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# Monitoring vegetation changes in the dust center of Southwest Iran

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# Abstract

An area equivalent to 26,000 hectares of the dust center of southwestern Iran, located in Khuzestan province, was stabilized between 2015 to 2021 in the form of a biological stabilization and water distribution program. For biological stabilization, *Prosopis juliflora* shrubs were used and irrigation was done with tankers or furrows at intervals. The objective of this study was to utilize remote sensing technologies, geographic information systems, and field investigation to determine the vegetation changes in two time periods in seven regions within the South West of Iran, during the years 2016 and 2021 (Before and after planting), to show the impact of the native planted species on the natural environment. As the processed images show, there have been wide fluctuations in vegetation in the study area from 2016 to 2021. The slope of changes was positive in all the investigated points. In the first year of the research, in some areas, no plant species were seen or they were very scattered, but in 2021, plant species such as *Salsola jurdanica, Atriplex leucoclada, Aeloropus lagopoides, and Bienertia cycloptera* were observed with a high percentage of coverage. Of course, it should be noted that the region has a good seed bank. The results of monitoring vegetation changes in the dust center of Southwest Iran (2016–2021), revealed that the irrigation method of seedling area and precipitation conservation structure has an effective role in species diversity of local vegetation in deserts or restoration of fragile rangelands.


# Introduction

Desertification is considered a serious environmental problem in arid and semi-arid regions worldwide (Abahussain et al. 2002; Alalwany et al. 2021; Duta and Chaudhuri, 2015). Therefore, much research has recently focused on mapping, assessing, and monitoring its effects based on regional and local scales. Ecologically, desertification is a severe hazard that has negative impacts on environmental sustainability (Salih et al. 2021). It is an important factor behind land degradation, which impacts agricultural productivity, bio-diversity, groundwater, and overall water availability (Joshi and Solanki 2009). As well, desertification leads to sand encroachment on urban areas, farms, roads and railways, air pollution, and the destruction of the natural habitats of variety of flora and fauna, threating the region's biodiversity (Kundu and Dutta 2011). Plants play a pivotal role in the stability of natural ecosystems (Duran Zuazo & Rodriguez Pleguezulo, 2008). As one of the basic concepts in natural resources management, diversity is essential to the health and production of ecosystems (Mesdaghi, 2005). While assessing the current state of vegetation, it is possible to provide appropriate management recommendations for the conservation and improvement of natural habitats by continuously measuring vegetation cover during different periods (Dinarvand et al., 2016; Dinarvand et al., 2022). Plants directly influence soil hydrology by creating a natural barrier, increasing infiltration, and improving evapotranspiration (Capilleri et al., 2016). The presence of an aerial cover along with the root system, rhizomes, and stolon physically prevents wind and water erosion (Gyssels et al., 2005). The native plants of such areas are valuable species due to their ability to adapt to harsh environmental conditions, and therefore their identification is of great importance (Dinarvand et al., 2022). In order to monitor vegetation changes, the use of satellite data in a large area has advantages compared to studies based on traditional methods (Pei et al., 2018). Also, unlike the traditional methods, nowadays satellites like Sentinel-2 can produce new data from every part of the earth in intervals of less than 5 days and currently provide it to everyone for free. The Sentinel 2 satellite includes two twin satellites named Sentinel-2A and Sentinel-2B and they move in the opposite direction in the orbit. The imaging sensor installed on Sentinel 2 is called MSI, which provides unique images (Probeck et al., 2019). Sentinel 2 satellite data contains a large amount of data with high spatial resolution (maximum 10 meters), spectral resolution (13 bands) and time (minimum 5 days) suitable for vegetation monitoring (Mousavi et al., 2020; Khorrami et al., 2021). One of the most widely used indicators for vegetation monitoring is the NDVI index, which is the basic criterion for vegetation change studies (Kundu et al., 2016). Many studies have been done based on monitoring the response of plants to climate fluctuations with the NDVI index (Bao et al. 2014; Bayat et al. 2016; Nasiri et al. 2022; Bayle et al., 2019; Rajah et al., 2019; Notti et al., 2022; Matthew et al., 2016; Plutalova et al., 2021; Li, et al., 2022). An area equivalent to 737790 hectares of the Khuzestan plain in Iran is considered dust sources (Abbasi, 2021). This area is broadly classified into seven sub-areas, namely southwest of Hoveyzeh, the north and east of Khorramshahr, east of Ahvaz, the south and southeast of Ahvaz, Bandar Imam to Omidieh, Mahshahr to Hindijan, and East Hindijan (Heidarian, et al., 2018). The objective of this study was to utilizing remote sensing technologies, geographic information systems, and and field investigation to determine the vegetation changes in two time periods in seven regions within the South West of Iran, during the years 2016 and 2021 (Before and after planting), to show the impact of the native planted species on the natural environment.

## Materials And Methods

# Study area

Khuzestan province covers an area of 64236 km$^2$ in the southwest of Iran and border of Iraq. It is situated in the latitudes of 29° 58´ to 32° 04´ N of the Equator and longitudes of 47° 41´ to 50° 49' E of the Greenwich Meridian (Heidarian et al, 2018). In Khuzestan, there are large rivers, such as Karun, Karkhe, Dez, Zohreh and Jarahi (Masoudi & Elhaeesahar 2016). The elevation ranges from 0 to 3500 meters above sea level in Sefidkoh Mountain (Masoudi & Elhaeesahar 2016). About 9% (349254 ha) of Khuzestan plain is sources of dust (Heidarian et al, 2018, Azhdari et al. 2015). The main dust center of the southeast of Ahvaz is located 25 km away from the Ahvaz city along the Ahvaz-Mahshahr highway between 48˚ 47’ to 49˚ 17’ E and 30˚ 45’ to 31˚ 15’ N. This area is limited to the airport from the north, Ghazaniyeh from the east, Shadegan wetland from the south, and Maleh creek from the west (Fig. 1). A total of 39 plant types have been identified in this area (Dinarvand et al. 2018). Based on the modified De Martonne climatic classification method, Khuzestan province can be divided into three climatic classes: hot semi-arid, hot arid, and hot hyper-arid (Dinarvand and Jamzad 2020). More than half of the area of the Khuzestan province, as well as the entire dust centers, is located in the hot hyper-arid climate category.

## Climate Data

Climate data from the Ahvaz synoptic station for the past 24 years (1996–2020) were obtained to prepare the ombrothermic diagram (Fig. 2). The average temperature of the study area is between 26.2 to 26.9 C°. The average maximum temperature ranges between 33 C in the east to 33.4 C and the west. The average minimum temperature falls between 19.2 C in the west of the region and 19.5 C in the east. Precipitation decreases from a maximum of 213 mm in the west to a minimum of 166 mm in the south. The area received ample rainfall in the fall of 2018 and spring of 2019, leading to seasonal floods (Table 1).

According to the Global Bioclimatic Classification System of Rivas Martinez, Khuzestan province has “Tropical desertic” and “Tropical xeric” in the south and “Mediterranean desertic continental” in the north (Djamali et al. 2012).

## Floristic Survey

Plant specimens were identified at species, subspecies and variety, using relevant Floras, mainly "*Flora of Khuzestan Province*" (Dinarvand, 2021), "*Flora Iranica*" (Rechinger 1963–2015), "*Flora of Iran*" (Assadi *et al*. 1988–2018), "*Flora of Khuzestan*" (Mozaffarian 1999), "*Flora of Iraq*" (Townsend & Guest 1974–1985), " *Flora of Turkey and the East Aegean Islands*" (Davis *et al*. 1967–1982), "*Flora Palestina*" (Zohary 1966–1986) and "*Trees and Shrubs of Iran*" (Mozaffarian 2005). The floristic list was presented alphabetically following the APG IV (2016) for the classification. The chorotype of each taxon was determined according to the distribution data extracted from the above-mentioned Floras and papers. Life forms of the plants were determined according to Raunkiaer (1934).

## Sampling Method

During the field survey, due to the uniformity of the plant species and the absence of noticeable topographic changes, a total of 210 fixed plots (one square meter in size) were located on 7 different sits of the planting area. The minimum plots size determined based on species–area curves produced for each unit sampled (Kent 2012, Asri 1995). The Braun Blanquet method was used in estimating canopy cover percentage of each species on plots (Van Der Maarel, 2005). The specifications of the plots were recorded for the following seasons with a GPS device.

Two points should be noted in the implementation of sampling points. First, using GIS, the raster layer of one of the created bands or vegetation indicators is converted into a point layer and the coordinates of the central points of each pixel in the sampling network are implemented on the ground. Second, the implementation of the sampling points in the field should be done on a sunny day and completely clear weather, so that the sampling error reaches a maximum of 4 meters and the sampling points outside the desired pixel are not considered (Ali Mahmoudi et al., 2022).

The studies conducted in Iran have suggested a surface of 0.75 square meters for the grasslands of the semi-steppe region of Merawa Tepe (Kirimi, 2002) and also other informants have suggested 0.5 to 1 meter for the semi-steppe areas (Moghadam,2001). Zaroa Chahoki et al. (2013) suggested the number of 40 plots of one square meter to investigate the vegetation cover of Bromus tomentellus type. According to the results of the research (Imani, 2018), which was stated, the more the sampling area is to the area of the sampling unit (one pixel), the more the area of the sample piece increases from 1 x 1 meter to 2 x 2 meters, there will not be much change. It seems that sampling intensity is very important in production estimation studies. In the present research, the sampling intensity of 0.01 pixels was considered. This intensity was suitable according to previous studies and also the vegetation conditions of the area. The data sampled in each year were classified into two categories. The first category was used for the classification of satellite images (70% of the sampling data as educational samples) and the second category (30% of the data) was used to check the classification accuracy and as ground reality.

## Preparation Of Satellite Images And Their Pre-processing

Considering the conditions of vegetation, cloudiness and dust in the study area, we tried to get images that have the maximum quality in a time range close to each other during the different years of 2016 and 2021. Therefore, the images of 09/27/2016 and 09/19/2021 were downloaded. To achieve the research goal, centile 2 data were downloaded from the USGS.org website (Table 1). The obtained data are at a level of atmospheric corrections and atmospheric corrections were applied to them using the Sen2cor plugin in the SNAP software. In order to check the geometrical accuracy of the images, the road route on the 1/25000 map was used for visual inspection. The results of the investigation showed that the images do not have geometric errors. Considering that the data were received in different years, an effort was made to ensure that the time frame of the images was the closest to each other and the best images were received. After performing appropriate pre-processing on the mentioned images using SNAP software, the vegetation percentage map was prepared for each year.

## Classification Of Satellite Images

Each type of cover and use has its own reflection and each phenomenon has a different reflection in different wavelengths. Therefore, these reflective properties can be used to classify and separate different uses. Educational samples were used for classification. One square meter polygon method was used to prepare educational samples and 210 educational samples were taken for each type of use (percentage of vegetation in different four classes).

In order to investigate the ability of spectral separation to separate vegetation classes, field samples were prepared and the necessary analyzes were performed on the educational samples obtained. The Jeffries-Matusita, Transformed Divergence test was used to calculate the appropriateness of educational sample points and their separability. The range of this test varies between 0 and 2, so that the number 2 means high resolution and the number 0 means weak resolution between educational samples. The results showed that the test coefficient was more than 1.5 in all classes, so the user classes have a good discrimination ability. Then, the maximum likelihood method was used to classify the considered uses. Despite the spread of different classification methods, this method has high accuracy and popularity (Alidost and Sobhzahedi, 2018). The maximum likelihood method of variance-covariance of classes is evaluated. In this method, it is assumed that the spectral data of the bands used in the educational areas have a statistically normal distribution. In this method, the probability of placing a pixel in a certain class is calculated, then the probability of placing it in other classes is estimated, and finally it is classified based on the highest similarity (maximum probability) in one of the classes. At this stage, using the educational samples taken, the images were classified into 4 classes based on the vegetation percentage, 0–25%, 25–50%, 50–75% and more than 75% canopy cover. Then, by using the unused data in the classification process, the error matrix of Rezaei Livari (2012), the accuracy of the generated maps and the overall accuracy, Kappa coefficient of Koch and Landis were calculated (Soffianian and Madanian, 2011). According to the research of Khedmatgozare Dovlati (2011) and Cunningham (2009), respectively, the overall accuracy and kappa coefficients should not be less than 0.85 and 0.61, and the kappa coefficient greater than 0.8 is excellent.

# Results

### *Flora of Dust sources*

This area includes four types of vegetation, wetland species, hygrophyte plants, terrestrial halophyte, and psamophytic plants. A total of 155 plant species belonging to 35 families were identified in the region. Also, Amaranthaceae (including Chenopodiaceae), the halophyte plant family with 31 species is the largest family in terms of the number of species. Although the main sources of dust rise have covered with two class of vegetation (Halophyte and Pasmophyte), the dune with 67 and salty soil places with 45 species, also 30 species adapted to both climate and soil of the areas (Figure 3).

In table 1, the species that have more dominance in the dry and wetland areas of the study area are mentioned. The number of 7 species of shrubs and pseudo-shrubs in the region are local *Tamarix* spp., *Seidlitzia rosmarinus*, *Capparis spinosa*, and *Suaeda vermiculata*.

**Table 1. The list of the species that have more dominance in the terrestrial and wetland of the study area. Life-forms: Ch (chamaephyte), C. g cryptophyte geophyte), C.h (cryptophyte hydrophyte), Ph (phanerophyte), Th (therophyte).**

| Family | Species | Life-form |
|---|---|---|
| Amaranthaceae | *Anabasis setifera* Moq. [s] | Ch |
| Amaranthaceae | *Atriplex leucoclada* Boiss. [s, s.d] | Ch |
| Amaranthaceae | *Bienertia cycloptera* Bunge m [s m] | Th |
| Amaranthaceae | *Cornulaca aucheri* Moq. [s.d] | Th |
| Amaranthaceae | *Cornulaca monacantha* Delile [s.d] | Ch |
| Amaranthaceae | *Halocharis sulphurea* (Moq.) Moq. [s.d,s] | Th |
| Amaranthaceae | *Halocnemum strobilaceum* (Pall.) M.Bieb. [s] | Ch |
| Amaranthaceae | *Salsola cressa* M.Bieb. [s.d, s] | Th |
| Amaranthaceae | *Salsola imbricate* Forssk. [s.d, s] | Ch |
| Amaranthaceae | *Salsola incanescens* C.A.Mey. [s.d, s] | Th |
| Amaranthaceae | *Salsola inermis* Forssk. [s.d, s] | Th |
| Amaranthaceae | *Salsola jordanicola* Eig. [s.d, s] | Th |
| Amaranthaceae | *Salsola nitraria* Pall. [s.d, s] | Th |
| Amaranthaceae | *Seidlitzia cinerea* (Moq.) Bunge ex Botsch. [s.d, s] | Th |
| Amaranthaceae | *Seidlitzia rosmarinus* (Ehrenb.) Bge. ex Boiss. [s.d, s m] | Ph |
| Amaranthaceae | *Suaeda acuminate* (C.A.Mey.) Moq. [s.d, s] | Th |
| Amaranthaceae | *Suaeda aegyptica* (Hasselq.) Zohary [s.d, s m] | Th |
| Amaranthaceae | *Suaeda vermiculata* Forssk. ex J.F.Gmel. [s.d, s] (=*Suaeda fruticosa* Forssk. ex J.F.Gmel.) | Ph |
| Capparaceae | *Capparis spinosa* L. [s.d, s, m] | Ph |
| Cyperaceae | *Cyperus eremicus* Kukkonen [s.d, m] | C.g |
| Cyperaceae | *Cyperus rotundus* L. [m] | C.g |
| Cyperaceae | *Pycreus flavidus* (Retz.) T.Koyama | Th |
| Cyperaceae | *Schoenoplectus litoralis* (schrad.) Palla | C.g |
| Cyperaceae | *Bolboschoenus glaucus* (Lam.) S.G.Sm. | C.g |

| | | |
|---|---|---|
| Cyperaceae | *Schoenoplectus lacustris* subsp. *hippolytii* (V.Krecz.) Kukkonen | C.g |
| Cyperaceae | *Schoenoplectus litoralis* (Schrad.) Palla | C.g |
| Cyperaceae | *Scirpoides holoschoenus* (L.) Sojak | C.g |
| Poaceae | *Phragmites australis* (Cav.) Trin. ex Steud. [s.d] | C.he |
| Poaceae | *Aeloropus lagopoides* (L.) Thwaites [s] | C.g |
| Tamaricaceae | *Tamarix kotschyi* Bunge [s.d, s] (=*Tamarix leptopetala* Bunge) | Ph |
| Tamaricaceae | *Tamarix meyeri* Boiss. [s.d, s] (=*Tamarix tetragyna* Ehrenb. var. *meyeri* (Boiss.) Boiss.) | Ph |
| Tamaricaceae | *Tamarix passerinoides* Del. var. *passerinoides* [s.d, s] | Ph |
| Tamaricaceae | *Tamarix passerinoides* var. *macrocarpa* Ehrenb. [s.d, s] | Ph |
| Typhaceae | *Typha domingensis* Persl | C.he |

**sd:** dune species, **s:** species of salty soil area**, m:** medicin species.

**Classification of Sentinel 2 images**

The classification results of Sentinel 2 images for the years 2016 and 2021 show that the overall accuracy coefficient and Kappa coefficient were 89.6, 0.78, 98.23, and 0.95, respectively (Table 2). Also, the results of the percentage of classification error showed that the percentage of classification error in different classes of vegetation is appropriate and acceptable (Table 3). Also, the results of the accuracy of the producer and the accuracy of the user in the classification of the images of 2016 and 2021 for different uses showed that the accuracy of the producer and the accuracy of the user were higher than 80% for the years under review and are acceptable (Table 4).

Table 2. Overall Accuracy and Kappa Coefficient of classification of vegetation percentage in 2016 and 2021

| Land Uses / Year | > 75 percent | |
|---|---|---|
| | Overall Accuracy | Kappa Coefficient |
| 2016 | 89.6 | 0.78 |
| 2021 | 98.23 | 0.95 |

Table 3. The percentage of maximum likelihood classification error in the images of 2016 and 2021

| Land Uses / Year | | < 25 percent | 25-50 | 50-75 | > 75 percent | Total |
|---|---|---|---|---|---|---|
| 2016 | < 25 percent | 96.36 | 2.06 | 0.00 | 0.00 | 4.65 |
| | 25-50 | 3.64 | 87.95 | 5.6 | 0.00 | 66.10 |
| | 50-75 | 0.00 | 9.99 | 93.3 | 4.5 | 17.81 |
| | > 75 percent | 0.00 | 0.00 | 1.1 | 95.5 | 11.44 |
| | Total | 100 | 100 | 100 | 100 | 100 |
| 2021 | < 25 percent | 99.02 | 0.00 | 1.35 | 0.00 | 11.96 |
| | 25-50 | 0.98 | 99.44 | 97.86 | 0.00 | 11.60 |
| | 50-75 | 0.00 | 0.56 | 0.79 | 0.00 | 72.61 |
| | > 75 percent | 0.00 | 0.00 | 0.00 | 0.00 | 3.83 |
| | Total | 100 | 100 | 100 | 100 | 100 |

Table 4- Producer accuracy and user accuracy in classifying images in 2016 and 2021

| Class | Vegetation (%) | 2016 | | 2021 | |
|---|---|---|---|---|---|
| | | Producer Accuracy | User Accuracy | Producer Accuracy | User Accuracy |
| 1 | < 25 | 96.36 | 67.09 | 99.02 | 100 |
| 2 | 25-50 | 87.95 | 98.93 | 99.44 | 90.36 |
| 3 | 50-75 | 93.03 | 55.30 | 97.86 | 99.92 |
| 4 | > 75 | 95.52 | 98.97 | 100 | 84.62 |

Table 5. Changes in the area of classes and the percentage of vegetation in the dust center of southeast Ahvaz in 2016 and 2021.

| Class | Vegetation (%) | Area (%) | | The percentage of changes compared to the total area of land use |
|---|---|---|---|---|
| | | 2016 | 2021 | |
| 1 | < 25 | 71.8 | 0.3 | -71.5 |
| 2 | 25-50 | 13.5 | 44.4 | -30.9 |
| 3 | 50-75 | 12.9 | 37.5 | 24.5 |
| 4 | > 75 | 1.8 | 17.8 | 16.1 |
| Total | | 100 | 100 | - |

As the processed images show, there have been wide fluctuations in vegetation in the study area from 2016 to 2021. The slope of changes was positive in all the investigated points (Figure 4,5). The percentage of vegetation cover of each species in the plots was measured in the field survey. In Table 6, the percentage of cover of dominant species extracted from 210 plots is mentioned.

Table 6. Average coverage percentage of dominant plant species in the studied areas (collected from the sampling plots, 2021)

| Region | Species | Cover % |
|---|---|---|
| Bagan | *Seidlitzia rosmarinus* | 52.7 |
| Sharifiieh | *Salsola jordanicola* | 30.7 |
| Sharifiieh | *Aeloropus lagopoides* | 27.2 |
| Sharifiieh | *Bienertia cycloptera* | 12.8 |
| Shoaimit Mandil | *Aeloropus lagopoides* | 21.1 |
| Shoaimit Mandil | *Salsola jordanicola* | 17.8 |
| Hofeireh | *Atriplex leucoclada* | 11.7 |
| Mosalemieh | *Aeloropus lagopoides* | 33.5 |
| Mosalemieh | *Salsola jordanicola* | 16.5 |
| Seyed Sharaf | *Aeloropus lagopoides* | 25.1 |
| Seyed Sharaf | *Atriplex leucoclada* | 24.6 |
| Seyed Sharaf | *Salsola jordanicola* | 11.7 |
| Seyed Sharaf | *Bienertia cycloptera* | 11.1 |

## Discussion

The native species have a great role in a desert region because vegetation has the ability to 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 (Al- Dousari et al, 2020; Meng et al., 2018). A total number of 985 species and infraspecific taxa of vascular plants of the study area, belonging to 487 genera and 93 plant families have been identified from Southwest Iran, Khuzestan province (Dinarvand et al., 2021; Dinarvand, 2018). In this study, 155 species and infraspecific taxa of vascular plants belonging to 35 plant families have been collected and identified from the dust area of Southwest Iran. Amaranthaceae (including Chenopodiaceae), the halophyte plant family with 31 species is the largest family in terms of the number of species. This area includes four types of vegetation, wetland species, hygrophyte plants, terrestrial halophyte, and psamophytic plants. Although the main sources of dust rise have covered with two classes of vegetation (Halophyte and Pasmophyte species), the wetland with 13, the sand dune with 67, salty soil places with 45 species, also 30 species adapted to both climate and soil of the areas (Fig. 3).

Rainfall and water storage exploitation and cultivation of suitable plant species are regularly prescribed for rangeland improvement in arid areas (Zare et al., 2020; Dinarvand et al., 2021). An area equivalent to 26,000 hectares of the dust center of southwestern Iran, located in Khuzestan province, was stabilized between 2015 to 2021 in the form of a biological stabilization and water distribution program (Dinarvand et al. 2022). For biological stabilization, *Prosopis juliflora* shrubs were used and irrigation was done with tankers or furrows at intervals. The distribution of water in Mansoureh lagoon was in an area equal to 7 thousand hectares. This operation had a significant impact on the return of native species in the region. In June 2016, after several times of watering, native cover, both annual and short-lived, as well as moisture-loving grasses such as *Aeloropus lagopoides*, quickly covered the area (Dinarvand et al., 2021 (. Extensive rains in the fall, winter, and spring of 2017–2018 caused extensive transformation and change in the nature of Khuzestan province and dust desert centers. Damages, creating floods and water erosion, on the one hand, and washing the surface salt of the soil, providing the necessary moisture, storing water in underground and flowing aquifers, and then the growth of native species on the other hand, cause The movement of nature became in its natural cycle. Rainfalls in the winter of 2017 and its increase of more than 200 mm compared to 2016, natural floods and water spreading in parts of Mansourieh Wetland caused noticeable changes in the type of plant species and the percentage of cover. Following the accumulation of water in Mansourieh wetland and the gradual emergence of wetland species such as (*Typha domingensis* Persl), (*Phragmites australis* (Cav.) Trin. ex Steud.), *Bolboschoenus glaucus* (Lam.) S.G.Sm., *Schoenoplectus litoralis* (Schrad) Palla was made with high density (100 percent) in such a way that the place of permanent plots was not accessible due to the high density of plants and the presence of water. As the processed images showed, we saw wide fluctuations in the area from 2016 to 2021, but what was important and confirmed by the results was that the slope of the changes was positive in all the examined points. The results showed that since 2016, when a severe drought occurred in the region because of, drought, the construction of dams, and other human disrupt to nature (Dargahian et al., 2019), planting and irrigation operations have been carried out until 2021, the results of water distribution operations, flooding of fields and inter-organizational cooperation of fields have progressed and grown. is, so that in 2021 we saw the peak of vegetation in the area. According to Tables 2 to 4, the results of the overall accuracy coefficient and the Kappa coefficient are high (89.6, 0.78, 98.23, and 0.95, respectively), as well as the results of the manufacturer's accuracy and the user's accuracy in classifying the images of the years 2016 and 2021 for users different (higher than 80 percent), so using Sentinel 2 data in vegetation classification is useful for the plain areas of the small round centers. These results show the effectiveness of the various restoration operations carried out in this area, along with the impact of the rains that occurred during the years under review. The survey of vegetation classes from the years 2016 to 2021 showed that the amount of vegetation in the region has grown significantly. So that the first layer of vegetation (less than 25% coverage) in the surveyed areas in 2016 had the highest percentage of the entire area (71.8%) and in 2021 this amount decreased to less than half a percent. Also, the fourth layer (more than 75% coverage) of vegetation increased from less than 2% of the total area to about 18% (Table 5 and Figs. 2 and 3). The above results show that biological stabilization and water distribution in this area have been successful. Of course, it should be noted that the region has a good seed bank (Dinarvand and Jamzad, 2016). The method of planting seedlings, the depth and volume of the holes created for planting seedlings, timely watering, and the presence or absence of furrow all effect on the richness and percentage of vegetation (Dinarvand et al., 2022). In Sharifiieh and Shoaimit Mandil region, due to the proximity to the water supply channel and a water storage pit, irrigation was carried out by gravity, and also the proximity to the Mansoureh lagoon and the water distribution site had a positive effect on the return of native species such as *Salsola jordanicola*, *Aeloropus lagopoides* and *Bienertia cycloptera* in the region (Fig. 4, 5A). In the Bagan region, despite the absence of furrows next to the plantations, the proximity of this region with the natural population of *Seidlitzia rosmarinus*, a perennial bush species, and the spread of this plant in the holes built with excavators and regular irrigation led to the development of native species in the region (Fig. 4, 5B). In the Hofeireh region, due to its proximity to the water supply channel and the main road of the highway (Ahvaz to Mahshahr), irrigation was done easily, and this caused the return of native species of the region, such as *Atriplex leucoclada* and *Halocharis sulphurea* (Fig. 4, 5C). The two areas of Mosalemieh and Seyed Sharaf were far from the water supply channel and the main road, which caused improper and irregular irrigation in the area. But the presence of farrows next to the plantations helped to store rainwater during the rainy season, and this factor helped the gradual return of native species such as *Atriplex leucoclada, Bienertia cycloptera* and *Salsola jordanicola*. However, due to the proximity of these areas to the Shadgan wetland, in some places, there was moisture necessary for the establishment of the *Aeloropus lagopoides* species. (Fig. 4, 5D). The benefits of contour furrowing and pitting techniques have been demonstrated for runoff collection, improving soil moisture content and vegetation establishment, and land rehabilitation in desert areas (Jahantigh M. & Pessarakli, 2009). Semi-circular bunds in the Gorik rangeland of Zahedan City caused a positive influence on yield, canopy cover, plant composition, and soil moisture (Delkhosh and Bagheri, 2012). In a study of three dust centers in the southeast of Ahvaz (Khuzestan province), results showed that various irrigation methods along with rainfall improved vegetation cover (frequency), the number of species, and species diversity from 2018 to 2020 (Dinarvand et al., 2022). Planting in degraded habitats acts as succession catalyst and causes the growth and establishment of native species through the formation of a microclimate (Van der Maarel, 2005). So the results of monitoring vegetation changes in the dust center of southwest Iran (2016–2021), revealed that the irrigation method of seedling area and precipitation conservation structure has an effective role in species diversity of local vegetation in deserts or restoration of fragile rangelands.

# Conclusion

From the above observations and results, it can be concluded that the region has a suitable native seed bank and if a suitable substrate is provided for these reserves and water is available, as this part of the province was flooded before, the native vegetation will be restored again. Spreading water and irrigation in farrows, while washing the surface salt of the soil, providing the necessary moisture, storing water in underground and flowing aquifers, causes the growth of native species and causes nature to move in its natural cycle. Despite the presence of suitable vegetation following the spreading of water, planting and recent rains, an important point that should be paid attention to, is the management, planning and use of the existing conditions. In addition to preventing agriculture in the region, there should be purposeful grazing management (proper grazing time, preventing excessive grazing, timely exit of livestock from the field, pasture rest for reconstruction and revitalization) in the region.

# Declarations

**Author Contribution** M.D. (Mehri Dinarvand) and S.A.A. (Seyed Abdolhossein Arami) presented the ideas, carried out and wrote the paper, and editing the final version of the manuscript, and took the responsibility for supervision. S.A.S. (Sajad Alimahmodi Sarab) contributed to figures 4-5 and the Processing of satellite images. K.H. (Kohzad Haidari) contributed to figures 1-2.

All authors have read and agreed to the published version of the manuscript.

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**Data Availability** The data presented in this study are available on request from the corresponding author.

**Conflict of Interest** The authors declare no competing interests.

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# Figures

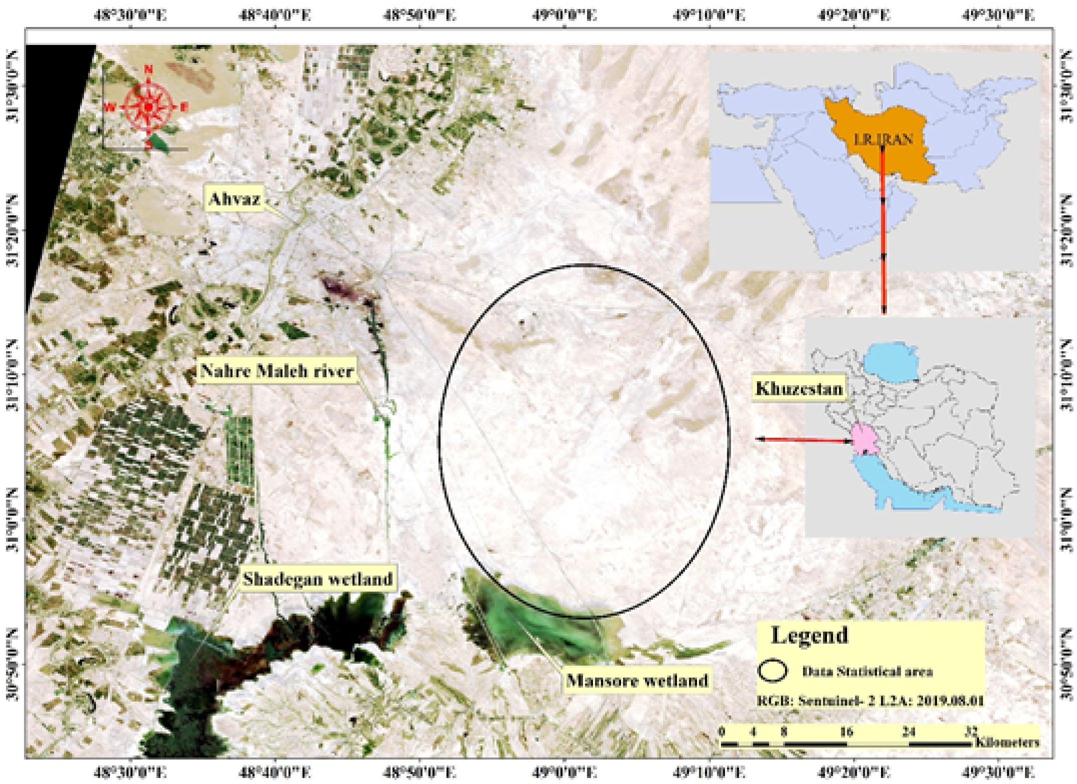



Figure 1

Location of the selected points in the dust center in south of Ahvaz

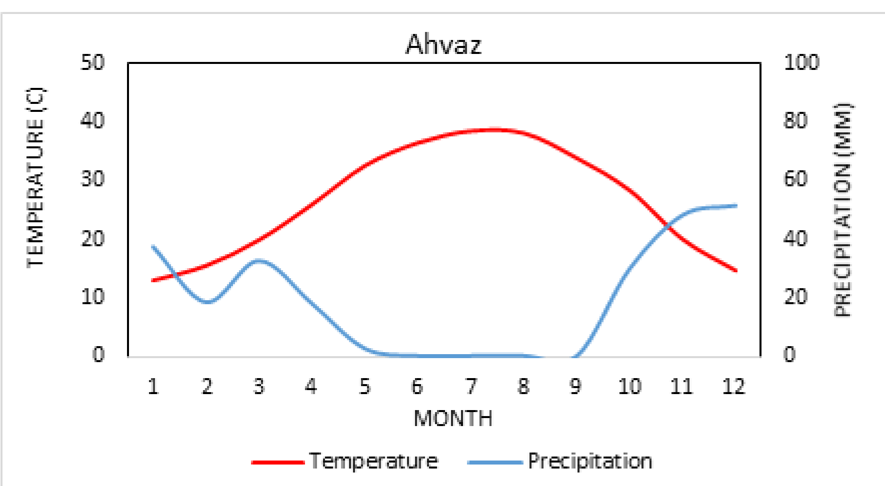


Figure 2

Ombrothermic diagram of Ahvaz city for the past 24 years (1996-2020)

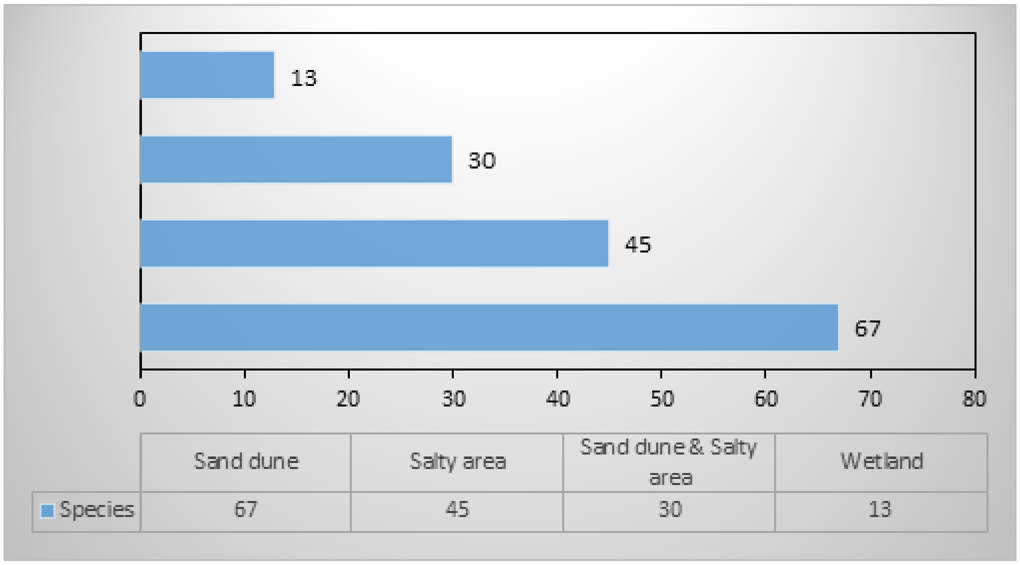
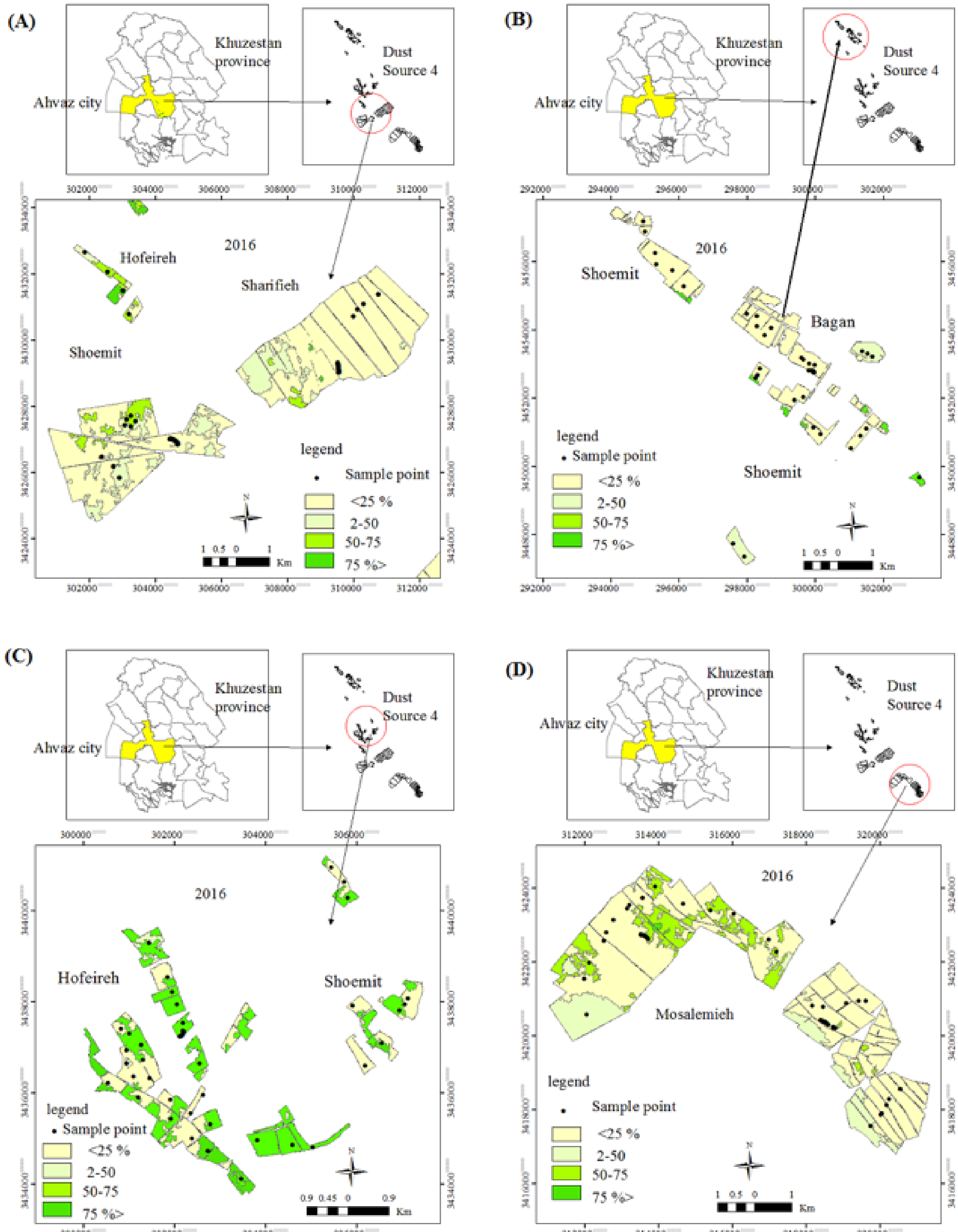


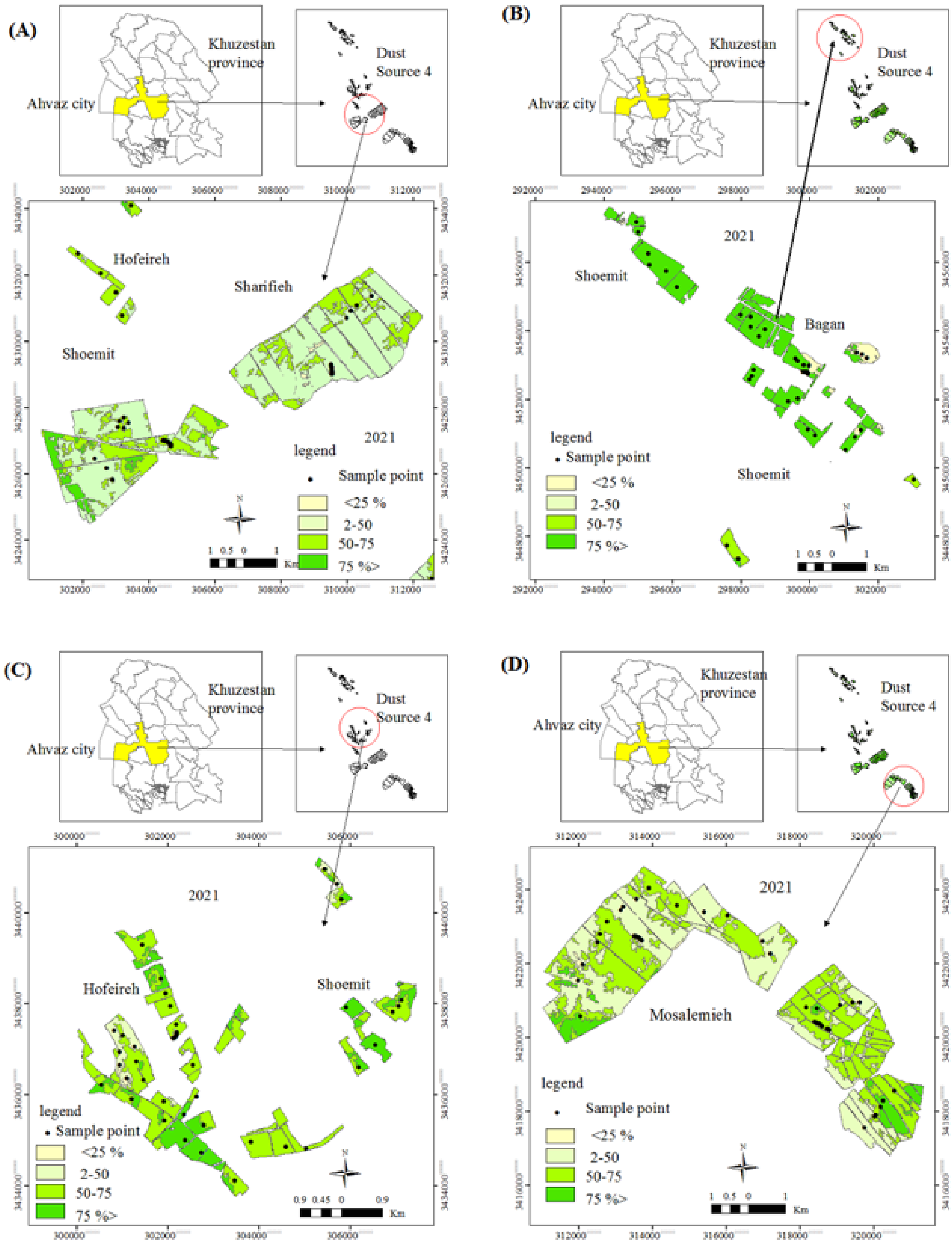

Figure 3

The number of species in the vegetation areas of dust centers in southwest Iran




## Figure 4

Vegetation classification in 2016 in the sampling areas of southern Iran (dust center)




## Figure 5

Vegetation classification in 2021 in the sampling areas of southern Iran (dust center)