Part 5

Sand Dune Landscapes Distribution, Formation and Management

Seven Case studies from several geographic regions in Africa, south-west Asia, north-east Asia are presented here to demonstrate the underlying mechanisms in dune formation and the diverse approaches to their management. Human impacts such sand mining, tourism development, combine with natural forces such as climate variability to challenge the realization of an optimum management strategy. Each chapter describes a unique and little-known dune system that because of remoteness or the unusualness are rarely reported on in English language publications. We are fortunate to be able to bring together experts who can give an authorative account of dunes in remote regions within the Arctic circle or in Iran's desert interior. The studies presented on the dunes that formed on the temperate coastal regions in Japan provides an opportunity to explore the anthropogenic impact on the geomorphology, and ecology of the dunes.

Chapter 31

Geomorphology and Sustainable Management for the Sand Dunes of Kuwait

Raafat Misak,* *Samira Omar* and *Ahmed Abdulhadi*

Introduction

Aeolian landforms represented by sand dunes, nebkhas and sand sheets are widely distributed in coastal and inland areas of Kuwait. They naturally occur due to the arid climatic conditions and the geographic location of Kuwait in the northeastern corner of the Arabian Peninsula. Significant changes in aeolian conditions have been observed in Kuwait. These changes were mainly related to dramatic changes in land-use and infrastructure expansions. In Kuwait, a great number of sectors exists under the direct threats of shifting sands. These include oil, defense, highways (public works), agriculture, water & electricity and residential. Monitoring sand movement was conducted in Kabd Research & Innovation Station (1988–2019). This station is located about 35 km to the southwest of Kuwait City. A notable increase in the amount of accumulated sand was observed by time. The accumulated sands ranged from almost 0% (1988–1989) to about 55% (January 2019). Sand dune movement during the period between August 2013 and August 2019 for four pilot sites was measured using remote sensing and GIS techniques. The average sand movement of sand dunes ranges between 17 m/yr to to 24 m/yr.

In the current study, two scenarios for managing the sand encroachment problem along Ali Al Salem Air Base are proposed. The first scenario is based on the establishment of integrated biological sand control system, few meters to the north of Ali Al Salem Air Base (upwind side). The approximate cost of the first scenario is KD 379,500 (1,252,350 USD). The cost includes the materials, labor and the expenses of 10 years maintenance program. The second scenario consists of five km length of porous fence, two meter high, 40–50% porosity (chain link type with slats), and five km length of green belt consisting of three rows of drought-resistant trees, e.g., *Ziziphus nummularia*, *Prosopis juliflora*, *Acacia pachyceras* and *Tamarix* sp. The approximate cost of second scenario is KD 368,500 (1,216050 USD).

There are primary perennial plants that are adapted to accretion of sand in Kuwait can play major role in sand dune stabilization, thus they have economic values in reducing cost of land maintenance. Such plants are: *Haloxylon salicornicum*, *Cyperus conglomeratus* and *Calligonum polygonoides*. Sand dune mitigation by using native plants requires understanding their abilities to withstand harsh climatic conditions, such as extreme droughts, windblown sand erosion and sand burial.

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Context and setting for this study

In this study, the Burgan-Managish area (lat.29 N long.47 E of about 1,760 km^2) was selected as a pilot site to investigate sand behaviour and assess factors affecting efforts to control sand dune migration and sand encroachment. Sand dunes in Kuwait naturally occur due to the arid climatic conditions and the geographic location of Kuwait in the northeastern corner of the Arabian Peninsula. The total area of Kuwait is 17,800 km^2 out of which sand dunes (including nebkhas) and sand sheets cover about 5093 km^2 (29% of the country). Sand dunes are located along the coastal zones and inland formulating different shapes based on their geomorphic characteristics, e.g., crescentic, star and falling dunes. Crescentic dunes are mainly observed in Al Atraf (west of Jahra City), northwestern and northeastern parts of the country, e.g., Al Huwaimiliya and Umm Al Negga. Several perennial native plant species are observed on the sand dunes such as: *Cyperus conglomeratus*, *Haloxylon salicornicum, Rhanterium epaposum* and *Caligonum commosom*. During rainy seasons the following annual plant species are commonly found including: *Farsetia burtonae*, *Spergularia diandra*, *Cakli arabica*, *Emex spinosa and Plantago boissieri.*

The central part of the terrestrial environment of Kuwait, which covers about 9,000 km^2, is an open theatre for extremely active aeolian processes. These processes represent one of the main threats on several agricultural farms, military camps, air bases, oil fields, residential areas and highways. In addition, these aeolian activities have *negative health effects*. Two air bases in Kuwait (Ahmad Al Jaber and Ali Al Salem) and several military camps at the northern parts of the country are severely attacked by active crescentic dunes causing serious damage to planes, runways and equipment. In addition, two main highways are under the threat of these active dunes (Jahra-Salmi and Umm AlNegga-Abdaly Roads). However, in protected areas such as Sabah Al Ahmad Nature Reserve (about 331 km^2) the sand dunes are more stable due to the rich vegetative cover that stabilizes their mobility. Coastal dunes occur in the south at Dubaeya and Nuwassib. They are mostly stable dunes that cause minor hazards on infrastructures.

Significant changes in aeolian conditions have been observed in Kuwait. These changes were mainly related to dramatic changes in land-use and infrastructure expansions. After the liberation of Kuwait in February, 1991, a border trench was established between Iraq and Kuwait, during 1993–1995. This trench is about 212 km long with average width and depth attaining about 7 m and 5 m respectively. A 50 km segment of the border trench acts as a huge artificial trap for shifting sands derived by the northwesterly winds from Iraq. The amount of trapped sand in the mentioned segment was close to 1,000,000 m^3 during the period 2004 to 2009. Currently, the encroaching sands are mechanically removed and placed in adjacent areas. This approach however, is a temporary solution that does not consider environmental and economic consequences. To alleviate sand dunes hazards, a sustainable management plan needs to be adopted in Kuwait. The main objectives of this chapter reported here are:

1. Characterize and classify sand dunes in Kuwait.
2. Map and monitor sand-dune movement in several pilot sites.
3. Identify the magnitude of hazards of the sand dunes.
4. To set up a hazard management plan for sand dunes in Kuwait.

To realize the objectives of the current study, the following activities were carried out:

1. Detailed literature review.
2. Field survey, mapping and monitoring sand dunes (pilot sites) using remote sensing and GIS.
3. Assessment and monitoring the current sand control measures.
4. Identify the socioeconomic impact of sand dunes.
5. Propose a sustainable management plan for sand dunes in Kuwait.

Managing the hazards of shifting sands

The Kuwaiti experience in managing the hazards of shifting sands and combating land degradation was started in the 1960s. Aeolian landforms represented by sand dunes, nebkhas and sand sheets are widely distributed in coastal and inland areas of Kuwait (Fig. 31.1, A). Geographically they are differentiated into three main units (A, B and C) and three minor ones (D, E and F). Field observations and analyses of remote sensing data at different dates, indicate that sand movement in Kuwait is very sensitive to changes in land-use types. During the period 2010 and 2017, two areas of about 119 km^2 were protected. Fencing of these two areas which are located in the heart of the main natural corridor of shifting sands, resulted in the dissection of this corridor into segments A and B (Fig. 31.1, B and C) . During June–October, 2018, Kuwait experienced waves of severe sand and dust storms. The wind speed reached 20 m/sec. Several road incidents were reported along Wafra Roads and a number of facilities were severely attacked by shifting sands (Fig. 31.1, D–F).

During 1993–1994, a border trench (close to 200 km length), was prepared by Kuwait along the border with Iraq. A segment of the border trench of about 42 km length acted as a huge trap for creeping sands migrating from Iraq. The mechanism of sand transport and the main components of the Demilitarized Zone (DMZ) between Iraq and Kuwait are shown in Fig. 31.2 A–D.

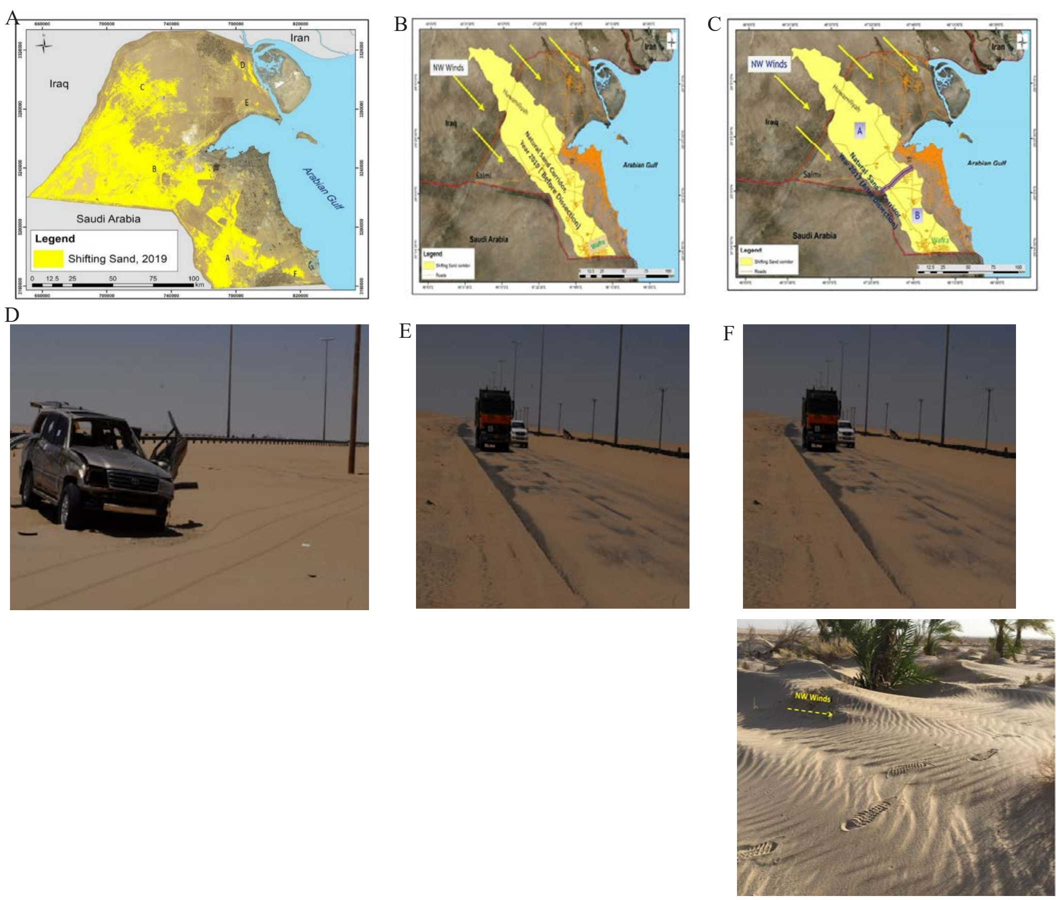

Figure 31.1. Aeolian landforms and sand encroachment problems.
A: Landsat Image 8, August, 2019 showing aeolian landforms (for legend see text); B: Conditions of the natural sand corridor, year 2010; C: Conditions of the natural sand corridor, year 2017 (dissected into two sections A & B); D: Road incident, Wafra-Kabd Road, August, 2018; E: Severe sand encroachment Kabd-Wafra Road, August, 2018; F: Sand encroachment along Kabd Research and Innovation Station, June, 2018 (note the new born nebkhas).

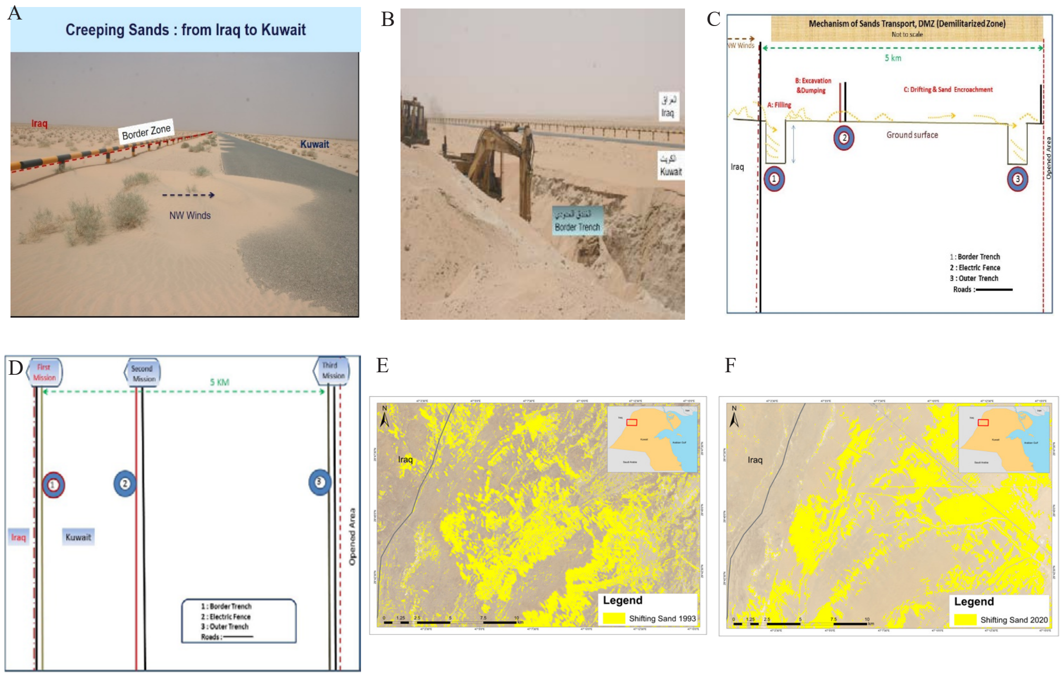

Figure 31.2. Border trench and shifting sands.
A: Creeping sands cross the border between Iraq and Kuwait (Khabari Al Awazem area); B: Iraq-Kuwait Border Trench sand clearing maintenance (Khabari Al Awazem); C: Mechanism of sand movement in the DMZ (Demilitarized zone); D: Sketch Section along the DMZ (Demilitarized Zone) between Iraq and Kuwait showing the border trench, electric fence, outer trench and outer fence; E: Landsat 8, June, 1993 (shifting sand class) Al Huwamiliyah area; F: Landsat 8, June, 2020 (shifting sand class) Al Huwamiliyah area.

For comparison between the mechanism of sand transport before and after digging the border trench, Al Huwamiliyah - Khabari Al Awazem border segment was selected. The comparison is based on the information from Landsat 8-June, 1993 (before) and Landsat 8–June, 2020, Fig. 31.2, E and F.

Ground survey and monitoring during 1993–2020 revealed that the border trench is filled by sands every 3–5 yr. After trench filling, the sands are mechanically removed and placed outside the trench (maintenance program).

Before digging the border trench, sand sheets and sand dunes crossed the border and entrained deeper into Kuwait as revealed in Landsat 8 of June, 1993 (Fig. 31.2, E). Some 26 yr after digging the border trench, a big change in sand transport was observed. Very few low sand dunes survive in the Demilitarized Zone between Iraq and Kuwait (5 km width) Landsat 8 image of Al Huwaimiliyah, June, 2020 indicated that after digging the border trench for about 26 yr, the area of shifting sands in Al Huwamiliyah decreased by at least 25% compared to Landsat 8 image of the same area of June, 1993 (Fig. 31.2, F). This is due to the trapping of millions of cubic metres of sands inside the border trench. Trapping/ capturing the shifting sands migrating from Iraq, has a negative impact on sand dunes morphology and dynamics. Cutting the main supply of sands results in the dune dwarfism followed by severe deflation.

Brief literature review

Al Dabi et al. (1997) studied the evolution of the sand dunes in the northwestern parts of Kuwait. They observed a sharp increase in dune formation shortly after the 1991 Gulf War as a result of the disruption of the desert of Kuwait. Al-Awadhi and Misak (2000) described aeolian processes and sand control measures in Kuwait. They mapped 14 desert facilities that are subjected to sand encroachment. Al Helal (2004) assessed the sand encroachment in Kuwait using Geographical Information System and statistical methods. In this study, the assessment of sand encroachment problems has been formulated as a Multi-Criteria Decision Making (MCDM) problem. Xhibao et al., 2004 stated that comprehensive studies suggest that the effective and feasible measures to control the blown sand include reed check board barriers, upright clustered reed fences, upright reed fences, upright nylon net fences, chemical and clay fixers and artificial vegetation. The sand dunes in the northwestern area of Kuwait were monitored and mapped by Al Dousari and Pye, 2005. The authors used aerial photographs of 1972, 1992 and 1997 for mapping 84 dunes. They stated that dune formation was very rapid and dunes migration rates ranged from 4m/yr to 60 m/yr with an average of 24 m/yr. Al sarawyi et al., 2006 mentioned that the sand dune fields in Kuwait occupy an area covering 350–500 km^2. They stated that the absence of major topographic barriers that are able to inhibit long distance wind transport accounts for the size of dune fields. Enezi et al., 2008 studied the morphological characteristics and development of falling dunes in northeastern parts of Kuwait. This study indicates that the development of falling dunes is significantly affected by a slope angle. Al Dousari et al., 2008 studied the main characteristics of nebkhas in relation to dominant perennial plant species in several areas in Kuwait. Misak, 2008 described the hazards of shifting sands in the terrestrial environment of Kuwait.

In this study, the Burgan-Managish area (about 1,760 km^2) was selected as a pilot site. Al-Dousari et al., 2008 investigated seven dune fields, including Al-Huwaimiliyah–Al-Atraf zone area and Um Al Negga (NE Kuwait). Pye and Tsoar 2009, stated that the negative effects of sand drift and dune migration include erosion of soils, abrasion damage to crops and paintwork, blocking of roads, canals and railways, infilling of wells and reservoirs and burial of buildings and industrial installations. Al Helal and Al Awadhi, 2009 assessed the sand encroachment problem in Kuwait using Geographic Information System and statistical methods. In this study, the Delphi method and the Analytical Hierarchy Process (AHP) were adopted. Al-Dousari and Al-Hazza, 2013 collected and analyzed 212 aeolian samples from the northwestern parts of Kuwait. The colour, shape, roundness, particle morphometry and surface area were taken into consideration. Their study indicated that the coarse and medium particles (about 80% of the whole aeolian sample) are dominantly derived from local sources. To manage the hazards of shifting sands in the terrestrial environment of Kuwait, three scenarios for afforestation and stabilization of active sand bodies were proposed by Misak et al., 2013. Khalaf et al., 2013 mentioned that the most common erosional landforms in Kuwait are: yardangs, desert pavement represented by pebbly lag, granule lag and mixed lag and granule ripples. The morphology of 52 nebkhas in the northern coastal plain of Kuwait Bay were investigated by Al-Awadhi et al., 2013. In this study, three types of nebkhas were recognized namely isolated, compound and complex. Generally, the studied nebkhas vary in length between 5.1 and 15.8 m with an average of 9.98 m. Their width ranges between 1.9 and 5.1 m with an average of 3.7 m. Ahmad et al., 2015 described approaches for controlling windblown sands along Abdaliyah–Managish Stretch, the western parts of Kuwait. Elrawi and Misak, 2015 assessed the sand encroachment problem along Al Salmi road. They stated that segment of Al Salmi road exists under the threat of active sand dunes (mainly barchan type) and active sand sheets. The rate of sand dune movement is around 17 m/yr. An integrated system for mobile sand control was proposed. Metwally et al., 2016 stated that it is important to plant windbreaks and to stabilize sand dunes to reduce the damage and loss of all areas of development aspects. Misak et al., 2016 assessed three different systems of mobile sand control in Kuwait. The first and second systems are located in the eastern and western sections of KISR Station for Research & Innovation (Kabd). The third one is situated along a segment of Kabd road (Road, 604). Zhao, 2017, stated that from 1980s and 1990s, the wind in China's Kubuqi Desert (18,600 km^2) brought dust and sand storm (SDS) even to Beijing, Tianjin and Hebei province, some 800 km away from the desert. Engel et al., 2018 assessed the migration of barchans dunes in Qatar. These dunes form small sand patches by windward deflation over a gradually developing low-angle slope, where grains eventually slide down a steeper leeward slope. As stated by Al Hemoud et al., 2019, sand and to lesser extent dust, were shown to be damaging and costly to the infrastructure of

Kuwait. The economic cost was estimated at US$ 9.36 million to the oil and gas industry alone. A total of 5159 non productive lost hours and 347,310 m^3 of annual sand removal. Biological–mechanical system can be a cost-saving endeavour. Al Dousari et al., 2019 delineated the off-road vehicle tracks and grazing points for the first time in Kuwait using Worldview and Rapid Eye images of 2017 and ArcGIS. The study revealed that off road vehicles are a leading cause for land degradation and soil compaction in Kuwait. The total area affected by soil compaction due to off-road vehicle tracks and grazing points in Kuwait is 1390.23 km^2 representing 7.8% of the total area of Kuwait. It was concluded that grazing points and off-road vehicle tracks are largely related to each other, and both increase to higher densities around the urban area and watering points. Al Dousari et al., 2020 described the changes in dominant perennial plant species from 1974 compared to the latest vegetation map of Kuwait (2001). The capabilities of several plant species in trapping sand and carbon dioxide were described economically and environmentally. Al-Hemoud et al., 2020 stated that Kuwait is vulnerable to Sand and Dust Storms (SDS) trajectories from the middle Euphrates region, especifically, from two "hot spot" areas (Al-Batha and Mamlahat Al-Samawah) of 4550 km^2 located 250 km from its northern border. The study explored the transboundary SDS jets originating from southern Iraq using Moderate Resolution Imaging Spectroradiometer (MODIS) images obtained from Aqua and Terra satellites over a 12-yr period (2007–2018). It was recommended that sustainable rehabilitation and land restoration of the "hot spot" area will result in the elimination of the long-range transport of SDS jet streams affecting the downwind Gulf countries.

Data and methodology

1. Data (Satellite images)

In this study, multispectral satellite images Landsat 8, Operational Land Manager (OLI) are used. Different dates with free cloud coverage (August, 2013 and August, 2019) were selected and downloaded from the (https://earthexplorer.usgs.gov) of the USGS (United States Geological Survey). The OLI sensor provides eight different spectral bands with a spatial resolution of 30 m and one panchromatic band with a resolution of 15 m. In addition to the blue, green, red and NIR bands (Table 31.1).

2. Methodology

The proposed method for extraction of shifting sands areas using Landsat-8 Operational Land Imager imagery comprised these major steps: preprocessing (atmospheric corrections and image

Table 31.1. The description of Landsat 8 bands.

Band Number	Description	Wavelength (Micrometres-µm)	Resolution (Metres)
1	Violet-Deep Blue	0.433–0.453	30 m
2	Blue	0.450–0.515	30 m
3	Green	0.525–0.600	30 m
4	Red	0.630–0.680	30 m
5	Near Infrared	0.845–0.885	30 m
6	Shortwave Infrared	1.560–1.660	30 m
7	Shortwave Infrared	2.100–2.300	30 m
8	Panchromatic	0.500–0.680	15 m
9	Cirrus Cloud	1.360–1.390	30 m
10	Thermal Infrared	10.6–11.2	100 m
11	Thermal Infrared	11.5–12.5	100 m

enhancement through pansharpening), development of the sand shifting area extraction method by using unsupervised classification and accuracy assessment.

2.1 Preprocessing of Landsat-8 OLI imagery

A preprocessing of satellite images was performed with the aim of achieving a reduction in scene-to-scene variability—different physical conditions of the scenes during acquisitions. The original quantized and calibrated, pixel values, were first converted to the corresponding radiance values and then translated into dimensionless surface reflectance values through the process of atmospheric correction. Consequently, atmospheric correction was performed with DOS1 (Dark Object Subtraction) procedure, also the image enhancement through pansharpening by reducing the pixel size from 30 m to 15 m, all these preprocessing methods were available in the QGI version 3.10.5 software by using Semi-Automatic Classification Plugin.

2.2 Unsupervised classification (K men clustering method)

The unsupervised classification model ware used to classify the Landsat 8 image into 36 classes also the signature file ware saved when running this model, ERDAS IMAGINE software ware was used to run this model. Then by using visual interpretation and the signature file the sand shifting classes were identified by using ArcGIS software using the reclassifying tool to classify the output images into two classes (sand shifting and others).

2.3 Accuracy assessment

Ground truth was used to verify the final output of shifting sand images. Ground truth was conducted in 24 sites representing the terrestrial environment of Kuwait. A flow chart showing the sequence of methods and materials of the current study is shown (Fig. 31.3).

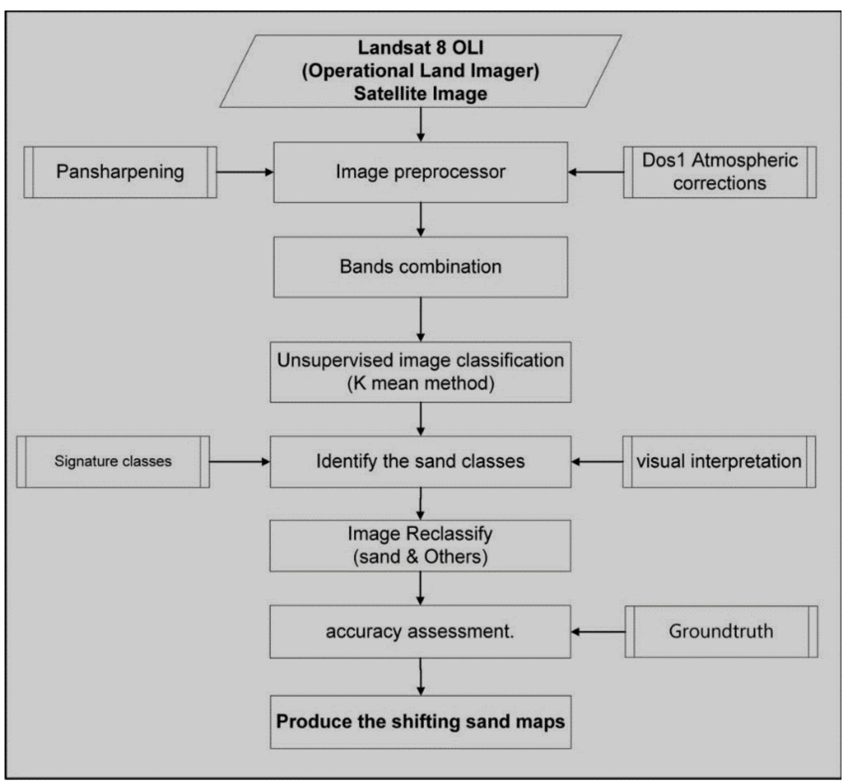

Figure 31.3. Flow chart showing methods and materials of the current study.

Monitoring sand movement—Kabd research and innovation station (1988–2019)

Kabd Research and Innovation Station is located about 35 km to the southwest of Kuwait city (Fig. 31.4). In this station, a system for mobile sand control was established in 1988. This system consists of two porous chain link fences, each is two metres high. The distance between the two fences is about 50 m.

Accumulated sand along selected fence was monitored during the period from 1988 to 2019 (32 yr). Monitoring was done at eight dates during 1988–2019. It was conducted along the same fence through field measurement of the height of accumulated sands on 12 iron posts (two metre high, one metre apart). Figure 31.5 summarizes the results of field monitoring of sand accumulation during 1988–2019.

A notable increase in the amount of accumulated sand was observed by time. The accumulated sands ranged from almost 0% (1988–1989) to about 55% (January, 2019). In 1992 the accumulated sand occupied about 5% of the total capacity of the fence. In 2008 and 2013 the sand increased to 15% (2008) and 40% (2013). In the period from 2015–2019 the amount of sand reached 45% in 2015 and 55% in 2019.

The remarkable increase in sand accumulation, from 28-7-2008 to 16-2-2013 was attributed to the drought period of seasons 2007–2008, 2008–2009, 2009–2010, 2010–2011, 2011–2012 (35 mm–75 mm rain). Since July, 2008, massive wind erosion and severe sand encroachment had been recorded in the Kabd Station. On 1-9-2018 the sand accumulation was bare of vegetation. On 5-1-2019, after about 5 mon, the sand was covered by dense vegetation, as a result of the heavy rainfall (close to 300 mm) in November, 2018. The most common plants are *Schimpera arabica, Plantago boissieri, Moltkiopsis ciliate and Silene villosa.* Table 31.2 and Fig. 31.6 show conditions of accumulated sands during 1988–2019.

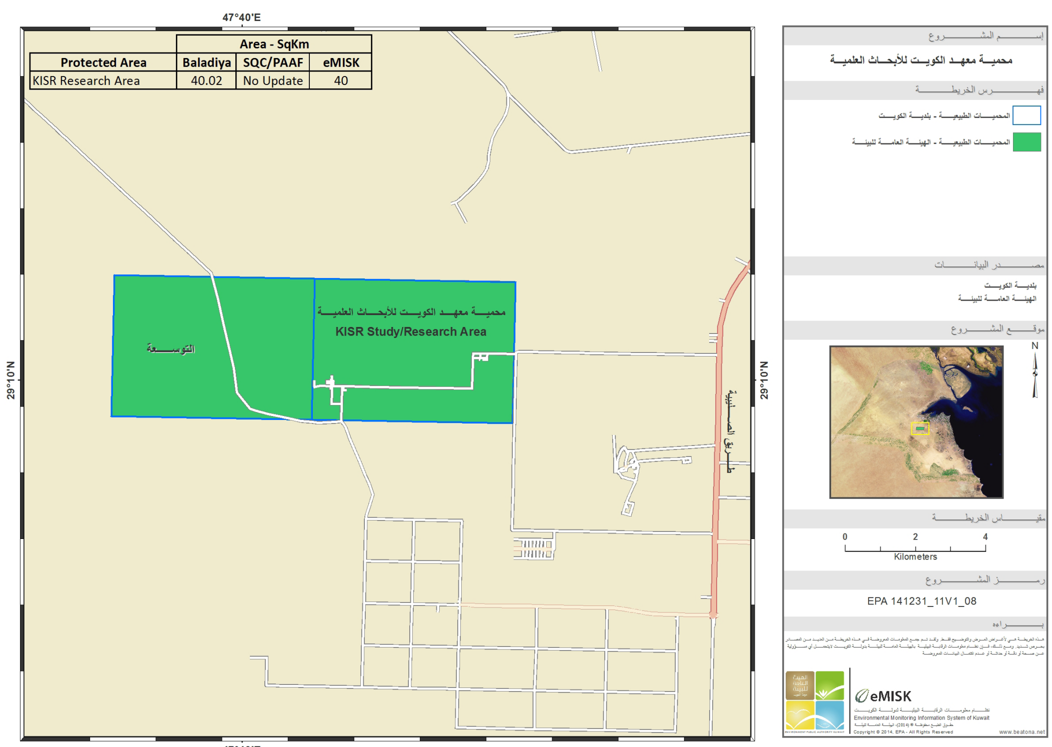

Figure 31.4. Location of Kabd Research and Innovation Station.

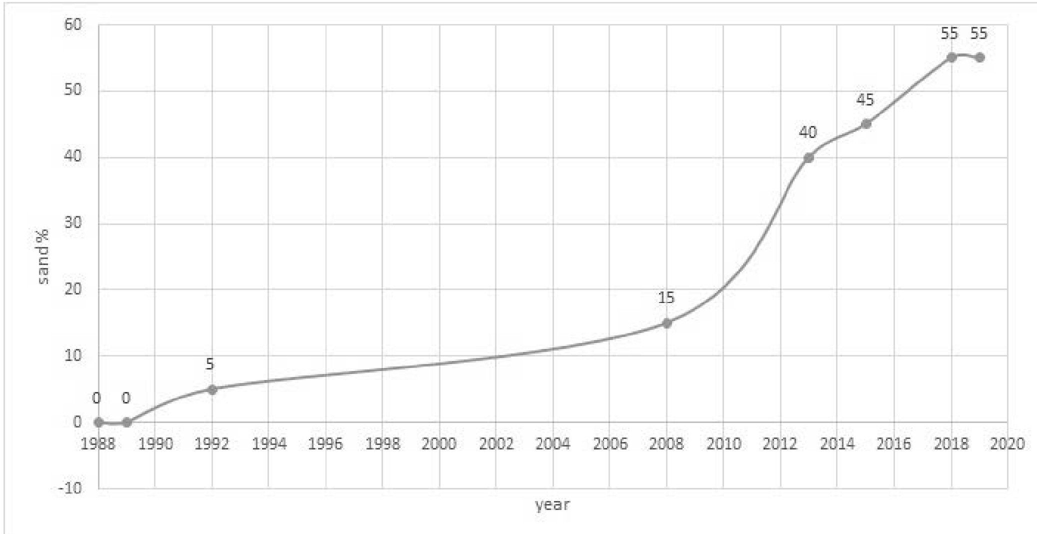

Figure 31.5. Monitoring of sand accumulation (1988–2019), Kabd Research and Innovation Station.

Table 31.2. Monitoring sand accumulation, Kabd Research and Innovation Station (1988–2019).

Period	% of accumulated sand relative to the capacity of the fence	Detected sand encroachment problems (Kabd Station)	Encroached facilities	Remarks
1988–1989	0		--	Very dense vegetation cover on the ground
1989–1992	5		--	
1992–July 2008	15	July, 2008	Main road	Sandblast and exposing root system
July 2008–February 2013	40	September, 2011	Main road and experiment sites	Sandblast and exposing root system
February 2013–June 2015	45			
June 2015–September 2018	55	July, 2015 and June–July, 2018	Main Road Cultivated date palms	Sandblast and exposing root system
September 2018–January 2019	55		Main Road	Dense vegetation on accumulated sands

General morphology and aerodynamic of sand dunes in Kuwait (Four cases)

This section deals with four case studies. These are Al Huwaimiliyah, Um Al Negga, Atraf sand dunes and Wafra sand sheets. The landforms, land use and targets under threat of shifting sands are shown in Table 31.3.

1. Al-Huwamiliya sand dunes (Northwest)

Al Huwamiliya sand dunes exist at the northwestern parts of Kuwait. They are formed from fields of active barchans dunes. The height of sand dunes ranges between 3–4 m in the Demilitarized Zone between Iraq and Kuwait to 5–8 m in the open area (Fig. 31.7). The rate of growth of Al Huwamiliya Sand Dunes is 17.5 m/yr.

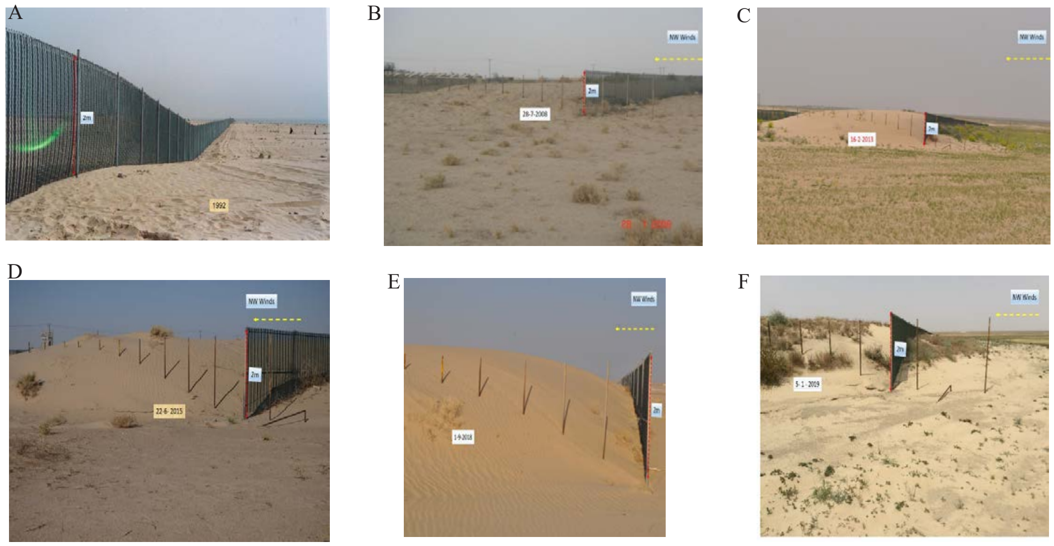

Figure 31.6. Sand accumulation at different dates - Kabd (1992–2019).
A: Sand accumulation 1992; B: Sand accumulation 28-7-2008; C: Sand accumulation 16-2-2013; D: Sand accumulation 22-6-2015; E: Sand accumulation1-9-2018; F: Sand accumulation 5-1-2019.

Table 31.3. Landforms, land use and targets under the threat of shifting sands in Al Huwaimiliyah, Um Al Negga and Atraf.

Area (site)	Land forms	Land use	Targets under threat of shifting sands
Al Huwaimiliyah sand dunes	Active sand dunes and sheets	Military Rangeland grazing	Al Adairah Military area
Um Al Negga sand dunes	Active sand dunes and sheets	Agriculture Oil Rangeland grazing	Umm Negga - Abdaly Road
Atraf sand dunes	Desert pavement Active and dunes and sheets	Rangeland grazing - Military	Ali Al Salem Air Base
Wafra sand sheets	Sand sheets Desert pavement	Rangeland grazing Protected areas Residential Oil	Sabah Al Ahmad residential city Segments of Wafra-Mena Abdullah Road Quran protected area Al Wafra animal production (Jawakheir) Wafra oil field

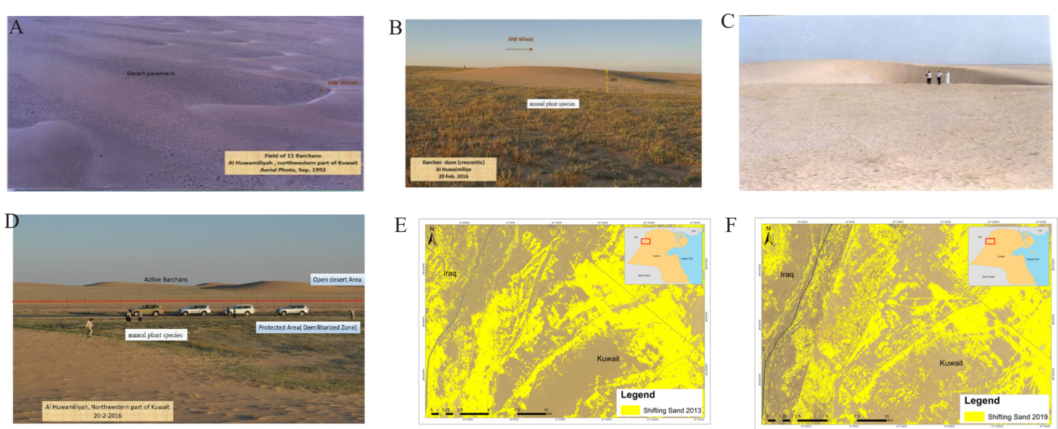

Figure 31.7. Al Huwamiliyah Sand Dunes.
A: Field of 15 Barchans, aerial photograph 1992; B: Barchan dune, February, 2016; C: Typical Barchan, 5 m high; D: sand dunes, out side the Demilitarized Zone 2016; E: Class of shifting sands (August, 2013); F: Class of shifting sands (August, 2019).

2. Um Al Negga sand dunes

In Um Negga, seven sand dunes (barchan type) are observed. The height of the dunes ranges between 5–8 m and the width from 15–18 m. The length rarely exceeds 15 m. Star dunes are temporarily shaped during the fall. At least four dunes of the total seven are highly disrupted by off-road vehicles (Adventure Tourism). The rate of growth of Um Al Negga dunes is 18.5 m/yr, Abdaly Farms which exists at the upwind side of Um Al Negga dunes act as a defence line against the northwesterly winds. The conditions of the dunes between August, 2013 and August, 2019 are shown in Fig. 31.8 C–F. A remarkable increase in shifting sands was observed in August, 2019.

3. Al Atraf sand dunes

Al Atraf sand dunes are found close to km 13 on the Salmi Road. They constitute a big field of active barchan dunes of different sizes. The dune advances slowly towards the Salmi Road (24 m/yr). Baby dunes about 50 cm high were observed, few metres in the downwind side of relatively larger barchan (2–3 m high). In general, the average height of the Al Atraf dunes is 6 m. The width is close to 12 m. During the rainy season the depth of wet horizon is 40 cm deep, November, 2014. A notable increase in the shifting sands in August, 2019 compared to August, 2019 (Fig. 31.9, E and F).

4. Wafra sand sheet

Wafra sand sheet constitutes a large triangle (close to 400 km^2), its head exists close to Ahmad Al Jaber Air Base, 32 km to the north of Wafra Oil Field. The base of the triangle reaches 35 km. This sand sheet is a main source of shifting sands for Wafra-Mena Abdullah Road, Al Qurain Protected Area and Sabah Al Ahmad residential city and Wafra animal production unit. Figure 31.10 shows Wafra shifting sands.

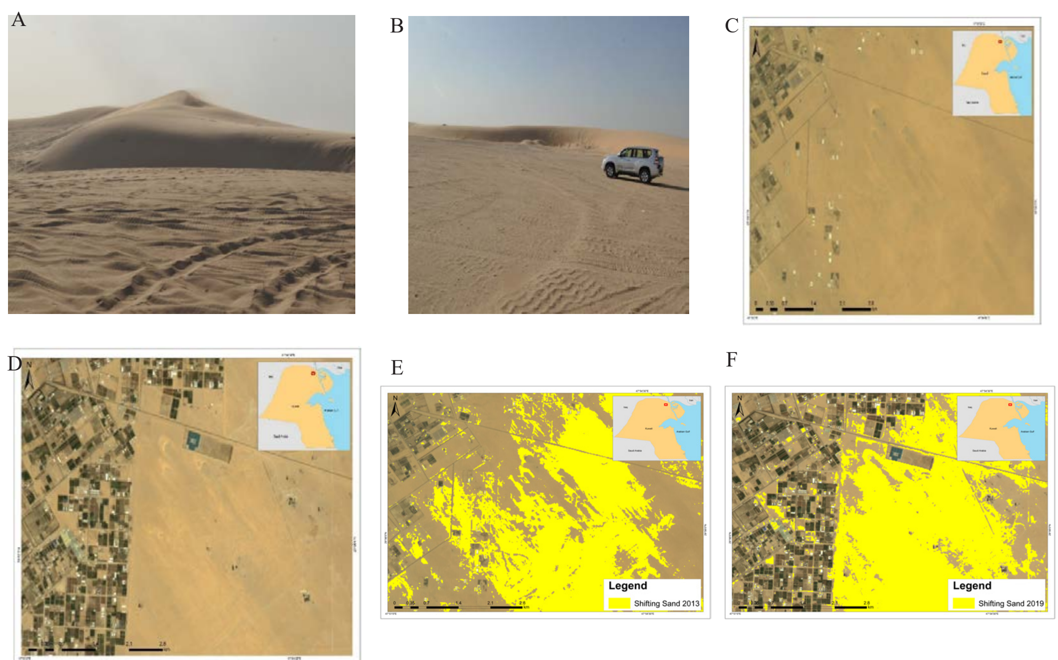

Figure 31.8. Um Al Negga Sand Dunes.
A: Star dune, October, 2017; B: Barchan Dune, 2012; C: Landsat 8 August, 2013; D: Landsat 8 August, 2019; E: Class of shifting sand August, 2013; F: Class of shifting sands, August, 2019.

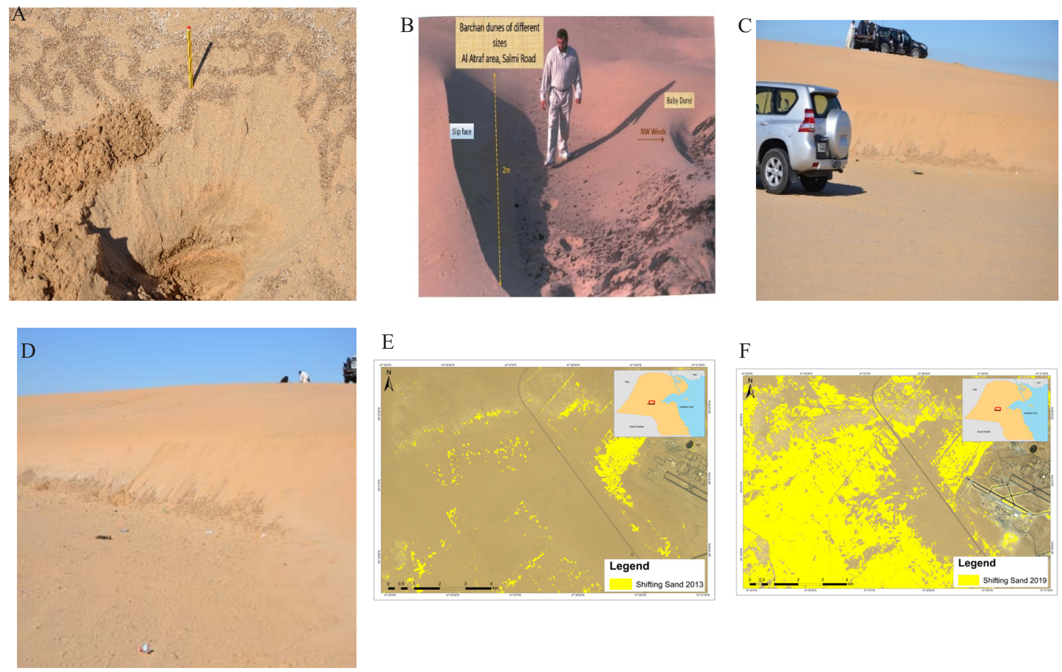

Figure 31.9. Al Atraf Sand Dunes.
A: Soil profile in the sand dune, wet zone 40 cm depth November, 2014; B: Two different barchan dunes of different sizes, C: Barchan dune, 6 metre high; D: Barchan dune 7 metre high, rich in organic materials, base of slip face; E: Class of shifting sands, August, 2013; F: Class of shifting sands in August, 2019.

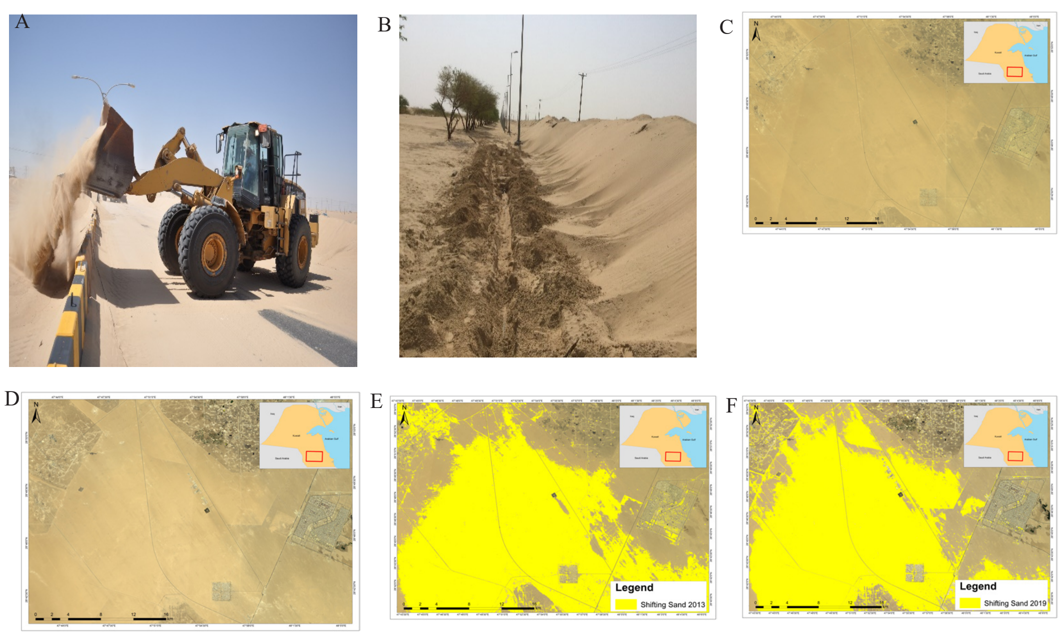

Figure 31.10. Wafra shifting sands 2013–2019.
SA: Sand encroachment Wafra-Mena Abdullah Road August, 2018; B: Wafra Animal production unit June, 2017; C: Landsat 8 image August, 2013; D: Landsat 8 image August, 2019; E: Class of shifting sands August, 2013; F: Class of shifting sands August, 2019.

Sand dunes movement (August 2013–August 2019)

The sand dune movement during the period between August 2013 and August 2019 for Al Huwamiliyah (northwest), Um Al Negga (northeast) and Al Atraf (Salmi Road) dune fields was measured using remote sensing and GIS techniques. For this purpose, three sand dunes from each field (total nine dunes) were selected. The movement for these nine dunes was estimated by measuring the distance cut (in metres) from August 2013 to August 2019 (6 yr). The yearly average distance (metres/yr) was estimated (Figs. 31.11 to 31.14 and Table 31.4).

For Al Huwamiliyah, the sand dunes movement from August, 2013 to August, 2019 ranged between 112 m and 90 m (average 102 m). This means that the average movement of sand dunes is close to 17 m/yr.

For Um Al Negga, the sand dunes movement from August, 2013 to August, 2019 ranged between 105 m and 115 m (average 111 m). This means that the average movement of sand dunes is close to 18.5 m/yr.

Al Atraf (Salmi Road) the sand dunes movement from August, 2013 to August, 2019 ranged between 165 m and 132 m (average 146 m). This means that average movement of sand dunes is close to 24 m/yr.

For Wafra, the movement of Wafra sand accumulation from August, 2013 to August, 2019 ranged between 626 m and 500 m (average 563 m). This means that the movement was 94 m/yr.

Managing the hazards of shifting sands

In Kuwait, a great number of sectors exists under the direct threats of shifting sands. These include oil, defence, highways (public works), agriculture, water and electricity and residential. Oil fields, agricultural farms, military camps and air bases vulnerable to sand encroachment problems are shown in Figs. 31.15 and 31.16.

Figures 31.13a,b,c–31.19 show a wide variety of mobile sand control measures.

Managing the hazards of shifting sands (Case study: Ali Al Salem Air Base)—background

Two air bases exist in Kuwait. These are Ali Al Salem (north) and Ahmad Al Jaber (south). Both bases are under the direct threat of shifting sands (sand dunes and sand sheets) as they are located in the natural wind corridor extending between Al Huwaimiliyah (northwest) and Wafra (southeast). Visual Analyses of Landsat images of August, 2013 and August, 2019 indicated a significant increase in the amount of shifting sands in August, 2019 compared with August, 2013. Figure 31.16 shows the sand encroachment along Ali Al Salem Air Base.

Magnitude of sand encroachment along the Air Bases

The magnitude of sand encroachment (yellow colour) along Ali Salem Air Base in 2013 and 2019 is shown in Fig. 31.17, A –D. Comparison between the conditions in year 2013 and 2019 indicated that the magnitude of the sand encroachment in 2019 was very severe. This is attributed to the extreme weather conditions especially those of June–October 2018 (very severe sand and dust storms with huge amounts of sand and dust).

Preliminary scenarios for managing the hazards of shifting sands (Case of Ali Al Salem Air Base)

Based on KISR experience (1988–2020), intensive field survey (1995–2020) by the first and second authors of this chapter and analyses and interpretation of Landsat 8 of August, 2013 and August,

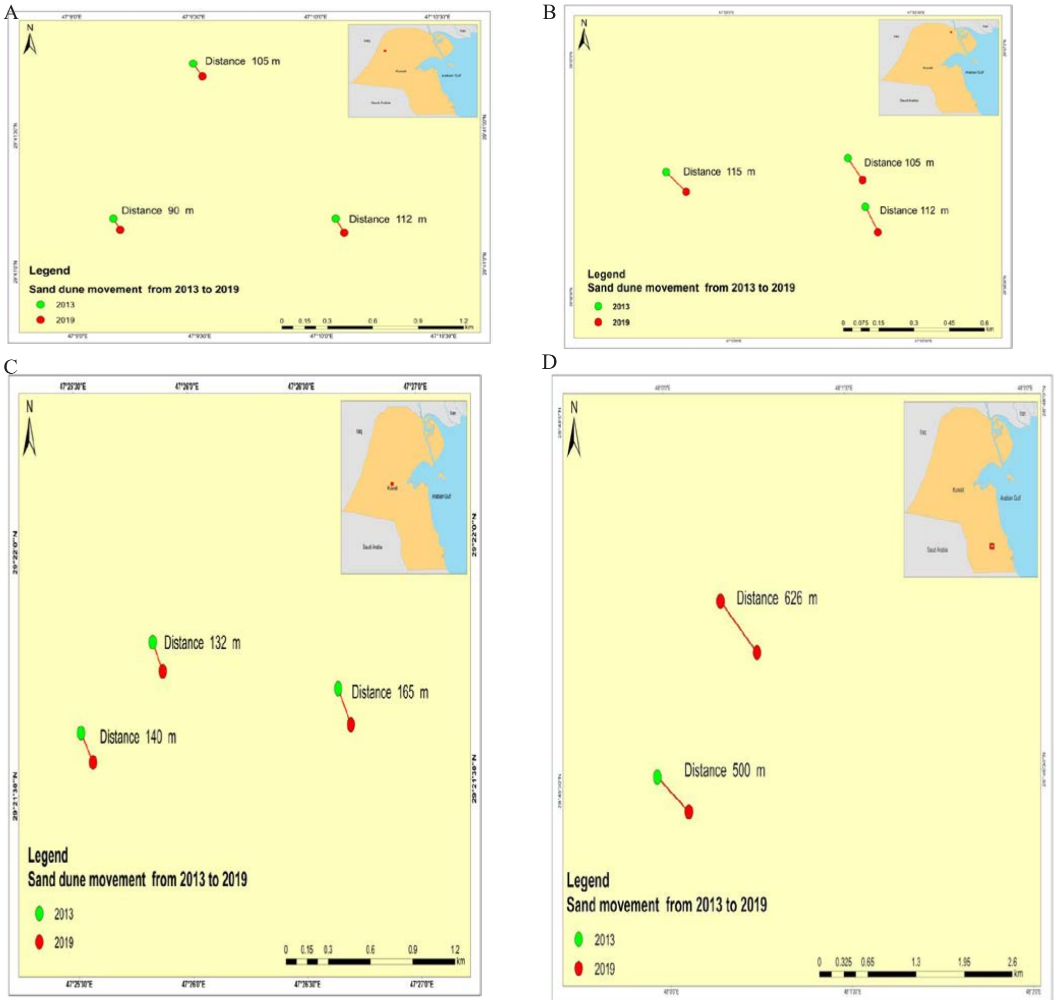

Figure 31.11. a. Dune movement (growth), Al Huwamiliyah; b. Dune movement (growth), Um Al Negga; c. Dune movement (growth) Al Atraf; d. Sand movement (growth) Al Wafra big sand accumulation.

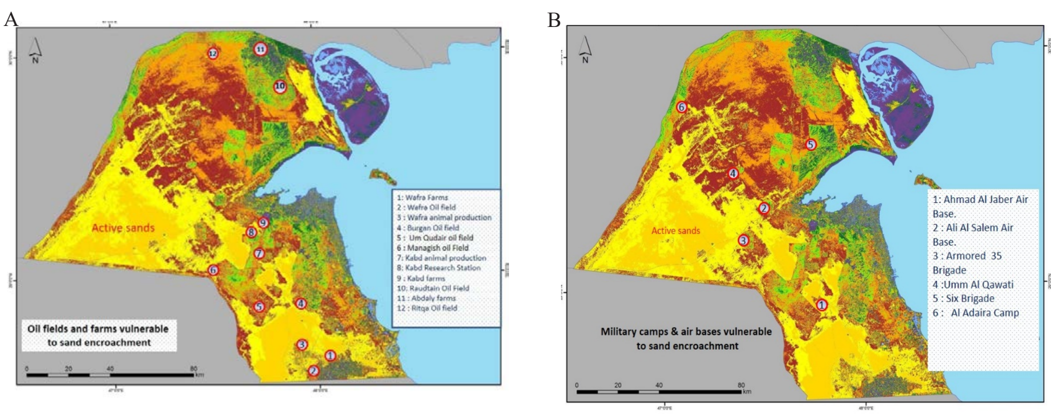

Figure 31.12a. Image of September, 2017 showing oil fields and farms vulnerable to sand encroachment; b. Image of September, 2017 showing military camps and air bases vulnerable to sand encroachment.

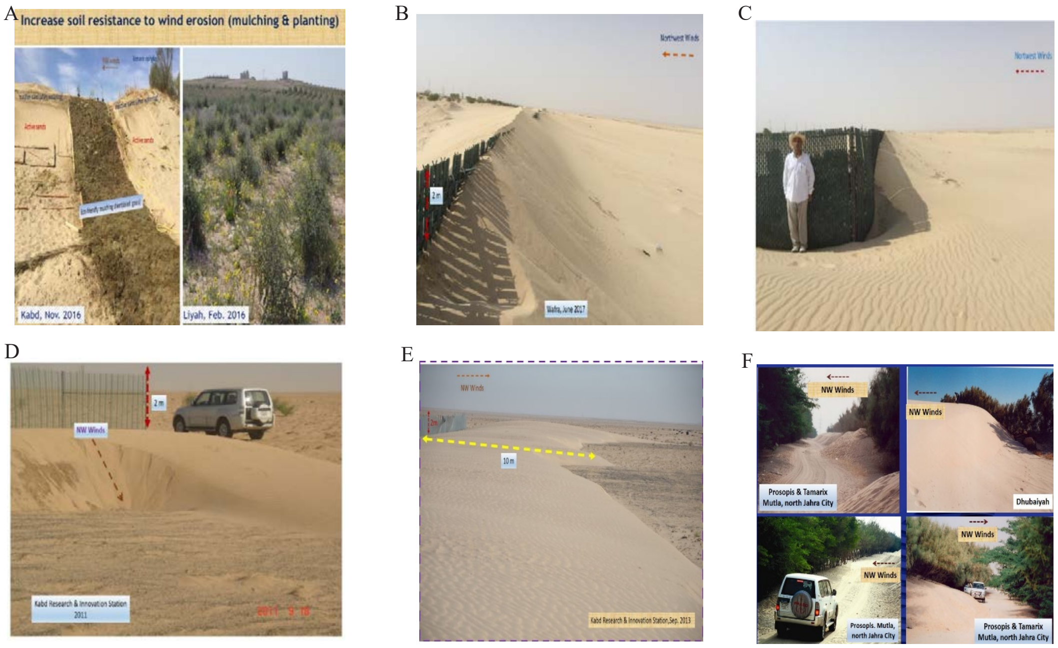

Figure 31.13a-f. Mechanical and Biological Measures of Controlling Shifting Sands.
A: Mulching and plantation to increase soil resistance to wind erosion (KISR); B: Impounding fence Wafra 2017, arrow indicates north western winds; C: Intersection of two impounding fences Wafra 2017; D: Kabd fence 2011; E: Kabd fence 2013; F: Green belts in several areas including Mutla (North Jahra city).

Figure 31.14. Field experiments, ecofriendly and other materials.
A: Liyah fence, 2011; B: Liyah fence, 2015; C: Liyah fence, 2018; D: Metal Checkerboard Liyah March, 2007; E: Ecomat sheets, gravel and tree branches, Shouaiba area September, 2006; F: Kabd Bamboo fence, 2016.

Table 31.4. Dune movement (August 2013–August 2019).

Sand dune	Dune/movement (m/yr)	Movement Obstacles	Threaten strategic targets
Al Huwamiliyah	17	Border trench Electric fence Outer fence	Edairah shooting range
Al Atraf	24	Bund walls	Salmi Road - Ali Al Salem Air Base
Um Negga	18.5	Fences	

Box 31.1. Principles of managing sand encroachment problems in Kuwait are

- Immediate reduction of wind speed through the establishment of a checkerboard system made up of date palm fronds, reed checkerboard barriers, upright tree branches (ecofriendly materials).
- Trapping wind-blown sands through creating areas of low wind speed at both the upwind and downwind sides of porous fences, 40–50% porosity, chain link type with slats (the case of Kabd Research and Innovation Station, KISR).
- Increasing soil resistance to wind erosion through mulching, planting and gravel paving.
- Assisting the natural regeneration of plant species and in turn soil stabilization through land protection for at least 5 yr (the case of Al Liyah protected area).

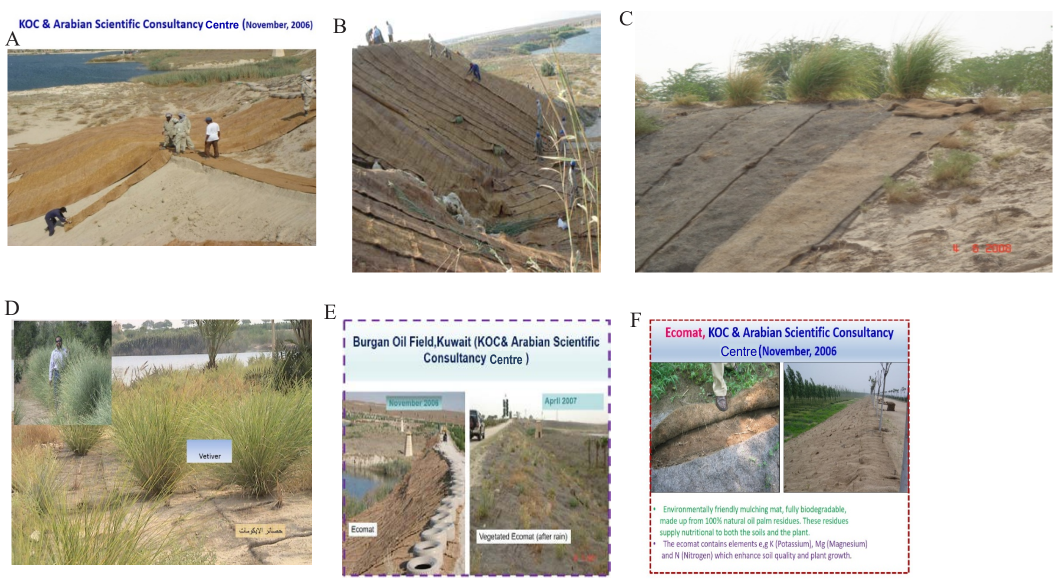

Figure 31.15a-f. Ecomat and Vetiver, Kuwait Oil Company Experience (2006–2008).
A: mulching by ecomat sheets; B: Controlling the Spirit of the Desert, Burgan oil field (2006/2007); C: Ecomat and Vetiver plantation, Burgan Oil field (slopes); D: 70 Ecomat and Vetiver plantation, Burgan Oil field (flat areas); E: vegetation cover on ecomat before and after rain; F: Benefits of ecomat.

2019, two scenarios for managing the sand encroachment problem along Ali Al Salem Air Base are proposed. The approach of the proposed scheme is to maintain the already existing green belt at the northwestern parts of Ali Al Salem Air Base. This green belt consists of four rows of *Tamarix* trees (Fig. 31.16).

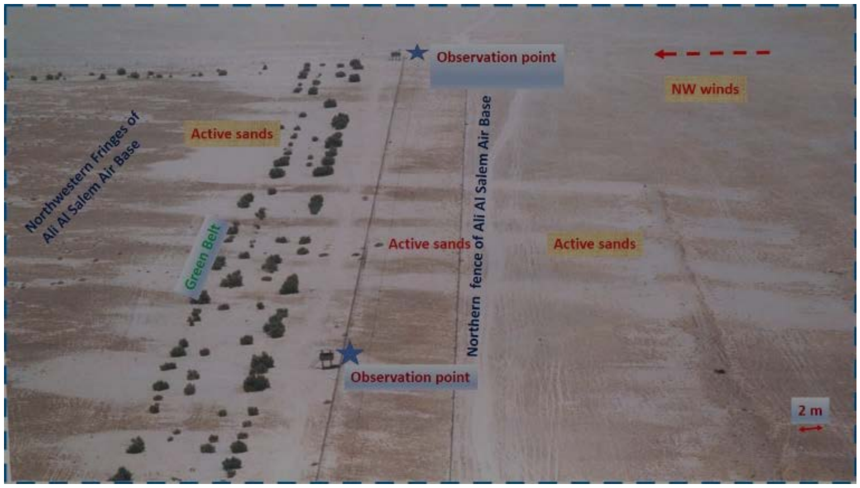

Figure 31.16. Low altitude aerial photograph showing the northwestern fringes of Ali Al Salem Air Base, note the existing green belt and the tongues of active sands (wind tunneling through gaps in the green belt).

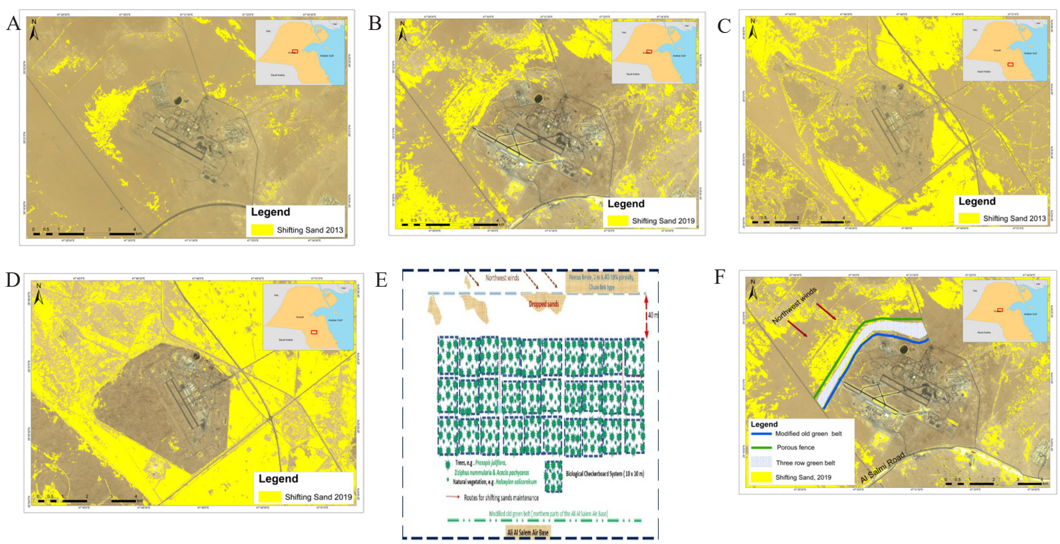

Figure 31.17a-f. Conditions of Ali Al Salem and Ahmad Al Jaber Air Bases.
A: Landsat 8 Image (August, 2013) showing the shifting sands (yellow) around Ali Al Salem Air Base; B: Landsat 8 Image (August, 2019) showing the shifting sands (yellow) around Ali Al Salem Air Base; C: Landsat 8 image (August, 2013) showing the shifting sands (yellow) around Ahmad Al Jaber Air Base; D: Landsat 8 image (August, 2019) showing the shifting sands (yellow) around Ahmad Al Jaber Air Base; E: Sketch, first scenario of mobile sand control; F: Sketch, second scenario of mobile sand control.

First scenario

The first scenario is based on the establishment of integrated biological sand control system, few metres to the north of Ali Al Salem Air Base (upwind side). The components of the first scenario, from upwind side to downwind side are as follow (Fig. 31.17 E).

- Five km length porous fence, two m high, 40–50% porosity (chain link type with slats).
- Five km length biological checkerboard system (30 m wide), 40 m downwind side of the porous fence.

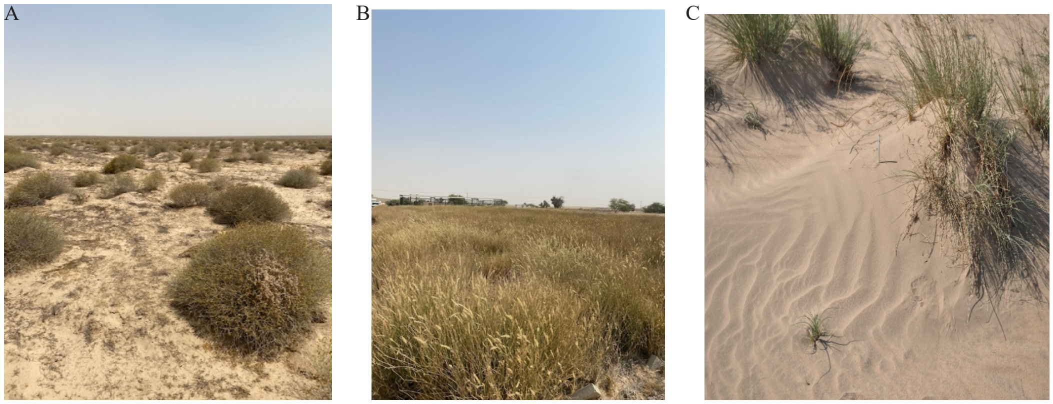

Figure 31.18. A: *Rhanterium eppaposum* community at Kabd KISR Research Station March 2020; B: *Pennisetum divisium* grown at Kabd KISR Research Station March 2020; C: *Cyperus conglomeratus* at Kabd KISR Research Station March, 2020.

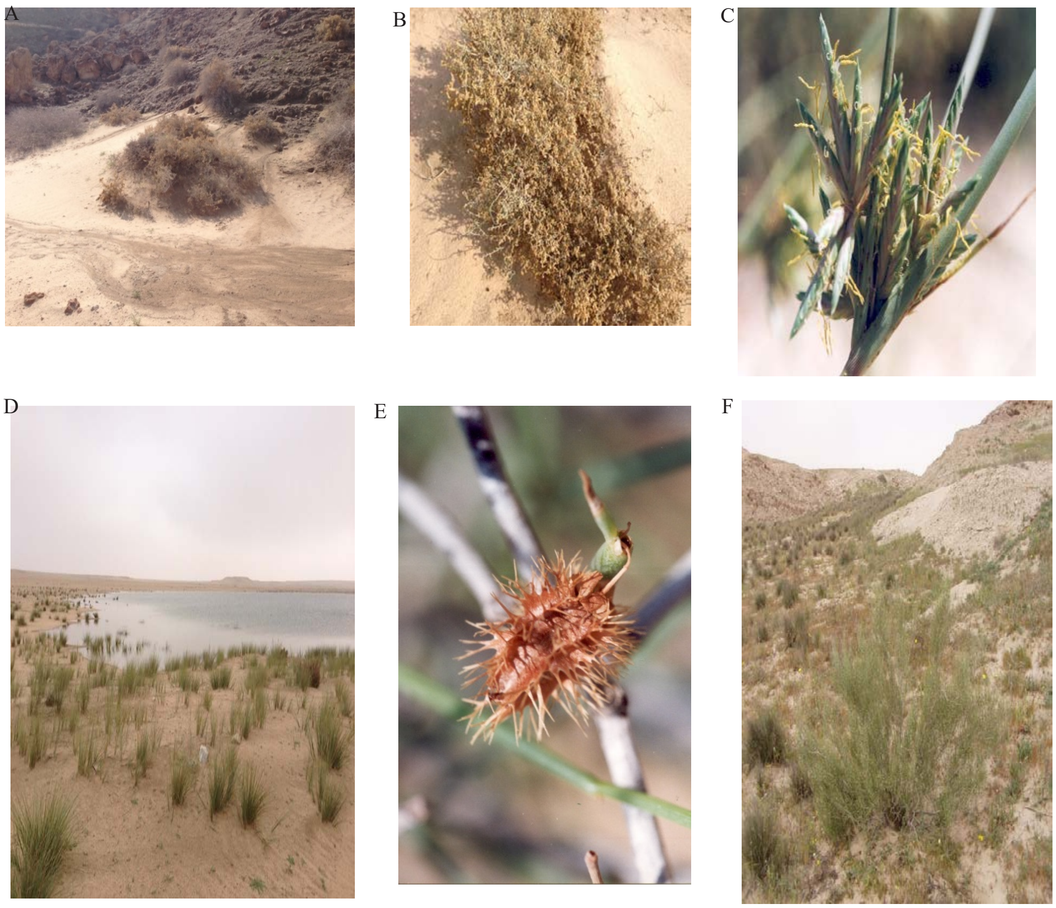

Figure 31.19a–e Several native plant species.
A: *Haloxylon salicornicum* fruits; B: *Haloxylon salicornicum* fruits;C: *Cyperus conglomeratus* spreading in Wadi Umm Al Rimam; D: *Cyperus conglomeratus* spreading in Wadi Umm Al Rimam (around the lake); E: *Calligonum polygonoides* fruit, at Wadi Al Batin; F: *Calligonum polygonoides* shrub at Wadi Al Batin, Kuwait.

This system consists of trees, e.g., *Prosopis juliflora*, *Ziziphus nummularia*, *Acacia pachyceras* and *Tamarix*. Spaces between trees will be planted by native plant species, e.g., *Haloxylon salicornicum, Cyperus conglomeratus*

- Five km of porous fence, 2 m high, 40–50% porosity (chain link type with slats).

Approximate cost

The approximate cost of the first scenario is KD 379,500 (USD 1,252,350). The cost includes the materials, labour and the expenses of 10 yr maintenance program. Breaking down costs are as follows:

- 10 km length of porous fence 2 metre high, 40–50% porosity (chain link type with slats) : KD 220,000 (USD 726,000)
- Five km length of green belt (mixed trees, e.g., *Prosopis juliflora, Ziziphus nummularia* and native plant species, e.g., *Haloxylon salicornicum*, *Cyperus conglomeratus :* KD 125,000 (USD 412,500). This cost includes irrigation system for 5 yr.
- 10-year maintenance program: KD 34,500 (USD 113,850).

The second scenario

The second scenario consists of the following components, from the upwind side to downwind: (Fig. 31.21, F).

- About five km length of porous fence, 2 metres high, 40–50% porosity, (chain link type with slats).
- About five km length of green belt consisting of three rows of drought-resistant trees, e.g., *Ziziphus nummularia*, *Prosopis juliflora*, *Acacia pachyceras* and *Tamarix* sp.

Approximate cost

The approximate cost of second scenario is KD 368,500 (USD 1,216050). This cost includes the materials, labour and 10 yr maintenance program. Breaking down costs are as follows:

- 10 km length of porous fence (chain link type with slats): KD 220,000 (USD 726,000).
- Five km length green belts, three rows of trees: KD 115,000 (USD 379,500) (includes irrigation system for 5 yr.
- 10-yr maintenance program KD 33,500 (USD110,550).

It is strongly suggested to conduct a cost benefit analyses and EIA (Environmental Impact Assessment) for the conditions of the two scenarios. In addition, wind tunnel experiments should be conducted to enhance the design of the scenarios.

Vegetation cover

Some plant species in arid and semi-arid regions develop physiological mechanisms to survive under harsh climatic conditions, such as extreme temperatures, dry wind, blasting sand particles, drought, salinity and others. Windblown sand and sand barriers are most damaging to plants however, some of the adaptive mechanisms in plants showed tolerance of some species, such as *Calligonum monogolicum* (Fan et al., 2018). Climate change further stresses plants impeding their productivity. Ahmad and Majeti, 2012 mentioned that plants evolve defence mechanisms to withstand these stresses, e.g., synthesis of osmolytes, osmoprotectants and antioxidants. Stress responsive genes and gene products including expressed proteins are implicated in conferring tolerance to the plant. Plant adaptation to abiotic stress has been reported in arid and semi-arid environments.

Figure 31.20. A: Porous impounding fence (2 m high and 40–50% porosity), Kabd Research and Innovation Station February, 2018; B: Vegetation survey by Kuwait Institute for Scientific Research. Burgan oil field Kuwait; C: Camel grazing outside Kuwait Oil Company exclosure at Kabd, Kuwait in April, 2020; D: Falling sand dunes resting on the edge of Wadi Umm Al Rimam, Kuwait.

Figure 31.21. a-f Seed harvesting, cleaning, testing and plant growth of native plants by Kuwait Institute for Scientific Research (KISR).

Figure 31.22. A: Typical nebkha, Kabd Research and Innovation Station, 2015; B: Sand encroachment, date palm cultivations, Kabd Research and Innovation Station, June 2018: C: Temporarily stabilized sand body, Kabd Research and Innovation Station, February, 2017.

Many authors in arid and semi-arid areas have assessed the relationship between sand dunes and vegetation. Some studies showed the benefits of plants in stabilizing sand dunes and in reducing erosion, sand encroachments and dust storms Al-Hemoud et al., 2019 and Modi et al., 2016. They act as windbreaks by trapping deposited sand particles. Most arid areas have open scrub type of vegetation dominated by shrubby perennial plants and grasses. When they are stabilized, they provide a good environment for a diversity of annual species. Brown and Porembski, 1998 indicated that the leeward side of micro-nebkhas (miniature dunes) offers favourable growth conditions for most native plant species in Kuwait. They also showed that species with both Saharo-Arabian and Irano-Turanian phytogeographical affinities predominate in the micro-nebkhas dunes. Al-Dousari et al., 2008 showed that nebkhas are stabilized dunes developed around dominant perennial plant species, such as *Cyperus conglomeratus*, *Haloxylon salicornicum, Rhanterium epapposum, Astragalus spinosus, Lycium shawii, Citrulus colocynthis and Panicum turgidum*.

Desert plants and green belts have been known for their economic importance in controlling mobile sand and dust hazards (Al-Dousari et al., 2019). Some common plant species identified in these studies are *Haloxylon salicornicum*, *Nitraria retusa*, *Lycium shawii* and *Calligonum polygonoides*. While sand-movement control measures showed that the sand drift fence design is a good physical barrier however, windbreaks and planting native plants have shown equal importance in controlling mobile sand in many parts of the world.

Al-Dousari et al., 2019 showed the economic values of native plants and green belts in controlling mobile sand and dust hazards. They reported that "*the average removal costs per cubic meter for aeolian encroachments around desert infrastructures in Kuwait increased from USD 1.2* *to USD 1.32, respectively, representing one of the highest expenses in the region in 1993 and 2013. Correspondingly, morphological properties of Aeolian deposits around 15 dominant species of native plants were determined, after which, the cost saving per plant was calculated equivalent to the cubic meter removal cost.* Nitraria retusa, Lycium shawii, Haloxylon salicornicum *and* Calligonum polygonoides *trapped the maximum mobile aeolian sediments up to 21.9, 15.5, 14.5, and 13.3 m^3, respectively, which make them the most efficient solutions for present and future applications in controlling Aeolian processes*". They further noted that "*native plants had a positive effect as they captured about 115 tonne of Aeolian sediments, thus saving USD 151800 as estimated removal cost of these accumulations all around human settlements. Native plants and green belts have also contributed to the reduction in the annual rates of mobile sand by 94 and 95.3%, and dust by 64.5 and 68.4%, respectively*." In addition, Ahmad et al., 2016 indicated that native plant species trapped an average of 2, 1.25, and 1.2 m^3, respectively, of mobile sand and fallen dust.

There are primary perennial plants that are adapted to accretion of sand in Kuwait that can play a major role in sand dune stabilization, thus they have economic values in reducing the cost of land maintenance. Such plants are: *Haloxylon salicornicum*, *Cyperus conglomeratus* and *Calligonum polygonoides.* Sand dune mitigation by using native plants requires understanding their abilities to withstand harsh climatic conditions, such as extreme droughts, windblown sand erosion and sand burial. In this chapter, these three plant species are presented as an example for their abilities to withstand harsh climatic conditions and explore their potential for sand dune and mobile sand control.

Dynamics of vegetation in sand dune habitats

Sand dunes provide habitats for a range of plants that can cope with the harsh environment. In Kuwait (Omar et al., 2000) identified six ecosystems. The sand dunes occurred in more than one ecosystem, these are: The coastal plain and lowland ecosystem; alluvial fan ecosystem and the barchan sand dune ecosystem. Here, emphasis is made on the sand dunes habitats in each ecosystem:

The coastal plain and lowland ecosystem

Sand dune ecosystem comprises a series of low coastal sand drifts and sand dunes along the southern and northern coastal strips. In the southern sand dunes, *Cornulaca aucheri* dominates. *Pennisetum divisium, Calligonum polygonoides* and *Cornulaca monocantha* occur in the northern sand dunes.

Alluvial fan ecosystem

This ecosystem occurs in the western, central and northern parts of the country. The high gypsum content in the soil is a chemical limitation to plant growth. Clumps of *Haloxylon salicornicum* occur on sand accumulations. Other species such as *Citrullus colocynthis*, *Cistanche tubulosa*, *Helianthemum* species, *Astragalus* species and *Schismus barbatus* are common.

Barchan sand dune ecosystem

In the northern part of Kuwait, two belts of barchan sand dunes extend in a northwest southeast direction. They are usually void of vegetation; however, they occur in areas that are potentially dominated by the *Haloxylon salicornicum* community type. Associated species are *Stipa capensis, Arnebia decumbens, Moltikiopsis ciliate, Silene villosa, Schimpera arabica, Polycarpaea repens* and *Asphodelus tenuifolius.*

Species adapted to accretion of sand

Some very specialized plants are adapted to the accretion of sand, surviving the continual burial of their shoots by sending up very rapid vertical growth. In sand-accreting situations small mounds of vegetation or debris form and tend to enlarge as the wind-speed drops in the lee of the mound, allowing blowing sand to fall out of the air stream. Plants and debris initiate the process of dune building by trapping windblown sand. The pioneering plants are physiologically adapted to withstand the problems and are good examples of stress tolerance, as well as having some ruderal characteristics. Example of such species in Kuwait are: *Haloxylon salicornicum*, *Cyperus conglomeratus* and *Calligonum poligonoides.*

Haloxylon salicornicum (Rimth) a perennial shrubby plant commonly found in the north and west of Kuwait, it is a common species in Arabia that grows up to 150 cm usually with accumulated sands around the base. It has thick branches, erect or ascending, bluish-green and fleshy when young. Flowers appear in dense lateral spikes at the end of the terminal and lateral shoots. The fruit is disc-shaped and winged, which cover plants with conspicuous pink or white paper wings. The fruits fall off the plants as they mature and can germinate within 24 hr when there is precipitation. It flowers late in the year usually from September to December. The shrub is grazed by camels and the fruits are sought after by ants. It is a great sand binder and many little animals such as lizards and beetles like to live under its branches. However, the plant is considered vulnerable in Kuwait due to human threats affecting the health and abundance of *Haloxylon* nebkhas and causing land degradation and species loss (Abd El-Wahab et al., 2014).

Cyperus conglomeratus (Thandah) this perennial summer growing sedge plant spreads in sandy areas particularly in areas where *Rhanterium epapposum* plant community has been reduced in population size. It is about 60 cm tall, spreads by short woody rhizomes and numerous thick wiry roots (about 0.5 mm thick) that are often covered by a thick greyish tomentum (fine hair), which is enveloped with dense coating sand that keeps moisture available for the plant. The roots form a rich cluster at the base protecting the meristematic tissues for regenerating new leaves. Its distinguished features are the spike heads that are arranged in clusters with stiff grooved and curving leaves. It is an excellent sand stabilizer as hillocks of fine sand form on the leeward side of the plant. The plant is grazed by camels and in some areas, it is used completely.

Calligonum polygonoides is a perennial shrub that can reach up to 200 cm with a wide distribution in Arabia. It is considered endangered (included in the Red data book of IUCN) having stem with nodes and internodes, white flowers in spike inflorescence and needle-like leaves. The fruits are red or greenish-yellow and are covered with branched stiff bristles that look like hairy strawberries. It is traditionally used to stabilize sand dunes, as fuel and in treatment of heat strokes by mixing with curd (Swarnkar et al., 2019). Figure 31.19 shows several native plant species in Wadi Umm Al Rimam and Wadi Al Batin.

Human disturbance at the sand dunes

Kuwait rangelands comprise 70% of total areas. They have been used for livestock grazing such as camel, sheep and goats. The numbers of livestock during festival seasons, where their prices go high, are beyond the capacity of the rangelands. In addition, livestock grazing is practiced continuously with extremely limited control by the government. This caused severe land degradation and complete removal of the primary plant communities such as *Haloxylon salicornicum, Rhanterium epapposum* and *Cyperus conglomeratus*. Vegetation survey and land degradation in Kuwait have been assessed by many authors (Al-Awadhi et al., 2003, 2005; Misak et al., 2002; Omar et al., 2006, 2008; Shahid et al., 1999). Today, these plants are confined in protected exclosures. They have been classified as endangered species and need polices issued for their protection.

Land degradation due to abiotic and anthropogenic factors in deserts cause more stress on plants and severe sand movement. Sand dunes are formed in many areas that are disturbed and can cause damage to roads, buildings, equipment and machines. Therefore, it is necessary to control overgrazing, camping, mining, off-road vehicle use and other human activities.

Some sand dunes are protected in Kuwait due to their location in areas classified as nature reserves. These areas are Sabah Al Ahmad Nature Reserve, Kabd Research and Innovation Station at and other new areas to be developed such as Al Huwaimiliyah. Active sand dunes are dynamic and vulnerable to continuously moving with high-speed winds. Therefore, it is difficult to stabilize them naturally or artificially with native plants. Compound fences have been used at Kabd Research and Innovation Station and found to be successful in accumulating and stabilizing sand. These dunes are now surrounded by a good coverage of native plants. Figure 31.20a-b shows a porous fence and vegetation survey respectively. Figures 31.20c and 31.20d show camel grazing and falling dunes respectively.

Mobile sand control measures by using native plants and green belts

Kuwait Institute for Scientific Research (KISR) established measures to control mobile sand by using compound fences and revegetation with native plants techniques. Green belts were established since the 60s by the Public Authority for Agriculture and Fish Resources (PAAFR). They were developed by planting some drought-tolerant exotic species in many locations around the city of Kuwait and other areas. Some introduced species are *Eucalyptus, Prosopis, Tamarix Acacia* and *Ziziphus*. Many other species were tested in less vulnerable locations to establish green belts (such as date palms).

The revegetation research conducted by KISR provided baseline information for mass production of native plants, seed collection and processing and revegetation methods. Some specific plant species were selected due to their ability to grow from seeds to plants. These include: *Rhanterium epapposum*, *Farsetia aegyptia, Calligonum commosum, Haloxylon salicornicum, Lycium shawi, Nitraria retusa, Ochradenus baccatus, Pennisetum divisium* and *Panicum turgidum*. The plants were grown in greenhouses and transferred to lathhouse and finally grown in the field. Some farmers in Kuwait became interested to produce plants particularly after Kuwait has been awarded millions of dollars by the United Nations Compensation Commission (UNCC) to rehabilitate damaged areas due to the Iraqi invasion of Kuwait in 1990. There have been many areas where revegetation by native plants was successfully demonstrated. This allowed considering native plants in stabilization of mobile sand in vulnerable areas along the sand belts. Native plants showed more benefits in street planting due to their ability to stand harsh climatic conditions and required minimal water. Figure shows seed harvesting and plant growth. Figures show nebkhas and temporarily stabilized sand body. Pl check

Conclusion

The total area of Kuwait is 17,800 km^2 out of which sand dunes (including nebkhas) and sand sheets cover about 5093 km^2 (29% of the country). Sand dunes are located along the coastal zones and inland formulating different shapes based on their geomorphic characteristics, e.g., crescentic, star and falling dunes. The central part of the terrestrial environment of Kuwait, which covers about 9,000 km^2, is an open theatre for extremely active aeolian processes. These processes represent one of the main threats on several agricultural farms, military camps, air bases, oil fields, residential areas and highways. To alleviate sand dunes hazards, a sustainable management plan needs to be adopted in Kuwait. The sand dune movement during the period between August 2013 and August 2019 for Al Huwamiliyah (northwest), Um Al Negga (northeast) and Al Atraf (Salmi Road) dune fields was measured using remote sensing and GIS techniques. The average movement of sand dunes ranges between 17 m/yr (Al Huwamiliyah) to to 24 m/yr (Al Atraf). Some plant species in arid and semi-arid regions develop physiological mechanisms to survive under harsh climatic conditions, such as extreme temperatures, dry wind, blasting sand particles, drought, salinity and others. Windblown sands are most damaging to plants however, some of the adaptive mechanisms in plants showed tolerance of some species, such as *Calligonum monogolicum*. Desert plants and green belts have been known for their economic importance in controlling mobile sand. Sand dunes provide habitats for a range of plants that can cope with the harsh environment. Examples are

Haloxylon salicornicum, *Nitraria retusa*, *Lycium shawii* and *Calligonum polygonoides*. Kuwait rangelands comprise 70% of total areas. They have been used for livestock grazing such as camel, sheep and goats. The numbers of livestock during festival seasons, where their prices go high, are beyond the capacity of the rangelands.

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