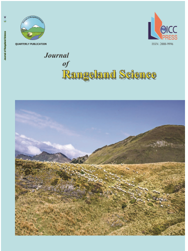

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Species diversity of desert and relationship to soil properties in dust sources of Khuzestan, southwest of Iran

Mehri Dinarvand[1]*, Hashem Keneshloo[2], Mohamad Fayaz[2], Farhad Khaksarian[3], Seyed Abdolhossein Arami[1], Kohzad Heydari[4]

[1]*Forests and Rangelands Research Department, Khuzestan Agricultural and Natural Resources Research and Education Center, Agricultural Research Education and Extension Organization (AREEO), Ahvaz, Iran.*
[2]*Research Institute of Forest and Rangelands, Agricultural Research Education and Extension Organization (AREEO), Tehran, Iran.*
[3]*Desert Research Division, Research Institute of Forests and Rangelands, Agricultural Research Education and Extension Organization (AREEO), Tehran, Iran.*
[4]*Gorgan University of Agricultural Sciences and Natural Resources, Iran.*

***Corresponding author**: m.dinarvand@areeo.ac.ir

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Abstract:
About 9% (349000 ha) of Khuzestan plain is the source of dust and it has seven dust hot spots. In this research, we investigated vegetation types, the floristic composition, life-form spectrum, and the phytogeography of the area during 2016–2020 by collecting vascular plants to provide an annotated checklist of the plants in Khuzestan province, Iran. In a period of five years, we focused on the vegetation of the septet areas as the source of dust and dune. A primary vegetation map was extracted from Google Earth images based on the texture, tone, and pattern, last vegetation map, and map of dust hot spots. To prepare vegetation types, they were checked in the field. The floristic composition, life-form spectrum, and the phytogeography of the area during five years were obtained by collecting vascular plants to provide a checklist of the sources of dust and dune. The 80 sample vegetation data from selected sites were analyzed using multivariate analysis methods. So, for assessing the relationship between plant species variation and environmental variation, the Canonical Correspondence Analysis (CCA) was used. The data of (80 samples of 8 species) and their soil factors (11 factors) were analysed using Rstudio software. The result showed that dust sources No. 1 and 2 had been covered by 24 vegetation types, and the species Seidlitzia rosmarinus, Halocnemum strobilaceum and Tamarix passerinoides were regarded as dominant. The dust source No. 3 was covered by 22 vegetation types and the species Halocnemum strobilaceum, Aeluropus lagopoides, Seidlitzia rosmarinus and Cornulaca monacantha regarded as dominant have been located in the east of Ahvaz. The dust source No. 4 had covered 39 vegetation types and dominant species were Aeluropus lagopoides, Halocnemum strobilaceum, Atriplex leucoclada, Salsola spp. Seidlitzia rosmarinus and Tamarix spp. in small rain reservoir. The dust sources No. 5, 6, 7 (with 249000 ha) were the major part of dust storm sources in Khuzestan, covered by 28 vegetation types. The CCA species-environment biplot showed that $CaCO_3$, EC, Na, SAR, ESP, OC, and CaMg from 11 soil factors were the key factors affecting vegetation in dust sources at our study site.

Keywords: Khuzestan; Dust; Floristic composition; Phytogeography; Life-form; Vascular plants

1. Introduction

The study of plant communities is the best way to learn about habit, habitat, niche, and vegetation structure as well as the various interactions among the plants in an ecosystem [1]. The relationships between vegetation and the environment are an important topic in community ecology [2,3]. Reduction of species diversity which is a significant threat to the earth has been found more important and has attracted attention among ecologists over recent years [4]. Plant species by origins are restricted to specific habitats and can be reached in that particular habitat due to the presence of optimum environmental factors (soil chemistry properties,

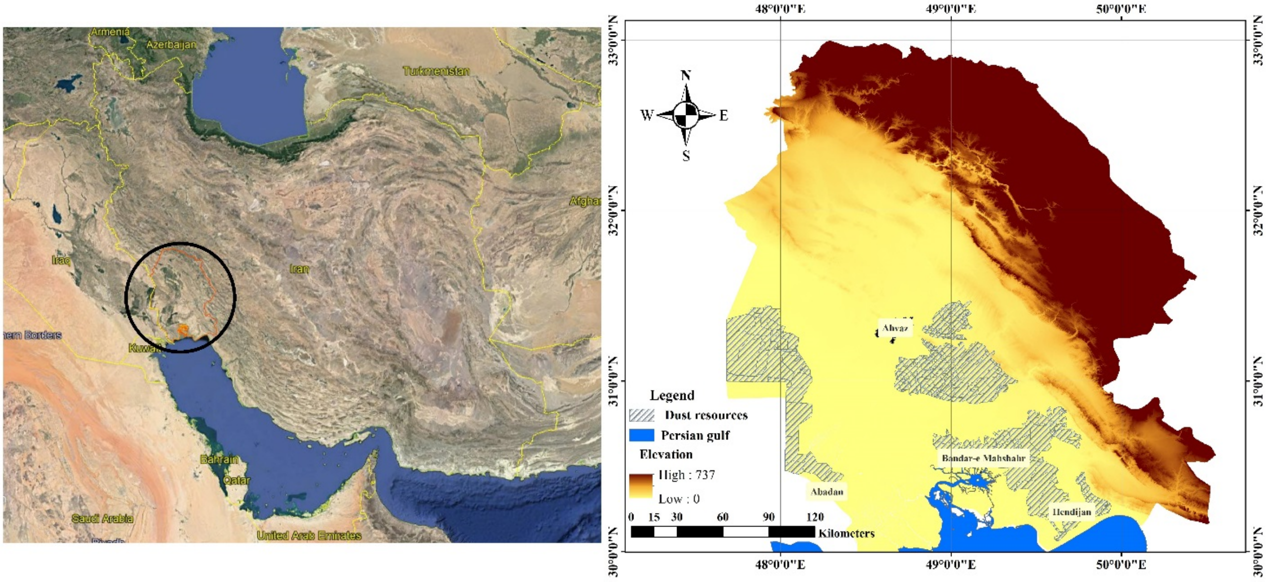

Figure 1. (Right): Map of Iran, the inset shows the position of Khuzestan province, (Left): Topographic map of Khuzestan province with dust source areas.

biotic and abiotic factors) which clearly show that plant community and vegetation composition change along with the environmental diversity from point to point [1]. Soil is a key factor controlling ecological processes in an ecosystem and plays a key role in the distribution and characteristics of community, because soil properties affect rainwater redistribution such as the dynamics of its runoff and infiltration [5–7]. Plant community and soil parameter dynamics cannot be separated in such a way that community distribution and diversity vary with chemical, physical, and microbiological properties of soils, especially in semi-arid and arid habitats [6, 8–10]. Studying the structure of vegetation in drylands, especially in dust sources has been of interest to many scientists because of its impression as a biological factor to soil fixing. Ecologists use a multivariate approach for seeking and summarizing an ecological set of plant data regarding environmental variables. The statistical study of these data helps to find an actual position of plant species in the field [11]. The multivariate statistical analysis programs assist the ecologists to analyze the effects of environmental variables on the whole numbers of species and to know the structure in the data set [12]. Canonical Correspondence Analysis (CCA) shows the relationship amongst the species as linear combinations of environmental variables graphically [13]. In recent decades, the dust phenomenon, as an environmental problem, has affected Human life in the Middle East. Dust storms are considered as an important environmental challenge in Iran. Dust storms are among the most severe environmental problems in certain regions of the world such as Iraq, Syria, Saudi Arabia, and Iran [14]. Most of the dust rose from the aeolian origin [15]. Sand and dust storms are usually developed in arid and semi-arid regions [16]. Iran with an area of 1.65 million Km^2 has a large area of salt deserts, sabkhas, and salt marshes [17]. The country's climate is mainly arid or semi-arid, except the northern coastal areas and mountain parts in Zagros and Alborz [18]. Khuzestan province covers an area of 64236 km^2 in the southwest of Iran and the border of Iraq is related to dust production sources [19]. An area of 349254 ha in Sahara-Sindian parts is the source of sand and dust storms in Khuzestan province [20–22]. These regions contain 7 areas: southwest of Hovizeh, northeast of Khoramshahr, east of Ahvaz, south, and southeast of Ahvaz, Bandar Emam to Omidieh, Mahshahr to Hendijan, and east of Hendijan [23]. According to the Global Bioclimatic Classification System of Rivas Martinez, this province has "Tropical desertic" and "Tropical xeric" in the south and "Mediterranean desertic continental" in the north [24].

This study was focused on dust sources area vegetation in the southwest of Iran.The research aim was to investigate plant species, desert vegetation types, and their relationships with soil parameters in dust sources in southwest of Iran. To characterize these patterns and interactions, 1) the plant community types of dust sources were described for the first time, and (2) primary soil elements influencing the dominant species in plant community types were identified. Studying these vegetation patterns and their relationships with soil improves plant conservation in fragile arid ecosystems by increasing our understanding of desert special dust sources ecosystem structure and function, as well as our ability to recover and protect desert ecosystems and species.

2. Materials and methods

2.1 Study area

2.2 Geography

Khuzestan province covers an area of 64236 km^2 in the southwest of Iran and the border of Iraq. It is situated in the latitude of 29°58′ to 32°04′ in North of the Equator and longitude of 47°41′ to 50°49′ in East of the Greenwich Meridian [19]. In Khuzestan, there are large rivers such as Karun, Karkhe, Dez, Zohreh and Jarahi [25]. The elevation

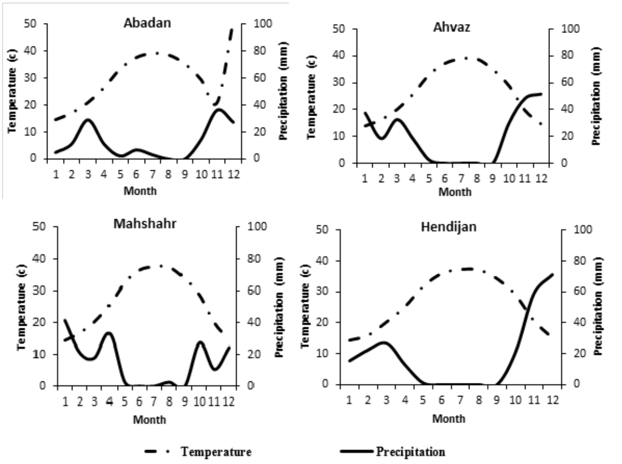

Figure 2. Ombrothermic graphs prepared using 2016 – 2020 data from synoptic stations close to the dust source areas.

ranges from 0 to 3500 m above sea level in Sefidkoh Mountain (Fig. 1) [25]. About 9% (349254 ha) of the Khuzestan plain are a source of dust [19, 21]. The research area is located in 7 dust hot spots: South of Horalazim (50000 ha) on subbasin of Karkheh river, south of Khorramshahr (28184 ha) on subbasin of Karoon river, east of Ahvaz (15620 ha), south and southeast of Ahvaz (112385 ha), Bandar Emam to Omidieh (86147 ha), Mahshahr to Omidiyeh (31980 ha), east of Hendijan (18836 ha) on the subbasin of Jarahi and Zohreh rivers (Fig. 1) [19, 22].

2.3 Climate

Most parts of the Khuzestan province are arid with average annual precipitation of 266 mm. However, in the northeastern parts, mean annual rainfall reaches 950 mm [25]. The main period of precipitation is during winter. The temperature in most parts reaches above 50°C during the summer (July). Most of this diversity is due to topographic factors and the proximity of the seas. From a climate perspective, the dust sources are located in semi-arid to humid areas so that these areas had no potential to produce dust [19]. Ombrothermic graphs were prepared for 2016 to 2020 (during the research years) data from synoptic stations close to the dust areas (Fig. 2).

2.4 Sampling method

Vegetation analysis of dust sources in Khuzestan province was carried out from 2016 to 2020. In this research, the Google Earth imagery database was used to estimate fractional tree and non-tree vegetation cover [26, 27]. A primary vegetation map was extracted from Google Earth images based on the texture, tone, and pattern, last vegetation map, and map of dust hot spots [19]. To prepare vegetation type, the inventory net method (2×2 km) was used and the intersection point was checked in the field with GPS. The dominant species in each homogeneous vegetation unit were the base to categorize the vegetation types based on [28]. At the next level, 8 dominant topic species were selected and 10 fixed plots established inhomogeneous vegetation types.

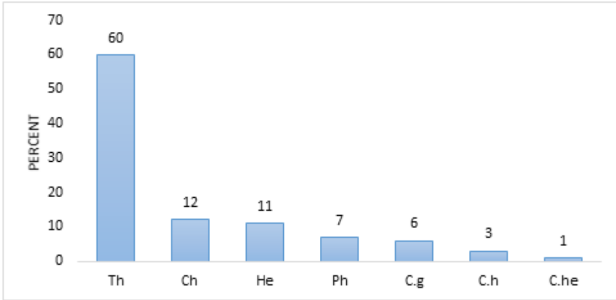

Figure 3. The life-form spectrum of the flora of dust source areas. Ch: chamaephyte, He: hemicryptophyte, Ph: phanerophyte, C: cryptophytes and Th: therophyte.

A total of 80 fixed plots were sampled. The minimum plot size was determined based on species-area curves produced for each unit sampled [29, 30]. The Braun Blanquet method was used in estimating the canopy cover percentage [31].

2.5 Floristic survey

Species richness was considered over five years (2016–2020); at this time, they focused on the vegetation of the septet areas of the source of dust and dune, during which vascular plant specimens were collected from 7 sources of dust hot spots. Collected plants were dried and labeled precisely for Khuzestan Agricultural and Natural Resources Research and Education Center herbarium specimens. Plant specimens were identified at levels of species, subspecies, and variety using relevant Floras, mainly ”Flora of Khuzestan Province”, ”Flora Iranica”, ”Flora of Iran”, ”Flora of Khuzestan”, ”Flora of Iraq” , ” Flora of Turkey and the East Aegean Islands”, ”Flora Palestina” and ”Trees and Shrubs of Iran” [32–39]. The floristic list was presented alphabetically following the (APGIV, 2016) for the classification. The chorotype of each taxon was determined according to the distribution data extracted from the above-mentioned Floras and papers. The terminology and delimitation of the main phytogeographical units (IT, Mediterranean, ES, and SS) were based on classical works [20, 40]. Life forms of the plants were determined [41].

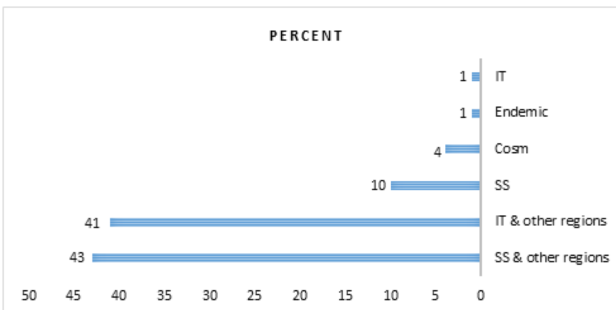

Figure 4. The proportion of the phytogeographical groups in the flora dust source areas. IT: Irano-Turanian, SS: Sahara-Sindian, Cosm: Cosmopolitan, Endemic.

Table 1. List of the most species-rich vascular plant families in dust source areas.

Families	Genera	Species
Amaranthaceae	16	30
Asteraceae	21	23
Poaceae	16	18
Fabaceae	7	9
Ressedaceae	2	7
Brassicaceae	4	6

2.6 Soil analysis

In eight selected sits, two soil samples were taken from 0 – 30 and 3 – 60 (cm) depths. Samples were air-dried and sieved to pass a 2 mm sieve to remove rock, gravel, and debris. Then, one subsample was labeled and kept in a plastic bag for physical and chemical property analysis in terms of properties such as texture, pH, electrical conductivity (EC), CaMg, organic carbon (OC), Na, and SAR. The soil analyses were conducted at the Soil Testing Laboratory of the Research Institute of Forests and Rangeland of Iran.

2.7 Data analysis

The 80 sample vegetation data from selected sites were analyzed using multivariate analysis methods. So, for assessing the relationship between plant species variation and environmental variation, the canonical correspondence analysis (CCA) was used [42]. The data of abundance-cover scale of all samples (80 samples of 8 species) and their soil factors (11 factors) were entered into Microsoft Excel sheets and then, transferred to the RStudio software. The canonical correspondence analysis (CCA) was performed using the package vegan, permute, lattice, labdsv, dave, and writexl from RStudio software (version 1.3.1093). For determining discriminate analysis, Wilk's Lambda was used.

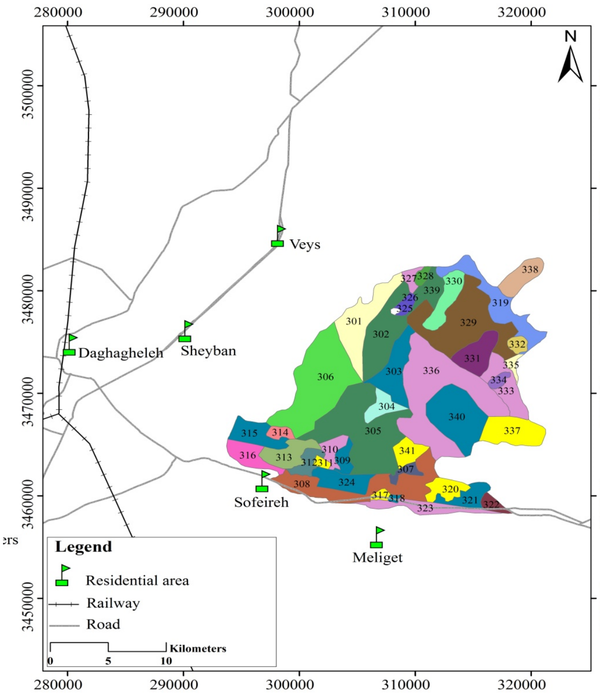

Figure 6. Map of vegetation types of dust sources No. 3.

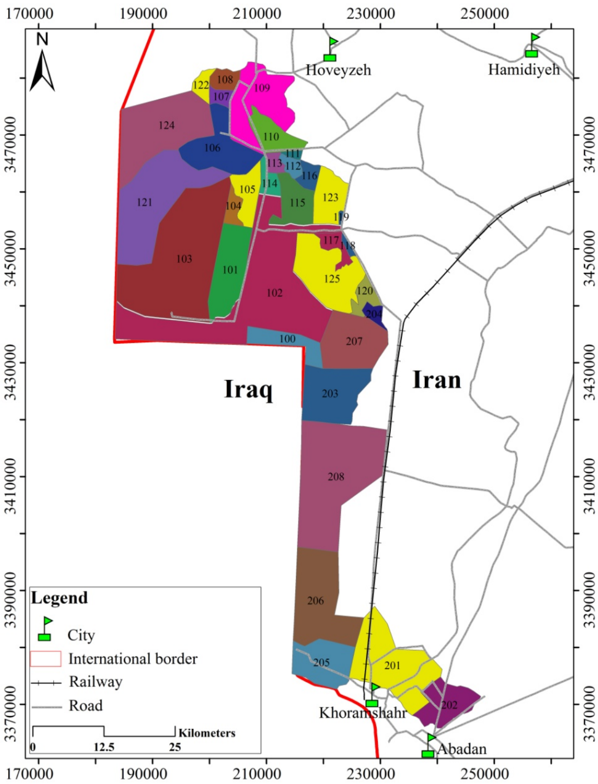

Figure 5. Map of vegetation types of dust sources No. 1, 2.

3. Results

a) Floristic composition

The total number of 151 species and infraspecific taxa of vascular plants belonging to 114 genera and 39 plant families has been collected and identified from the study area. Angiosperms include Dicots with 128 species, 92 genera, and 33 families followed by Monocots with 24 species, 22 genera, and 6 families. The richest families are Amaranthaceae Juss. (Including Chenopodiaceae) (16 genera/30 species) (Table 1). All of the herbarium specimens have been preserved in Khuzestan Agricultural and Natural Resources Research and Education Center Herbarium.

b) Life form

Therophytes (60%), chamaephyte (12%), hemicryptophyte (11%), and phanerophyte (7%) are the dominant life forms in dust sources. Finally, cryptophytes (geophytes, hydrophytes, and hygrophytes) having different regenerating bodies include 10% of the species. (Fig. 3).

c) Phytogeography

Most of the species belong to the Sahara-Sindian and other floristic regions, Irano-Turanian and others are on the second time. Phytogeographical elements of the study area are; SS and other regions, IT and other regions, SS, Cosm,

Table 2. Vegetation type of dust sources No. 1, 2.
(A: Agriculture, B: Bare, C: cultivated area, S.m: Salt marsh, Halo: Halocnemum strobilaceum (Pall.) M.Bieb., Aelu: Aeluropus lagopoides (L.) Thwaites, Suae: Suaeda vermiculata Forssk. ex J.F.Gmel., Tama: Tamarix passerinoides Del., Lyci: Lycium depressum Stocks, Alha: Alhagi graecorum Boiss., Phra: Phragmites australis (Cav.) Trin. ex Steud., Sals: Salsola jordanicola Eig., Seid: Seidlitzia rosmarinus (Ehrenb.) Bge. ex Boiss., Atri: Atriplex leucoclada Boiss.)

Type	Code	Type	Code
A	114	Seid, Lyci, Suae, Tama	102, 117
B	100, 112, 205	Suae	107
C	105, 122, 123, 125, 201	Suae, Aelu, Atri	204
Halo	104	Suae, Aelu, Lyci	111
Halo, Aelu, Suae, Tama	106	Suae, Aelu, Lyci, Phra	113
Halo, Aelu, Tama	208, 124	Suae, Aelu, Lyci, Seid	120
Lyci, Alha, Suae	108	Suae, Atri, Seid, Tama	119, 203
Lyci,Suae, Tama	110	Suae, Lyci, Seid	109
Phra	101	Suae, Lyci, Tama	116, 118
Sals, Suae	202	Tama, Aelu, Atri, Suae	115
S.m	206	Tama, Halo, Phra	121
Seid, Aelu, Tama	207	Tama, Suae	103

Endemic and, IT with 43% (species), 41% (757), 10% (77), 4% (100), 1% (77), 1% (214), respectively (Fig. 4).

d) **Vegetation type**

The dust sources No. 1 and 2 are located in the southwest of Hovayzeh and northeast of Khoramshahr. These areas are covered with 24 various vegetation types (Table 2). All of them are named with the number code in Fig. 5. Vegetation types are named according to the generic name of four dominant species in the area.

The dust source No. 3 is located in the east of Ahvaz, between Sofeireh and Vays area. These areas are covered with 21 various vegetation types (Table 3). All of them are named with the number code in Fig. 6.

The dust source No. 4 is located in the south and southeast of Ahvaz. These areas are covered with 41 various vegetation types (Table 4). All of them are named with the number code in Fig. 7.

The dust sources No. 5, 6, and 7 are located in Sarbandar to Omidyeh and Mahshahr to Hendijan. These areas are covered with 29 various vegetation types (Table 5). All of them are named with the number code in Fig. 8.

e) **Vegetation and physiognomy**

These regions contain 7 areas: South of Horalazim (50000 ha) on subbasin of Karkheh river, south of Khorramshahr

Table 3. Vegetation type of dust sources No. 3.
(B: Bare, C: cultivated area, Halo: Halocnemum strobilaceum (Pall.) M. Bieb., Aelu: Aeluropus lagopoides (L.) Thwaites, Tama: Tamarix passerinoides Del., Alha: Alhagi graecorum Boiss., Sals: Salsola jordanicola Eig., Seid: Seidlitzia rosmarinus (Ehrenb.) Bge. ex Boiss., Penn: Pennisetum divisum (Forssk. ex J.F. Gmel.) Henrard, Pros: Prosopis farcta (Banks and Sol.) J.F.Macbr., Haloch: Halocharis sulphurea (Moq.) Moq., Corn: Cornulaca aucheri Moq., Capp: Capparis spinosa L., Conv: Convolvulus oxyphyllus Boiss.)

Vegetation Type	Code	Vegetation Type	Code
Aelu, Halo	302, 305, 339	Halo, Aelu	310, 312, 323, 327, 333, 336
Aelu, Halo, Penn, Pros	329	Halo, Aelu, Conv	313
Aelu, Haloch, Halo	328	Halo, Aelu, Haloch	304
Alha	338	Halo, Aelu, Tama	316
B	301, 335	Halo, Corn, Haloch	334
C	311, 317, 320, 322, 337, 341	Halo, Sals	307
Corn	306	Pros, Aelu, Corn	325, 326
Corn, Aelu, Halo	314	Pros, Corn, + Haloch, Halo	331
Corn, Alha, Tama	330	Pros, Corn, Halo	332
Corn, Capp	319	Seid, Aelu, Tama	308
Halo	303, 309, 315, 318, 321, 324, 340		

Table 4. Vegetation type of dust sources No. 4.
(A: Agriculture, B: Bare, C: cultivated area, Halo: Halocnemum strobilaceum (Pall.) M.Bieb., Aelu: Aeluropus lagopoides (L.) Thwaites, Suae: Suaeda vermiculata Forssk. ex J.F.Gmel., Tama: Tamarix passerinoides Del., Lyci: Lycium depressum Stocks, Alha: Alhagi graecorum Boiss., Sals: Salsola jordanicola Eig., Seid: Seidlitzia rosmarinus (Ehrenb.) Bge. ex Boiss., Atri: Atriplex leucoclada Boiss., Corn: Cornulaca aucheri Moq., Conv: Convolvulus oxyphyllus Boiss. Pros: Prosopis farcta (Banks and Sol.) J.F.Macbr., Haloth: Halothamnus iranicus Botsch., Penn: Pennisetum divisum (Forssk. ex J.F.Gmel.) Henrard, Cres: Cressa cretica L., Malv: Malva parviflora L., Haloch: Halocharis sulphurea (Moq.) Moq., Psyl: Psylliostachys spicata (Willd.) Nevski Scro: Scrophularia deserti Delile, Ducr: Ducrosia anethifolia (DC.) Boiss.)

Vegetation Type	Code	Vegetation Type	Code
Aelu	455	Penn, Conv	480
Aelu, Alha, Corn, Haloth	470	Sals, Alha, Psyl	437
Aelu, Atri	431, 432	Scro, Ducr	402
Aelu, Atri, Halo, Sals	414	Scro, Ducr, Pros	403
Aelu, Atri, Sals, Tama	412, 434	Seid	430, 438, 444, 452
Aelu, Atri, Tama	433	Seid, Aelu	464
Aelu, Cres, Tama	456	Seid, Aelu, Lyci	463
Aelu, Halo	410	Seid, Atri, Haloch	462
Aelu, Halo, Sals	418	Seid, Corn, Haloth	467
A	478	Seid, Halo, Haloth	466
Alha	401, 404, 417, 426	Seid, Lyci, Tama	460
Alha, Haloth, Tama, Pros	469	Tama, Aelu	485
Alha, Tama	411, 424	Tama, Aelu, Seid, Suae	457
Atri, Aelu, Malv	419, 461	Tama, Alha, Sals	473
B	405, 406, 408, 421, 422, 429, 439, 440, 474, 475, 477, 479	Tama, Alha, Seid	459
C	407, 409, 415, 423, 425, 443, 458, 465, 468, 471, 472, 481, 482, 483, 484	Tama, Atri, Seid	454
Halo	413, 436, 441, 448	Tama, Halo	451
Halo, Aelu	450	Tama, Halo, Sals	416
Halo, Alha, Sals	446, 447, 453	Tama, Halo, Seid	445
Halo, Lyci	476	Tama, Psyl	427, 428, 435, 442
Haloch, Alha, Sals, Suae	449		

(28184 ha) on subbasin of Karoon river, east of Ahvaz (15620 ha), south and southeast of Ahvaz (112385 ha), Bandar Emam to Omidiyeh (86147 ha), Mahshahr to Omidiyeh (31980 ha), east of Hendijan (18836 ha) on subbasin of Jarahi and Zohreh rivers. This area includes four types of vegetation, wetland species, hygrophyte plants, terrestrial halophyte, and psamophytic plants. Although the main sources of dust rise have been covered with two classes of vegetation (Halophyte and Pasmophyte species), the dune with 77 and salty soil places with 43 species, also 28 species adapted to both climate and soil of the areas.

f) Ordination

The relationship between selected species, and soil variation as environmental factors was assessed using canonical correspondence analysis (CCA). The cumulative variance percentages of species-environment relation for axes of CCA (and their eigenvalues) are 45.19 (0.856) and 77.88 (0.789) for axes 1 and 2, respectively. The species-environment correlations calculated by the first two axes of CCA are: 0.45 and 0.32 (Table 6)

Correlations between the first two CCA axes and soil factors were determined in a way that the strongest correlations with the first CCA axis were $CaCO_3$, EC, Na, CaMg, SAR, and ESP. The second CCA axis was correlated with organic carbon (OC) (Table 7)

Correlations between the first two CCA axes and species were shown in Table 8. The species Atriplex leucoclada Boiss., Halocnemum strobilaceum (Pall.) M. Bieb. have the highest positive correlation and Capparis spinosa L. had high negative correlation with the first axis. The species Lycium depressum Stocks and Salsola jordanicola Eig. have the highest positive correlation to second axis.

The CCA species-environment biplot of the first two axes (Fig. 9) Shows that each species reflects the ecological relationships between species and its environment. The first CCA axis represents $CaCO_3$, EC, Na, and SAR, increasing from left to right. The second axis reflects organic carbon (OC) gradually increasing from bottom to top along the second axis. The species Lycium depressum Stocks and Salsola jordanicola Eig. influenced by clay, Halocnemum strobilaceum (Pall.) M.Bieb. present at a place with high EC and Na in soil. The species Atriplex leucoclada Boiss. and Suaeda aegyptica (Hasselq.) Zohary occurred at alkali soil with high pH. The species Suaeda vermiculata Forssk. ex J. F. Gmel. closed to silty and Capparis spinosa L. to sandy soil but the distribution of Seidlitzia rosmarinus (Ehrenb.) Bge. ex Boiss. related to ESP, OC, and CaMg in soil.

4. Discussion

a) Vegetation community

The structure and composition of a desert, semi-desert, and steppification of desert plant communities are simple; the species diversity is low and dominated by small xeric,

Table 5. Vegetation type of dust sources No. 5, 6, 7.
(A: Agriculture, B: Bare, C: cultivated area, Halo: Halocnemum strobilaceum (Pall.) M.Bieb., Aelu: Aeluropus lagopoides (L.) Thwaites, Suae: Suaeda vermiculata Forssk. ex J.F.Gmel., Tama: Tamarix passerinoides Del., Alha: Alhagi graecorum Boiss., Sals: Salsola jordanicola Eig., Seid: Seidlitzia rosmarinus (Ehrenb.) Bge. ex Boiss., Atri: Atriplex leucoclada Boiss., Pros: Prosopis farcta (Banks and Sol.) J.F.Macbr., Haloth: Halothamnus iranicus Botsch., Penn: Pennisetum divisum (Forssk. ex J.F.Gmel.) Henrard, Cres: Cressa cretica L., Haloch: Halocharis sulphurea (Moq.) Moq., Psyl: Psylliostachys spicata (Willd.) Nevski, Capp: Capparis spinosa L., Anab: Anabasis setifera Moq., Ruta: Ruta buxbaumii Poir., Stip: Stipa capensis Thunb., Suae. ae: Suaeda aegyptica (Hasselq.) Zohary, Achi: Achillea santolinoides subsp. wilhelmsii (K.Koch) Greuter).

Vegetation Type	**Code**	**Vegetation Type**	**Code**
Achi, Alha, Haloch	517	Halo, Aelu, Psyl	712
Aelu	519, 703	Halo, Aelu, Tama	526, 702
Aelu, Atri, Suae	710	Halo, Tama	513, 516, 717
Aelu, Cres	512	Ruta	522
Aelu, Cres, Halo	514	Seid, Atri, Halo	707
Aelu, Pros	504	Seid, Atri, Suae	709
Aelur, Halo, Sals, Suae	515	Seid, Halo, Haloth	711
A	506	Stip, Tama	502
Anab, Aelu	417	Suae	713
Atri, Capp	501	Suae, Halo	716
B	510, 511, 518, 521, 523, 605, 701, 704, 706, 715	Suae. ae	527
C	505, 509, 520, 524, 705, 708, 718	Tama, Aelu, Halo	602
Halo	601	Tama, Aelu, Suae	525
Halo, Aelu	503, 603, 604	Wetland+ Saltland	508
Halo, Aelu, Cres, Suae	507		

halophilic, hyper-xeric shrubs, and perennial herb plants that are capable of surviving the regions harsh and variable environmental conditions [3]. Desert vegetation is often the main element in arid and semi-arid regions because of landscape preservation, wind-breaking, soil fixation [43]. A glance to Khuzestan province after 10 years (2009–2018) field surveys found a territory with more than 60% alluvial plain that was covered by the arid and warm climate, an area with 349254 ha as the source of dust [23]. It has fragile desert ecosystems like other neighboring countries including Kuwait, Iraq, the Arabian Peninsula, and the margin of the Red Sea that need strong management to survive [16, 44, 45]. Dust storms are one of the present problems in the west and southwest of Iran [46]. About 9% of the Khuzestan plain area is related to dust production sources [19]. The elevation in this area varies from sea level to 150 m above sea level. Geomorphologically, the area is composed of an alluvial plain [47]. Five main geomorphological elements in the area are saline and sandy shores, saline and highly saline plains, wetlands, and rivers, dune areas, agricultural and urban or rural lands [48]. The identified sources based on the type of usage and area include demolished pastures, abandoned rain-fed agricultural lands, dried wetlands, ponds, and irrigated agricultural lands [19]. All dust resources have poor species richness because of a flat plane, covered with tiny alluvials or sandy places without any geographic gradients, but variations in soil characters and human activity are the main causes of different vegetations in all parts of areas [21, 22]. The main sources of dust rise have been covered with two classes of vegetation (Halophyte and Pasmophyte species). From the 985 species of Khuzestan province, 153 equivalent 15.5% are found in these areas, the dune with 77, salty soil places with 43 and 28 species adapted to both climate and soil of the areas [23]. Most of them belong to therophytes (88 species) and then,

Table 6. Eigenvalues and Species-environment correlations of the four CCA axes.

	CCA1	CCA2	CCA3	CCA4
Eigenvalue	<u>0.856</u>	<u>0.789</u>	0.682	0.608
Species-environment correlations	0.451	0.327	0.209	0.002
Cumulative variance%	45.19	77.88	98.87	99.15

Table 7. Intra-set correlations of environmental factors with the four CCA axes.

Variables	CCA1	CCA2	CCA3	CCA4
pH	0.239	-0.317	-0.409	0.361
EC	0.488	0.184	0.404	0.395
$CaCO_3$	0.703	0.014	0.125	0.348
Na	0.511	0.141	0.259	0.147
CaMg	-0.471	0.377	0.034	-0.052
SAR	0.610	0.106	0.247	0.338
ESP	-0.425	0.192	0.215	0.337
Sand	-0.261	-0.346	-0.239	0.844
Silt	0.044	-0.152	0.344	-0.683
Clay	0.190	0.306	-0.017	0.118
OC	-0.323	0.432	0.344	-0.092

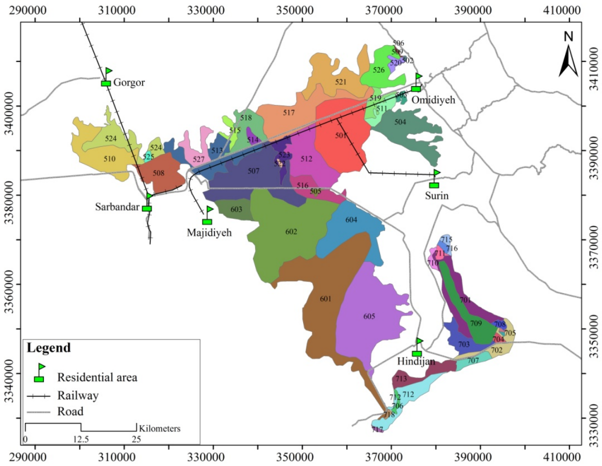

Figure 8. Map of vegetation types of dust sources No. 5, 6 and 7.

chamaephyte (18), hemicryptophyte (13), phanerophyte (11), and cryptophyte (10). In dust sources No. 1 and 2, (with 258622 ha) 24 vegetation types were found. The species Seidlitzia rosmarinus (Ehrenb.) Bge. ex Boiss., Halocnemum strobilaceum (Pall.) M. Bieb. and Tamarix passerinoides Del. are dominant. The area is covered with other halophytes (such as Suaeda vermiculata Forssk. ex J.F.Gmel.) and hydrophyte species (such as Phragmites australis (Cav.) Trin. ex Steud.). Also in this region, there are Margins of Horalazim with 14135 ha, a bare area with 12195 ha, afforestation (Prosopis juliflora (Sw.) DC.) with 1578 ha and cultivated area 34957 ha (Table 2). In the dust source No. 3 (with 42586 ha), the species Halocnemum strobilaceum (Pall.) M.Bieb., Aeluropus lagopoides (L.) Thwaites, Seidlitzia rosmarinus (Ehrenb.) Bge. ex Boiss. and Cornulaca aucheri Moq. are dominant. They covered the area with other psamophyte (such as Pennisetum divisum (Forssk. ex J.F.Gmel.) Henrard) and Prosopis farcta (Banks and Sol.) J.F.Macbr., Convolvulus oxyphyllus Boiss. and Carthamus oxyacantha M.Bieb. on demolition area. In this region, 22 vegetation types were found. Bare area (2005 ha) and cultivated area (2931 ha) were coved as patches. The dust source No. 4 with 186598 ha area covered with 39 vegetation types. The species Aeluropus lagopoides (L.) Thwaites, Halocnemum strobilaceum (Pall.) M.Bieb., Atriplex leucoclada Boiss. Salsola spp. Seidlitzia rosmarinus (Ehrenb.) Bge. ex Boiss. and Tamarix spp. in small rain reservoirs are dominant.

The bare and cultivated areas with 23202 and 64396 ha respectively are the vast parts. Seasonal flood causes to genesis two wetlands (Sharifieh and Mansoryeh) as a part of Shadegan international wetland. In recent years, these wetlands have been going dry because of drought, the construction of dams and other human disrupt in nature [49]. The dust sources, No. 5, 6, and 7 (with 249986 ha) are the major parts of dust storm sources in Khuzestan. In this region, 28 vegetation types were found. The species Atriplex leucoclada Boiss., Tamarix passerinoides Del. and Halocnemum strobilaceum (Pall.) M.Bieb. are dominant. The biggest bare area (58037 ha) in Khuzestan is coved as patches in these sources of dust. The flood plain between Jarahy and Zohreh rivers causes to genesis

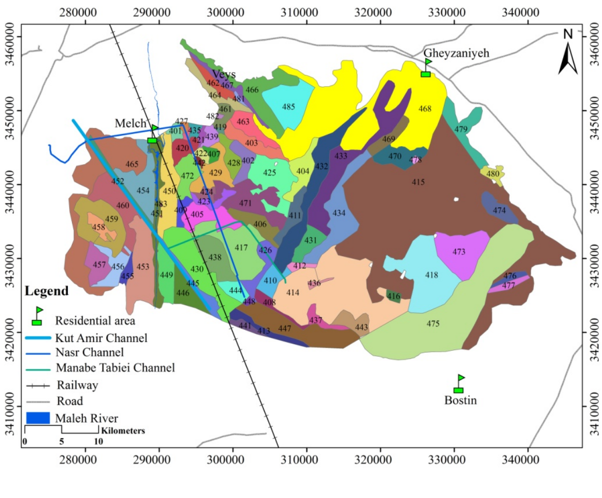

Figure 7. Map of vegetation types of dust sources No. 4.

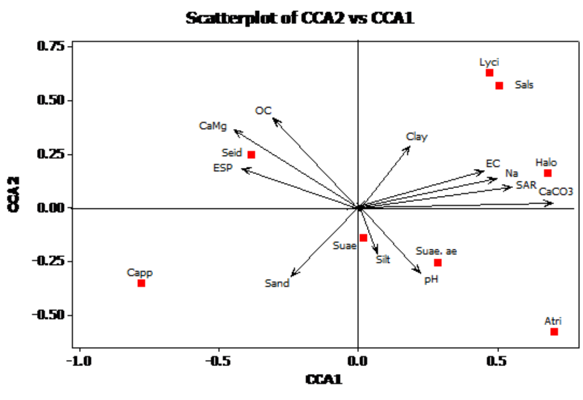

Figure 9. CCA species-environment biplot of the first two axes, with arrows representing the environmental factors and abbreviation name indicating the 8 species.

Table 8. Intra-set correlations of species with the four CCA axes.

Species name	Abbrev.	CCA1	CCA2	CCA3	CCA4
Atriplex leucoclada Boiss.	Atri	0.703	-0.576	-0.341	0.231
Capparis spinosa L.	Capp	-0.783	-0.350	0.190	-0.370
Halocnemum strobilaceum (Pall.) M.Bieb	Halo	0.681	0.162	-0.322	0.295
Lycium depressum Stocks	Lyci	0.472	0.627	-0.523	-0.157
Salsola jordanicola Eig.	Sals	0.507	0.566	-0.221	-0.162
Seidlitzia rosmarinus (Ehrenb.) Bge. ex Boiss.	Seid	-0.387	0.247	0.129	-0.114
Suaeda aegyptica (Hasselq.) Zohary	Suae. ae	0.284	-0.254	-0.227	0.385
Suaeda vermiculata Forssk. ex J.F.Gmel	Suae	0.017	-0.138	-0.240	0.387

Hore Shrayee wetland. This wetland is covered with Halocnemum strobilaceum (Pall.) M.Bieb. and Aeluropus lagopoides as dominance species. Unfortunately, just like wetlands Sharifieh and Mansoryeh wetlands, it is going dry because of drought, construction of dams and other human disrupt in nature [50]. The most important limiting factor for plant growth is water shortage. Drought could significantly change the natural vegetation cover. In Iraq and Syria, rainfall reduction and Turkey intense human activities such as dam construction have reduced vegetation cover so that dust storms have increased. Therefore, these areas have a high potential to increase dust particles in the environment. Hence, these countries (Iraq, Turkey, and Syria) could be considered as the main focus areas of dust, particularly affecting the western provinces of Iran [51]. The most significant factor of intense dust storms is vegetation removal [52]. Regardless of the reason, our observation showed that a negative correlation is especially significant in dust sources just like in Mongolia of China when vegetation decreases, the occurrence of dust storms increases [53].

b) Environmental gradient

Understanding the relationships between environmental variables and vegetation distribution helps us to apply these findings in the management, reclamation, and development of arid and semi-arid ecosystems [54]. For a quantitative account of vegetation-environmental factor, the relationships in the dust sources of the southwest of Iran were regarded using the vegetation type map (community groups) and CCA. The dominant species (8 topic species) in each homogeneous vegetation unit were selected. In all parts of areas, the flat plane is covered with tiny alluvials or sandy place without any geographic gradients, so the variation in soil characters was one of the main causes of environmental factors. Numerous studies have shown that soil properties play an important role in the determination of vegetation groups [55–58]. The CCA species-environment biplot showed that $CaCO_3$, EC, Na, SAR, ESP, OC, and CaMg from 11 soil factors are the key factors affecting vegetation in dust sources at our study site. The soil properties and selected species can be summarized as the species Lycium depressum Stocks and Salsola jordanicola Eig. influenced by clay, Halocnemum strobilaceum (Pall.) M.Bieb. present at a place with high EC and Na in soil. The species Atriplex leucoclada Boiss. and Suaeda aegyptica (Hasselq.) Zohary occurred at alkali soil with high pH. The species Suaeda vermiculata Forssk. ex J.F.Gmel close to silty and Capparis spinosa L. to sandy soil, but the distribution of Seidlitzia Rosmarinus (Ehrenb.) Bge. ex Boiss. related to ESP, OC, and CaMg in soil. Gholinejad and Jonaidi Jafari showed that soil physical factors are the most important factors in the distribution of plant community in Saral rangelands of Kurdistan proven that is not consistent with our study [59].

5. Conclusion

The harsh climate and Human activities and their impacts in various forms such as industrial, civil activities, agriculture, changing aquatic resources, grazing, and developing artificial landscapes are major reasons for the gradual reduction of species richness. Khuzestan province has fragile ecosystems that need strong management to survive. Poor vegetation coverage is one of the important factors for the frequent occurrence of dust storms. Vegetation can increase the entrapment of mobile sand and dust, and decrease soil loss by the wind as a result of reduction of soil erodibility and wind speed. Shrubs such as Tamarix spp., Halocnemum strobilaceum (Pall.) M.Bieb. and perennial species like Seidlitzia rosmarinus (Ehrenb.) Bge. ex Boiss., Atriplex leucoclada Boiss. are the best natural cover, this represents their successful adaptation to climate and soil of the area, so this local species can be the best cases for biological fixation of soil. The main species in seven dust sources are Therophytes species (60%); they are divided into spring species like Matricaria aurea (Loefl.) Schultz-Bip. and autumn halophytes such as Bienertia cycloptera (Fig. 11 l) Bunge and Salsola jordanicola Eig.; however, they can help pedogenesis and reform the bed.

Conflict of interest statement:
The authors declare that they have no conflict of interest.

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