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RECOVERY OF PLANT SPECIES, RICHNESS AND COMPOSITION IN ABANDONED GRASSLAND IN ARID REGION

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A harsh ecosystem in a semi-arid area is the target of the current study. Restoration pattern was not well understood due to the lack of studies. Botanical surveys were performed over the years 2005 through 2011 in the semi-arid area in Jordan. Our objectives were to identify the vegetative cover types and the extent of restoration. Quantitative and qualitative analysis on plant species were conducted. The potential and pattern of restoration in term of plant species richness and vegetative cover composition were measured. Results showed that 34 different plant species were found to be grown in the study area, and they belonged to 14 plant families and 4 chorotypes. Mediterranean–Irano-Turanian was the dominant. We concluded that the composition of the vegetation cover did not recover as similar to the original composition after abandonment. However, further researches are needed to precisely track the effect of abandonment on vegetative cover development and restoration.

Key words: biodiversity, conservation biology, habitat fragmentation, plant population and community dynamics, reproductive ecology, restoration ecology

INTRODUCTION

Agro-abandonment caused by several factors, such as changes in land usage. Land-use changes considered among the most important factors, which increase the levels of land abandonment worldwide. Such changes affect the mode and intensity of land utilisation. These changes have negative consequences on biodiversity and landscape characteristics (Tappeiner *et al*. 2003, Tasser *et al*. 2005). Moreover, land-use changing is a main factor that negatively affected the original vegetative cover form; whether it is native, cultivated, or endemic. This process enables intensification of cultivation in the productive soil. Also, it enhances degradation as indicated by the changes in type of vegetative cover. Abandonment can coexist even at a local scale within the same area, where it can produce fragmentation of the species rich semi-natural grasslands. Thus, abandonment along with habitat deterioration, are the main factors causing loss of plant population and species (Erikson and Ehrlen 2001, Harrison and Bruna 1999). The interaction of the cultivation legacy, inherent soil characteristics, and vegetation types determine the dynamics of plant community assembly and development on native lands. Those native lands are currently called old fields, and they indicate the level of efforts to restore the native vegetation status.

There is a variety of human activities that affects the interaction of natural and anthropogenic environmental factors. Agricultural practices have been documented to be a significant reason of landscape modification (Fazey *et al.* 2005, Haila 2002). For example, tillage can change the physical properties of soil, such as the infiltration rate and the surface runoff. Another example of the agricultural practices, which play important roles in agroabandonment, is the high intensity cultivation. High intensity cultivation in arable soils led to the deterioration of the remaining fragile plant diversity (EC 1998, Hallingbäck 1998), especially in fragile ecosystems of Mediterranean lands (Haines and Uren 1990, Wuest 2001). One example of the harsh ecosystems in the Middle East is the target area of the current study namely, Al-Khirbah Al-Samra strip in Jordan. This strip had been widely investigated by many researchers in Jordan (Al-Eisawi 1989, El-Sallag 1996, Fardous *et al.* 2004, Shishani 2006). The significance of this area refers to four main points: first, it was considered as part of the Jordanian rangeland with high land plateau plants. Second, it was considered an agrosystem of open grassy remnant of different species of chenopods. Examples of these species are *Anabasis syriaca*, *Hammada* spp. and *Retama raetam*, which were grown in poor sandy soils. Third, it was considered an important bird habitat by BirdLife International (Evans 1994). This study area was considered as an important staging and wintering area in addition to a wide range of migratory water flow species (Budieri and Al-Husseini 1994, Evans 1994).

Finally, studies regarding changes in this area are rare. Lack of information regarding this ecoregion makes this study the first work, which focuses on the extent of such changes. In addition, this study focuses on the endemism that had been developed for future studies in dry ecoregion evaluation and classification.

Globally, dry land ecoregions were selected on the basis of species richness, species endemism, unique higher taxa, unusual ecological or evolutionary phenomena, and global scarcity of major habitat types (Olson and Dinerstein 1997).

Abandonment and improvement in water quality flow, after the renovation and upgrading happened to the Al-Khirbah Al-Samra Waste Water Treatment plant (KAWWTP) in 2010, might influence the natural vegetative cover restoration and endemism pattern. There is still a lack of general information and real studies to judge the pattern of restoration and endemism. There is also a lack of a suitable model to predict the response of vegetation in term of restoration of the area after disturbance.

Treated waste water was pumped to Al-Khirbah Al-Samra strip. This waste water supplies the Zarqa River with water effluent of a discharge rate of 13,500 m^3 per day. Moreover, this water is considered an important supply of surface water to King Talal Dam, which is used mainly for irrigation.

Anthropogenic factors are usually viewed as major forms of ecosystem modification and biomass reduction. Examples of these factors include traditional farming practices with periodic ploughing, fertilisation, and irrigation with saline water (TDS of 930–1,230 ppm). These factors have influenced this agrosystem for many years. The water quality of the aquifers was declined, because of the unorganised over-pumping, which aided to discharge of saline water to soil surface. Several studies found that salinity of water was a result of anthropogenic activity (El-Sallag 1996). Thus, it is highly expected that irrigation with treated waste water and continuous agricultural activities had changed functions of ecosystems in the study area of this research. Agricultural practices and farming practices create important influence on the ecosystems. Agricultural activities affect the distribution, quantity, and quality of land resources. Farming practices have a great influence on biodiversity, since they cause disturbance. Disturbance level could be measured so it can be used to predict the maximum diversity at an intermediate disturbance level. This could be achieved by using the intermediate disturbance theory, which was adopted by Grime (1973). Farming practices pushed those types of agricultural systems toward abandonment, leaving natural restoration and natural re-vegetation take their roles.

Air pollution has a major impact on ecosystems, especially at the study area. Air pollution at Al-Hashemeyia Municipality, where Al-Khirbah Al-Samra is located, causes a serious environmental problem. According to the Royal Scientific Committee (RSC 2002), Al-Hashemeyia area was reported to be one of the most air-polluted areas in Jordan.

The abandonment of traditional agricultural lands in arable lands will create old fields that require limited or no restoration. Restoring habitat, especially flora, is affected biologically by their chemical and physical properties based on the stabilisation of soil (Tasser *et al.* 2003), carbon sequestration

(Houghton *et al.* 1999), organic matter availability and decomposability, and temporary increase in biodiversity (Laiolo *et al.* 2004). Abandonment resulted from human agricultural activities for long periods, and adapted to restrict environmental conditions and biological diversity (Naveh and Liberman 1984). This is true if the agricultural traditions depend upon the use of reclaimed waste water in irrigation. In this context, we refer to the concept of land abandonment as stopping of the traditional or recent use of land by agriculture (Pinto-Correia 1993).

The hypothesis of this study complies with the fact that the natural environment has the potential to restore its dynamic positions through its resilience capacity especially in the non-productive habitat. In that cultivation abandonment produces changes in the floristical composition, plant richness, and species frequency in areas far from the water-flow strip (dry habitat) more than areas near the water-flow strip (wet habitat). Wet and dry habitats were compared as productive and non-productive habitats, respectively.

The objectives of this study were to identify the vegetative cover types, which were restored after cultivation abandonment, and to evaluate the extent of restoration in lands affected by treated waste water flow and cultivation.

MATERIALS AND METHODS

Study area

The study area is located within the areas adjacent to Al-Hashemeyia Municipality (56.863208′ N, 13.143608′ E; 503–520 m a.s.l.), at Zarqa city, in the northern highlands of Jordan. It is extended from Al-Khirbah Al-Samra waste water treatment plant to the northeast of Al-Hashemeyia Municipality. The location extends alongside the treated waste water channel to transport the treated waste water from Al-Khirbah Al-Samra, through Al-Sukhneh Municipality in the northwest to reach King Talal Dam.

Zarqa Governorate lies in the junction of the Mediterranean and Irano-Turanian biogeographical regions with semi-arid Mediterranean bio-climate. The climate of the study area has been characterised by arid Mediterranean, with mild rain winters and dry hot summers. Soils of the study area are calcareous and sedimentary. The USDA classification is xerochreptic camborthids, calcixerollic xerochrepts, and lithic xerothents.

Experimental design

The experimental design was split plot design using transect quadrate method. Randomly distributed transects were selected perpendicular to the baseline at random locations in the same direction. The baseline forms one of the outer boundaries of the assigned area. The availability and abundance of species were considered baselines for future monitoring studies.

State of the problem

Dry lands cover forms 41% of the Earth's surface worldwide. However, little attention was paid to foster sustainable dry land development. Unfortunately, the paucity of information on plant composition and grazing regimes before cultivation in the study areas make the accuracy of judgment unreliable. Lands in the study area were frequently grazed or irrigated.

Most indigenous vegetations were cleared or substantially altered since the running of KAWWTP (El-Sallag 1996). It was reported that the study area had been cultivated with various crops for the previous sixteen years. And it was irrigated with treated waste water from KAWWTP. This action could create changes in the environmental quality of the study area. Example of such environmental situation is the pollution of some unconfined aquifers of Dhuleil area. The shallow unconfined aquifers of Dhuleil showed signs of pollution after few years of construction. Salinity was detected in those aquifers. For instance, the total dissolved solids (TDS) in one of those aquifers were found to be 500 mg/L. The TDS value was increased up to 4,700 mg/L in the following years (El-Sallag 1996). This deterioration was attributed to the infiltration of waste water from the pond bottom and along the valley (Fardous *et al.* 2004). Furthermore; the groundwater in the study area contains high concentrations of nitrates, ammonium, and fecal coliforms.

The original grassland ecosystems are now extinct according to the unpublished data of the Ministry of Agriculture (RMA 2011). Visual observations also showed that uncultivated grazed rail-line sites and roadsides contained more native species per unit area than the pre-cultivated sites.

Sampling and data collection

The field survey was carried out from February to June throughout the years 2005, 2007, 2009, and 2011. Species richness and composition of recently restored habitats change with time in terms of canopy gaps and micro-scale variations in physiographical and soil condition (Hattori *et al.* 2003, 2004). So, the survey plots were established in fixed zones for repeated visits for monitoring and evaluation purposes. Visual plant cover estimates were used to estimate the percent of ground cover of different classes of vegetation within an area or quadrate.

Selected sampling sites were implemented through monitoring over three years. They were surveyed for vegetative cover type. Herbaceous cover was surveyed by using a mesh-like structure quadrate of 1 m^2 (1 meter on either side of the transect line). All hosts were visually scanned within the mesh blocks for each plot. Two sampling sites reflecting habitats in the study area were identified and chosen for sampling. The first sampling site, nominated as D1, was nested with 8 quadrates (d1q1–d1q8). It was dominated with alluvial plain level landform pattern with extremely low relief. The shallow to deep alluvial stream channels were sparse to widely spaced, forming a unidirectional integrated network. Plots of D1 were located in the southern and northern bank of the valley. They were close to the water strip and characterised by wet and productive habitat. This plot had not been cultivated at all.

The second sampling site was dominated by a plateau landform to a rolling landform pattern of plains, which are rise or low hills. Plots of the second exploitation were located in the northern bank adjacent to D1 area. This exploitation was dry and non-productive and was located in the upper part of the terrain at the bottom of the adjacent hill near water channel. It was divided into two parts according to the proximity, general vegetative cover features, and the previous land-use. The first plot, D2, was adjacent to D1 area, and it was cultivated with forages. Forage crops were represented in this study through 7 quadrates, d2q1 through d2q7. The second plot was cultivated by fresh consumed crops, such as lettuce, garlic, onion, and watercress. It was represented through 8 quadrates, d3q1 through d3q8.

Regarding the native vegetation, the study area was dominated by grasses, which were herbaceous, rarely woody plants, slightly woody, perennial, or annual. Those plants were generally erect or spread and some were arising from stolons, tubers, bulbs, rhizomes or seeds. The area was mainly covered by some steppe vegetation, especially by *Retama raetam; Artemisia herba-alba*, and *Hammada* spp. For the Mediterranean vegetation, *Capparis spinosa* and *Sarcopoterium spinosum* were the expected dominant vegetation type. According to reports of the Ministry of Agriculture in Jordan (RMA 2011), the noteworthy flora indicates the lack of information and scientific researches about that field.

Species diversity analysis

Plant species diversity was analysed by using qualitative and quantitative measurements. Qualitative measurements included calculating plant density and plant frequency, quantitative measurements included species diversity tools, such as species richness, alpha diversity, beta diversity, gamma diversity, Shannon–Wiener index, and Simpson index. Moreover, chorotype analysis was used.

To study land revegetation, the vegetative cover afforded by all species was visually estimated and allocated to plant density measurement. Plant density measurement was expressed as the number of individual plant species in question divided by the total number of plant species in the quadrates. Plants were calculated if 50% of the plant biomass existed inside the quadrate. It is well known that density depends on the size of the sampling frame, and consequently high densities were recorded in some areas, while no data were recorded in other areas.

Species richness alone does not reveal anything about which species had been conserved, or the differences in composition among sites. Therefore, beta diversity was used to encounter the variation in species composition among sites in a geographical region. Beta diversity gives the total number of species that are unique to each of the ecosystems being compared. Beta diversity is represented by the equation: $\beta = (S1-c) + (S2-c)$; where 'S1' is the total number of species recorded in the first community (D1); 'S2' is the total number of species recorded in the second community (D2); and 'c' is the number of species common to both communities (D1 and D2), (D2 and D3), and (D1 and D3).

Gamma diversity (γ-diversity) or the geographical scale species diversity measures the total biodiversity of several ecosystems within an entire region. Gamma diversity refers to the total species richness over a large area. Like alpha diversity, gamma diversity is a quality, which simply has an indirect magnitude, and can be represented by a single number (a scalar). Gamma diversity was measured by applying the equation: $\gamma = S1 + S2 + S3 - (c1 + c2 + c3)$; where 'S1' is the total number of species recorded in the first community; 'S2' is the total number of species recorded in the second community, 'S3' is the total number of species recorded in the third community; and 'c' is the number of species common to communities.

The Shannon–Wiener index (H') was measured by the equation: $H' = \sum n/N * Ln(n/N)$; where 'n_i' is the number of individuals or amount; and 'N' is the total number of individuals (or amount) for the site. Evenness can be measured from the Shannon–Weiner index (H'). Evenness (E) is a measure of how similar the abundances of different species are. When there are similar proportions of all subspecies, then evenness equals one. But when the abundances are very dissimilar (some rare and some common species), then the value increases. Evenness can range from close to 0, where most species are rare and just a few are abundant, to 1, where most species are common and much abundant.

To clarify similarity in species composition between the three plots, modified Sørensen's coefficient of community (cc) was calculated and measured using the formula: $cc = 2\sum nc/(n1 + n2 + n3)$; where 'nc' is the number of common species between sites, 'n1' is the number of individuals of site 1, 'n2' is the number of individuals of site 2, and 'n3' is the number of individuals of site 3.

For further analysis, chorotype identification was originally defined by Baroni-Urbani *et al.* (1978) as an elementary distribution pattern followed by one or several species that can be operatively recognised within a territory.

RESULTS

Floristical composition

Results showed that the expected steppe vegetation in the study area were mostly grassy remnants, and they were dominated by plants, which belonged to chenopods of different species, such as *Anabasis syriaca*, *Arthrocnemum macrostachyum*, *Noaea mucronata*, *Salsola vermiculata*, *Suaeda vermiculata*. Plants of Papilionaceae family were also recorded. Examples were *Retama raetam* and *Ziziphus lotus* (Table 1, unpublished data).

Species detected in the study area belonged to 14 families (Table 2), in which 23 species of D1 belonged to 12 families, 30 species in D2 belonged to 10 families, and 34 species in D3 belonged to 14 families (Table 2).

A total of 34 different plant species were detected in the study area, where the Asteraceae family (Table 2) was the most abundant vegetative cover type. D2 and D3 contain more species compared to D1 (Table 2). Cruciferae were common in D1, D2 and D3 with 4 species per plot. Chenopodiaceae family was most abundant in D2 and D3 compared to D1, while Xanthorrhoeaceae family was the lowest in D3 (Table 2).

Table 3 shows that the majority of plants detected were of Mediterranean–Irano-Turanian chorotype. This chorotype contains 12 different species. The Mediterranean chorotype contains 10 species, the Irano-Turanian chorotype contains 6 species, and the Saharo-Arabian chorotype contains 6 species.

Table 1
Expected common steppe vegetation in the study area

Plant species	Family	Plant species	Family
Retama raetam	Papilionaceae	*Artemisia herba-alba*	Asteraceae
Anabasis syriaca	Chenopodiaceae	*Ziziphus nummularia*	Rhamnaceae
Tamarix spp.	Tamaricaceae	*Gypsophila arabica*	Caryophyllaceae
Noaea mucronata	Chenopodiaceae	*Ziziphus lotus*	Rhamnaceae
Asphodelus aestivus	Liliaceae	*Urginea maritima*	Hyacinthaceae
Ferula communis	Umbelliferae	*Hammada* spp.	Chenopodiaceae
Salsola spp.	Chenopodiaceae	*Astragalus spinosus*	Papilionaceae
Crocus moabiticus	Iridaceae	*Pistacia atlantica*	Anacardiaceae

Table 2
Average number of species in plots

Family	D1	D2	D3
Asteraceae	7	11	11
Fumariaceae	1	1	1
Cruciferae	4	4	4
Papaveraceae	1		1
Papilionaceae	1		1
Urticaceae	1	1	1
Chenopodiaceae	3	5	5
Geraniaceae	1	1	1
Boraginaceae	1	2	2
Polygonaceae	1	2	2
Scrophulariaceae	1		1
Malvaceae	1	1	1
Labiatae		2	2
Xanthorrhoeaceae			1
Alpha = sum of species number	23	30	34

Species richness, similarity index and heterogeneity

There were significant differences in number of plant species and in number of plants of each quadrate. Species similarity between wet and dry habitats in the study area was measured using the modified Sørensen's coefficient of community (cc) and similarity index measurement (Table 4). Among exploitations, the floristical similarity between D1 and D2 exploitations was measured with 20 species, which were common in both plots. Thirty species were common in D2 and D3, and 23 species were common between D1 and D3. Moreover, the common species between all plots were 20 species. Similarity index were measured through common species in D1 vs. D2, D2 vs. D3,

Table 3
Biogeographical or chorotype distribution of surveyed plants

Mediterranean	10 species
Mediterranean–Irano-Turanian	12 species
Irano-Turanian	6 species
Saharo-Arabian	6 species

Table 4
Beta, gamma diversity and similarity index in the study area ecosystems

Plots interfere	Common spp.	Similarity index	Beta = (S1–c) + (S2–c)
D1-D2	21	79.25	11
D2-D3	30	93.75	4
D1-D3	23	80.7	11
In all	21	47.06	
Gamma diversity index	34		

and D1 vs. D3. It was found to be 0.79, 0.94, and 0.81, respectively (Table 4). Lower value was recorded for all plots (0.47). Our data indicated that similarity between D1 vs. D2 was 79.25%, D2 vs. D3 was 93.75%, and D1 vs. D3 was 80.7%. On the other hand, similarity between all plots in the study area (D1 vs. D2 vs. D3) was 47%. Thus, the greatest similarity was observed in D2 vs. D3 (Table 4).

Beta diversity (Table 4) analysis showed that the unique species were found in (D1-D2) and their count was 13 species (not common in both). Number of unique species found in (D2-D3) was 4 species, and there were 11 unique species in the (D1-D3) plots. Thus, the number of unique species decreased with movement from D2 to D3 (Table 4). The results of gamma diversity showed that gamma analysis value was 34. This means that there were 34 species in the study area.

Table 5 shows that diversity was greater for D3 compared to D2 and D1. Generally, more disturbed and less stable environments should have lower H′ values. Based on this, D1 might be considered the most disturbed habitat and the least stable environment, because it had the lowest value of diversity. High values of H′ indicated more diverse communities (Table 5). Values of H′ range from 0 to 5 (Table 5). In this study, H′ values range was between the standard values (1.5–3.5). D3 had the highest H′ value, followed by D2, and D1. This indicates that D3 was the most diverse community (Table 5). D3 had the greatest species richness (34 species), followed by D2, while the lowest richness was in D1.

The results showed some exotic species, such as *Matricaria chamomilla* in D1, which had the highest density and a high frequency rate compared to D2 and D3 (Table 6). D2 and D3 had an intermediate value and low frequency, respectively. Another species was *Halopeplis amplexicaulis*, which was denser in D2 than in D1. D3 showed the lowest density compared to D1 and D2 (Table 6). *Centaurea calcitrapa* showed the greater frequency in D2 compared to D1. Other examples of common plant species in the study area include *Halopeplis amplexicaulis*, *Papaver humile*, *Verbascum thapsus*.

Table 5
Shannon–Wiener index (H′)

Family name	D1 (average spp.)	n/N*Ln (n/N)	D2 (average spp.)	n/N*Ln (n/N)	D3 (average spp.)	n/N*Ln (n/N)
Asteraceae	7	–0.36	11	–0.37	11	–0.37
Crucifera	4	–0.30	4	–0.27	4	–0.26
Chenopodiaceae	3	–0.27	5	–0.30	5	–0.29
Boraginaceae	1	–0.14	2	–0.18	2	–0.12
Polygonaceae	1	–0.14	2	–0.18	2	–0.17
Scrophulariaceae	1	–0.14			1	–0.11
Papaveraceae	1	–0.14			1	–0.11
Urticaceae	1	–0.14	1	–0.11	1	–0.11
Fumariaceae	1	–0.14	1	–0.11	1	–0.11
Geraniaceae	1	–0.14	1	–0.11	1	–0.11
Labiatae			2	–0.18	2	–0.17
Malvaceae	1	–0.14	1	–0.11	1	–0.11
Xanthorrhoeaceae					1	–0.11
Papilionaceae	1	–0.14			1	–0.11
Shannon–Wiener index (H′)	23	–1.62	30	–1.93	34	–2.27
	1.62		1.93		2.27	
Evenness (E)	1.19		1.30		1.48	

Table 6
The vegetative cover analysis in terms of density and frequency (freq.) in the study area and grades

Species in D1	D1		D2		D3	
	freq.	density	freq.	density	freq.	density
Lactuca serriola			42.86	3.62	37.50	3.09
Lavandula stoechas			42.86	4.52	50.00	3.09
Phlomis syriaca			28.57	1.81	37.50	1.23
Rumex acetosa			42.86	4.52	37.50	3.09
Matricaria aurea	62.5	14.67	28.57	15.38	37.50	17.28
Anthemis palestina	12.5	0.00	42.86	1.81	25.00	1.23
Artemisia herba-alba	37.5	0.86	42.86	1.81	75.00	1.23
Carlina hispanica	50	4.31	71.43	4.52	50.00	1.23
Leontodon tuberosus			14.29	2.71	12.50	1.23

Table 6 (continued)

Species in D1	D1		D2		D3	
	freq.	density	freq.	density	freq.	density
Notabasis syriaca	12.5	4.31	14.29	2.71	37.50	3.09
Anabasis setifera			14.29	1.81	25.00	1.23
Fumaria densiflora	12.5	0.86	42.86	1.81	37.50	1.23
Carrichtera annua	12.5	3.45	28.57	2.71	25.00	6.17
Diplotaxis erucoides	12.5	0.86	42.86	0.90	50.00	1.23
Matthiola tricuspidata	12.5	0.86	57.14	1.81	25.00	0.62
Urtica pilulifera	25.0	6.04	42.86	5.43	25.00	2.47
Atriplex halimus	25.0	3.45	57.14	2.71	50.00	4.94
Halopeplis amplexicaulis	62.5	5.52	100.00	6.33	100.00	2.47
Erodium malacoides	12.5	0.86	42.86	0.90	50.00	0.62
Dittrichia viscosa	12.5	2.59	14.29	1.81	12.50	0.62
Anchusa italica	25.0	3.45	71.43	1.81	12.50	1.85
Malvella sherardiana	37.5	2.59	57.14	2.71	37.50	1.85
Artemisia inculta			57.14	1.81	87.50	1.85
Centaurea halolepis	62.5	15.53	100.00	10.86	75.00	9.26
Anchusa milleri			14.29	1.81	25.00	1.23
Anabasis syriaca	50.0	1.73	28.57	1.36	62.50	3.70
Calligonum comosum	37.5	2.59	42.86	1.81	37.50	1.85
Cardaria draba	12.5	3.45	28.57	2.71	25.00	6.17
Matricaria chamomilla	87.5	15.53	42.86	4.52	25.00	5.56
Atriplex stylosa			14.29	0.90	37.50	0.62
Verbascum thapsus	25.0	2.59			25.00	2.47
Papaver humile	25.0	3.88			50.00	1.23
Asphodelus aestivus					62.50	4.32
Retama raetam					25.00	0.62

DISCUSSION

Floristical composition

The study area has a wide spatial and temporal heterogeneity in the soil and climatic conditions. This might reflect the level of richness in the area, especially in the presence of detected anthropogenic impacts. Significant changes in the floristical composition were observed. Although the main factor explaining changes in the floristical composition in the study area was the proximity of plots to water channel strip, the abandonment of cultivation was also associated with the profound variation in restored floristical composition. This was in agreement with many researchers (Bignal and McCracken 1996, Grubb 1977, Huston 1979, Provoost *et al.* 2004), who emphasised the importance of land abandonment as the main cause of changes in plant types and diversity. This might be due to the changes in the competitive relationships between species and habitat. Proximity of plots to water channel strip is an important factor, which arises from the general review of the pattern of similarity in plots, and its effect on the productivity gradient.

Species richness and heterogeneity

Similarity index showed a significant connection between the three habitat types. However, the connectivity appeared in the analysis was based on species data, which connect habitats according to their degree of disturbance, as well as the potential of these habitats to accept changes in vegetative cover type during restoration. The D1 shared approximately 53% of the species presented in D2 and D3. D1 was uncultivated, in which its richness and diversity resulted either from naturally adapted species grown over time, or through the effect of fluvial actions. This was supported by findings of Malanson (1993) who reported that fluvial disturbance and water stress were two of the primary factors that influence vegetation patterns along sides of arid region rivers. Moreover, Brown and Peet (2003) revealed that diversity shows continuous declines in species richness from river channel bars to flood plains and to uplands. This was consistent with Ali *et al.* (2000) who found that soil moisture was a prime determinant of species richness for fluvial systems. On the other hand, D2 and D3 were previously cultivated and affected by cultivation for a long time. Consequently, their dynamic restoration to the proximate species types and levels is still running as it was largely affected by species transformation from D1. Furthermore, there was invading of certain non-native species of plants in D2 and D3, which play an important role in vegetative cover restoration. Moreover, seed banks present in these habitats from different origins had an important impact on the determination of recovered plant type. This needs further investigations and studies.

Our results showed high diversity (beta diversity analysis) between D1 and both D2 and D3, and between D2 and D3. This represents a transitional state (edge species) due to presence of two contrasting environments in a small area as in the case of D2 and D3. Increasing edge effects enhance biodiversity within the area, while moving from D2 to D3. This could make unique habitats more accessible to the adjacent communities. So, more plants can get support from the adjacent communities and create travel lanes along borders. Thus, equilibrium and recovery of the vegetation cover might reach a stable condition.

Table 5 shows that the evenness values for D1, D2, and D3 were very close to one, the abundance of rare and some common and uncommon species in the study area were dissimilar. This could be explained by the increased value of evenness as we moved from D1 to D2.

The greatest difference regarding the species richness of the different plants was observed for the number of individuals of the Asteraceae family. It was higher in D3 as indicated by plant density (Table 6). Although some species had the highest density value, their frequencies were not the highest. This means that the potential of having these species in all quadrates will not be reflected through the density value as a dominant species. To overcome this conflict, frequency can be used as an indication of the potential of availability. The most abundant species found in the study area were seen to have different plant densities and frequencies.

It might be true that abandonment and the subsequent invasion by shrubs can improve plant diversity over time. Natural and direct human disturbances were known to promote invasive exotic species (D'Antonio *et al.* 1999, Hobbs and Huenneke 1992, Lozon and MacIsaac 1997). This was agreed with our present findings obtained through the comparison of vegetative cover types in the three plots, which showed the presence of certain species not pronounced to be natively grown in the study area. The common species between plots revealed the edge effect in D2 as it was a transitional habitat between D1 and D3 as indicated by the similarity index, which increased with movement toward D3. This was supported by increased diversity indices in the abandoned dry land compared to the transitional and the wet land.

Asphodelus aestivus shared *Retama* spp. its unique availability in D3, but its density and frequency were higher than that for *Asphodelus aestivus* (Table 6). Many plant species in this study were found to be common in one plot, but not the other. Examples are *Asphodelus aestivus* and *Retama raetam* were found in D3, but not in other plots (Table 6).

Habitat loss and fragmentation had negative effects on biodiversity (Wilcove and Chen 1998). The consequences might lead to invasion by non-native species. Non-native plant species (exotic) are the major causes of species declining and native habitat degradation (Vitousek *et al.* 1997, Wilcove and Chen 1998). Exotic species may play a role in the restoration process. During restoration, exotic species were one of the relevant forms that accompanied the natural plant species restored. Therefore, it has become a management problem. Thus, further studies and investigations are needed in the study area to investigate the mechanisms of seed dispersal, growth form and persistent soil seed banks, since it influences post-disturbance changes in species richness.

Current study showed an effect of abandonment on frequency of plant species and density. Regarding plant species richness, the values observed reflect the relationship between plant species through comparing plants behaviour in the three plots. For example *Matricaria chamomilla* was a dominant species in D3, but not in D1 and D2. *Centaurea calcitrapa* followed the same pattern of availability as *Matricaria* spp. This might be due to the changes in the habitat characteristics, while wetting. This means that species density had declined according to the distance from water resource reaching the farthest plot (D3), which could be attributed to D2.

Abundances of various plant species explain issues regarding post-disturbance, abandonment processes, and vegetative cover recovery. Present results showed that floristical overlap between plots and similar species richness at 1 m^2 scales. This could be referred to the substantial vegetation recovery, which occurred over the previous years in the study area. The absence of some species as non-common species was recorded in all plots. Based on the expected vegetative cover, the low species packing in the recovery sites indicates the coexistence of a high number of species at small scales, which might consume longer time until achieving high values.

The dynamics of land condition is affected by environmental factors and land-use. This was supported by Samuel and Hart (1994), who argued that the slow and uncertain rate of return of herbaceous species composition to the original status after severe disturbance was a major problem. This study revealed that the competition between species will take certain time until a stable state is reached, when the existence of species will be affected by the local environment and species coexisted in high diversity systems. This might be referred to competitive equilibrium. It is thought that coexistence of species was a non-equilibrium state. This explanation is consistent with a study of Hutchinson (1961), who argued that the large number of species in most plant communities was remarkable in view of the competitive exclusion principle.

The objectives of this study are mandatory for determination of biological diversity particularly those aspects important for conservation and sustainable use. Thus, this research will initiate a data bank for the study area regarding abandonment and vegetative type restoration.

Our current study is considered to be the first research to report data about restoration of plant vegetative cover in Al-Khirbah Al-Samra area. This study is important for devising appropriate management or restoration plans in the future. Further work is needed to investigate the critical thresholds of soil disturbance intensity, persistence of seed banks, rates of recovery relative to soil types, and biodiversity pattern in terms of seasonal patterns.

CONCLUSIONS

It was concluded that vegetative cover composition did not recover similar to the original or expected composition after abandonment, and even changes in land-use could cause loss of plant species richness in the short term, as well as the entrance of new plant species as invaders and exotic plant compared to non-abandoned ones. Nevertheless, restoration represents a significant ecosystem re-establishment to reduce the risk of desertification, through newly adapted plants. The knowledge and data obtained can be used as a base for future studies to evaluate the pattern of restoration taking place to determine the best management practice that might be used by incorporating an adequate method, which could enhance recovery. Indeed, the lower competition between native and exotic plants that characterises the study area, as well as the proper management method together with the environmental factors would probably favour the development of restored ecosystem.

*

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