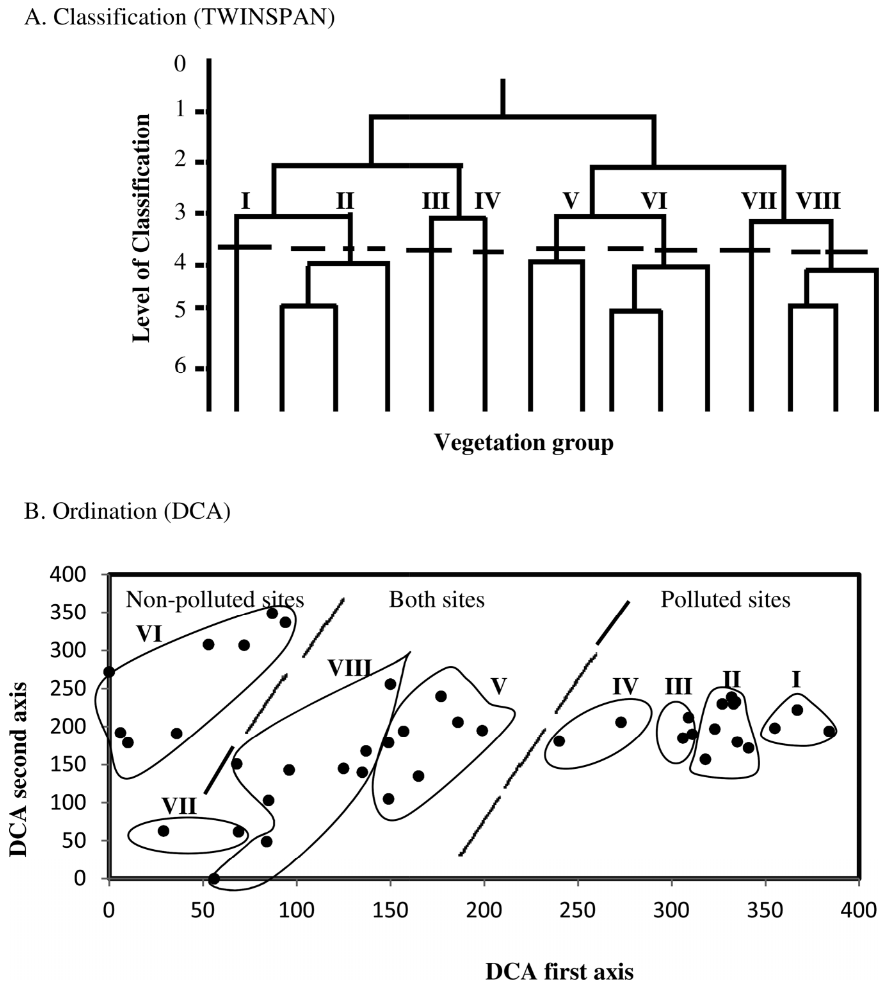

Figure 2. Classification (A) and ordination (B) of the 42 sampled stands in Al-Marj plain. The names of these groups are: I: *Cynara scolymus – Centaurea alexandrina*, II: *Sarcopoterium spinosum – Pistacia lentiscus*, III: *Sarcopoterium spinosum – Juniperus phoenicea*, IV: *Juniperus phoenicea – Ceratonia siliqua*, V: *Juniperus phoenicea – Olea europaea*, VI: *Juniperus phoenicea – Olea europaea*, VII: *Foeniculum vulgare – Nicotiana glauca*, VIII: *Ricinus communis – Chrysanthemum coronarium*.

Table 2. Characteristics of the 8 vegetation groups resulted after the application of TWINSPAN classification on the 42 sampled stands in Al-Marj plain. VG: vegetation group, Np: Non-polluted sites and Pl: polluted sites. *P*: presence percentage

VG	No. of stands		No. of species	Species richness	Species turnover	First dominant species	*P* (%)	Second dominant species	*P* (%)
	Np	Pl							
Polluted site									
I	–	3	21	16.7	1.5	*Cynara scolymus*	100	*Centaurea alexandrina*	100
II	–	8	30	14.5	2.1	*Sarcopoterium spinosum*	100	*Pistacia lentiscus*	100
III	–	3	23	10.3	2.2	*Sarcopotarium spinosum*	66.7	*Juniperus phoenicea*	66.7
IV	–	2	28	18.0	1.6	*Juniperus phoenicea*	100	*Ceratonia siliqua*	50.0
Non-polluted site									
VI	8	–	37	21.6	1.7	*Juniperus phoenicea*	100	*Olea europaea*	100
VII	2	–	32	39.7	1.4	*Foeniculum vulgare*	75.0	*Nicotiana glauca*	50.0
Both types of sites									
V	4	3	45	22.4	2.0	*Juniperus phoenicea*	50.0	*Olea europaea*	50.0
VIII	7	2	71	20.5	1.0	*Ricinus communis*	66.7	*Chrysanthemum coronarium*	75.0

In the polluted site, the soil of VG (I) had the highest value of carbonates (199.3%), while that of VG (II) had the highest of moisture (5.4%), salinity (2.39 mS cm^{-1}), sulphate (154.4 mg 100 g^{-1}), calcium (165.7 mg 100 g^{-1}) and potassium (50.7 mg 100 g^{-1}), but the lowest pH of 7.2 (Table 3). Vegetation group (III) had the highest value of sand (53.3%), but the lowest of silt (26.7%) and chloride (2.9 mg 100 g^{-1}). In addition, VG (IV) had the highest values of soil organic matter (13.3%), chloride (53.5 mg 100 g^{-1}) and magnesium (78.8 mg 100 g^{-1}), but the lowest of carbonates (45 mg 100 g^{-1}). On the other hand, the non-polluted soils of group (VI) had the lowest values of organic matter (3.2%), salinity (0.32 mS cm^{-1}) and magnesium (6.6%); and those of group (VII) had the highest of clay (44.3%) and pH (8), but the lowest of sand (25%), sulphate (6 mg 100 g^{-1}), calcium (25.5 mg 100 g^{-1}), potassium (1.1 mg 100 g^{-1}) and sodium (8 mg 100 g^{-1}). However, the soils of group (V), representing both polluted and non-polluted sites, had the highest values of silt (37.7%) and sodium (143.2 mg 100 g^{-1}), but the lowest of clay (26%), while those of group (VIII) had the lowest moisture contents (1.0%).

Table 3. Soil characters of the 8 vegetation groups in Al-Marj plain. The lowest and highest values are underlined

Veg. group	Soil character													
	Sand	Silt	Clay	O.M	Moisture	pH	E.C ($mScm^{-1}$)	CO_3	Cl	SO_4	Ca	Mg	K	Na
	%							mg 100 g^{-1}						
Polluted sites														
I	29.7	34.0	38.9	10.2	4.7	7.9	0.55	99.7	3.9	129.5	119.9	6.9	28.4	18.4
II	42.6	32.0	26.8	9.13	5.4	7.2	2.39	91.6	8.5	154.4	165.7	11.7	50.7	83.4
III	53.3	26.7	19.6	12.3	3.3	7.5	0.83	56.7	2.9	77.9	83.9	4	15.9	27
IV	32.5	33.7	30.3	13.3	2.9	7.7	1.57	45.0	53.5	92.5	71	78.8	30.8	160.8
Non-polluted sites														
VI	27.3	31.0	40.6	3.2	1.7	7.8	0.32	59.5	3.3	8.7	26.4	3.3	2.7	8.5
VII	25	28.2	44.3	4.25	1.7	8.0	0.33	56.5	7.5	6	25.5	7.3	1.1	8
Both types of sites														
V	35.3	37.7	26.0	7.8	1.6	7.9	1.32	63.5	46.0	71.3	70.6	66.7	20.8	143.2
VIII	26.2	26.9	47.1	7.2	1.0	7.8	0.91	53.4	27.1	43.1	42.9	37	12.4	86.1

Table 4. Mean concentrations (±SD) of the estimated heavy metals in the soils samples (μg g^{-1}) collected from the polluted and non-polluted sites in Al-Marj plain

Heavy metal	Polluted site		Non-polluted site		*p*
	Range	M ± SD	M ± SD	Range	
Pb	2.5–5.5	4.11 ± 0.99	0.23 ± 0.14	0.08–0.75	<0.001
Cd	2.2–7.0	4.37 ± 1.44	0.51 ± 0.16	0.24–0.81	<0.001
Cu	41.6–89.9	68.83 ± 14.55	3.23 ± 1.04	1.57–5.37	<0.001
Ni	87.1–156.1	115.76 ± 23.05	20.23 ± 9.82	7.24–29.3	<0.001
Cr	30.9–48.3	37.90 ± 5.57	4.88 ± 1.42	2.49–7.02	<0.001

p: probability value for student *t*-test for comparison between the polluted and non-polluted sites.

The data of heavy metals analysis indicated significant (at $p < 0.001$) higher concentrations in the soils of the polluted than non-polluted sites (Table 4). The ranges of heavy metals in the polluted soils are (in μg g^{-1}): Pb 2.5–5.5, Cd 2.2–7.0, Cu 41.6–89.9, Ni 87.1–156.1 and Cr 30.9–48.3. On the other hand, the concentrations of heavy metals in the waste water had significant (at $p < 0.05$) higher values, in the vegetation groups of the polluted site, than those of the non-polluted one (Fig. 3). They had the following ranges (in μg ml^{-1}): Pb 0.01–0.08, Cd 0.26–0.87, Cr 0.29–1.44, Cu: 0.11–0.82 and Ni: 1.5–7.64.

The soil-vegetation relationship resulted from the application of CCA indicated the effectiveness of most soil variables, except carbonates, sodium, magnesium and chlorides (Fig. 4). Vegetation groups of the polluted sites were highly affected by sand, organic matter, calcium, sulphate and potassium (group I by sand and organic matter; group II by calcium, sulphate, potassium and salinity; group III by organic matter and calcium), while vegetation groups of the non-polluted sites (VG VII and VI) were highly affected by clay and pH, respectively.

4 Discussion

One hundred and fifty-six species belonging to 115 genera and 46 families were recorded in the polluted and non-polluted sites of Al-Marj plain, Libya. This number represents 7.5% of the flora of Libya, 11.1% of the flora of Cyrenaica (Jafri and El-Gadi 1977–1993), and 65.8–82.5% of the flora of Al-Jabal Al-Akhder (Al-Sodany et al. 2003; El-Barasi et al. 2011; Hegazy et al. 2011). Five of these species (*D. innoxia, N. glauca, N. oleander*, *J. rigidus* and *P. australis*) were recently recorded in the study area (Asker 1998; Al-Hamedi 1999; Al-Juhary 2002; Al-Sodany et al., 2003; Abdul Khaliq 2007; El-Barasi et al. 2011 and Hegazy et al. 2011). Asteraceae had the highest contribution to the flora of Al-Marj plain in agreement with the study of Abusaief and Dakhil (2013), which indicated that asteraceae is most common in the arid and semi arid regions of the subtropical and lower temperate latitudes.

The life form spectra provide information, which may help in assessing the response of vegetation to the variation in the environmental factors (Ayyad and El-Ghareeb, 1982). Raunkiaer (1937) designated the Mediterranean climate as a "therophyte climate type" because of the high percentage of this life form (>50% of the total species) in several Mediterranean floras (Raven, 1971). The present study reported that therophytes had the highest contribution followed by chamaephytes, phanerophytes and cryptophytes. Heneidy and Bidak (2001) reported that the dominance of therophytes over the other life forms seems to be a response to the hot-dry climate, topographic variation and biotic influence. Also, Wang et al. (2002) and Da Costa et al. (2007) reported that therophytes were the most dominant life form in arid and semi-arid areas. Therophytes are well adapted to mild moist winters and dry summers, and often account for 40–50% of the species present in the Mediterranean region. Cryptophytes are also well adapted to the Mediterranean climate, where their under-ground parts (e.g. bulbs, corms or rhizomes) stay dormant during summer, and produce vegetative and reproductive above-ground organs during winter and spring (Heneidy and Bidak, 2001).

In the present study, *Arum cyrenaicum*, *Anthemis cyrenaica* var. *cyrenaica*, *Centaurea cyrenaica*, *Echinops cyrenaicus*, *Linaria tarhunensis* and *Scabiosa libyca* were recorded as endemic species in Al-Jabal Al-Akhdar, which is one of four major centers of endemism that holds about half of the endemic species in Libya (Boulos, 1997). This was due to its unique physiographic and climatic conditions that isolate the region from the rest of the country; these conditions have an excellent ecological niche and contributed to restriction of many endemic species (Qaiser and El- Gadi, 1984).

Application of TWINSPAN classification technique on the sampled stands in the present study resulted in 8 vegetation groups: 4 represented the polluted site, 2 for the non-polluted site and other 2 in both sites. The most

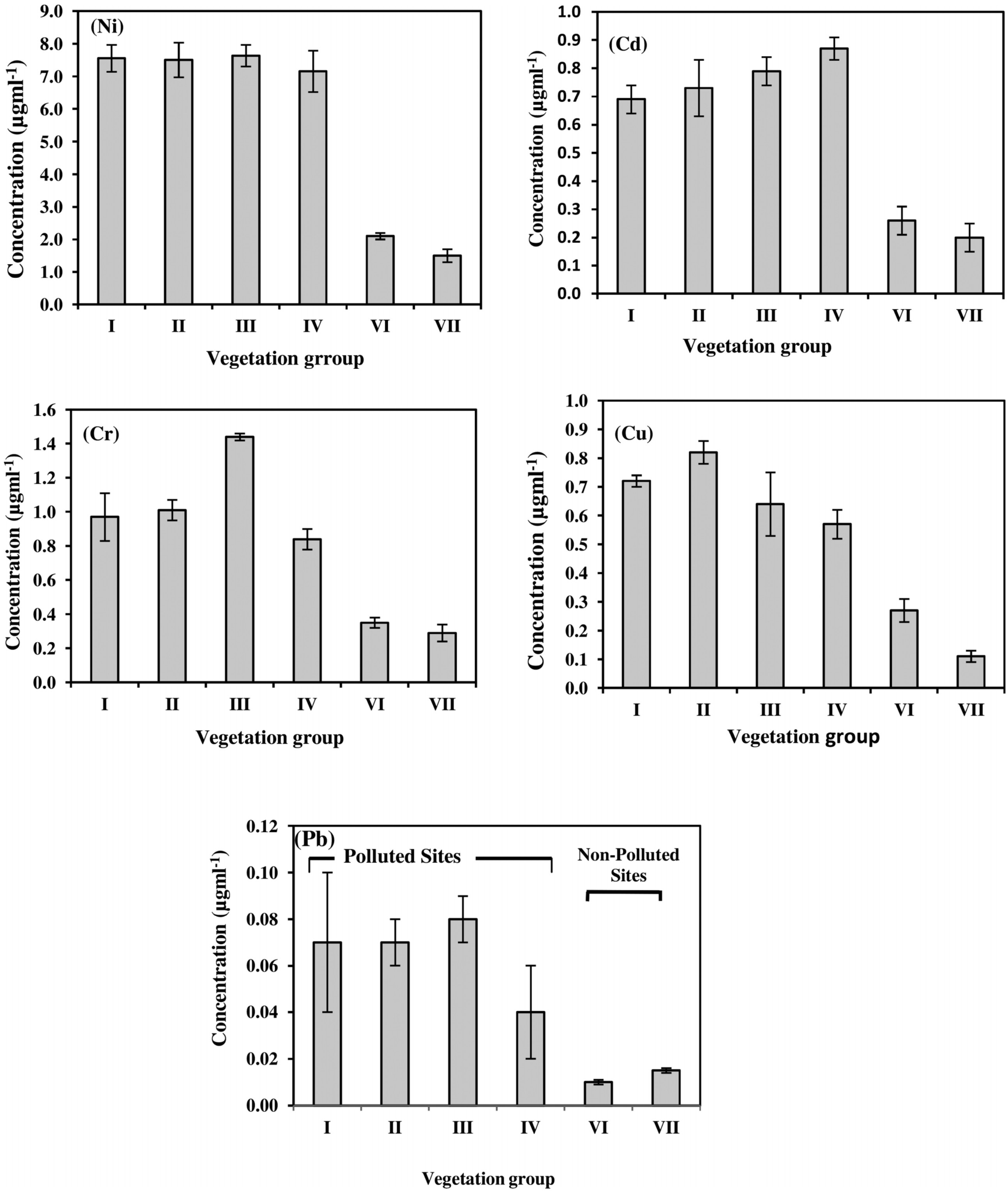

Figure 3. Means of the estimated heavy metals in the waste water samples (µg ml^{-1}) of the vegetation groups in the polluted and non-polluted sites. Groups of the polluted sites are I: *Cynara scolymus – Centaurea alexandrina*, II: *Sarcopoterium spinosum – Pistacia lentiscus*, III: *Sarcopoterium spinosum – Juniperus phoenicea* and IV: *Juniperus phoenicea – Ceratonia siliqua.* Groups of the non-polluted sites are VI: *Juniperus phoenicea – Olea europaea* and VII: *Foeniculum vulgare – Nicotiana glauca*. The vertical bars represent the standard deviations of the means (SD). The variations in the concentration of all heavy metals in relation to the vegetation groups were statistically significant at $p \leq 0.05$.

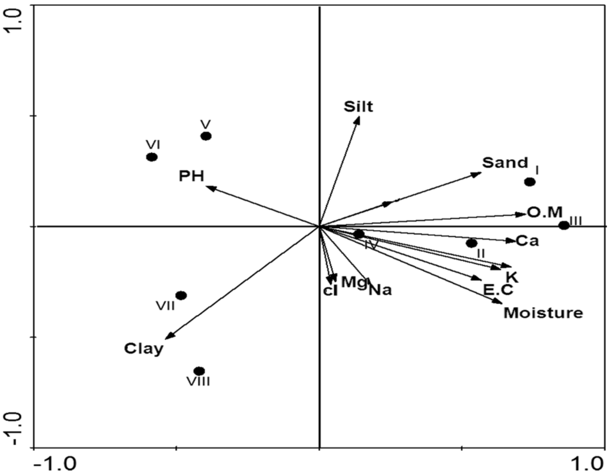

Figure 4. CCA of the vegetation groups (represented by dots) and the soil characters (represented by arrows) in Al-Marj plain. The groups are: I: *Cynara scolymus – Centaurea alexandrina,* II: *Sarcopoterium spinosum – Pistacia lentiscus*, III: *Sarcopoterium spinosum – Juniperus phoenicea*, IV: *Juniperus phoenicea – Ceratonia siliqua*, V: *Juniperus phoenicea – Olea europaea*, VI: *Juniperus phoenicea – Olea europaea*, VII*: Foeniculum vulgare – Nicotiana glauca*, VIII*: Ricinus communis – Chrysanthemum coronarium*.

dominant species were *S. spinosum* and *J. phoenicea*; this coincided with the study of Shaltout et al. (2014), who recorded *S. spinosum* and *J. phoenicea* as dominant species in the polluted areas in this region. They also reported that the polluted areas were more diverse than the non-polluted ones, while the present study indicated that the vegetation groups of non-polluted sites were more diverse than that of the polluted ones, which coincided with the studies of Hegazy et al. (2011) and Al-Sodany et al. (2003) at Al-Gabal Al-Akhdr. In addition, Gough et al. (2000) reported that the pH gradient was one of the factors which affect the distribution of plant communities and found that wide species diversity occurs at higher pH values regardless of the mechanism influencing acidity. This finding coincided with the present study which indicated that the vegetation groups in non-polluted sites were more diverse and mostly affected by the pH gradient.

Haller et al. (1974) indicated that plants are quite sensitive to salinity (cannot tolerate concentrations >2.5 ppt) and high concentration of heavy metals. In the present study, salinity and heavy metal concentrations in the soil and waste water samples of the polluted site were higher than those in the non-polluted sites; and exceed the upper limit of the US Environmental Protection Agency (EPA 2006) and Syrian Standard (2003). On the other hand, the high salinity and waste water that poured into the polluted sites may support the growth of saline tolerant plant species as *Juncus rigidus*, and emergent helophytes such as *Phragmites australis* (it is recorded as invasive species in the study area). This finding coincided with the study of Silvertown (1981), who reported that the distribution and abundance of a plant species within a particular climatic zone is determined by the environmental factors, especially soil conditions, interaction with other species and dispersal. Sculthorpe (1985) reported that shallow water and high electrolyte requirements were among the factors that affect the distribution of plant communities, this coincided with the present study which indicated that the vegetation groups in the polluted sites were more affected by calcium, potassium, sulphate and salinity.

The threat that heavy metals pose upon the health of all biota (human, plants and animals) is aggravated by their long-term persistence in the environment (Gisbert et al., 2003). Most of the heavy metals are extremely toxic because of their solubility in water. Nowadays, heavy metals were ubiquitous because of their excessive use in industrial applications; water contains substantial amounts of toxic heavy metals which create problems (Singh et al., 2004; Chen et al., 2005). In the present study, concentrations of the heavy metals in the soil and waste water samples from the polluted sites were higher than those from the non-polluted sites; and all above the standard levels of Syrian Standard (0.01, 0.2, 0.1, 0.2 ug ml^{-1} for Cd, Cu, Cr and Ni, respectively). In the same region, this finding coincided with that of Shaltout et al. (2014) who reported that the concentration of Cd and Cr were higher in the polluted areas than in the un-polluted ones.

5 Conclusion

In the course of this study, it can be concluded that the natural plant species suffer from population decline, limited regeneration and replacement by invasive weeds as result of pollution. Thus, the waste water should be treated and poured outside the study area (the most important hot spot for plant diversity in Libya). Also, strict legislation must be applied to conserve the unique features of Al-Gabal Al-Akhdar ecosystems. In conclusion, the pollution by waste water had significant impact on the plant diversity and community structure in Al-Marj plain; thus, the present study helps in focusing the attention towards the management and conservation of plant diversity in North Libya in general and Al-Gabal Al-Akhdar in particular.

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