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Developments in Soil Classification, Land Use Planning and Policy Implications

Innovative Thinking of Soil Inventory for Land Use Planning and Management of Land Resources

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Chapter 41
Managing the Hazards of Drought and Shifting Sands in Dry Lands: The Case Study of Kuwait

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Abstract Dry lands cover about 41% of the global terrestrial areas. These are characterized by low average annual rainfall and large variations. Drought is a serious natural hazard in Kuwait and its adjacent countries. During the last four decades, Kuwait experienced a number of dry seasons with rainfall below average (<110 mm year^{-1}). During 2007–2008 and 2008–2009 dry seasons, total rainfall of 35 and 65 mm was recorded, respectively. The consequences of the drought seasons were the massive soil losses (750–1,000 m^3 ha^{-1} in the west Managish area in July 2008); severe sand encroachment even in areas protected for decades, e.g., KISR experimental station at Kabd; relatively longer period of sand and dust storms (May–September 2008 and July–August 2009); and depletion of soil moisture and dryness of natural vegetation.

Sustainable land-use planning in Kuwait is the first defensive step to mitigate the consequences of drought and to reduce land degradation. In the past 15 years, significant changes in land use were observed in Kuwait. Some of these changes have positive and others have negative ecological and environmental impacts. Establishment of the buffer zone (15 km wide and >200 km long) between Iraq and

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Kuwait in 1993–1994 enhanced the vegetation cover and improved biodiversity and soil conditions, while border trenches (3 m deep, 5 m wide, and hundreds of kilometers long) and the construction of bund walls (2–3 m high, 3–5 m wide, and hundreds of kilometers long) have negatively affected surface water and natural vegetation. It is visualized that in Kuwait sustainable measures to mitigate the consequences of drought are not well adopted. Based on the vast KISR experience in managing dry lands, four programs are proposed to manage the hazards of drought in Kuwait. These are watershed management and restoration, mitigating hydrological drought, managing the hazards of shifting sands, and setting up sustainable land-use plans. The main objective of this study was to adopt integrated approach to mitigate drought in Kuwait. To achieve the objective, intensive fieldwork including experiments and surveys accompanied by analyses and interpretation of remote sensing data were carried out and reported in this chapter.

Keywords Hydrological drought • Kuwait • Rainwater harvesting • Shifting sands • Sustainable land-use plans

41.1 Introduction

Kuwait covers 17,818 km^2 area, of which 85% is covered by terrestrial environment, where 19 land uses are identified. Of these uses, the rangeland grazing constitutes about 75% (KISR 1999). The soil survey of Kuwait (KISR 1999) mapped eight major soil great groups in the terrestrial environment of Kuwait, of which the Petrogypsids constitute 33% (KISR 1999). A vegetation map of Kuwait was published by Omar et al. (2001).

The map was prepared through field surveys and integrating soil and vegetation information in a geographic information system (GIS) environment. The vegetation map presents eight vegetation units: Haloxyletum (22.7%), Rhanterium (2.1%), Cypertum (26.9%), Stipagrostietum (39.3%), Zygophylletum (0.3%), Centropodietum (1%), Panicetum (0.7%), and Halophyletum (1.9%). The study (Omar et al. 2001) also revealed intensive land degradation and retrogression of shrub by species in particular Rhanterium epapposum.

The rainfall in Kuwait is scanty and irregular; the rainy season extends between October and April. The average annual rainfall is about 110 mm. The rainfall fluctuates annually ranging from a reported high of 351.7 mm at Al Ahmadi in the south during 1971–1972 season to the lows of only 20.1 mm at Umm El Eish, in the north, during 1963–1964 season (Omar et al. 2001). During the last four decades, Kuwait experienced a number of dry seasons (2007–2008, 2008–2009) during which rainfall was below the average level of 110 mm. The prevailing wind direction is from northwest and average speed is about 4 m s^{-1}.

During dry seasons of 2007–2009, there was limitless supply of drifting sands in the desert of Kuwait, especially in areas of wind corridors (Huwaimiliyah-Wafra and Umm Qasr-Ras Al-Sabiyah). Massive soil losses (750–1,000 m^3 ha^{-1}) in the west Managish area in July 2008 and severe sand encroachment even in areas protected for decades, e.g., KISR experimental station at Kabd, were the consequences of the dry seasons. Rainfall deficiency resulted in rapid depletion of soil moisture and degradation of vegetation cover. Wide areas experienced unusual sand and dust storms (Civil Aviation of Kuwait April 2009). The absence of drought preparedness plan and adequate early warning systems in Kuwait has exacerbated the impacts of droughts in the last 2 years.

Five-year (2003–2008) protection of highly degraded terrains, e.g., Al Liyah area (north of Al Jahra City), resulted in soil stabilization and recovery of great number of native plants and animals. Use of eco-friendly mulching materials (eco-mat and plant residues) in desert sandy soils resulted in immediate soil stabilization and soil improvement. In these mulched soils, soil moisture in the upper 60-cm depth was 2.5 times greater than the moisture in untreated soils (Misak et al. 2007).

A national action plan to control land degradation and to mitigate the drought effects currently does not exist in Kuwait, and hence, sustainable land-use planning is lacking. Activities like grazing and military exercises are allowed in highly vulnerable areas, such as Al Edairah in northwestern parts of the country. Water harvesting programs for large catchment areas such as Wadi Al Batin (western part of the country) and Jal Az Zour (northeastern part of Kuwait) are not designed. However, measures to manage flash floods are applied in several areas, e.g., Jahra City (west of Kuwait City) and Shuaiba Industrial Area (south of Kuwait City).

In order to address certain issues in the deserts of Kuwait, a study was started with the objective to formulate a management plan to mitigate the impacts of drought in the deserts of Kuwait.

41.1.1 Drought Events and Consequences

During the past four decades, Kuwait has experienced a number of dry seasons. During these dry seasons, rainfall was below the annual average level (110 mm year^{-1}). A meteorological record of dry seasons shows total rainfall as 28.1 mm (1963–1964), 39.7 mm (1972–1973), 31.6 mm (1988–1989), 28.3 mm (1993–1994), 35 mm (2007–2008), and 65 mm (2008–2009). In addition to short dry seasons, Kuwait experienced drought periods that lasted for more than three seasons, e.g., 1962–1967 (28.1–87.7-mm rainfall) and 1987–1990 (31.6–84-mm rainfall). Figure 41.1 presents rainfall data from 1957 to 2005.

Field observations during the dry seasons of 2007–2008 and 2008–2009 revealed that landforms and local ecosystems have differently responded to drought. Eolian forms (barchans, falling dunes, nabkhas, and sand sheets), hydrographic basins (wadis and depressions), and wetlands (coastal and inland sabkhas) are sensitive, in varying degrees to drought (Table 41.1).

In relative sense, native plant species exhibit three degrees of susceptibility to drought: extremely high, high, and medium. The *Stipagrostis plumosa* is most

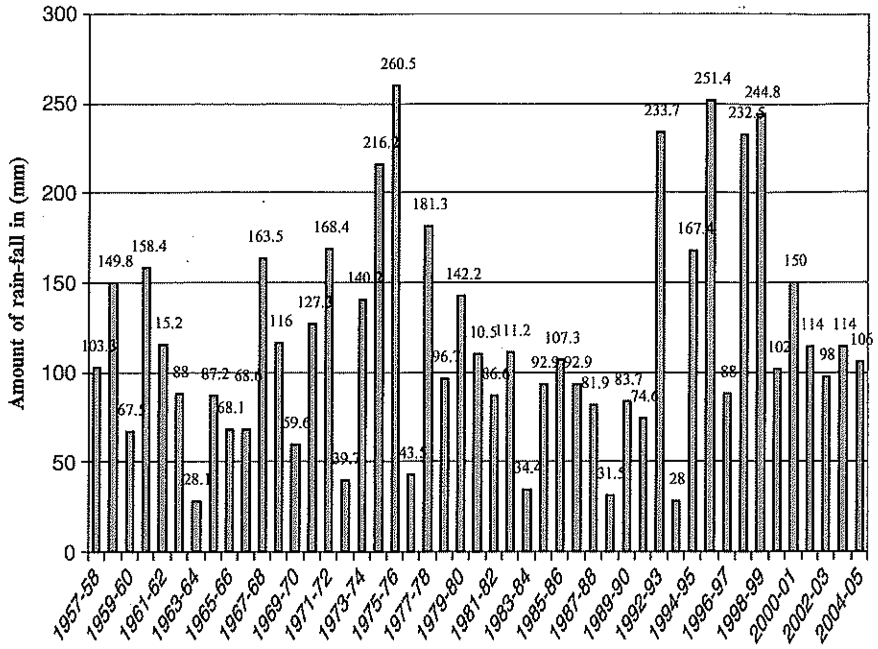

Fig. 41.1 Rainfall in Kuwait 1957–2005 (Al-Dousari et al. 2007)

Table 41.1 Responses of several ecosystems to drought in Kuwait

Landform/ecosystem	Response to drought	Remarks
Eolian	Depletion of stored moisture Disappearance of annuals High rates of soil losses (by wind) Degradation of perennial vegetation (through wind blasting and exposing roots) Deterioration of wildlife	Eolian landforms cover about 50% of the surface of the desert of Kuwait
Wadis and depressions	Drop of water table of wadi fill aquifers Vegetation degradation Increase of soil dryness Increase of soil losses by wind and water (in coming wet seasons)	
Sabkha	Concentration of surface salts Increase groundwater salinity Deterioration of natural vegetation, especially annuals growing in sandy patches within the sabkhas Erosion of fine particles from topsoil	Coastal and inland sabkhas cover about 8% of the surface of Kuwait

susceptible to drought, while *Haloxylon salicornicum* and *Cyperus conglomeratus* are highly susceptible. On the other side, *Rhanterium epapposum* has medium susceptibility to drought conditions (due to its ability to become dormant during summer and low-rainfall conditions).

In the terrestrial environment of Kuwait, drought indicators are diversified and are differentiated into physical and biological. Physical indicators are sand drifting, formation of active sandy sheets and prevalence of dust and sand storms, development of salt crusts, mud cracking, and others, while biological indicators are represented by root exposure and removal and dryness of vegetation.

41.2 Methodology

To achieve the objective of the present study, a number of activities were accomplished. Kuwait was geographically classified into four sectors: NE (2,200 km^2), SE (4,627 km^2), SW (4,750 km^2), and NW (3,981 km^2). The soils, vegetation cover, landforms, and land-use types of different sectors were generally reviewed. These include soil (KISR 1999), vegetation (Omar et al. 2001), and land-use/land cover maps of Kuwait (KISR 1999).

Latest information on the soils, vegetation, land use, land degradation types, and hydrologic disruption was obtained through intensive field surveys (May 2008–May 2010) and measurements. To complete this task, ten pilot sites representing the prevailing conditions and land-use types were selected (Fig. 41.2).

Interpretations of Landsat Thematic Mapper (TM) band 2, 4, and 7 color composite (March 1995); Landsat 7 Enhanced Thematic Mapper (ETM+) band 2, 4, and 7 color composite mosaicked images recorded 31 January and 26 March 2000; Landsat Thematic Mapper (TM) of 2004; and aerial photos of 2003 were made. These images were used in the delineation of main landforms, areas of hydrologic disruption, extent of catchment areas, and areas affected by shifting sands. Ground truth for remote sensing information was conducted in more than 50 ground stations distributed in different parts of the terrestrial environment of Kuwait. The ESRI Arc Map GIS & Arc Info GIS is used to map 11 surface hydrologic units. A field criterion for the assessment of the long-term impacts of the main land-use types in the terrestrial environment of Kuwait was established. The criterion indicates the vertical extent of damage into the soils. Based on this criterion, land uses are differentiated into three categories, extremely destructive (damage extends 1.5–5 m), destructive (damage extends 50–75 cm), and nondestructive (no observable damage).

Assessment of the sand encroachment problem in Kabd area (southwest of Kuwait city) was made using field surveys and remote sensing information. The locations of encroached facilities were recorded using GPS equipment (Global Positioning System). The current measures and practices of mobile sand control were assessed based on their efficiency and durability.

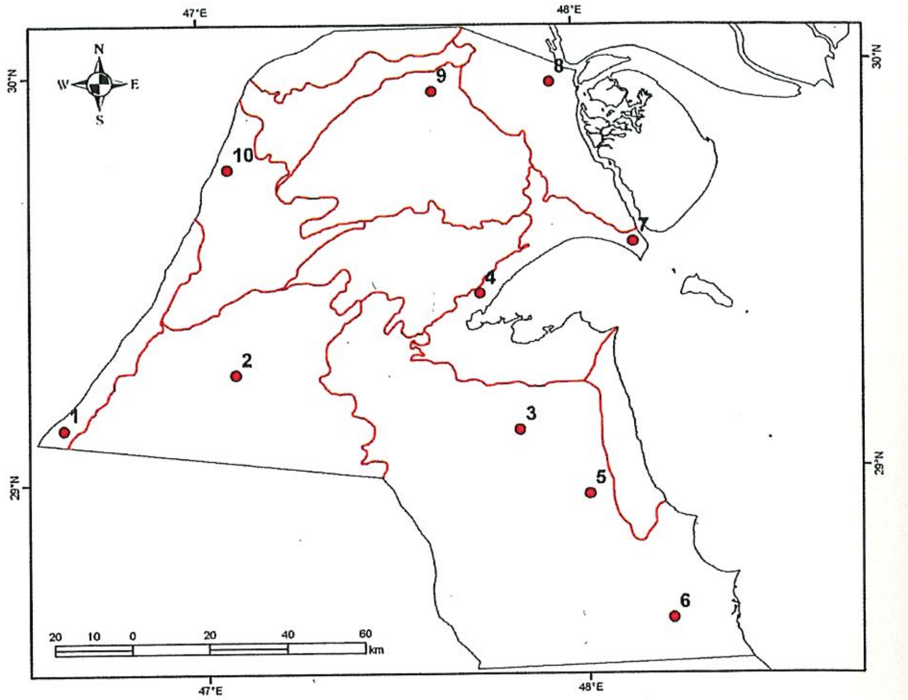

Fig. 41.2 Map showing the locations of pilot sites

A number of field tests and experiments were designed and implemented to control mobile sands, combating land degradation and managing micro watershed areas. These tests include gravel paving of active sandy sheet (Managish pilot site); development of checkerboard system on active sandy sheets (Managish pilot site); protection of a desert facility through erection of fences made up of plant residues, about 1 m high (Managish pilot site); mulching of sandy soils using ecomat, plant residues, and gravel (Al Liyah, Shuaiba, and Subahiyah sites); trapping and then biological stabilization of drift sands using vetiver (Al Managish pilot site); shattering thick soil crusts to enhance soil infiltration capacity and to encourage the growth of natural vegetation (Al Liyah and Subahiyah sites); and water harvesting techniques (mainly earth dykes and terraces) (Liyah, Shuaiba, and Subahiyah sites).

41.3 Results and Discussion

To achieve successful results in mitigating the effects of drought requires detailed understanding of local and regional environmental conditions, potential of natural resources, and past and current land-use and socioeconomic conditions. In addition, it is essential to assess and monitor drought conditions (duration, frequency, and severity) and drought impacts on short-, medium-, and long-term basis. Based on

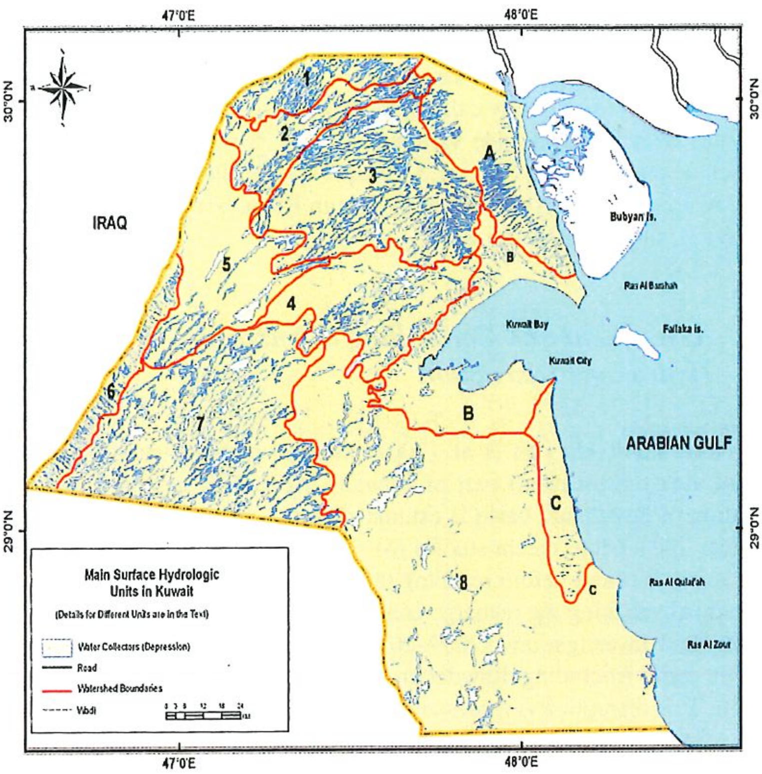

Fig. 41.3 Main surface hydrologic units in Kuwait

the long experience of KISR in managing dry lands and restoration of degraded terrains, the following programs are proposed for mitigating the drought in Kuwait: (1) watershed management, (2) mitigating hydrological drought, (3) managing the hazards of shifting sands, and (4) setting up of sustainable land-use plans

41.3.1 Watershed Management

Based on the nature and location of discharging sites, hydrographic basins in Kuwait are distinguished into the following two main categories, described below.

41.3.1.1 Exterior Basins

This set of basins discharges into surrounding water bodies, i.e., Khor As Sabiyah, Kuwait Bay, and Arabian Gulf. These basins are geographically classified into three subsets. These occur from north to south (Fig. 41.3): Khor As Sabiyah (A), Kuwait Bay (B), and Arabian Gulf (C).

41.3.1.2 Interior Basins

This set of basins discharges into inland hollows (playas) and plains, e.g., Rawdatain-Umm El Eish collectors (locally called khabari). These basins are differentiated into several units which exhibit wide variations in size, features, and land use. These basins include the following (Fig. 41.3): Ritqa (1), Abdaly (2), Rawdatain-Umm El Eish (3), Al Liyah-Umm Al Rimmam (4), Umm Ruwaysat (5), Wadi Al Batin (6), Dibidibah (7), and Kabd-Wafra (8).

41.3.2 Assessment and Controlling of Surface Hydrologic Disruption

In a previous study, Ud Din et al. (2007) mapped and evaluated the Rawdatain catchment area (northeastern part of Kuwait). According to this study, the total precipitation of Rawdatain basin is estimated at 334 million cubic meters (MCM) for the year 2003. More recent studies (Misak 2009) indicate that huge amount of runoff water is blocked before reaching to Rawdatain basin. This factor should be considered in evaluating the recharge conditions of this basin.

Recent field investigations (2009–2010 season) reveal that almost all of the hydrologic units (including Rawdatain catchment) are subjected to hydrologic disruption. This disruption is represented by the following forms.

41.3.2.1 Degradation of Ground Cover (Soils and Vegetation)

This form of degradation is caused by various human activities specially overgrazing and camping and recreation. It negatively influences the local hydrologic conditions (mainly soil infiltration capacity). Al-Dousari et al. (2000) assessed the impact of ground cover degradation on local hydrologic conditions in a part of hydrologic unit no. 7 (Dibidibah). According to this study, the infiltration capacity of the degraded soil has decreased by 18.46–91.96% in comparison with nondegraded soils in the same unit. In Ahmadi-Al Daher area (hydrologic unit C), the infiltration rate of degraded soils has decreased by 61.45% in comparison to non-degraded soils of the same unit (Al-Awadhi et al. 2005).

41.3.2.2 Modification/Blockage

Modification/blockage of the natural flow of runoff water and in turn disruption of recharge conditions of shallow aquifers have also been observed, such as roads of Mutlaa-Abdaly (about 75 km) and bund walls such as those of Sabah Al Ahmad Natural Reserve (about 117-km length) and Wadi Al Batin that block and modify runoff water.

The areas, land use, vegetation and soil types, mechanism of hydrologic disruption, and proposed mitigation measures for the different surface hydrologic units are presented in Table 41.2.

Table 41.2 Field data on surface hydrologic units

Hydrologic unit	Map symbol	Area (km^2)	Land use	Vegetation types (Omar et al. 2001)	Soil types (KISR 1999)	Mechanisms of surface hydrologic disruption	Recommended mitigation measures
Khor As Sabiyah	A	1,010	R, C	Hs, Cc, Re, Sp, H	Gc, Ch, Sa	Dg	Md
Kuwait Bay	B	1,097	U	H, Hs, Sp	Sa, To	Dg	
Arabian Gulf	C	439	U, R, I	Cc, H	Sa, To	Dg	
Ritqa	1	473	P	Hs	Gp	Dg, Ms	
Abdaly	2	613	A, R, Me	Hs, Sp	Gp	Dg, Ms	
Rawdatain-Umm El Eish	3	1,886	R, O	Hs, Cc, Sp	Gc, Ch	Dg, Ms, Mg	Md, Re, Br
Al Liyah-Umm Al Rimmam	4	1,122	R	Sp, Cc	Gp, Ch, Cp	Dg, Ms	Md
Umm Ruwaysat	5	1,209	R, Me	Hs	Gp	Dg	
Wadi Al Batin	6	402	P	Hs, Sp	Gp	Ms, Mg	Md
Dibidibah	7	2,608	R, C	Sp	Gp	Dg	Md, Re, Br
Kabd-Wafra	8	5,559	R, O, A, C	Cc, Sp	Ts, Sa, Ch	Dg	

Land use
Rangelands grazing (R), camping and recreation (C), military exercises (Me), oil extraction (O), protected areas (P), agricultural (A), urban (U), industrial (I)
Vegetation type:
Haloxylon salicornicum (Hs), *Cyperus conglomerates* (Cc), *Stipagrostis plumose* (Sp), *Panicum turgidum* (Pt), *Rhanterium epapposum* (Re), *Halophyletum (Nitraria retusa, Tamarix aucheriana, and others)* (H)
Soil types
Haplocalcids (Ch), Petrocalcids (Cp), Calcigypsids (Gc), Petrogypsids (Gp), Aquisalids (Sa), Torriorthents (To), Torripsamments (Ts)
Mechanism of surface hydrologic disruption:
Degradation of groundcover (Dg), modification/blockage of the surface runoff (Ms), disruption of groundwater recharge conditions (Mg)
Recommended mitigation measures
Maintenance of drainage: establishing open cuts in the bund walls or culverts under roads to allow the free movement of runoff water to basins (Md); revegetation of native plants (Re); breaking soil crusts to enhance infiltration rates (Br)

41.3.3 Floods in Kuwait

In Kuwait floods occur during heavy rainstorms with rainfall amounting 30–40 mm in one storm (Al-Dousari et al. 2007). Historic and recorded flood events in Kuwait took place in the following dates: 27 December 1934, 30 November 1954, 2 February 1993 (40 mm within 6–8 h), 11 November 1997 (105 mm within 3–4 h), January 2004, January 2007, April 2008, and November 2009.

41.3.4 Water Harvesting (A Case Study)

In a previous study, Kwarteng et al. (2000) mapped large depressions and playas, paleo-drainage patterns, and catchment areas in northeastern part of Kuwait using aerial photographs, Landsat Thematic Mapper (TM), and digital elevation model (DEM) datasets. They stated that under specific conditions in Kuwait, large volume of rain accumulates in depressions and recharges shallow groundwater aquifers.

Runoff water is developed in the majority of watershed areas during intensive rainfall. These watersheds include Jal Az Zour (northeastern part of Kuwait), Al Ahmadi (south of Kuwait City), and Wadi Al Batin (western part of Kuwait). In general, considerable amount of rainwater is often wasted due to inappropriate land-use types.

To minimize the impact of drought in Kuwait, local water collectors need to capture rainfall water and store it as much as possible. Even under low- and variable-rainfall conditions, efficient soil moisture management before, during, and after rainy seasons is a good approach for improving local water supplies for vegetation use. In addition, runoff water should be collected and stored. In 2006, water harvesting systems were established in Shuaiba Industrial Area (Al-Dousari et al. 2007). The system consists of check dykes (1.5–2 m high, 2–3 m wide) in the main course of an active wadi (Fig. 41.4).

Our long experience in Kuwait indicates that there is reasonable potential for water harvesting in Jal Az Zour, Wadi Al Batin, and Ahmadi ridge during good rainy seasons (when total annual rainfall exceeds 120 mm and to be distributed in a number of heavy showers each at least 20 mm). Water harvesting systems have numerous benefits. In addition to collection and storage of rainwater, they minimize the hazards of flash flooding (if properly designed).

41.3.5 Mitigation of Hydrological Drought

Although climate is a primary contributor to hydrological drought, other factors such as changes in land use, e.g., clearance of vegetation; construction of bund walls (1.5–2 m high, 3–5 m wide, and 10 km long); and digging of trenches (2–3 m deep, 3–5 m wide, and 10 km long) negatively affect the local hydrological

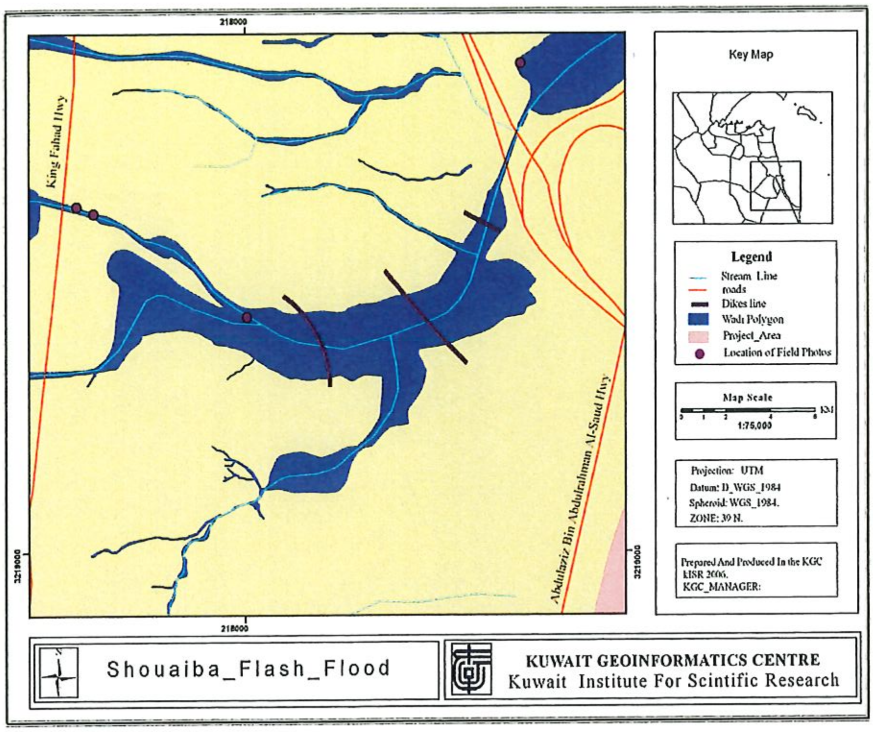

Fig. 41.4 Location of check dykes in the course of main Wadi at Shuaiba Industrial Area (Al-Dousari et al. 2007)

characteristics and the mechanisms of shallow groundwater recharge. In some cases, bund walls act as dams or check dykes, which block the surface runoff and prevent recharge at downstream portions. This is the case at Umm El Eish and Rawdatain basins (northeastern parts of Kuwait) and to some extent Wadi Al Batin (western parts of Kuwait).

41.3.5.1 Forms of Hydrological Drought

Recent field observations (2009–2010 season) indicate that a number of land uses have negative impact on recharge conditions of vital shallow groundwater reservoirs. The flow of runoff water of several catchment areas is disrupted. In some cases such as the case of Rawdatain-Umm El Eish catchment, at least 40% of runoff water does not reach to discharging areas. Figure 41.5 shows the main catchment area of Rawdatain-Umm El Eish basin. In the case of Umm El Eish and Rawdatain basins, hydrological drought is mainly represented by deficiency of runoff water in the downstream portions as a direct result of land-use changes. Runoff water is blocked in the upstream portions by solid bund wall (2 m high). This bund wall is

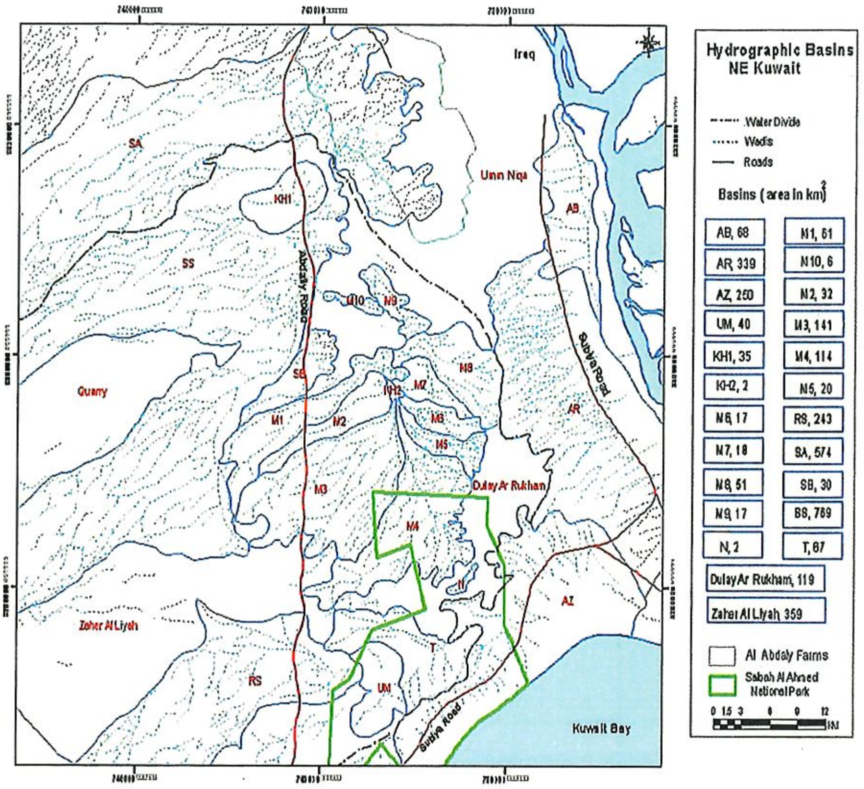

Fig. 41.5 Rawdatain-Umm El Eish catchment area (Misak et al. 2008)

constructed at the northern side of Sabah Al Ahmad Natural Reserve (Fig. 41.6). This results in acute shortage of runoff in the downstream portions and the consequent depletion of soil moisture, i.e., hydrological drought.

41.3.5.2 Restoration of Hydrologic Drought (A Case Study)

To mitigate hydrologic drought at the southern part of Umm El Eish catchment area (case study), it is proposed to (1) map the catchment area using Arc GIS 9.2; (2) locate the bund walls which cut the catchment area using GPS; (3) assess the impact of bund walls on surface water conditions, i.e., runoff and soil conditions; (4) compare between the soil conditions (moisture and texture) and vegetation (types, density, biomass, and biodiversity) in two sites, one in the upstream of the bund wall and the second in downstream side; (5) identify sites where runoff of main water courses is blocked by the bund walls; (6) design an action plan to modify the bund walls through establishing culverts (cuts) to allow the free flow of surface runoff to its discharging basin (Umm El Eish water collector) (culverts in bund

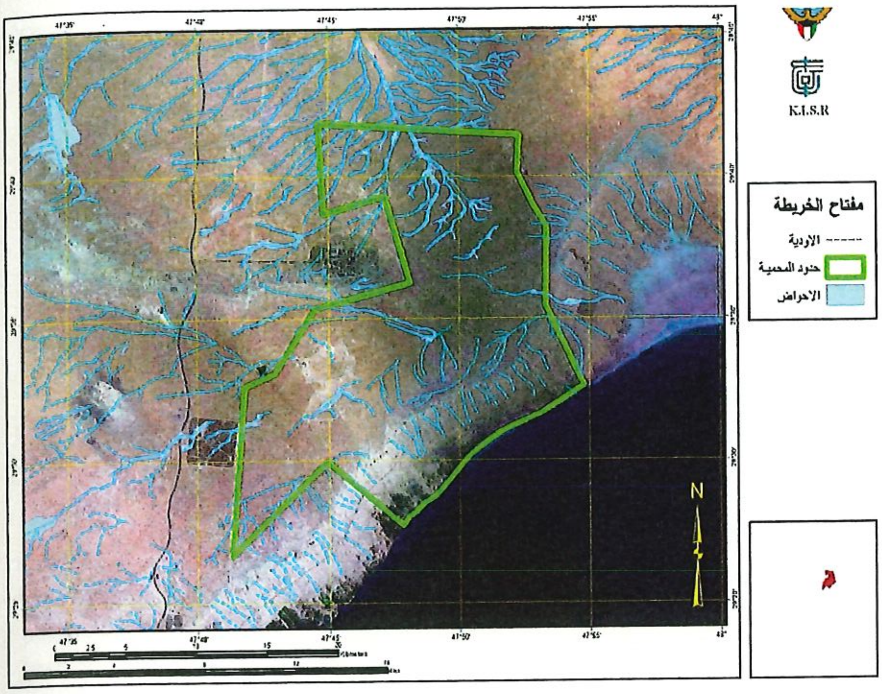

Fig. 41.6 An image showing Sabah Al Ahmad Natural Reserve (fenced area). Note the dissection of the drainage basins by the outer fence (bund wall)

walls were successively applied in Shuaiba Industrial Area by the Ministry of Public Works in 2009); (7) establish the terms of reference (TOR) for bund walls maintenance (specifications and location of cuts); and (8) estimate the cost of bund walls maintenance.

41.3.6 Managing the Hazards of Shifting Sands (Different Scenarios)

Al-Awadhi and Misak (2000) mapped 14 desert facilities which are subjected to sand encroachment. Most facilities are centrally located in the desert of Kuwait (Al Huwaimiliyah-Wafra natural wind pass). The measures used in sand control include bund walls (sand ridges), porous fences, and greenbelts.

Al-Awadhi et al. (2003) mentioned that very severe desertification prevails in Kuwait due to increasing formations of new active sandy bodies, deterioration of many areas of natural vegetation cover to less than 10%, and limited water resources for large-scale forage production. Recent mapping of areas affected by shifting sands using Arc GIS 9.2 indicates that Al Atraf-Kabd area

Table 41.3 Statistics on sand encroachment problem in Kuwait

Facility/infrastructure	Total number	Number of affected facilities	Percentage affected (%)	Sustainable action plans for mobile sand control
Agricultural areas (farms)	3	2	66.6	Not available
Animal production	2	2	100	Not available
Desert highways	7	6	85	Not available
Air bases	2	2	100	Not available
Military camps	8	4	50	Not available
Oil fields	14	14	100	Available (not implemented)
New cities	3	3	100	Available (not implemented)

(about 1,655 km^2) is severely encroached by active sands. This area is located 50 km to the south of Kuwait City, where at least 11 strategic facilities including airbases, military camps, and highways are threatened by shifting sands (Misak 2009).

As stated by Misak and Alhajraf (2005), development sectors of Kuwait suffer serious problems caused by sand encroachment (Table 41.3). In the agricultural sector, the majority of farms and animal production facilities are affected by sand encroachment. Wafra and Sulaibiyah farms, as well as Wafra and Kabd animal production facilities, are examples of severely encroached facilities in the agricultural sector. In the public works sector, 85% of the highways are influenced by shifting sands. Wafra-Mina Abdullah, Kabd, Abdaly, and Salmi roads are highly impacted by shifting sands. In the defense sector, 100% of the airbases and 50% of the military camps are suffering from serious sand encroachment problems. Ali Al-Salem and Ahmad Al Jaber Air Bases are severely affected by shifting sands. In the oil sector, 100% of the oil fields are affected by shifting sands of different degrees. Managish, Umm Gudair oil fields (west Kuwait), and Wafra oil field (south) are examples of highly affected fields. In the housing sector, 100% of the new cities are affected by sand encroachment. Wafra, Ras Al-Sabiyah, and Erfjan new cities are additional examples where sand encroachments exist (Misak and Alhajraf 2005).

It has been observed that the development sectors (oil, defense, public works, agriculture, etc.) deal with the sand encroachment problem in their affected sites, but without coordination. Their approach for controlling drift sands depends in almost, if not all cases, on the periodical removal of the accumulated sand, which is dropped in open desert areas. Dropping of drift sands in open desert areas causes many problems as they can be re-shifted and attack new areas. Establishing greenbelts of drought-resistant plants in open desert areas to minimize sand encroachment

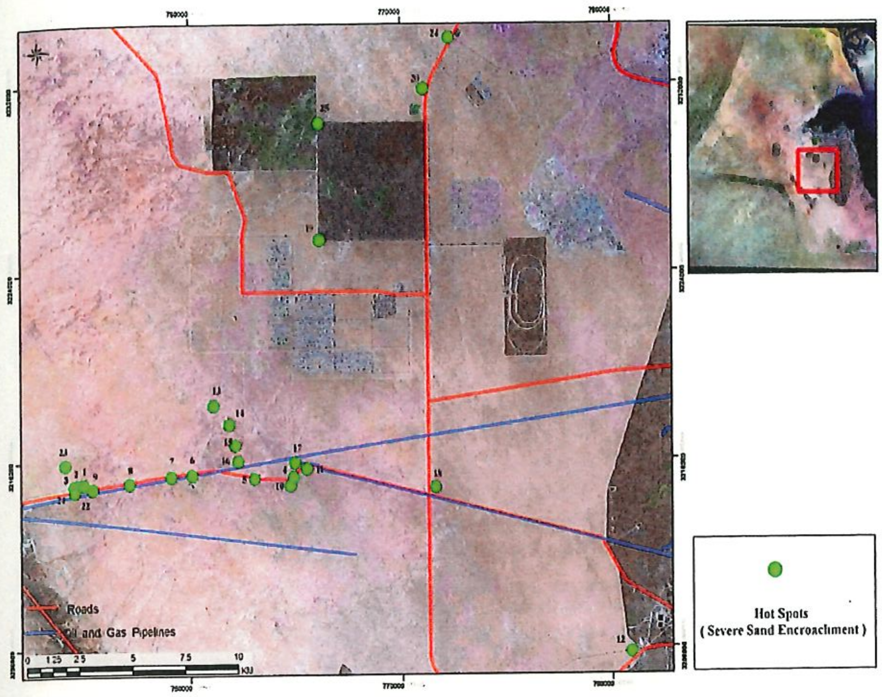

Fig. 41.7 Image showing facilities influenced by shifting sands in 25 locations

problems has not yet been considered in future plans; however, afforestation is focused in the urban areas.

41.3.6.1 Magnitude of Sand Encroachment in South Kabd Area (Case Study)

South Kabd area (30×40 km) covers 1,200 km^2 (about 7% of Kuwait). The concerned area is located in the heart of the main natural wind pass extending between Al Huwaimiliyah at the northwest and Al Wafra at the southeast. This area and nearby areas are severely attacked by shifting sands. All the facilities including flow lines, water wells, farms, roads, fences, and encampments are encroached by drifting sands. In May–July 2008, the concerned area, as well as other areas in Kuwait, experienced severe sand encroachment problems and terrible dust storms. In south Kabd area, a number of facilities are severely attacked by sands (Fig. 41.7). Several stretches of the existing roads, e.g., West Burgan-Ahmad Al Jaber Air Base, Abdaliyah-Managish, and Kabd main road (Road 604), were severely encroached by sands. Information on the location and nature of sand-encroached facilities is shown on Table 41.4.

The concerned area is characterized by heavy human pressure and intensive land uses including oil exploration and exploitation, agriculture and animal production,

Table 41.4 Field information on 25 sand-encroached facilities in the south Kabd area

Serial No.	GPS	Locality	Type of affected facility	Remarks
1	E: 0754883 N:3214988	Managish (close to gate 2)	Flow lines (KOC)	Huge amount of shifting sands
2	E: 0754658 N:3214961	Managish (close to gate 2)	Flow lines (KOC)	
3	E: 0754496 N:3214938	Managish (close to gate 2)	Flow lines (KOC)	
4	E: 0764925 N:3215261	Managish-Abdaliyah	Managish main road	
5	E: 0763057 N:3215218	Managish-Abdaliyah	Managish main road	
6	E: 0760092 N:3215374	Managish-Abdaliyah	Managish main road	
7	E: 0759097 N:3215304	Managish-Abdaliyah	Managish main road	
8	E: 0757123 N:3215020	Managish-Abdaliyah	Managish main road	
9	E: 0755374 N:3214804	Managish-Abdaliyah	Managish main road	
10	E: 0764760 N:3214908	Managish-Abdaliyah	Water well	
11	E: 0765544 N:3215624	Managish-Abdaliyah	Security facility	
12	E: 0780894 N:3207775	West Burgan	Burgan (GC2)-Ahmad Al Jaber road	
13	E: 0761097 N:3218318	North Abdaliyah	Flow line	
14	E: 0761866 N:3217519	Abdaliyah	Water well	
15	E: 0762146 N:3216629	Abdaliyah	Desert camp	
16	E: 0762275 N:3215947	Abdaliyah	Water well	
17	E: 0764993 N:3215877	Abdaliyah	Pump house	Severe encroachment
18	E: 0771605 N:3214798	East Abdaliyah	Road	
19	E: 0766182 N:3225332	Kabd	Kabd transmission station (NE corner)	
20	E: 0771092 N:3231748	Kabd	Farm	Very severe encroachment
21	E: 0754536 N:3214692	Managish	Gate no. 2	
22	E: 0754962 N:3214996	Managish	Oil facility	
23	E: 0754091 N:3215845	Managish	Bund wall	
24	E: 0772311 N:3233931	Kabd	Gasoline station	New facility
25	E: 0766159 N:3230295	Kabd	Experimental farm	

military activities, recreation and camping, and grazing. Controlling wind erosion and sand encroachment problems in the area will definitely minimize the problem in areas located at the downwind side, e.g., Wafra and southwest Burgan oil field.

41.3.6.2 Proposed Action Plan for Managing the Hazards of Shifting Sands

To manage the hazards of shifting sands in the terrestrial environment of Kuwait, three scenarios are proposed (Misak et al. 2009).

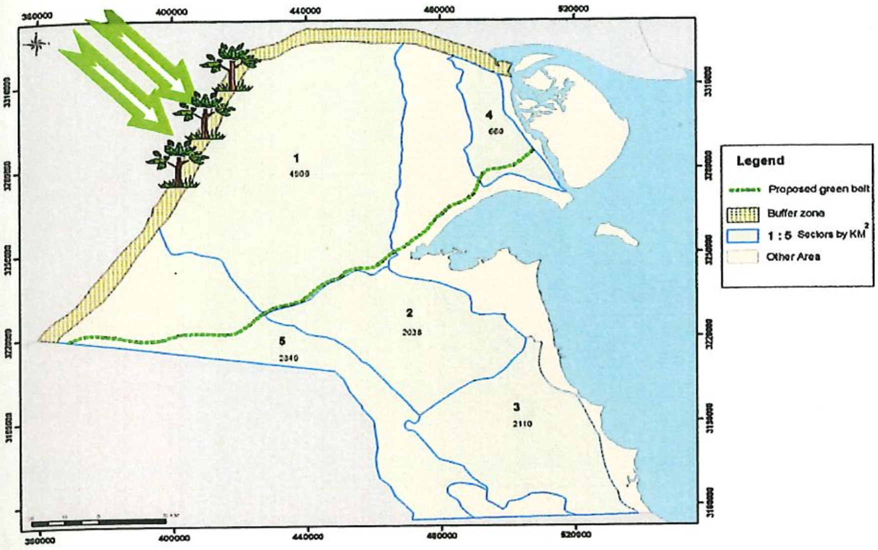

Fig. 41.8 First scenario, frontal greenbelt: Huwaimiliyah, ten-row greenbelt (25-km length and 187,500 trees). *Arrows* indicate the prevailing NW winds

First Scenario

The first scenario proposed by Misak (2009) includes the following measures:

- Establishment of two greenbelts (each has at least 10 rows of *Prosopis juliflora, Ziziphus spina-christi, and Tamarix aphylla* trees). The first belt (25-km length) is at Al Huwaimiliyah area (Fig. 41.8). The other belt (130-km length) is at Ras Al-Sabiyah-Al Salmi (Fig. 41.9). The selection of sites for two belts is based on information gained through field survey and remote sensing imagery interpretation of the area.
- Stabilization of active sandy bodies between the two belts as well as some active bodies in the south, using environmentally friendly materials: ecomat, coir, plant residues, etc.

Second Scenario

The second scenario consists of the following main measures:

- Afforestation: Plantation of *Prosopis juliflora, Ziziphus spina-christi, and Tamarix aphylla* trees along Huwaimiliyah-Al Wafra corridor (Fig. 41.10). The areas proposed for afforestation cover about 615 km^2. Treated sewage water has the potential to be used to irrigate these plantations for at least 1 year.
- Conservation/revegetation of native shrubs such as *Haloxylon salicornicum* and *Rhanterium epapposum* which are very effective in trapping shifting sands.

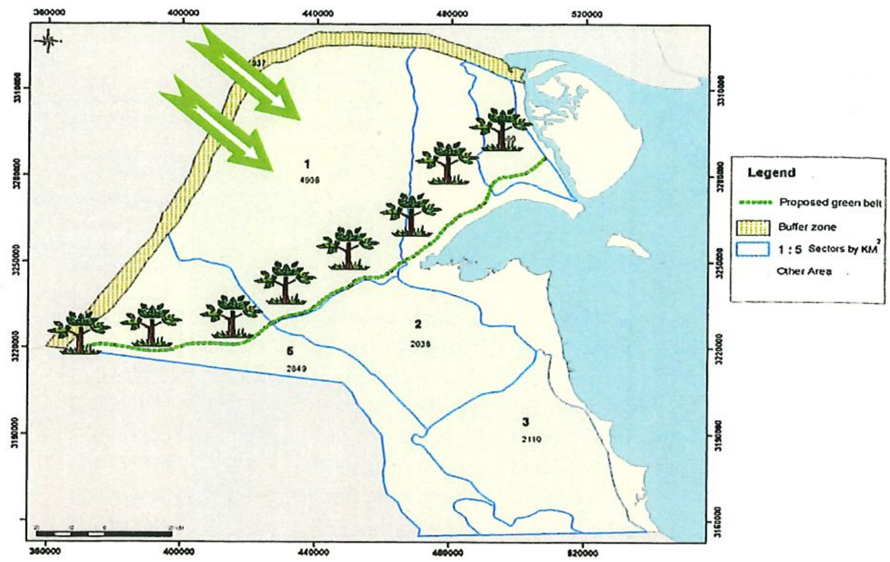

Fig. 41.9 First scenario, second belt: Ras Al-Sabiyah-Al Salmi, 10-row greenbelt (130-km length and 975,500 trees). *Arrows* indicate the prevailing NW winds

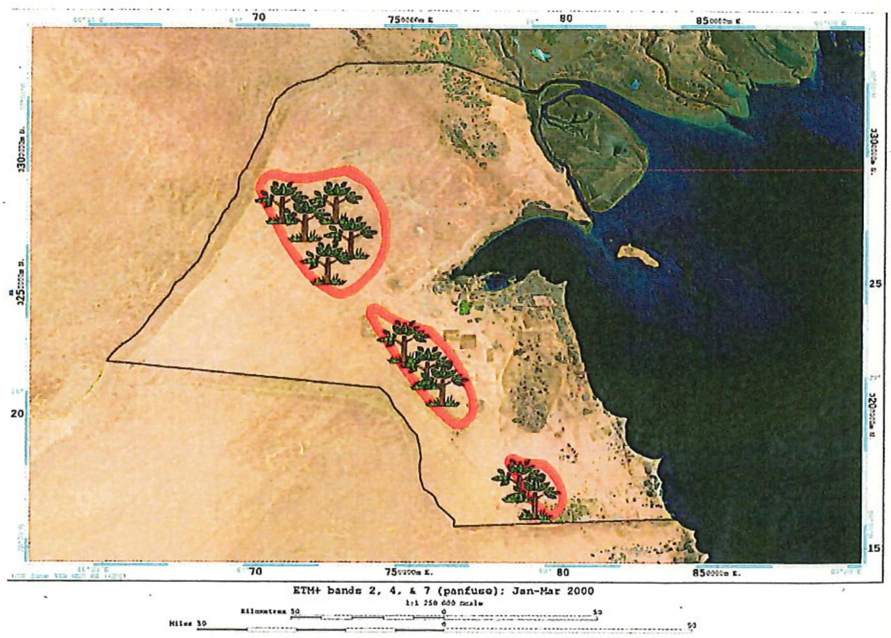

Fig. 41.10 An image showing areas proposed for afforestation (second scenario)

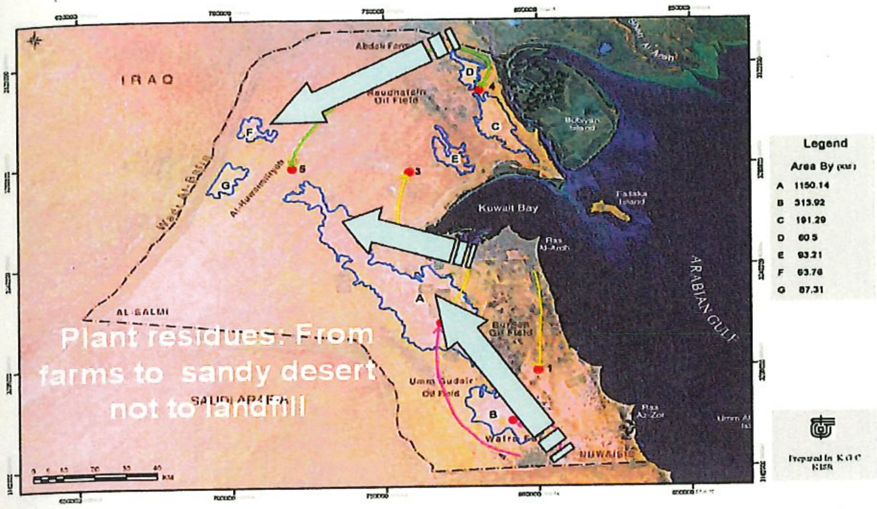

Fig. 41.11 An image showing the locations of main sources of greenery residues

Table 41.5 Second scenario: areas proposed for afforestation

Site	Area (km^2)	Remarks
Huwaimiliyah	151	Sand dunes and sand sheet complex
Patches in Al Atraf-Kabd	150	Sand sheets and dunes
North Wafra	314	Sand sheets

- Stabilization of active sandy bodies along segments of Huwaimiliyah-Al Wafra corridor using greenery residues of Abdaly, Kabd, Wafra, and urban areas in Kuwait (recycling of greenery residues). Figure 41.11 shows the locations of main sources of greenery residues. Areas proposed for afforestation are shown in Table 41.5.

Third Scenario

The third scenario consists of the following main measures:

- Establishments of greenbelts in northern and central parts of Kuwait (Fig. 41.12).
- Revegetation of native plants such as *Rhanterium epapposum* in the southern parts of Kuwait.
- Immediate stabilization of active sandy bodies and local sources of dust using greenery residues and mulching sheets, e.g., ecomat and other environmentally friendly mulching materials.

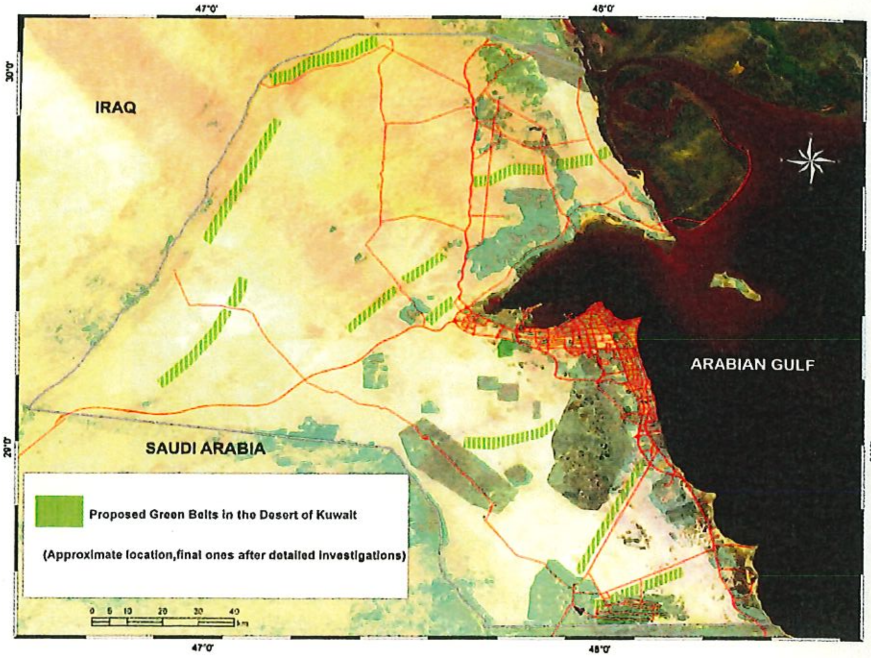

Fig. 41.12 An image showing the proposed greenbelts for the third scenario

The cost, efficiency, and environmental sustainability of the proposed scenarios will be assessed by a multidisciplinary team of experts. For the final design of greenbelt, wind tunnel experiments will be conducted, and the most cost-effective and environmentally sound scenario will be selected.

41.4 Setting Up Guidelines for Sustainable Land-Use Plans

Under hyperarid environmental conditions of Kuwait, sustainable land-use planning is the first defensive line in managing the drought and desertification. During the last 15 years, significant changes in land use were observed in Kuwait. Some of these changes have positive environmental impacts, while others have negative. Establishment of the buffer zone (15 km wide and more than 200 km long) between Iraq and Kuwait in 1993–1994 resulted in the enhancement of ecological conditions, while digging of border trench (2–3 m deep, 3–5 m wide, and about 200 km long) and construction of long bund walls (about 2–3 m high) have negative impact on soil, surface hydrologic conditions, and natural vegetation. Update information on the current land use suggests corrective measures are significantly required for managing drought. Figure 41.13 shows the current land-use types in Kuwait. Table 41.6 presents information on specific land-use types in the terrestrial environment of Kuwait.

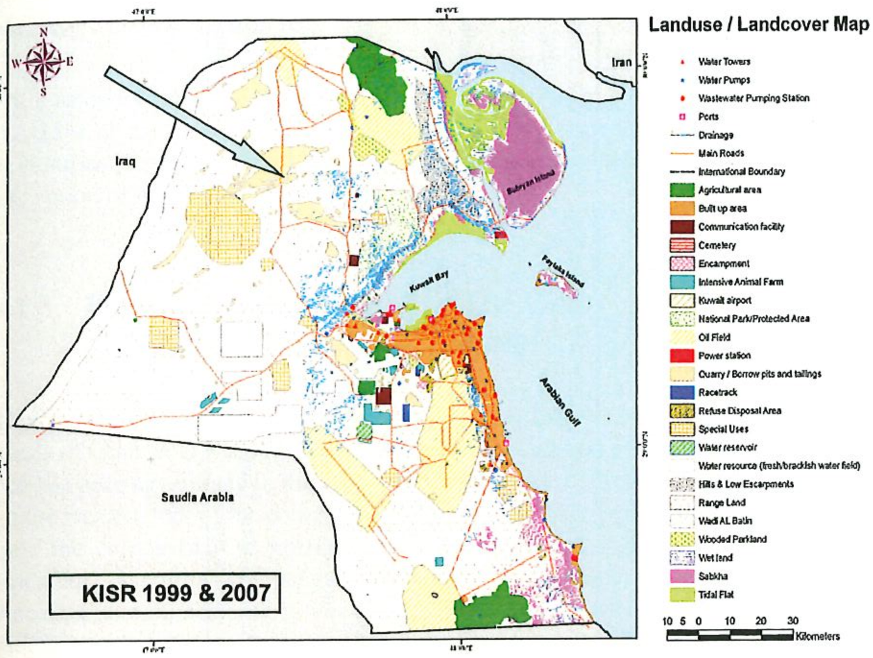

Fig. 41.13 Land-use/land cover map, *arrow* indicates prevailing wind direction (KISR 2006)

Generally, the current land-use types are differentiated into the following three categories.

41.4.1 Extremely Destructive

This category includes current military exercises and life shooting in the northwestern parts of Kuwait, establishment of bund walls and trenches in wide areas of the country, and the development of great number of gatch pits in Kuwait Oil Company operational areas (for clean soil quarrying). In KOC oil fields, some 83 gatch pits are found (KOC 2010). Damage caused by these types of land uses extends between 1.5 and 5 m from ground surface.

41.4.2 Destructive

This category includes rangeland grazing (close to 75% of total land-use types) and camping and recreation in scattered areas in Kuwait (5–10% of Kuwait). Damage caused by these types of land uses is restricted to the most upper part of soils (50–75 cm thick).

Table 41.6 Examples of land-use types and their impacts

Degree of impact	Impacts	Location(s)	Duration/year	Land-use type
Extremely destructive	Soil losses by wind, soil mining, soil compaction and sealing, surface deformation, hydrological disruption, vegetation degradation, loss of biodiversity, and deterioration of wildlife habitats	Al Edairah (northwest)	About 9 months/year	Military exercises and shooting ranges
Destructive	Soil compaction and sealing, vegetation degradation, and loss of biodiversity	Open desert areas	Ongoing	Rangeland grazing
Destructive	Vegetation degradation, soil compaction and sealing, loss of biodiversity, and deterioration of wildlife habitats	Open desert areas	October–April	Camping and recreation
Extremely destructive	Soil losses by wind, soil mining, soil compaction and sealing, surface deformation, hydrological disruption, vegetation degradation, loss of biodiversity, and deterioration of wildlife habitats	Al Huwamiliyah (northwest)	Ongoing	Sand quarrying
Nondestructive	Soil stabilization/enhancement of soil properties, vegetation cover, wildlife, and biological diversity	Al Salmi-Umm Qasr buffer zone	Ongoing	Land protection/ conservation

41.4.3 Nondestructive

This category includes protected and restricted areas in Kuwait which constitute 12–15% of the country. Natural recovery of ecosystems occurs under protection conditions. In this category, damage to ground surface is not noticeable (with the exception of war-related damage).

41.5 Proposed Sustainable Land-Use Plans (The Case of Rangeland Grazing)

Rangeland grazing represents about 75% of land use (KISR 1999). Based on the study of Omar et al. (2001), some 925,000 sheep, 112,000 goats, and 23,000 camels are the grazing animals in the rangelands of Kuwait. Currently, grazing is allowed in the western half of the country, while it is prohibited in the eastern side. We suggest the current map of grazing areas (PAAFR 1988) should be considered for updating. According to personal communication (Omar, 13 September 2009, Personal communication), it was apparent that the map was prepared without considering range management aspects (type of vegetation cover, animal numbers and distribution, seasonal variation, and intensity of grazing).

For sustainable rangeland grazing, it is suggested to develop a new map considering the shortcomings of the current map. From the authors' point of view, the shortcomings are discussed in the following part:

- Dividing the State of Kuwait into two parts, western (where grazing is allowed) and eastern (where grazing is prohibited), is not scientifically and environmentally justified.
- The western half of Kuwait is cut by a NW-SE natural hollow (about 25-km average width and 145-km length, approximate area is about 3,625 km^2). The hollow starts in the Iraqi territories and acts as an active wind corridor for the prevailing NW winds. Grazing in the wind corridors (as indicated in the current map) is a destructive land-use type.
- More than 70% of the soils of the mentioned corridor are Torripsamments (sandy soils), which have very high vulnerability to wind erosion relative to developed soils (Haplocalcids, Haplogypsids, Petrocalcids, Petrogypsids, etc.) especially during dry years. Grazing in this corridor accelerates soil deflation processes causing sand and dust storms especially during summer and spring seasons.
- The natural vegetation represented by Haloxylon salicornicum and Stipagrostis plumosa in the corridor is severely to completely degraded. Vegetation cover is less than 5%. Dry relics of natural vegetation are common in the natural corridor. Thus, it is essential to restore vegetation in the corridor.
- The eastern half of Kuwait is influenced by another natural wind corridor. This corridor extends for about 50 km between Umm Qasr and Ras Al-Sabiyah (northeastern part of Kuwait). The corridor width ranges between 10 km (at its middle

Table 41.7 History of land-use of Wadi Al Batin

Period	Land use and activities	Remarks
Pre-Iraqi invasion of Kuwait (before August 1990)	Open area for livestock grazing	Borders with Iraq and Saudi Arabia were opened (no barriers)
Invasion and occupation of Kuwait (August 1990–February 1991)	Military activities *Iraqi troops*: establishment of mine fields, development of oil trenches, and construction of bunkers and weapon pits *Coalition forces*: crossing Wadi Al Batin during liberation of Kuwait (desert storm)	Severe ecological deterioration
March 1991–July 1993	Demining and EOD (Explosive Ordnance Demolition), refilling and ground leveling of bunkers	Degradation of soils and vegetation cover
1993–1995	*UN*: border demarcation and buffer zone establishment *Kuwait*: establishment of security system, border trench, electric fence, eastern trench, and bund walls	Positive ecological and environmental changes

part) and about 2 km (at its extreme southern part). Grazing in this corridor enhances sand movement. Shifting sand is a hazard for the new Ras Al-Sabiyah settlement (population 0.60–0.55 million).

- For range management, grazing in both wind corridors should be prohibited at least for 5–10 years.

41.5.1 Proposed Corrective Measures (The Case of Wadi Al Batin)

Wadi Al Batin constitutes a huge catchment area and is located at the western part of Kuwait. It extends in northeast direction from Al Salmi area (extreme southwestern part of Kuwait) for about 100 km. This wadi consists of a main channel of about 10-km width and eastern and western cliffs. The western cliff is located in Iraq. The Kuwaiti-Iraqi border runs in the main channel of the wadi.

During 1993–1995, a system of security measures was established by Kuwait along Iraq-Kuwait border. This system consists of two trenches. One of these trenches was dug along the borderline. The width and depth of this trench average 5 and 3 m, respectively, and the length is 212 km. The second trench is located about 5 km to the east of the border trench. The history of land use of Wadi Al Batin is shown in Table 41.7.

41.5.1.1 Consequences of the Current Land Use of Wadi Al Batin

- Hydrological disruption leading by time to ecological deterioration: dryness of plant species and deterioration of wildlife (Misak 2009)
- Loss of runoff water through discharging into trenches (border and eastern trenches)
- Disturbance of the mechanism of local groundwater recharge from the wadi banks to the main channel, where a shallow wadi fill aquifer exists

41.5.1.2 Proposed Action Plan for the Restoration of Wadi Al Batin

As stated by Alenezil et al. (2010), oil-polluted soils of Wadi Al Batin (about 125,000 m^3) should be excavated. Clean soils (fresh eolian sands) should replace oil-polluted soils. The excavated heavy polluted soils could be used for road paving for off-road tracks to minimize land degradation.

To restore hydrological disruption and to recover the long-term impact of destructive land use of Wadi Al Batin, the following are proposed:

- Refilling the trenches (border and eastern trenches) to maintain surface hydrologic and recharge conditions
- Leveling north-south bund walls stretching parallel to Wadi Al Batin to avoid blocking of runoff flowing to the main channel of the wadi
- Breaking soil crusting, sealing, and compaction in the main water course of the wadi to enhance the infiltration of rainfall into the soil (mechanical breaking and plantation)

41.6 Conclusions and Recommendations

To accomplish the objective, managing the hazards of drought and shifting sands in Kuwait, intensive field work accompanied by analyses and interpretation of satellite images was carried out. We are proposing four programs, the watershed management, mitigating hydrological drought, managing the hazards of shifting sands, and setting up sustainable land-use plans.

Based on the findings of the present study, the following recommendations are made. It is recommended to review the current land-use plans considering number of important issues, such as exploring new site for military exercises as an alternative to Al Edairah highly sensitive area (northwestern part of Kuwait). This area has been used since two decades for exercises and shooting ranges. Currently Al Edairah area (about 400 km^2) acts as a main source of sands and dust in Kuwait. Protecting the area for about 5 years is likely to enhance soil properties and vegetation potentials and in turn increase soil stability. Managing livestock grazing in highly fragile areas such as the two natural corridors of drift sand, i.e., Al Huwaimiliyah-Wafra (northwestern part of Kuwait) and Umm Qasr-Ras Al-Sabiyah (northeastern part of

Kuwait). Controlling grazing and camping in these corridors for at least 5 years is a sustainable land-use approach. Establishment of an action plan for watershed management including restoration of hydrologic disruption and water harvesting. First priority should be given to Rawdatain and Umm El Eish basins (northeastern part of Kuwait) and Wadi Al Batin (western part of Kuwait). Second priority to be given to Jal Az Zour (northeastern part of Kuwait) and Ahmadi (south of Kuwait City). Guidelines for this action plan are available in the section of watershed management and mitigation of hydrologic drought of this chapter. Establishment of an integrated action plan for managing the hazards of shifting sands considering the proposed three scenarios of mobile sand control. Development of a drought preparedness plan for the State of Kuwait including the establishment of a drought monitor consisting of advanced remote sensing systems and ground observatory stations.

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