CATRINA (2015), 11 (1): 41 -50

Effect of human recreation on vegetation composition and diversity of inland desert dunes in Al-Ghada Nature Reserve, Central Saudi Arabia

Magdy I. El-Bana[1] and Mohammed D. Aldakhil[2]
[1]Department of Botany, Faculty of Science, Port Said University, Port Said, Egypt
[2]Department of Geography, Social Science College, Imam Mohammed Ibn Saud Islamic University, Riyadh, Saudi Arabia

ABSTRACT
Inland desert dunes are regarded as the most fragile ecosystem in arid regions. A field study was conducted to evaluate the effect of human recreational camping on vegetation assemblages at four sites belonging to none, low, moderate and heavy recreational intensities on the sand dunes of Al-Ghada Nature Reserve. In each study site, four 10 × 100 m transects were established in the four cardinal directions to measure the different vegetation attributes. The results showed that all recreational levels significantly reduced the total vegetation cover, plant density, number of species, as well as Shannon-Wiener diversity and evenness indices. Heavy recreational intensities decreased the cover of the woody and grass species, and increased that of annual and weedy species. Non-metric Multidimensional Scaling ordination (NMDS) of vegetation presented a clear spatial separation of the four sampling sites reflecting their differences in vegetation association according to the recreational pressure. Indicator species value analysis (INDVAL) showed that the four recreational intensities were characterized by different indicator species with highest constancy and fidelity. The study concluded that recreational pressure significantly alters vegetation structure and diversity, and recreation activities should be restricted to conserve the ecosystem function of desert dunes that are sensitive to disturbance.
Keywords: Camping, inland desert dunes, management, recreational activities, species diversity, vegetation

INTRODUCTION

Plant species composition of sand dunes is associated with spatial heterogeneity and dynamics (Allen, 1988; Danin, 1996), which may be determined by sand accumulation and anthropogenic activities (Avis and Lubke, 1996; El-Bana *et al.,* 2003, 2007). The dune system is highly fragile and can be severely damaged by recreational activities such as camping, off-road vehicles and trampling (Bowles and Maun, 1982; Hercock, 1999; Lemauviel and Roze, 2003; Gallet *et al.,* 2004; Kerbiriou *et al.,* 2008; Hesp *et al.,* 2010; Schlacher*et al.,* 2011).These activities often resulting in destruction of dune vegetation, increased wind erosion and biodiversity loss (Rickard *et al.,* 1994; Kutiel *et al.,* 1999; Schlacher *et al.,* 2011). Therefore, monitoring and understanding recreation impacts on vegetation patterns is an important ecological component for conserving and managing the natural resources of the dune ecosystems.

Vegetation composition and diversity can be affected by recreational activities in different ways. One of the most obvious effects of recreational activities is the destruction of vegetation through direct crushing, shearing-off and uprooting (Kuss,1986; Liddle, 1997; Newsome *et al.,* 2002; Andres-Abellan *et al.,* 2005; Groom *et al.,* 2007). In arid sand dunes, such impacts lead to a decrease in vegetation cover, plant height, species richness and diversity (Lathrop, 1983; Rickard *et al.,* 1994; Kutiel *et al.,* 1999, 2000). Several researchers have reported that plant species exhibit varying degrees of vulnerability to recreation intensity (Hercock, 1999; Lemauviel and Roze, 2003; Gallet *et al.,* 2004), and consequently changes in vegetation composition and dominant life forms (Liddle and Greig-Smith, 1975; Kuss, 1986). Herbaceous vegetation, and particularly annuals, are more resistant to recreational stresses than woody shrubs and trees (Kuss, 1986; Hall and Kuss, 1989; Cole, 1995; Yorks *et al.,* 1997).

In Saudi Arabia, the vast territory and the attractive ecological diversity of inland sand dunes make them popular national parks for tourism and recreation (Vincent, 2008). Camping is the popular form of recreation on inland dunes in the central region of Saudi Arabia. It is associated with other recreational activities like trampling and off-road vehicles which can change vegetation composition and diversity at the campsites. Therefore, the main objective of the current study was to determine whether human disturbance associated with long-established campsites results in spatial changes to plant community and diversity on the stabilized inland dunes in Al Ghada Nature Reserve. We further aimed to determine whether these changes related to the size and intensity of campers. To reach these goals, we compared the botanical composition at three campsites representing low, moderate and severe recreation intensities, as well as one site without human disturbance.

MATERIALS AND METHODS

The Study Area

Al Ghada Nature Reserve (26˚ 01' 20.4"N, 43˚ 51' 06.3" E) is located in Ashgaygahs and dunes of Qassim region, Central Saudi Arabia (Fig. 1). It covers about 115.5 km² and its name is driven from the dominance of *Haloxylon persicum* Bunge (Ghada) tree which is endangered and needs specific conservation measures in the Arabian Peninsula (Al-Khalifah and Shanavaskhan, 2007; Mohamed *et al.,* 2013). The reserve is surrounded by five big cities namely: Al

* *Corresponding author:* mag_bana@yahoo.co.uk

Bukayriyah, Buraydah, Unayzah, Al Badai and AlMithnab (Fig. 1). The climate is characterized by hot dry summers and rainy winters. The highest average daily temperature (in July) is 42.6 ˚C and the lowest (in January) is 15.8˚C (Al-Swilem, 1999).

The average annual precipitation is 115 mm and characterized by spatial and temporal variations (Al-Swilem, 1999). Human recreation is one of the most important land uses in the reserve with a continued growth in recent years due to the annual establishment of Al Ghada Festival and installation of permanent campsites. The long-established camping sites with different occupied areas are located on the stabilized dunes and regulated by Agricultural Authority of Unayzah. They have signs of human recreation activities such as campfires, off-road vehicle tracks, cutting woody shrubs and trees and disposal of food scraps.

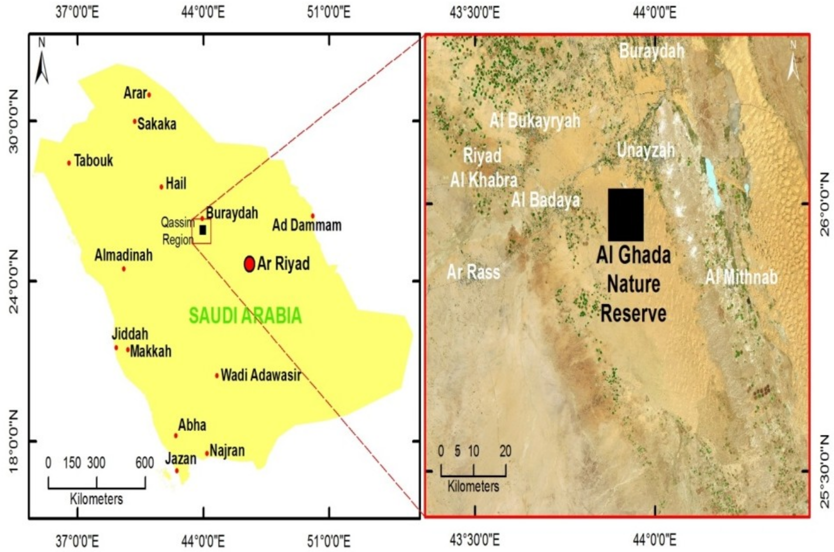

Figure 1: A map showing the location of Al-Ghada Nature Reserve in Qassim region, Central Saudi Arabia.

Field Survey

Three levels of recreational pressure (low, moderate and severe) depending on the type of campers, number of tents and in addition to area of each campsite were listed in Table 1. The low recreational pressure is related to small size campsites with three small tents and an average area of 324 m^2 (12 m × 27 m). The moderate recreational pressure is belonging to the medium size family campsites with at least six tents and an average area of 1908 m^2 (36 m × 53 m). The severe recreational pressure is confined to the large governmental campsites such as campsite of Unayzah Province (6160 m^2) and Agricultural Authority of Unayzah campsite (14850 m^2).

The reserve management has also set aside several fenced areas which represent control sites with no evidence of human disturbance. Three potential campsites and three control sites in fenced areas were located for each type of recreational camping as described above. On each campsite, four 10 m × 100 m transects were oriented in each of the cardinal directions from the centre of each camp. Wooden stakes were placed in the centre of each of the three selected control fenced sites. On each control site, similarly four 10 m × 100 m transects were established in each of the cardinal directions from the centre stake. In both control and campsites, the density and percent cover of plant species were measured in 10 5 m × 5 m plots situated on 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 m along each transect.

The result was a matrix of 480 sampling plots (4 sites × 3 replicates × 4 transects × 10 sampling). Cover values were visually calculated to the nearest percent with total cover adding up to 100 percent. The importance values index was calculated for each species as the sum of relative values of density and cover. Additionally, the recorded species were classified into five functional growth-form groups: grass species; shrubs, trees, annuals and weeds. Plants were identified and classified using Chaudhary (1989, 2000) and Chaudhary and Akram (1987).

Table 1: Campsites in Al-Ghada Nature Reserve.

Campsite size (type)	Total no. in the reserve	Average no. of tents	Average occupied area (m^2)	Estimated recreational intensity
Small (single campers)	45	3	324	Low
Medium (family campers)	156	6	1908	Moderate
Large (governmental campers)	4	3	6160	Sever

Treatment of Data

Species diversity indices across the four recreational camping levels (none, low, moderate and severe) were calculated using total number of species and average species richness (S) (Magurran, 1988; Krebs, 1989). Shannon-Wiener diversity index (H) and Evenness index (E) were calculated as follow:

$$H = -\sum_{i=1}^{S} (Pi \ln Pi), \qquad E = \frac{H}{\ln S}$$

Where Pi is the relative importance value of i species.

Ordination and classification analysis was used to test the interrelationship between the changes in recreational camping intensities and vegetation composition using the statistical package PC-Ord (McCune and Mefford, 1999). The data from the four cardinal transects were pooled into a single value, and used that value in subsequent analysis. The classification was performed using the association Bray-Curtis index (McCune and Grace, 2002).

Non-metric Multidimensional Scaling ordination (NMDS) was applied as an ordination method with Sorensen's coefficient as distance measure. To avoid the problem of local minima, we ran the NMDS analysis in an autopilot mode, letting the program choose the best solution at each dimensionality (McCune and Mefford, 1999).

Species indicative for each plant community was estimated using indicator value method (INDVAL) and indices of constancy and fidelity (Dufrêne and Legendre, 1997). This approach calculates relative frequencies (RF) as constancy index and relative abundances (RA) as fidelity index of species in each group and derive an indicator value (IV) for each species across the groups. A threshold level of 25% for the index IndVal was chosen, supposing that a characteristic (indicator) species is present in at least 50% of one site group (considered constant species) and that its relative abundance in that group reaches at least 50% (considered faithful species).

The significance of the indicator value for each species was tested by a Monte Carlo randomization test with 1000 permutations. The statistical comparisons of mean values of vegetation attributes were analyzed with one-way ANOVA. Significant differences for all statistical tests were evaluated at the level of $P \leq 0.05$. All data analyses were conducted with the SPSS software (SPSS for Windows, Version 16.0, Chinago, IL, USA).

RESULTS

Sixty-one plant species were recorded in the surveyed plots of the areas with and without recreational campsites (Appendix 1). The results showed that total vegetation cover, total plant density, total species number, species richness index, Shannon-Wiener diversity index and evenness index decreased significantly with increasing recreational camping intensities (Fig.2a-f). None recreational camping plots had greater total vegetation cover by 121.6% and total plant density by 35.6% in comparison to severe recreational camping.

Similarly, the total number of species and species richness index were greater in none recreational campsites by 2.9 and 3.9 times, respectively, than in severe recreational campsites. The Shannon-Wiener diversity and evenness indices were greater for none recreational campsites, than the severe recreational campsites, by 3.1 and 1.5 times, respectively. Recreational camping intensity significantly decreased density and cover of grass species, shrubs and trees, but increased density and covers of annuals and weedy species (Fig. 3a and b).

The density and cover of annuals were increased in severe recreational camping by 34.4% and 45.1%, respectively, in comparison to none recreational campsites. Similarly, the density and cover of weedy species were greater in severe recreational campsites by 94.1% and 84.3%, respectively, than in none recreational campsites. The first two dimensions of the Non-metric Multidimensional Scaling ordination (NMDS) of vegetation (Fig. 4) revealed a clear spatial separation of the four sampling sites. The different vegetation associations thus appear to reflect differences in the recreational camping pressure. The plots of severe recreational camping and none recreational campsites were located at the lower and the higher end of the first NMDS axis, respectively. However, the plots of low, moderate and severe recreational campsites were clearly separated along the second NMDS axis.

Cluster analysis classified the 120 sampling plots into four plant communities (Fig. 5) namely groups A-D. Indicator species analysis showed that each group was characterized by different indicator species with maximum relative constancy and fidelity (Table 2).

The classification dendrogram shows the discrimination of none recreational camping plots (group A) ata first divisive level with dissimilarity index of 99.5% and with *Calligonum comosum*, *Haloxylon persicum* and *Centropodia forskalii* as indicator species. The low recreational camping plots (group B) were separated at a second divisive level with dissimilarity index of 72.4% and with indicators *H. persicum, Haloxylon salicornicum*, *Scrophularia hypericifolia* and *Stipagrostis drarii*.

At a third divisive level and dissimilarity index of 52.3%, the plots of moderate recreational camping (group C) with *Heliotropium curassavicum* and *Citrullus colocynthis* indicators were discriminated from those of sever recreational camping (group D) with *Cynodon dactylon*, *C. colocynthis* and *Malva parviflora* indicators.

Table (2): Results of the indicator value analysis (INDVAL) with the indices of constancy and fidelity of the diagnostic species. The highest indicator values are in bold type.

Species	Constancy (%)				Fidelity (%)				Indicator value			
	Group				Group				Group			
	A	B	C	D	A	B	C	D	A	B	C	D
Calligonum comosum	78.3	0	0	0	66.7	0	0	0	58.4	0	0	0
Centropodia forskalii	58.4	0	0	0	52.8	0	0	0	48.6	0	0	0
Citrullus colocynthis	0	0	55.1	98.7	0	0	52.8	58.2	0	0	40.8	52.5
Cleome amblyocarpa	0	0	0	42.1	0	0	0	18.3	0	0	0	16.7
Cynodon dactylon	0	0	0	84.6	0	0	0	64.9	0	0	0	59.2
Cyperus conglomerates	42.4	33.2	0	0	18.1	15.2	0	0	6.3	4.5	0	0
Haloxylon persicum	66.2	74.5	0	0	52.8	64.9	0	0	52.8	66.2	0	0
Haloxylon salicornicum	42.4	98.7	0	0	18.1	66.2	0	0	10.4	62.5	0	0
Heliotropium curassavicum	0	0	55.4	18.2	0	0	66.2	22.5	0	0	62.5	15.2
Malva parviflora	0	0	0	62.2	0	0	0	53.7	0	0	0	58.4
Neurada procumbens	0	35.2	28.4	0	0	22.3	18.1	0	0	15.2	22.1	0
Scrophularia hypericifolia	0	75.2	0	0	0	58.2	0	0	0	62.5	0	0
Stipagro stisdrarii	18.2	66.2	0	0	9.5	52.1	0	0	10.4	51.2	0	0

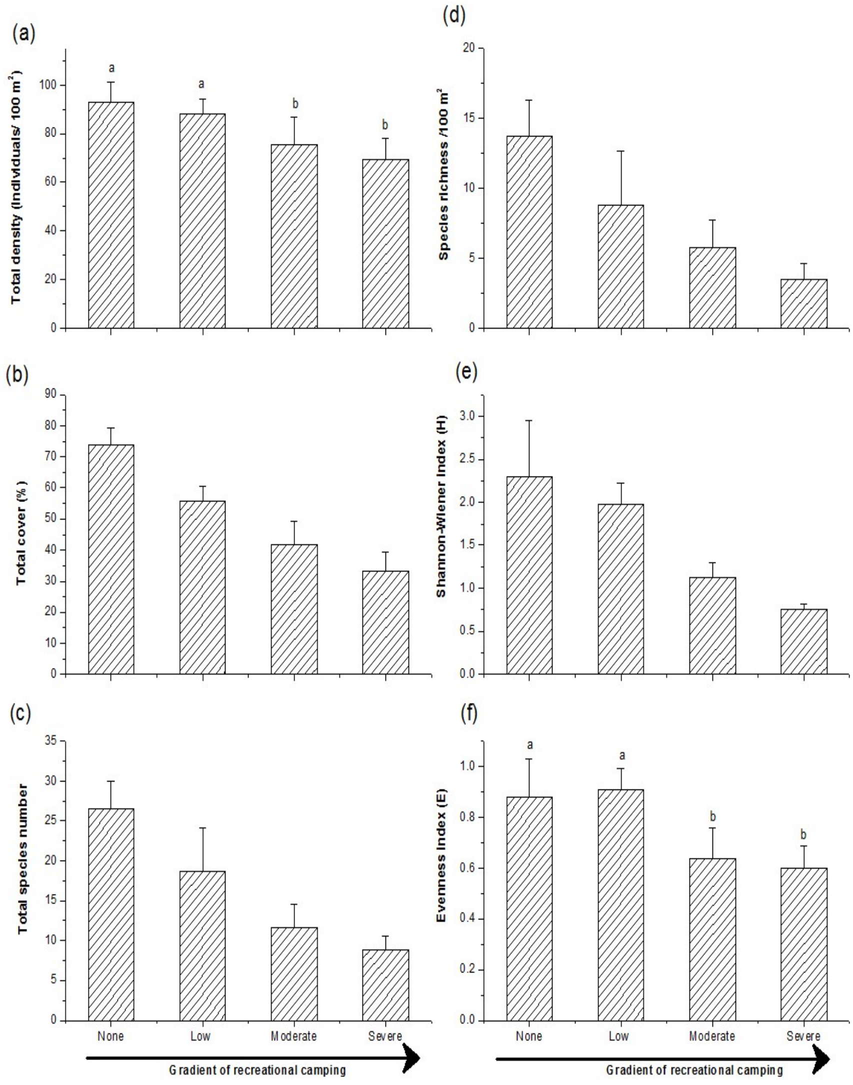

Figure (2): Variation in total plant density (a), total cover (b), total species number (c), species richness index (d), Shannon-Wiener index (e) and evenness index (f) across a gradient of recreational camping intensity in Al-Ghada Nature Resreve. Bars with the same letters are not significantly different at $P \leq 0.05$ (Tukey's studentized test).

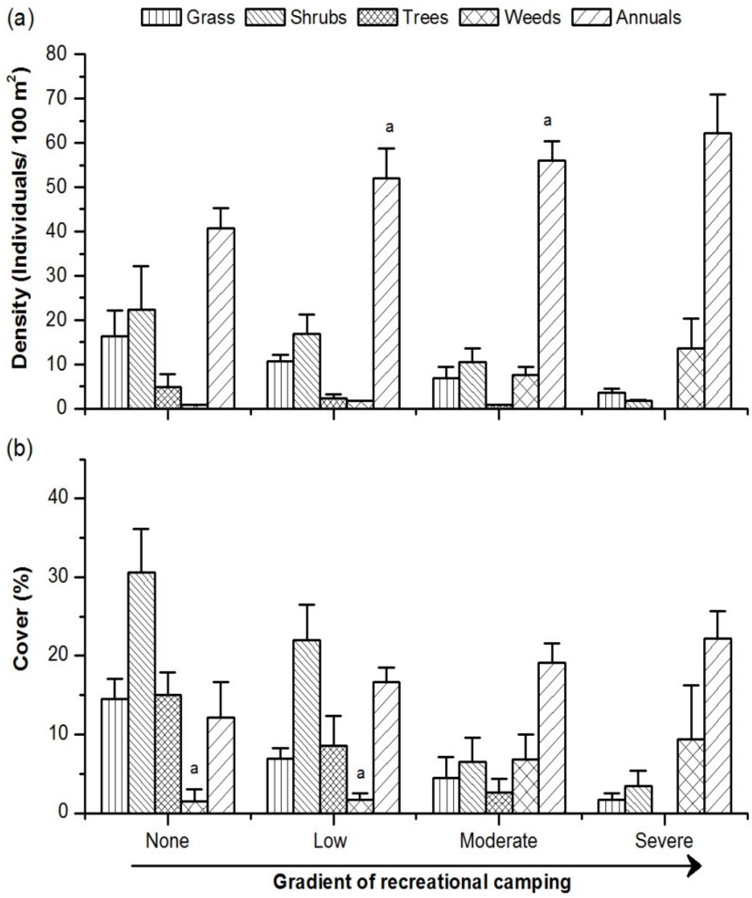

Figure (3): Changes in plant density (a) and covers (b) of different functional groups across a gradient of recreational camping intensity in Al-Ghada Nature Reserve**.** Bars with the same letters are not significantly different at $P \leq 0.05$ (Tukey's studentized test).

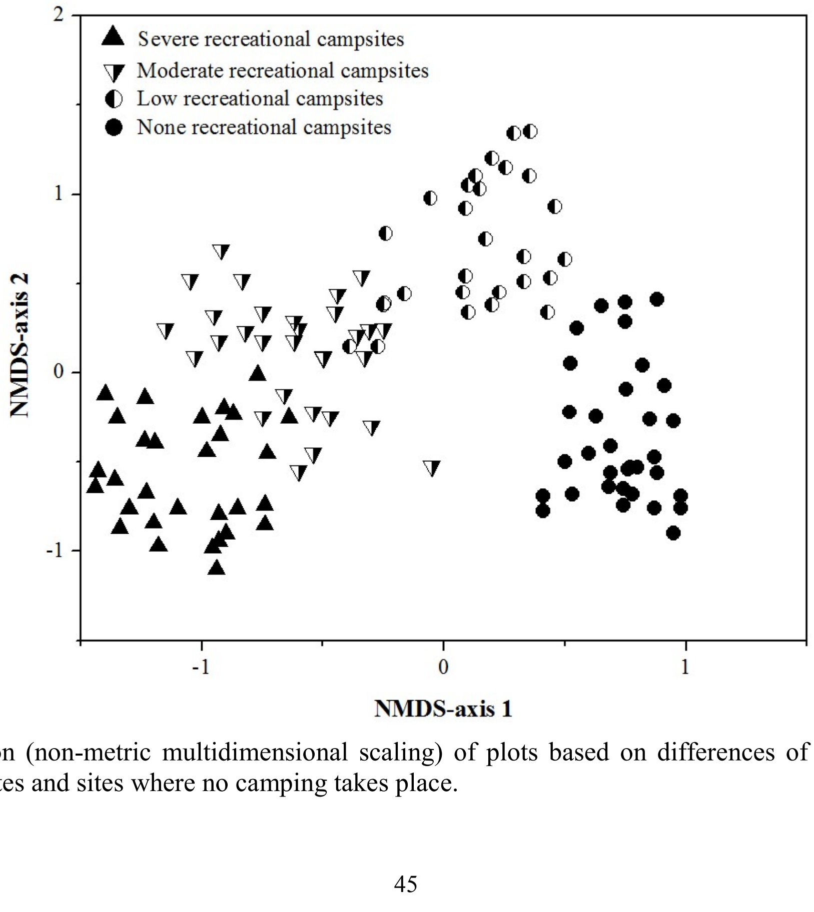

Figure (4): Ordination (non-metric multidimensional scaling) of plots based on differences of plant assemblages of recreational campsites and sites where no camping takes place.

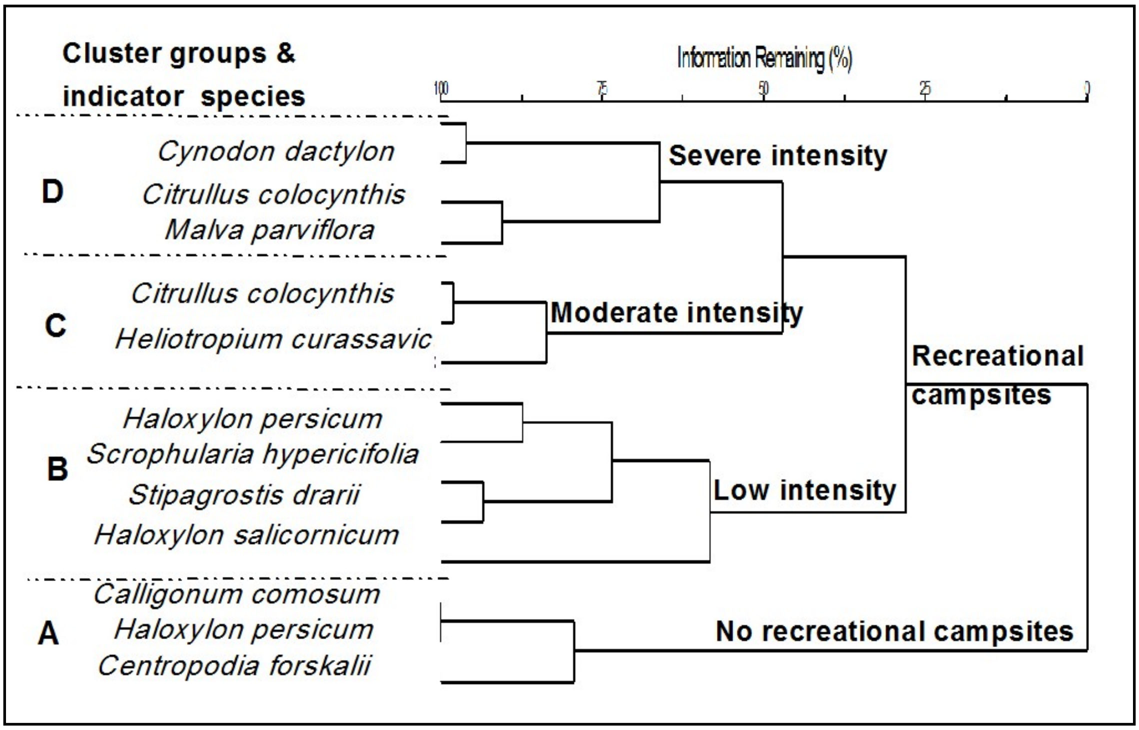

Figure (5): Dendrogram of classification analysis showing the recognized vegetation communities (A-D) of the sites without and with different recreational camping intensities in Al-Ghada Nature Reserve.

DISCUSSION

Several studies have demonstrated that human recreational activities induce changes in vegetation abundance, composition and diversity (Yorks *et al.,* 1997; Kutiel *et al.,* 1999; 2000; Gallet *et al.,* 2004; Hill and Pickering, 2006; Groom *et al.,* 2007; Hesp *et al.,* 2010). Kutiel *et al.* (1999, 2000) demonstrated that intense recreational activities often result in reduction of vegetation cover and richness. However, low or moderate levels of recreational activities may have a positive effect on vegetation abundance and diversity (Kutiel *et al.,* 2000). The current study showed that even low levels of recreational camping considerably decreased all vegetation characteristics of the stabilized inland dunes in the study area. Low recreational camping resulted in a 32.2% decrease in cover, moderate camping decreased cover of species or species groups by more than 50%, and severe camping decreased cover by more than 85%. These changes in vegetation abundance are similar to the results documented for the effect of recreational activities on the coastal dunes (Kutiel *et al.,* 1999; Lemauviel and Roze, 2003; Schlacher *et al.,* 2011). Kutiel *et al.* (1999) found that vegetation cover decreased by ~5 times, and Andres-Abellan *et al.* (2005) by ~2 times under recreational trampling pressure. Gómez Limón and Lucio (1995) reported that recreation effects such as camping and trampling often lead to the loss of species diversity. They found that number of species and diversity were reduced by ~1.5-8 times, respectively, under recreational trampling pressure.

Similarly, the results of the present study indicate that recreational camping has resulted in a decrease in the total number of species and species diversity compared to none recreational campsites. This was particularly evident on the moderate and severe recreational campsites. This outcome may be attributed to the type and behaviour of the campers. On the moderate and severe recreational campsites that designed for family and governmental campers, off-road vehicle access to campsites is not managed which leading to physical destroy and clearing of vegetation (Kutiel *et al.,* 2000; Al-Nafie, 2007). Moreover, these campers often recreate together in groups that induce intense trampling with low species richness and diversity of dune plants (Kutiel *et al.,* 1999, 2000). Our results showed that different plant functional groups had a variable trend to recreational camping. The density and cover of annuals and weeds were higher in severe recreational campsites compared to none recreational ones, but the reverse was true for native grasses, shrubs and trees.

Therefore, the grass species, shrubs and trees seemed to be susceptible to recreational camping, but annuals and weed species appeared to be more tolerant. Such tolerance strategy results from mechanisms of both resistance and resilience to the disturbance on dune ecosystem (Lemauviel and Roze, 2003; Hesp *et al.,* 2010). The sensitivity of native grasses and woody species could be linked to their perennially and breakable nature during drought months (Yorks *et al.,* 1997).

Cole (1995) found that erect morphological growth form of plants (e.g. perennial grasses and shrubs) is the least resistant to recreational disturbance. On the other hand, creepers and fast growing plants (e.g. annuals and noxious weeds, often anthropic) display a high resistance to recreational disturbance (Sun and Liddle, 1993; Cole, 1995; Yorks *et al.,* 1997).

Andres-Abellan *et al.* (2005) indicated that intense recreational activities leads to the progressive disappearance of the most sensitive species and to the colonisation by species that are more resilient to these activities. The results indicated that plant composition differed significantly between areas without and with recreational camping pressure. The typical native psammophytic species of sand dunes such as *C. comosum*, *H. persicum*, *C. forskalii* and *S. drarii* (Danin, 1996; Al-Khalifah and Shanavaskhan, 2007; El-Bana *et al.,* 2007) were indicators on plots in none and in low recreational campsites. On the contrary, both moderate and severe recreational campsites were characterized by annuals and weeds that belong to an anthropic group and are resistant to disturbance (i.e. C. *dactylon*, *C. colocynthis, H. curassavicum* and *M. parviflora*) (Chaudhary and Akram, 1987; Hegazy, 1994; Gomaa, 2012). This indicates that sensitive and diverse dune vegetation gradually starts to change towards more tolerant and homogenous annual vegetation communities due to recreational activities.

IMPLICATION FOR MANAGEMENT

Identification of plant communities and diversity associated with different intensities of recreational activities is important for managing rare natural resources (Yorks *et al.,* 1997; Gallet *et al.,* 2004), particularly in the fragile ecosystem such as sand dunes (Lemauviel and Roze, 2003; Hesp *et al*., 2010). The current results showed which plants communities are more affected by recreational camping and whether diversity or abundance of vegetation is relevant to the intensity of campers in Al Ghada Nature Reserve. The management plan should be considered the spatial distribution of campers in the reserve to conserve habitats of rare and sensitive species like *C. comosum*, *H. persicum* and *S. hypericifolia*.

In this respect, new areas of native perennial grasses and woody habitats would be fenced, which could assist in the establishment of many species and in preserving biodiversity. Furthermore, the impacted campsites can be restored by means of planting *C. comosum* and *H. persicum* which can trap windblown sediments and forming phytogenic hummocks within and around their canopies (Al-Khalifah and Shanavaskhan, 2007). This will enhance the establishment and growth of many native herbecous species both within and around hummocks which is important in maintaing plant diversity in degraded sandy habitats (Brown and Porembski, 1997, 2000; El-Bana *et al.,* 2003, 2007). The study also suggests that the establishment of managed fixed tracks and parks for cars would be a useful strategy to prevent or minimize vegetation destruction and fragmentation from unmanaged off-road driving and parking within the reserve.

ACKNOWLEDGEMENT

This study was supported by National Science, Technology and Innovation plan (No.: 09 - ENV 919-08) Science and Technology Unit at Imam Mohammed Ibn saud Islamic University, KSA.

REFERENCES

AL-KHALIFAH, N.S., A.E. SHANAVASKHAN. 2007. On the distribution, status and phenology of Ghada (*Haloxylon persicum* Bunge) in the Arabian Peninsula. Tropical Ecology **48**: 51-60.

ALLEN, B. 1988. The Reconstruction of Disturbed Arid Lands. West view Press, Colorado, USA.

AL-MESHIL, A. H., M. QWAS. 2001. Effect of partial protection on vegetation in Algadah Protected Area, Unaizah. Arab Gulf Journal **19**: 170-173.

AL-NAFIE, A. H. 2007.The effect of off-road driving on the plant cover of natural recreational areas in Central of Saudi Arabia. Saudi Journal of Biological Sciences **14**: 53-72.

AL-SWILEM, A. M. 1999. Temporal and spatial variations of rainfall in northwest of Saudi Arabia. Ph.D. Thesis, Sheffield, Department of Geography, University of Sheffield, UK.

ANDRES-ABELLAN, M., J.B. DEL ALAMO, T. LANDETE-CASTILLEJOS, F.R. LOPEZ-SERRANO, F.A. GARCIA-MOROTE, A. DEL CERRO-BARJA. 2005. Impact of visitors on soil and vegetation of the recreational area "Nachimiento Del Rio Mundo" (Castilla-La Mancha, Spain). Environmental Monitoring Assessment **101**: 55- 67.

AVIS, A.M., R.A. LUBKE. 1996. Dynamics and succession of coastal dune vegetation in the Eastern Cape, South Africa. Landscape and Urban Planning **34**: 237-254.

BOWLES, J.M., M.A. MAUN. 1982. A study of the effects of trampling on the vegetation of Lake Huron sand dunes at Pinery Provincial Park. Biological Conservation **24**: 273-283.

BROWN, G., S. POREMBSKI. 1997. The maintenance of species diversity by miniature dunes in a sand-depleted *Haloxylon salicornicum* community in Kuwait. Journal of Arid Environments **37**: 461-473.

BROWN, G., S. POREMBSKI. 2000. Phytogenic hillocks and blow-outs as "safe sites" for plants in an oil-contaminated area of northern Kuwait. Environmental Conservation **27**: 242-249.

CHAUDHARY, S. 1989. Grasses of Saudi Arabia. Ministry of Agriculture and Water, Riyadh, Saudi Arabia.

CHAUDHARY, S. 2000. Flora of the Kingdom of Saudi Arabia. Ministry of Agriculture and Water,

Riyadh, Saudi Arabia.
CHAUDHARY, S.A., M. AKRAM. 1987. Weeds of Saudi Arabia and the Arabian Peninsula. National Herbarium, Regional Agriculture and Water Research Center, Ministry of Agriculture and Water, Riyadh, Saudi Arabia.
COLE, D. N. 1995. Experimental trampling of vegetation I. Relationship between tramping intensity and vegetation response. Journal of Applied Ecology **32**: 203-214.
DANIN, A. 1996. Plants of desert dunes. Springer-Verlag, Berlin, Germany.
DUFRÊNE, M., P. LEGENDRE. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monograph **67**: 345-366.
EL-BANA, M. I., I. NIJS, A. A. KHEDR. 2003. The importance of phytogenic mounds (Nebkhas) for restoration of arid degraded rangelands in Northern Sinai. Restoration Ecology **11**: 317-324.
EL-BANA, M. I., Z. Q. LI, I. NIJS. 2007. Role of host identity in effects of phytogenic mounds on plant assemblages and species richness on coastal arid dunes. Journal of Vegetation Science **18**: 635-644.
GALLET, S., S. LEMAUVIEL, F. ROZE. 2004. Responses of three heathland shrubs to single or repeated experimental trampling. Environmental Management **33**: 821-829.
GOMAA, N. 2012. Composition and diversity of weed communities in Al-Jouf province, northern Saudi Arabia. Saudi Journal of Biological Sciences **19**: 369-376.
GÓMEZ-LIMÓN F.J., J. LUCIO. 1995. Recreational activities and loss of diversity in grasslands in Alta Manzanares Natural Park, Spain. Biological Conservation **74**: 99-105.
GROOM, J. D., L. B. MCKINNEY, L. C. BALL, C. S. WINCHELL. 2007. Quantifying off-highway vehicle impacts on density and survival of a threatened dune-endemic plant. Biological Conservation **135**: 119-134.
HALL, C. N., F. R. KUSS. 1989. Vegetation alternation along trails in Shenandoah National Park, Virginia. Biological Conservation **48**: 211-227.
HEGAZY, A. K. 1994. Trade-off between sexual and vegetative reproduction of the weedy *Heliotropium curassavicum* L. Journal of Arid Environments**127**: 209-220.
HERCOCK, M. 1999. The impacts of recreation and tourism in the remote North Kimberly region of Western Australia. The Environmentalist **19**: 259-275.
HESP, P., P. SCHMUTZA, M.L. MARTINEZ, L. DRISKELL, R. ORGERA, K. RENKEN, N.A. REVELO, O. A.J. OROCIO. 2010. The effect on coastal vegetation of trampling on a parabolic dune. Aeolian Research **2**: 105-111.
HILL W., C. M. PICKERING. 2006. Vegetation associated with different walking track types in the Kosciuszko alpine area, Australia. Journal Environmental Management **78**: 24-34.
KREBS, C.J. 1989. Ecological Methodology. Harper and Row, New York, USA.
KERBIRIOU, C., I. LEVIOL, F. JIGUET, R. JULLIARD. 2008. The impact of human frequentation on coastal vegetation in a biosphere reserve. Journal of Environmental Management **88**: 715-28.
KUSS, F.R. 1986. A review of major factors influencing plant responses to recreation impacts. Journal of Environmental Management **10**: 637-650.
KUTIEL, P., H. ZHEVELEV, R. HARRISON. 1999. The effect of recreational impacts on soil and vegetation of stabilised coastal dunes in the Sharon Park, Israel. Ocean and Coastal Management **42**: 1041-1060.
KUTIEL, P., E. EDEN, Y. ZHEVELEV. 2000. Effect of experimental trampling and off-road motorcycle traffic on soil and vegetation of stabilized coastal dunes, Israel. Environmental Conservation **27**: 14-23.
LATHROP, E.W. 1983. The effect of vehicle use on desert vegetation. In: R.H. Webb and H.G. Wilshire (Eds.), Environmental Effects of Off-Road Vehicles. Springer-Verlag, New York, USA.
LEMAUVIEL, S., ROZE, F., 2003. Response of three plant communities to trampling in a sand dune system in brittany (France). Environmental Management **31**: 227-235.
LIDDLE, M. 1997. Recreation Ecology. Chapman and Hall, London, UK.
LIDDLE, M. J., P. GREIG-SMITH. 1975. A survey of tracks and paths in a sand dune ecosystem. I. Soils. Journal of Applied Ecology **12**: 893-908.
MAGURRAN, A. 1988. Ecological Diversity and its Measurement. Croom Helm, London, UK.
MCcUNE, B., J. B. GRACE. 2002. Analysis of Ecological Communities. Ordination of plant communities, 99–149. MJM Press. Dr. W. Junk Publisher, The Hague, The Netherlands.
MCcUNE, B., M.J. MEFFORD. 1999. PC-ORD. Multivariate Analysis of Ecological Data, Version 4.14. MjM Software, Gleneden Beach, Oregon, USA.
MOHAMED, M. A., A. M. ASSAEED, H. N. YOUSUF. 2013. Micropropagation of the endangered desert shrub *Haloxylon persicum*. Australian Journal of Crop Sciences 7: 255-260
NEWSOME, D., S. A. MOORE, R. K. DOWLING. 2002. Natural Area Tourism: Ecology, Impacts and Management. Channel View Publications, Clevedon, UK.
RICKARD, C. A., A. MCLACHLAN, G. I. H. KERLEY. 1994. The effects of vehicular and pedestrian traffic on dune vegetation in South Africa. Ocean and Coastal Management **23**: 225-247.
SCHLACHER, T.A., R. DE JAGER, T. NIELSEN. 2011. Vegetation and ghost crabs in coastal dunes as

indicators of putative stressors from tourism. Ecological Indicators **11**: 284-294.

SUN, D., M.J. LIDDLE. 1993. Plant morphological characteristic and resistance to simulated trampling. Environmental Management **17**: 511-521.

VINCENT, P. 2008. Saudi Arabia: an environmental overview. CRC Press: London, UK.

Yorks, T., N. E. WEST, R.J. MUELLER, S.D.WARREN. 1997. Toleration of traffic by vegetation: Life form conclusions and summary extracts from a comprehensive data base. Environmental Management **21**: 121-31.

Appendix (1): Alist of plant species with their presence percentage recorded in none and three recreational camping pressure sites on the fixed dunes of Al-Ghada Nature Reserve, central Saudi Arabia.

Family	Species	Functional group	Recreational camping pressure			
			None	Low	Moderate	Severe
Apiaceae	*Devera triradiata* Hochst. ex Boiss.	Shrub	16.6			
	Anisosciadium lanatum Boiss	Annual	6.7			
Asphodelaceae	*Asphodelus fistulosus L.*	Annual		10	6.7	
Asteraceae	*Anthemis deserti* Boiss.	Annual	33.3			
	Calendula arvensis L.	Annual		23.3		
	Echinops spinosissimus Turra	Shrub	26.6			
	Ifloga spicata (Forssk.) Sch.	Annual		30	26.6	
	Launaea capitata (Spreng.) Dandy	Annual			6.7	40
	Picris cyanocarpa Boiss.	Annual	13.3			
	Reichardia tingitana (L.) Roth.	Annual			16.6	20
	Rhanterium epapposum Oliv.	Shrub	23.3	10		
	Senecio glaucus subsp. *coronopifolius* (Maire) C. Alexander L.	Annual			53.3	66.6
Boraginaceae	*Arnebia hispidissima* (Lehm.) DC.	Annual			26.6	
	Heliotropium curassavicum L.	Weed			73.3	20
	Moltkiopsis ciliata (Forssk) I.M. Johnston	Shrub	16.7	6.6		
	Trichodesma ehrenbergii Schweinf.	Shrub	10			
Brassicaceae	*Cakile arabica* Velen. & Bornm.	Annual			10	23.3
	Diplotaxis harra (Forssk.) Boiss	Annual			6.7	10
	Eremobium aegyptiacum (Spreng.) Asch. & Schweinf. ex Boiss.	Annual		20		
	Erucaria hispanica L.	Annual				16.7
	Farsetia aegyptia Turra	Shrub	23.3	6.7		
	Zilla spinosa Prantl	Shrub		10	3.3	
Caesalpiniaceae	*Senna italica* Mill.	Weed			33.3	20
Capparaceae	*Cleome amblyocarpa* Barr. & Murb.	Weed			23.3	
Caryophyllaceae	*Gymnocarpos decander* Forssk.	Shrub	16.7			
	Sclerocephalus arabicus Boiss.	Weed			26.7	
	Silene vilosa Forssk.	Annual	36.7	20		
	Spergularia fallax (Lowe) E.H.L.Krause	Annual				46.6
Chenopodiaceae	*Bassia muricata* (L.) Asch.	Annual			33.3	10
	Cornulaca monacantha Delile	Shrub		26.7		
	Haloxylon persicum Bunge	Tree	60	73.3		
	Haloxylon salicornicum (Moq.) Bge.	Shrub	43.3	83.3		
Cistaceae	*Helianthemum lipii* (L.) Dum.Cours	Shrub	33.3			
Convolvulaceae	*Convolvulus oxyphyllus* Boiss.*ssp. oxycladus* Rech.f.	Shrub	16.7			
	Convolvulus arvensis L.	Weed				26.7
Cucurbitaceae	*Citrullus colocynthis* (L.) Schrad.	Weed			76.7	70
Ephederaceae	*Ephedra alata* Decne.	Shrub	20	6.7		
Geraniaceae	*Monsonia nivea* (Decne.) Decne. ex Webb	Annual	10			
Lamiaceae	*Salvia aegyptiaca* L.	Shrub	6.7			
Malvaceae	*Malva parviflora* L.	Weed			30	80
Neuradaceae	*Neurada procumbens* L.	Annual		33.3		
Papilionaceae	*Astragalus spinosus* (Forssk.) Muschl.	Shrub	10			
	Medicago laciniata (L.) Mill.	Weed			40	10
	Trigonella stellata Forssk.	Annual	6.7			
Plantaginaceae	*Plantago amplexicaulis* Cav.	Annual	13.3			
	P. ovata Forssk.	Annual		20		
Polygonaceae	*Calligonum comosum* L'Her.	Tree	73.3			
	Emex spinosa (L.) Campd.	Weed			30	
	Rumex vesicarius L.	Annual	10			

Family	Species	Functional group	Recreational camping pressure			
			None	Low	Moderate	Severe
Resedaceae	*Ochradenus baccatus* Delile	Shrub	6.7			
Scrophulariaceae	*Scrophularia hypericifolia* Wydler	Shrub	30	60		
Solanaceae	*Lycium shawii* Roem. Et Schult.	Tree	16	20		
Zygophyllaceae	*Fagonia glutinosa* Delile	Shrub		1		
Poaceae	*Cenchrus ciliaris*	Grass	6.7	10		
	Centropodia forskalii (Yahl) Cope	Grass	67.7	13.3		
	Cynodon dactylon (L.) Pers.	Weed				83.3
	Panicum turgidum Forssk.	Grass	40			
	Pennisetum divisum (Gmel.) Henr.	Grass	10			
	Schismus barbatus (L.) Thell.	Annual			13.3	26.6
	Stipagrostis drarii (Taeck.) de Winter	Grass		76.7		
Cyperaceae	*Cyperus conglomeratus* Rottb.	Grass	16.7	10		