Journal of King Saud University – Science 32 (2020) 600–605

Contents lists available at ScienceDirect

Journal of King Saud University – Science

journal homepage: www.sciencedirect.com

Impact of disturbance on species diversity and composition of *Cyperus conglomeratus* plant community in southern Jeddah, Saudi Arabia

Amal M. Fakhry [a,*], Mulook M. khazzan [b], Ghalia S. Aljedaani [b]

[a] Botany and Microbiology Department, Faculty of Science, Alexandria University, Egypt
[b] Biology Department, Faculty of Science, King Abdulaziz University, Saudi Arabia

ARTICLE INFO

Article history:
Received 22 March 2018
Accepted 8 September 2018
Available online 10 September 2018

Keywords:
Disturbance
Species diversity, *Cyperus conglomeratus*
Saudi Arabia

ABSTRACT

The changes in species diversity and composition of *Cyperus conglomeratus* plant community caused by anthropogenic disturbance were estimated and analyzed in four selected sites at southern Jeddah in Saudi Arabia. The ecological disturbances in the study area have their major effect on species richness, where about 76% of the perennial species in the study area were disappeared as the result of the human impact on *C. conglomeratus* community in the most disturbed sites. Interspecific competition results from C. *conglomeratus* indicated that it is a competitor species led to exclusion of the other species from the highly disturbed sites which affected by the Industrial City in Jeddah. Therefore, resulting in a remarkable decrease in species diversity (Shannon's index = 0.664) coinciding with maximum dominance of *C. conglomeratus* (Simpson's index = 0.656). The general trend of plant species richness and diversity in moderately disturbed sites in the study area showed remarkable increase in both richness (S = 16 species) and diversity (Shannon's index = 1.792), coinciding with minimum dominance (Simpson's index = 0.253). The resulting graphs of species abundance distribution models representing the highly disturbed sites tend toward geometric series pattern of species abundances, where one (*C. conglomeratus*) species dominate the community with the remainder fairly uncommon, assuming competitive exclusion and resource exhaustion in such degraded and harsh ecosystems.

1. Introduction

Diversity of plant communities has never been more highly valued than it is now, as they become increasingly threatened by environmental disturbances. In fact, diversity lies at the root of some of the most fundamental and exiting questions in theoretical and applied ecology (Magurran, 1988). Saudi Arabia is an arid desert covers the majority of the Arabian Peninsula. The flora of Saudi Arabia is one of the richest bio diversities in the Arabian Peninsula and comprises very important genetic resources of crops and medicinal plants (Atiqur Rahman et al., 2004). The distribution of life form is closely related to topography and landform (Zohary, 1973, Fakhireh et al., 2012). Establishment, growth, regeneration and distribution of plant communities in deserts of Saudi Arabia are controlled by many factors such as geographical position, physiographic features, and human impact (Alatar et al., 2012, Korkmaz and Ozcelik, 2013). Human activities in the desert landscape have been increased recently, due to rapid development in the study area. Jeddah 2nd Industrial City seen since its inception in 2009, developed rapidly in order to keep pace with the steady increase in demand for industrial land in the region. It occupies an area of about 8 million m^2. The Industrial City includes 236 factories including productive, existing, under construction and under formation factories in various industrial fields. In fact, the Industrial City of Jeddah has been a serious problem and has adversely affected the vegetation in the study area. Local inhabitants of the study area belt livestock rearing, which has always been a problem adversely affected the desert vegetation.

The vegetation in the study area located close to the Industrial City was dominated by the perennial herb *C. conglomeratus.* It is an Erect, tufted, rhizomatous perennial, 60–70 cm tall, belonging to family Cyperaceae. Much of its economic importance is due to its medicinal properties. The plant is used in traditional medicine as antimicrobial, emollient, diuretic, stimulant, anthelmintic and analgesic treatment (Feizbakhsh and Naeemy, 2011). Al-Hazmi

* Corresponding author.
E-mail address: amalfakhry@live.com (A.M. Fakhry).
Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.jksus.2018.09.003
1018-3647/

et al. (2018) proved the anti candidal activity of *C. conglomeratus* and isolate the bioactive compounds from it. Hisham et al. (2012) also showed the antibacterial activities of the essential oil compositions of the rhizomes of *C. conglomeratus* collected from Oman.

The objective of the present study is to provide an overview of species diversity of *C. conglomeratus* plant community and to evaluate the impacts of land use and human manipulations on its composition and species diversity.

2. Materials and methods

2.1. Study area

The study area is located in the western region of Saudi Arabia and extends 50 km southern Jeddah governorate. It lies within the subtropical dry zone. It has a very hot summer and a mild winter. Precipitation is scanty and unpredictable.

2.2. Selection of studied sites

The study was carried out in southern Jeddah from November 2014 to April 2015 during the active plant growth period, when most species were expected to be present. Only one plant community was detected near the Industrial city that is dominated by *C. conglomeratus*. The *C. conglomeratus* community was then sampled in the first site, which is located close to the Industrial City, and then three other sites were selected at the southern direction where the same plant community was found. The first site was the nearest to the Industrial City, and so it was the highly disturbed by solid wastes. The second site was located about 10 km from the Industrial City and was subjected to fewer disturbances than site one, where the solid wastes was much less. The third site was subjected to mild grazing, but it was not affected by the Industrial City, as it was located about 30 km far from it. The fourth site was a fenced area protected from grazing by the local inhabitants about fifteen years ago.

2.3. Assessment of species abundances

Ten stands (30 × 40 m each) were selected to represent *C. conglomeratus* plant community in each of the selected sites in the study area. A floristic list was recorded in each stand and quantitative determination of perennial species abundance was carried out. The mean relative density and frequency of each species was calculated in every site. Relative species cover was estimated using line intercept method. The sum of relative density, relative frequency and relative cover gave the importance value for different species (Ludwig and Reynolds, 1988). Plant nomenclature is according to Migahid (1996) and Collenette (1999).

2.4. Application of diversity measures

As many ecological concepts, diversity is an intuitive concept whose origin is in field observations. Diversity must be a function of the number of species (richness), and of the regularity of individual distribution among the species (evenness or equitability). Diversity measures applied in the present study are according to Ludwig and Reynolds (1988) and, Magurran (1988). Seven of the more popular indices of alpha diversity were applied on *C. conglomeratus* community as follows:

Richness = number of species recorded in each site.

Shannon's diversity index (H') = $-\sum p_i \ln p_i$.

Where p_i is the proportional abundance of the *i*th species = m (n_i/N).

Simpson's index of dominance (D) = $\sum p_i^2$.

Hill's number 1(N1) = exponential Shannon's index = $e^{H'}$.

Hill's number 2 (N2) = reciprocal of Simpson's index = 1/D

Shannon- Evenness index (E1) = H'/H_{max} = H'/ln S

Modified Hill's ratio (E5) = $[(1/D)-1]/[e^{H'}-1] = [N2-1]/[N1-1]$.

2.5. Soil sampling and analysis

In each of the selected stands, three soil samples were collected at 15–25 cm depth. The samples were air-dried, then passed through a 2 mm sieve to get rid of debris. These air-dried samples were analyzed for determination of soil texture, organic matter and electric conductivity. Methods of determination are according to Allen et al. (1974).

3. Results

3.1. Floristic composition

Nineteen perennial species were recorded in the study area. Twelve of them are woody perennials, five are herbaceous species, and two are grasses. These species belong to thirteen families (Table 1). *Cyperus conglomeratus* and *Panicum turgidum* are the

Table 1
Species composition of *Cyperus conglomeratus* community recorded in the selected sites southern Jeddah in Saudi Arabia.

Family	Species	Life-form	Importance value			
			site 1 HD	site 2 MD	site 3 SD	site 4 PA
Apocynaceae	*Rhazya stricta* Decne	Undershrub on hummocks		32.95		
Asclepiadaceae	*Steinheilia radicans* Decne	Procumbent herb				2.3
Boraginaceae	*Hliotropium bacciferum* Forssk.	Erect undershrub		1.57		2.79
Capparaceae	*Dipterygium glaucum* Decne	Deciduous undershrub		4.66	4.74	66.65
Caryophyllaceae	*Paronychia desertorum* Fres.	Prostrate herb		21.04	8.94	59.07
Chenopodiaceae	*Salsola vermiculata* L.	Shrub				12.51
Cleomaceae	*Cleome chrysantha* Decne	Shrub		6.07		
Convolvulaceae	*Convolvulus arvensis* L.	Prostrate herb		1.56		
	Convolvulus hystrix Vahl	Spinescent shrub	2.62	14.25		
Cyperaceae	*Cyperus conglomeratus* Rottb.	Perennial herb	176.64	95.35	163.58	51.92
Poaceae	*Stipagrostis plumusa* (L.)Munro ex T Anders	Perennial grass		1.56	2.74	
	Panicum turgidum Forssk.	Perennial grass	91.14	3.79	114.52	104.75
Fabaceae	*Argyrolobium uniflorum* (Decne) Jaub. Et Sp.	SHRUBLET		17.47		
	Cassia italica (Mill.)Lam. Ex Steud	Undershrub		1.56		
	Cassia senna L.	Undershrub		92.97		
	Indigofera spinosa Forssk.	Spiny shrub	29.6	1.57	2.73	
	Taverniera aegyptiaca Boiss.	Small shrub			2.73	
Malvaceae	*Abutilon pannosum* (Forst.f.)Schlecht.	Shrub		1.56		
Zygophyllaceae	*Fagonia indica* Burm.f.	Perennial herb		2.28		

HD: high disturbance, MD: moderate disturbance, SD: slight disturbance, PA: protected area.

most dominant species in the study area. The two species exhibit a considerably higher importance values in the four selected sites compared to the other species. *C. conglomeratus* has a high importance value ranging from 95.35 to 176.64 in the disturbed sites compared with 51.92 in the protected site. While *P. turgidum* exhibits a low importance value ranging from 3.79 to 91.14 in the disturbed sites compared to 104.75 in the protected site and 114.52 in the slightly disturbed site. The data also indicates that only four species could resist the high disturbance level exerted by the Industrial City: *Cyperus conglomeratus*, *Panicum turgidum, Convolvulus hystrix and Indigofera spinosa.* It is also notable that *Taverniera aegyptiaca* is completely lost in the disturbed and protected sites. Eight species are adapted only to moderate disturbance: *Rhazya stricta, Cleome chrysantha, Convolvulus arvensis, Argyrolobium uniflorum, Cassia italica, Cassia senna, Abutilon pannosum* and *Fagonia indica*. Two species are adapted only to protection: *Steinheilia radicans* and *Salsola vermiculata.*

3.2. Species diversity

Variations in the results of species diversity (Table 2) indicates that species diversity shows a considerable increase in both moderately disturbed and protected sites (H′ = 1.792 and 1.423 respectively), compared to the slightly disturbed site where H′ = 0.929. While a considerable decrease in diversity of species abundance is noticed in the highly disturbed site (H′ = 0.664), accompanied by a considerable increase in dominance as confirmed by Simpson's index (D = 0.656). The number of most frequent species (N2) and the number of equally common species (N1) were estimated to be equal about two and three species respectively in the slightly disturbed site that increased to a maximum of about four and six species respectively under moderate disturbance. While under protection both N2 and N1 equal about four species. This clarifies the increase in evenness of species relative abundance in both the moderately disturbed and protected sites (E1 = 0.646 and 0.731 respectively).

Species abundance distribution models are the method of presenting species abundance data. Species abundance was plotted on a logarithmic scale against the species rank in the sequence of species from most to least dominant (Fig. 1). It is notable that the resulting species abundance model representing the highly disturbed site tend toward geometric pattern of species abundances, where species richness is low and only one species (*C. conglomeratus*) is dominant with the remainder fairly uncommon. The geometric pattern of species distribution appears as a straight line when plotted on a log abundance/species rank graph. The curves representing other sites in the present study are less steep as more species are added, and the species abundance pattern grades into those of the log series distribution, with the increase in species with intermediate abundance. This is more obvious in the moderately disturbed site in the present study.

Table 2
Species diversity of *Cyperus conglomeratus* community in the selected sites southern Jeddah in Saudi Arabia.

Diversity index	Site			
	1 HD	2 MD	3 SD	4 PA
Richness (S)	4	16	7	7
Simpson (D)	0.656	0.253	0.462	0.278
Shannon (H')	0.664	1.792	0.929	1.423
Hill no. 1 (N1)	1.943	5.999	2.533	4.151
Hill no. 2 (N2)	1.525	3.957	2.166	3.591
Shannon-evenness (E1)	0.479	0.646	0.478	0.731
Modified Hill's ratio (E5)	0.557	0.591	0.760	0.822

HD: high disturbance, MD: moderate disturbance, SD: slight disturbance, PA: protected area.

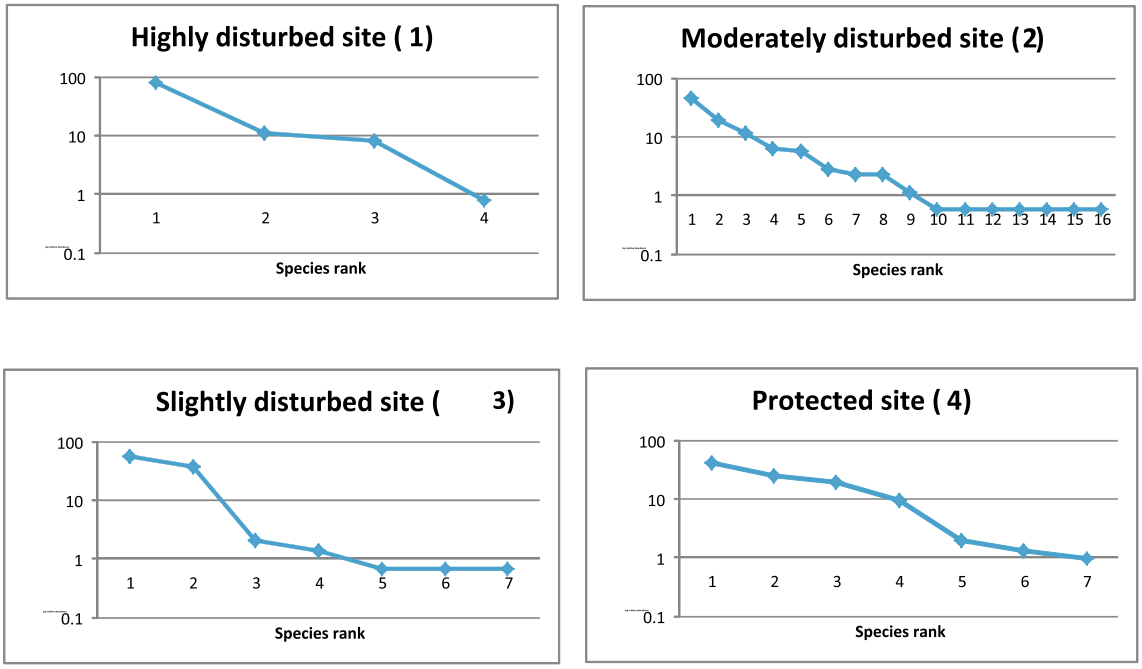

Fig. 1. Species abundance distribution models of *Cyperus conglomeratus* community in the selected sites southern Jeddah in Saudi Arabia.

3.3. Species behavior

Fig. 2 show the species behavior by using importance factor of both *C. conglomeratus* and *P. turgidum* in response to some soil factors in different studied sites. The soil salinity was considerably low ranged from 0.08 to 0.28 mmohs cm^{-1} while organic matter ranges from 0.48 in the highly disturbed site to 1.83 in the moderately disturbed site. It is notable that the EC values attain its maximum under high disturbance while organic matter percentage decreased to a minimum value in the highly disturbed site (Table 3). The behavior of the two most important species in the study area might be affected in response to the change in EC concentration and organic matter percentage. It is remarkable that *P. turgidum* is negatively affected by disturbance when compared to *C. conglomeratus,* which attains its maximum dominance under the highest disturbance in the study area. It is also remarkable that protection had a negative effect on *C. conglomeratus* reducing its importance value to the minimum in the study area, while *P. turgidum* become the dominant species in the protected site. Gravel percentage attains a maximum percentage at the moderately disturbed site. The highly disturbed site attained with the lowest sand percentage (87) and the highest silt and clay percentages (7.5 and 5.5). Inspection of the results shows that soil texture may have no effect on the behavior of the two species. On the other hand, soil texture may affect species diversity, which increased under moderate disturbance where gravel reaches maximum percentages.

4. Discussion

The primary cause of the decay of biodiversity is not direct human exploitation or malevolence, but the habitat destruction that inevitably results from the expansion of human populations and human activities (Wilson, 1988). There is a consensus that land use has a negative effect on plant biodiversity and ecosystem processes, but at the same time, there is empirical evidence that there is a large heterogeneity in the response (Rocabado et al., 2016). The study area has been subjected to ecosystem degradation and species impoverishment due to the ways in which man has used and misused the natural resources of the region. The Industrial City of Jeddah has adversely affected the vegetation in the study area especially by solid wastes that thrown from different factories in the nearby area. The net result has been the reduction of vegetation cover and the impoverishment of flora.

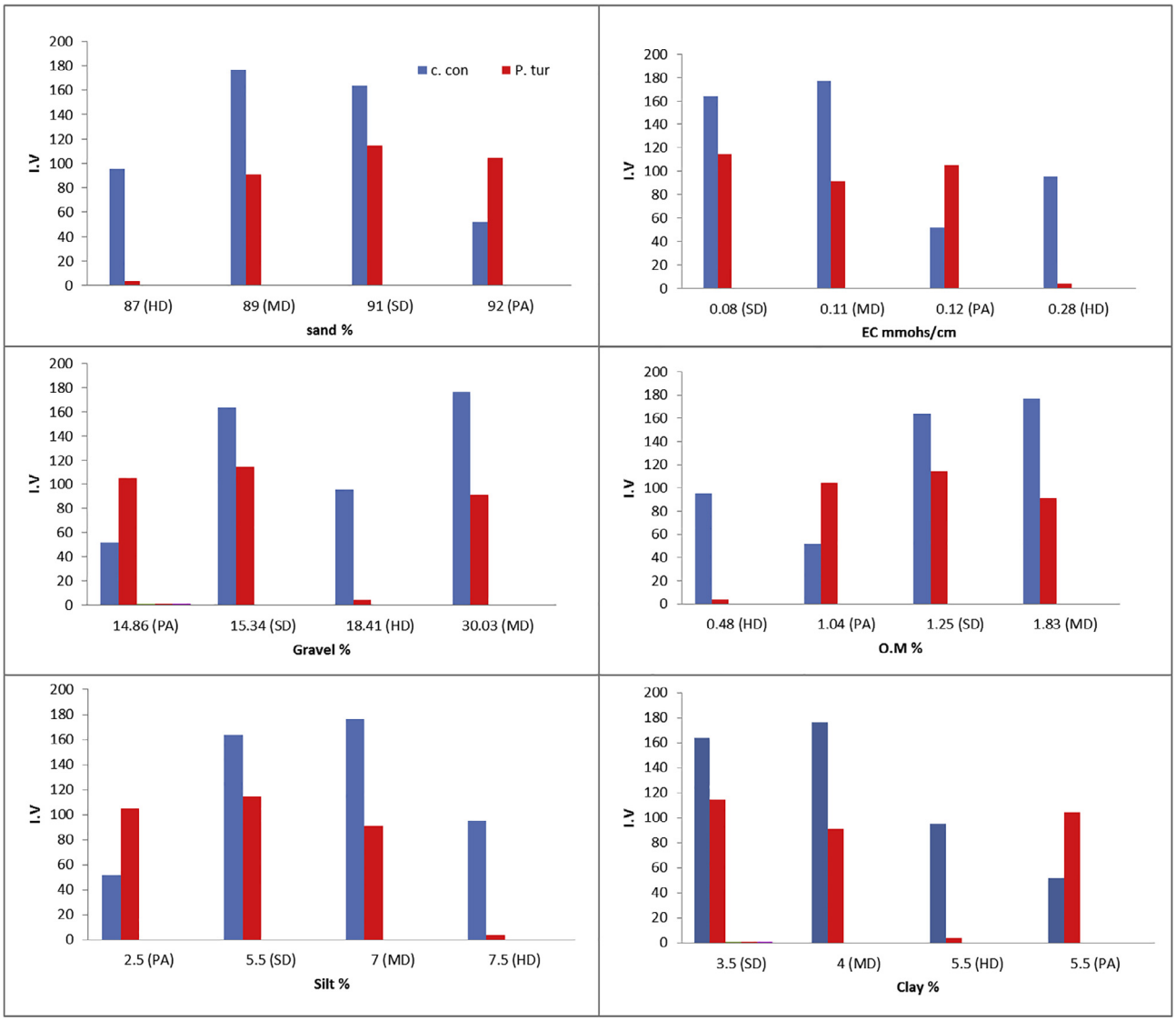

Fig. 2. Importance values of *Cyperus conglomeratus* (C. con) and *Panicum turgidum* (*P. tur*) in response to soil factors estimated in the selected sites southern Jeddah in Saudi Arabia (HD: high disturbance, MD: moderate disturbance, SD: slight disturbance, PA: protected area).

Table 3
Comparison between the four selected sites according to soil factors.

Site	Soil Texture				OM% (n = 10)	EC (mmohs/cm) (n = 10)
	Gravel (n = 10)	Sand (n = 10)	Silt (n = 10)	Clay (n = 10)		
1 (HD)	$18.41^{b} \pm 0.67$	$87^{d} \pm 1.0$	$7.5^{a} \pm 1.0$	$5.5^{a} \pm 0.5$	$0.48^{c} \pm 0.03$	$0.28^{a} \pm 0.05$
2 (MD)	$30.03^{a} \pm 2.15$	$89^{c} \pm 1.0$	$7.0^{a} \pm 0.6$	$4.0^{b} \pm 0.6$	$1.83^{a} \pm 0.07$	$0.11^{bc} \pm 0.02$
3 (SD)	$15.34^{c} \pm 0.51$	$91^{b} \pm 1.0$	$5.5^{b} \pm 0.5$	$3.5^{b} \pm 0.5$	$1.25^{b} \pm 0.01$	$0.08^{c} \pm 0.002$
4 (PA)	$14.86^{d} \pm 0.14$	$92^{a} \pm 1.0$	$2.5^{c} \pm 0.5$	$5.5^{a} \pm 0.5$	$1.04^{b} \pm 0.01$	$0.12^{b} \pm 0.001$
F	375.753*	49.167*	108.871*	38.288*	2074.222*	111.417*
P	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
LSD	1.050	0.908	0.619	0.479	0.041	0.029

F and p values for **ANOVA** test, significance between groups was done using Post Hoc Test **(LSD)**.
Means with **common letters** are not significant (Means with different letters are significant).
* Statistically significant at $p \leq 0.05$.

The vegetation in the study area located close to the Industrial City was dominated by the perennial herb *C. conglomeratus*. It is a geophyte belonging to family Cyperaceae. Much of the economic importance of the plant is due to its medicinal value as it was proved by many studies such as Feizbakhsh and Naeemy (2011), Hisham et al. (2012) and Al-Hazmi et al. (2018).

The structure of plant communities in many natural ecosystems is largely influenced by the disturbances, frequently occurring in the system naturally or due anthropogenic activities (Lalfkawma et al., 2009). In many of these systems, disturbances change overall community structure (Shea et al., 2004; Shaforth et al., 2002) which in turn can ultimately affect community and population dynamics. The ecological disturbances in the study area have their major effect on species richness, where about 76% of the perennial species in the study area were disappeared as the result of the human impact on *C. conglomeratus* community in the most disturbed sites. Interspecific competition results from C. *conglomeratus* indicated that it is a competitor species led to exclusion of the other species from the highly disturbed sites which affected by the Industrial City in Jeddah. Therefore, the resulting of a remarkable decrease in species diversity was coinciding with maximum dominance of *C. conglomeratus*. Vegetation analysis revealed that only three species *C. conglomeratus*, *P. turgidum, and I. spinosa*, could resist the high disturbance exerted by the Industrial City. While *C. hystrix* was found to adopt post, disturbance condition as it was recorded only in the disturbed sites. *T. aegyptiaca* is the only species completely disappeared in the all disturbed and protected sites. It is also remarkable that protection had a negative effect on *C. conglomeratus* reducing its importance value to the minimum in the study area, while *P. turgidum* become the dominant species. These functional changes within dominant grasses have been also observed in grasslands of Uruguay (Rodriguez et al., 2003). This may support the view of Altesor et al. (2005) which revealed that there was a shift of dominant species between the grazed and protected treatments. Baker et al. (2015) indicate that species with lower wood density, and therefore presumably higher rates of diameter growth, and those with lighter seeds, and therefore greater dispersal ability, are favored by disturbance.

It is notable that species diversity is considerably reduced because of increasing the level of disturbance exerted by the Industrial City of Jeddah, and consequently high dominance is estimated in the highly disturbed site. It is also notable that species diversity increased in the moderately disturbed site. This coincided with the theoretical analysis that often predicts a peak of species diversity at intermediate disturbance intensity (Huston, 1979; Shekhar and Azim 2010). However, it may be argued that the characteristics of the system and the type of disturbance might be responsible for this trend (Rao et al., 1990). Each diversity index tested in the present study indicates that species diversity showed a considerable increase under moderate disturbance.

Species abundance distribution models are the method of presenting species abundance data (Magurran, 1988). In these graphs, the abundance of each species was plotted on a logarithmic scale against the species rank in the sequence of species from most to least dominant. It is notable that the resulting species abundance models representing the community under high disturbance approaches the geometric pattern of species distribution. This is corroborating the niche preemption hypothesis (Whittaker, 1975). Here one dominant species (*C. conglomeratus*) occupies a large fraction of the total niche; the second species (*P. turgidum*) occupies a similar fraction of the niche space, and so on. In other words, the ratio of abundance of species to the abundance of its predecessor is almost constant through the ranked list of species, and that is why the series will appear as a straight line when plotted on log abundance/species rank graph. Whittaker (1972) reveals that field data that have shown the geometric series pattern of species abundance is found primarily in species-poor and often harsh environments or in very early stages of succession. This is also found by Ayyad and Fakhry (1996). As conditions improve, the patterns of species abundance grade into those of the log series. This is obvious in the moderately disturbed, slightly disturbed and protected sites in the present study, where the curves become less steep as more species are added.

Zheng et al. (2017) found that tree species diversity influenced the soil texture to some extent, while Species richness did not have a positive influence on the soil properties. In the present study, it is notable that the highly disturbed site shows the highest soil electric conductivity value and the lowest percentage organic matter coincided with the lowest species diversity and highest dominance as compared with other sites in the present study. While the moderately disturbed site shows the highest percentage of both organic matter and gravel, coincided with the highest species diversity and lowest dominance as compared with other sites in the present study.

In conclusion, the nature of human impact on biodiversity of *C. conglomeratus* community in the study area may be either sudden or radical, such as the effect of the Industrial City, or it may be gradual and conservative such as the effect of protection. In the first case, loss of species is the ultimate result. The few species which are endowed with the ability to survive such drastic changes of the habitat dominate the *C. conglomeratus* community to a considerable extent, and species diversity deteriorates. In the second case, the effect of protection on species diversity is considered to be gradual and conservative. It is also notable that species diversity increased under moderate disturbance.

References

Alatar, A., El-Sheikh, M.A., Thomas, J., 2012. Vegetation analysis of Wadi Al-Jufair, a hyper-arid region in Najd, Saudi Arabia. Saudi J. Biol. Sci. 19, 357–368.
Al-Hazmi, G.H., Awaad, A.S., Alothman, M.R., Alqasoumi, S.I., 2018. Anticandidal activity of the extract and compounds isolated from *Cyperus conglomertus* Rottb. Saudi Pharm. J. https://doi.org/10.1016/j.jsps.2018.03.007 (in press).

Allen, S., Grimshaw, H.M., Parkinson, J.A., Quarmby, C., 1974. Chemical Analysis of Ecological Materials. Blackwell Scientific Publications Osney, Oxford, London, p. 565.
Altesor, A., Oesterheld, M., Leoni, E., Lezama, F., Rodriguez, C., 2005. Effect of grazing on community structure and productivity of a Uruguayan grassland. Plant Ecol. 179, 83–91.
Atiqur Rahman, M., Mossa, J.S., Al-Said, M.S., Al- Yahya, M.A., 2004. Medicinal plant diversity in the flora of Saudi Arabia. 1: A report on seven plant families. Fitoterapia 75, 149–161.
Ayyad, M., Fakhry, A., 1996. Plant biodiversity in the western Mediterranean desert of Egypt. Verhandlungen der Gesellschaft fur Okologie 25, 56–76.
Baker, T.R., Vela Dıaz, D.M., Moscoso, V.C., Navarro, G., Monteagudo, A., Pinto, R., Cangani, K., Fyllas, N.M., Gonzalez, J.L., Laurance, W.F., Lewis, S.L., Lloyd, J., Steege, H., Terborgh, J.W., Phillips, O.L., 2015. Consistent, small effects of treefall disturbances on the composition and diversity of four Amazonian forests. J. Ecol., 1–10
Collenette, S., 1999. Wildflowers of Saudi Arabia National Commission for Wild life Conservation and. Development (NCWCD) KSA.
Fakhireh, A., Ajorlo, M., Shahryari, A., Mansouri, S., Nouri, S., Pahlavanravi, A., 2012. Thevautecological characterstics of *Desmostachya bipinnata* in hyper-arid regions. Turkish J. Botany 36, 690–696.
Feizbakhsh, A., Naeemy, A., 2011. Chemical composition of the essential oil of *Cyperus conglomeratus* Rottb. From Iran. E-J. Chem. 8 (S1), S293–S296.
Hisham, A., Rameshkumar, K.B., Sherwani, N., Al-Saidi, S., Al-Kindy, S., 2012. The composition and antimicrobial activities of *Cyperus conglomeratus*, Desmos chinensis var. lawii and Cyathocalyx zeylanicus essential oils. Nat. Prod. Commun. 7 (5), 663–666.
Huston, M.A., 1979. A general hypothesis of species diversity. Am. Naturalist 113, 81–101.
Korkmaz, M., Ozcelik, H., 2013. Soil-plant relations in the annual *Gypsophila* (Caryophyllaceae) taxa of Turkey. Turkish J. Botany 37, 85–98.
Lalfkawma, U.K., Sahoo, S., Roy, K., Vanlalhriatpuia, P.C., 2009. Community composition and tree population structure in undisturbed and disturbed tropical semi-evergreen forest stands of north- east India. Appl. Ecol. Environ. Res. 7 (4), 303–318.
Ludwig, J.A., Reynolds, J.F., 1988. Statistical ecology. In: A Primer on Methods and Computing. Wiley, New York, p. 337.
Magurran, A.E., 1988. Ecological Diversity and Its Measurment. Princeton University Press, Princeton, New Jersey, p. 179.
Migahid, A.M., 1996. Flora of Saudi Arabia. King Saud University, Riyadh, KSA.
Rao, P., Barik, S.K., Pandey, H.N., Tripathi, R.S., 1990. Community composition and tree population structure in a sub-tropical broad-leaved forest along a disturbance gradient. Vegetatio 88, 151–162.
Rocabado, G., Claros, M., Bongers, F., Quetier, S., Chuvina, J., Poorter, L., 2016. Land-use intensifi cation effects on functional properties in tropical plant communities. Ecol. Appl. 26 (1), 174–189.
Rodriguez, C., Leoni, E., Lezama, F., Altesor, A., 2003. Temporal trends in species composition and plant traits in natural grasslands of Uruguay. J. Veget. Sci. 14, 433–440.
Shaforth, P.B., Stromberg, J.C., Patten, D.T., 2002. Riparian vegetation response to altered disturbance and stress regimes. Ecol. Appl. 12, 107–123.
Shea, K., Roxburgh, S.H., Rauschert, E.S.J., 2004. Moving from pattern to process: coexistence mechanisms under intermediate disturbance regimes. Ecol Lett. 7 (6), 491–508.
Shekhar, R., Azim, U., 2010. Disturbance effects on species diversity and functional diversity in riparian and upland plant communities. Ecology 91 (1), 28–35.
Whittaker, R.H., 1972. Evolution and measurement of species diversity. Taxon 21, 213–251.
Whittaker, R.H., 1975. Communities and Ecosystems. MacMillan, New York.
Wilson, E.O., 1988. Biodiversity. National Academy Press, Washington, D.C..
Zheng, X., Wei, X., Zhang, S., 2017. Tree species diversity and identity effects on soil properties in the Huoditang area of the Qinling Mountains, China. Ecosphere 8 (3), 1–8.
Zohary, M., 1973. Geobotanical Foundations of the Middle East. Gustav Fischer Verlag, Stuttgart.