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Characterization and Mapping Land Degradation Hotspots in the Terrestrial Ecosystem of Kuwait

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Abbreviations: LDH: Land Degradation Hotspots; GIS: Geographic Information System; GPS: global positioning system; LDN: Land Degradation Neutrality

ABSTRACT

Land degradation processes prevail in about 50.6 % of the terrestrial ecosystem of Kuwait. This ecosystem which covers about 15,000 km^2 (about 85 % of Kuwait) is dotted by a high number of land degradation hotspots (LDH). A hot spot is a severely degraded area, where land degradation indicators are observable. The main objectives of this study are to detect land degradation hotspots and to quantify the impact of land uses on the natural vegetation and soil types. Detection of land degradation hot spots is a significant prerequisite for Land degradation control. The land degradation hotspots were delineated and characterized using Geographic Information System (ArcGIS S/W 10.5) and satellite image (Landsat 8 of September 2017). A ground truth activity followed the Landsat analyses. The approach of detection and mapping land degradation hotspots is simple and applicable in Kuwait and the surrounding countries. The results of the study showed 58 hotspots with a total area of about 7590.3 Km^2 (50.6 % of the terrestrial environment). The study reveals a significant variation in the areas, land use and indicators of land degradation of the hotspots. The areas range from about 2000 km2 to 1.2 km^2. In all of the hot spots, the soils, vegetation cover and micro land features are highly degraded due to destructive land use types including overgrazing, offroad vehicles, camping and recreation, and soil mining. The total length of off-road vehicles is around 14,774.67 Km (0.98 Km/Km^2) and the percentage of degraded vegetation and disturbed soil was 48.7% and 47% respectively.

Introduction

In Kuwait, the lack of quantitative information and geo-referenced data on the extent of degraded lands represents one of the significant challenges facing the development of an action plan for land degradation control. Application of remote sensing and GIS, besides ground truth and intensive field surveys, is a practical and cost-effective tool for mapping and characterization of land degradation. In the present study, the term land degradation hotspots (LDH) is used to characterize areas of different sizes, where the vegetation cover and the soil types are severely degraded. Degradation was caused by excessive human pressure under drought conditions. The past land uses for the majority of the hotspots were rangeland grazing and seasonal recreation activities. The vegetation map [1] indicates that the lands of the hot spots were covered with perennial vegetation. The present study indicates that this perennial vegetation is totally disappeared, and the soils are highly degraded due to destructive land use types. The most common soil degradation processes are soil losses (by both wind and water), soil compaction and sealing and soil mining. Currently, the majority of the hotspots act as anthropogenic sources for sands and dust (through offroad vehicles). Figure 1 Shows the interaction between land use types and the status of vegetation.

Kuwait covers 17,800 km^2. It consists of two main ecosystems. These are the terrestrial (about 85%) and the coastal and marine (15%). The harsh environmental conditions of Kuwait (including prolonged drought such as that of 2007 to 2017 besides land misuse and over-exploitation of soils and vegetation are the main driving forces for land degradation. Some 75.1% of the lands of Kuwait is used for grazing activities and desert recreation [2]. During the last three decades, the terrestrial environment in Kuwait was subjected to different mechanisms of land degradation. In August. 1990 - Feb.1991, the country was occupied by Iraqi Troops. Military operations represented by troops transport on the fragile desert sur-

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face, maneuvering and construction of defense lines resulted in severe surface disruption. As stated by Misak 2003, some 6000 Iraqi Tanks & Tracked Vehicles and 5145 Coalition Tanks & Vehicles were moving on the desert of Kuwait. In addition, some 240,000 ground fortifications were established in Kuwait. Between 2007/2008 and 2017/2018 seasons, Kuwait experienced a drought episode. The average annual rainfall during the drought episode fluctuated between 35- and 75-mm. Strong winds with high speed, ranging between 50-60 km/ hour were recorded during the drought episode. As indicated in a huge number of publications, e.g., Omar et al. [1] Khalaf et al. [3] and Misak et al. [4], one of the main consequences of drought is the deterioration of vegetation cover.

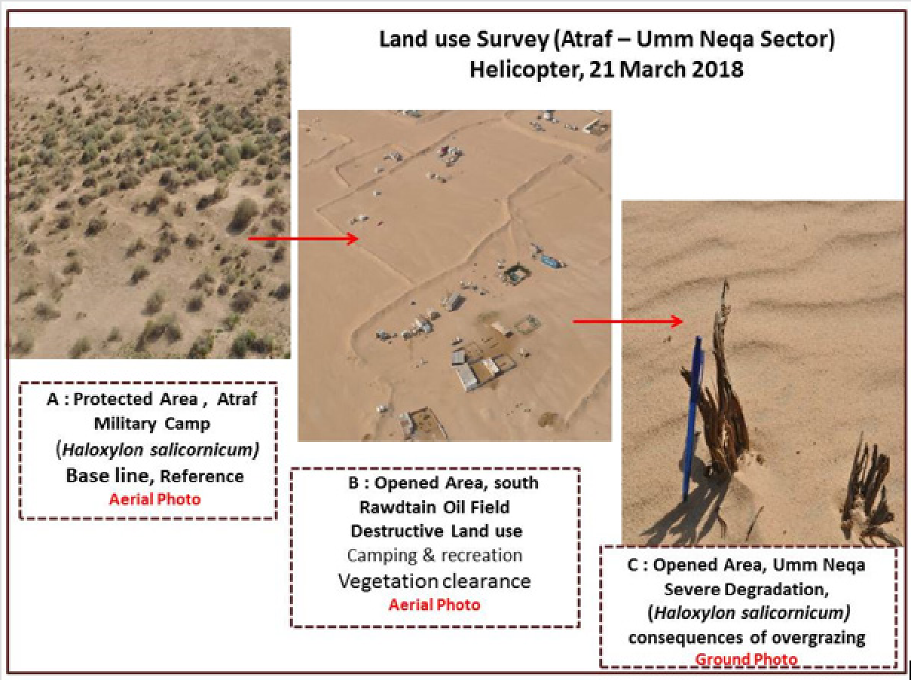

Figure 1: The interaction between land use types and land degradation (three cases).

Omar et al. [1] mapped eight major vegetation units in the terrestrial environment of Kuwait. The vegetation map was prepared by integrating the soil and vegetation information on a Geographic Information System (GIS). The vegetation units are: Haloxyletum (22.70 %), Rhanterietum (2.10%), Cyperetum (26.90%), Stipagrastietum (39.30%), Zygophylletum (0.30%), Centropodietum (1%), Panicetum (0.70%) and Halophyletum (1.90%). The mentioned vegetation map was used as a baseline for comparison with the conditions of the year 2017. Justifications for selecting this map as a baseline include:

a) The map was developed based on advanced technology (Remote Sensing &GIS) and

b) Some 8351 observation points were assessed for vegetation cover and soils.

On the other side, eight soil units were mapped by KISR1999. These soil units are: Aquisalids (7%), Calcigypsids (6%), Haplocalcids (8 %), Haplogypsids (0.05%), Petrocalcids (11 %), Petrogypsids (33%), Torriorthent (0.08%) and Torripsamments (27%). In Kuwait, land degradation directly affects economic and biological productivity as well as public health. The majority of the early studies on land degradation were focused on symptoms and causes of land degradation which are mainly related to socioeconomic conditions and natural factors. Mapping land degradation in Kuwait was not tackled in previous studies.

Land degradation processes prevail in the majority of the terrestrial environment of Kuwait. These processes include soil salinization and waterlogging (agricultural areas), loss of top soils (through both wind and water erosion), soil crusting, sealing and compaction, soil mining, vegetation degradation and loss of biodiversity. Several biophysical and socioeconomic land degradation indicators were identified by several authors, e.g., Khalaf et al. [5-9], Brown and Porembski [10,11], Al-Dousari, Al-Awadhi et al. [12,13], ; Omar et al. [1,14] , Misak [4], Al Dousari, Khalaf et al. [15], Misak et al. [15], the Kuwait National Committee for Combating Desertification (2014 & 2015), Misak and Suleiman 2014 and Misak and Al Ghazali 2017. These indicators are differentiated into biophysical, socioeconomic and land use. Land degradation indicators in three different land uses were discussed by Misak [4]. These land uses are rangeland (75% of the terrestrial environment of Kuwait), agricultural areas (2.71% of the terrestrial environment of Kuwait) and quarry and dumps (2.2% of the terrestrial environment of Kuwait). In these different land uses, soil, and vegetation degradation, loss of biodiversity and hydrological degradation prevail.

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Reversing the processes of land degradation through serious and sustainable control measures, as well as appropriate land use planning are the most significant challenges facing the real development of the terrestrial environment of Kuwait. The current study indicates that the total length of off-road vehicles is around 14,774.67 Km (0.98 Km/Km^2) of terrain environment of Kuwait Figure 2. As indicated from Figure 2, the off-road vehicles result in surface disruption for all land use types including protected areas (about 18 % of the country) and rangeland grazing (close to 51 % of the country). In addition, the off-road vehicles dissect all geomorphological units including sand dunes, playas, dry wadis, and hilly terrain Figure 3. shows the disruption caused by off-road vehicles. The goal of this study is to identify and characterize the land degradation hotspots (LDH) in the terrestrial environment of Kuwait and to discuss the interaction between land use types and the status of vegetation cover and soils types.

Figure 2: Map showing off-road vehicles in Kuwait, as of September 2017(Source: Kuwait Municipality, 2017).

Figure 3: Surface disruption by offroad vehicles, Kabd Area (southwest Kuwait City), May 2018.

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Materials and methods

Remote Sensing and Geographic Information System

This study aims to detect and identify the land degradation hotspots (LDH). For this purpose, a low spatial resolution satellite image (Landsat 8, 25 September 2017, 15 m resolution) was used for the detection and delineation of hotspots and the analytical potential of GIS was effectively used to produce the final analysis and design in the form of maps. The primary data was collected from the entire study area and has been identified the locations of the degraded areas using the global positioning system (GPS) with extreme precision (latitude and longitude coordinates) and was saved in the system as a layer. For identification of hot spots using remote sensing, some observable ground objects were delineated. These include large trucks, water tankers, caravans, water wells, livestock sheds, portable livestock shelters and stores of animal feeds.

These objects which represent the tools for camping and grazing in the desert appear as black dots on the satellite image; therefore, the areas where the black dots appear on satellite image densely and confirmed by field survey are defined as hotspots where the soil and vegetation cover in these areas were subjected to severe deterioration due to human actions. The (ArcGIS S/W 10.5) was used in the current study to integrate the information of ground truth and satellite image to create a hotspots map. Three GIS map layers were overlayed on the hotspots map. These are offroad vehicles, soil types, and vegetation cover (Figures 4, 8 & 9) respictively. These maps gave answers to many questions related to the extent of deterioration and its causes in the study area, and the economic, environmental and social impact on the Kuwaiti environment, then to determine the control measurements by the decision makers to mitigate and reduce this deterioration.

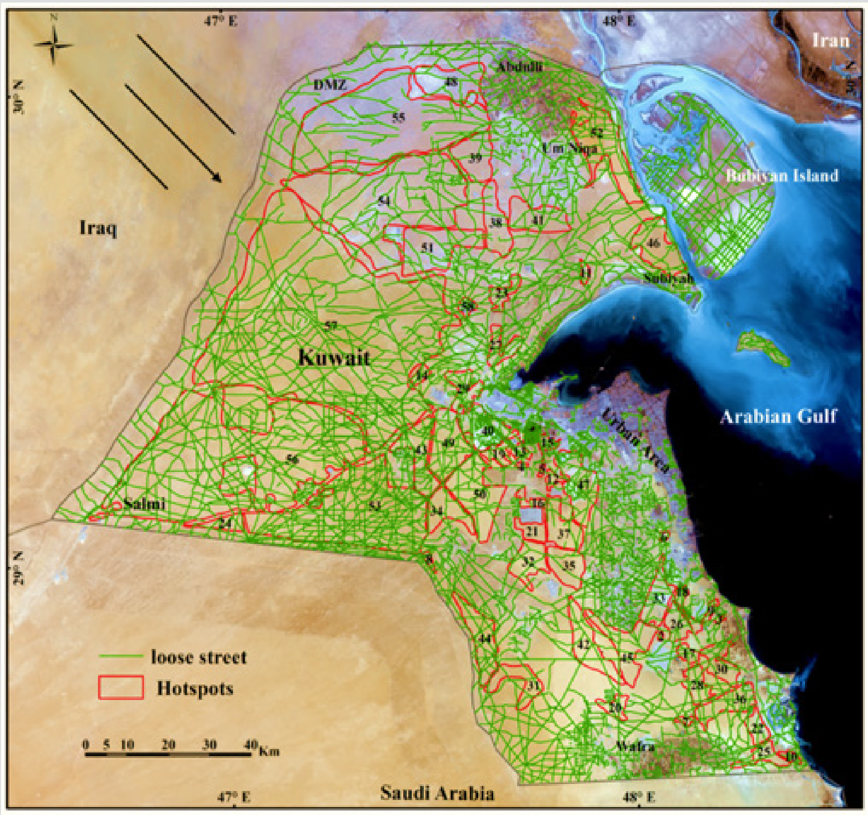

Figure 4: Hotspots on offroad vehicles (loose streets).

The Ground Truth & Field Observations

During November 2017 – March 2018, seven field trips were arranged to several areas in the Terrestrial Environment of Kuwait. On 21 March 2018, an exploratory survey using low altitude of the low-speed helicopter was arranged to the northeastern part of Kuwait (16 % of the country). The purpose of this reconnaissance survey was to get information on current land uses. During the ground field trips, 25 observation points (O1 - O25) and 19 control sites (C1-C19) were selected, Figure 5. shows the locations of the observation points and control sites. The 19 control sites are located in protected areas (including the Demilitarized Zone between Iraq and Kuwait). So they were used as a reference for the original healthy vegetation which is protected for at last two decades. The field survey for land degradation indicators of the hot spots was based on visual field evidence (Table 1).

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Table 1: land degradation indicators of the hot spots.

Land Degradation Indicators of the Hot Spots		
Land Degradation Indicator	**Field Evidence**	**Remarks**
Vegetation degradation& loss of biodiversity	- No visible vegetation(bare land) in comparison to the vegetation map of Omar et al. 2001) and available control sites - Terrain dissection by intensive trials created by off-road vehicles (density at last 83%)	Image of trails created by off-road vehicles of 2017 was examined
Soil losses (by wind)	Deflated land features, e.g. granule ripples	
Soil losses (by water)	- Rills and gullies - Exposed bedrocks in water channels	
Soil crusting, sealing, and compaction	- Continuous driving (4x4 jeeps and trucks) on the fragile desert surface - Soil crusts of clayey soils	
Soil mining	- Exploiting the soil for the establishment of berms and bund walls of 1.5-2m high to protect facilities - Piles of excavated soils	

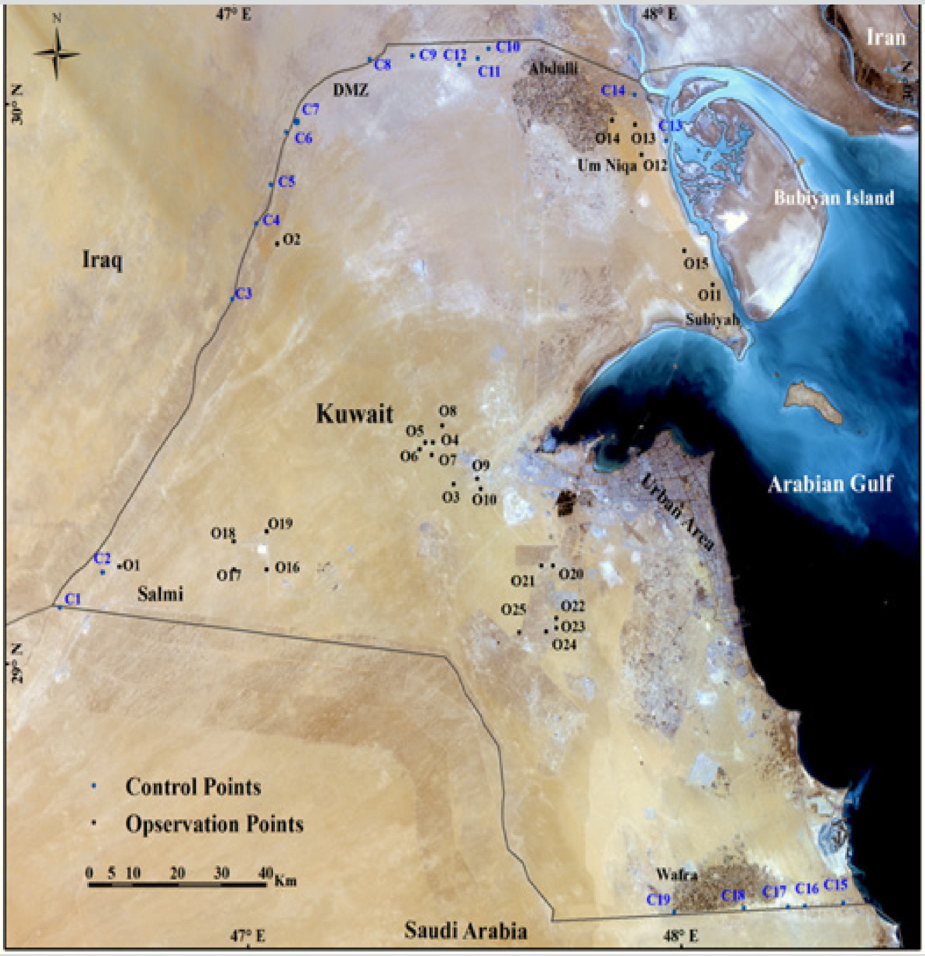

Figure 5: Landsat image, September 25, 2017, showing the observation points (black O1-25) and control points (blue C1-C32) truth.

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Results and Discussion

The development of low cost and simple techniques for detecting land degradation hot spots is a significant approach for monitoring and assessment of land degradation. The final output of the current study is maps, GIS layers and low-resolution satellite images for land degradation in Kuwait .Similar studies were carried in Ethiopia (Tor-G. Vager et al., 2013). The mentioned study demonstrated the utility of Landsat ETM + imagery for landscape-level assessments of land degradation risk and soil condition through a combination of systematic field methodologies, infrared (IR) spectroscopy and ensemble modeling techniques. Kobayashi, & Oki (2015) detected land degradation in Western Australia using free data like Landsat and Shuttle Radar Topography Mission DEM. Lanfredi et al. [16] proposed a procedure that integrates multi-spectral satellite observations and air temperature data to detect areas where the current status of local vegetation and climate shows evident departures from the mean conditions of the investigated region.

Field Surveys

A field survey was carried out through observations, measurements, ground truth (for the remote sensing information) and photography. Some 25 observation points were assessed for vegetation, soils, land features, land degradation, and land use. The coordinates, ground elevation and the land features for the 25 observation points are shown in Table 2. The ground elevation varies between 267 m above sea level (observation point O1) to 3 m above sea level (observation point O11)

Table 2: List of observation points for ground truth.

List of Observation Points for Ground Truth				
NO.	Coordinates	Elevation	Land Features	
	N	E	(m)	
O1	29.1705	46.71458	267	Wadi Al Rimth (Tributary of Wadi Al-Batin)
O2	29.74282	47.09312	126	sand dune_Al-Huwaimliyah (sumood)
O3	29.30533	47.49463	143	Al-Atraf area, southwest Ali Al Salem Air Base
O4	29.38142	47.44798	169	Al-Atraf area, northwest, Ali Al Salem Air Base
O5	29.38177	47.43047	178	Al-Atraf area, nort Salmi Road
O6	29.36977	47.41682	171	Al-Atraf area, northwest Ali Al Salem Air Base
O7	29.35932	47.44507	158	Al-Atraf area, west Ali Al Salem Air Base
O8	29.41057	47.47035	159	Al-Atraf area, north Ali Al Salem Air Base
O9	29.31467	47.54877	126	Al-Atraf area, south of Salmi Road
O10	29.29647	47.55707	117	Al-Atraf area, south of Salmi Road
O11	29.6497	48.10832	3	Sand sheet, Al Maghasil Area, Sabiyah –Umm Nega Road
O12	29.88498	47.9481	13	Degraded sand sheet, the intersection between a cut to a military camp and Sabiya-Umm Neqa Road main road.
O13	29.93972	47.93493	15	Sand accumulation, the intersection between Abdali farms and Sabiya-Umm Neqa Roads
O14	29.94838	47.88202	19	Umm Neqa dune
O15	29.71235	48.0436	21	Excavation for civil project.
O16	29.16028	47.05643	253	Sand sheet, Shaqiah site, south-east
O17	29.16141	46.97946	262	Sand sheet, Shaqiah site, southwest
O18	29.21212	46.98034	239	Sand sheet, Shaqiah site, northwest
O19	29.22915	47.05784	233	Sand sheet, Shaqiah site, northeast
O20	29.15535	47.72223	74	Sandy plain, southeast Kabd Station (KISR)
O21	29.15618	47.69472	94	Sandy plain, south Kabd Station (KISR)
O22	29.06112	47.7268	100	Sandy plain, Kabd animal production (Jawakheir)
O23	29.04352	47.72678	110	Sandy plain, Abdaliyah, eastern side
O24	29.03778	47.70333	118	Sandy plain, Abdaliyah, near the main gate
O25	29.03768	47.64077	154	Sandy plain, Abdaliyah, south-west

In general, the common characteristics of the majority of the 58 hotspots are:

a) Almost 100% vegetation degradation and loss of biodiversity

b) Observable dead plant remains (stems and roots) Figure 6.

c) Development of granule ripples which indicate severe wind erosion (abrasion) under drought conditions.

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d) Adoption of nonsustainable measures such as earth berms & bund walls.

e) Offroad vehicles which cause soil compaction

f) Gullies and rills which indicate soil loss by runoff water

These hot spots with a total area of 7590.3 K are delineated Figure 7. The study reveals a significant variation in the areas of the hot spots, ranging from about 2000 km^2 (hot spot 57) to 1.2 km^2(hot spot 1) with average 132.9 Km^2. Based on their areas, the hot spots are categorized into five classes. These are: (Table 3).

Figure 6: Degradation of *Haloxylon salicornicum* , hot spot no 52, the northeastern part of Kuwait. Note the difference in grain size and the active sand sheets (November 2017-March 2018).

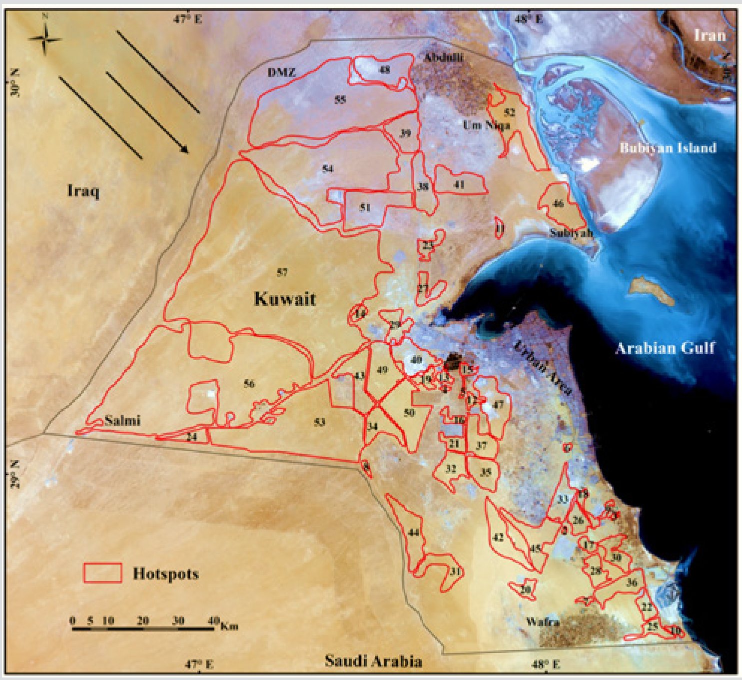

Figure 7: Landsat image acquired on September 25, 2017, with land degradation hotspots (LDH). The arrow indicates the northwesterly winds.

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Table 3: Basic information on the hotspots in Kuwait.

Basic Information on the Hotspots in Kuwait				
Hotspot	Area (Km²)	Size	Land Use*	Land Degradation Indicators**
1	1.247	very small	A& B	1&2
2	2.144	very small	A& B	1&2
3	3.042	very small	A& B	1& 2
4	3.156	very small	A& B	1& 2
5	3.847	very small	A& B	1&2
6	4.323	very small	A &C	1&2
7	6.053	very small	A&B	1&2
8	6.919	very small	A&B	1, 2&3
9	7.99	very small	A&B	1, 2&3
10	9.053	very small	A&B	1, 2 & 3
11	9.075	very small	A&B	1,2, 3 & 4
12	10.575	medium	A&B	1, 2 &4
13	12.191	medium	A&B	1, 2&4
14	12.342	medium	A & B	1& 2
15	12.736	medium	A&B	1& 2
16	15.542	medium	A & B	1,2 &4
17	15.796	medium	A&B	1,2&4
18	19.509	medium	A&B	1,2&4
19	22.14	medium	A&B	1,2, 3 &4
20	24.011	medium	A&B	1, 2, 3 & 4
21	28.477	medium	A & B	1,2&4
22	28.602	medium	A&B	1,2&4
23	29.391	medium	A&B	1,2&4
24	30.584	medium	A&B	1,2 &3
25	32.633	medium	A&B	1,2&4
26	36.361	medium	A&B	1,2&4
27	39.058	medium	A&B	1, 2, 3&4
28	39.958	medium	A&B	1,2 &4
29	48.205	large	A& B	1,2,3&4
30	51.193	large	A&B	1,2 &4
31	60.536	very large	A&B	1&2
32	62.916	very large	A&B	1&2
33	64.253	very large	A, B & C	1&2
34	64.324	very large	A&B	1&2
35	64.744	very large	A&B	1,2& 3
36	67.714	very large	A, B &C	1,2&4
37	69.613	very large	A&B	1,2, 3& 4
38	79.271	very large	A&B	1,2,3 & 4
39	81.063	very large	A&B	1, 2 & 3
40	82.289	very large	A, C	12,3 & 4
41	86.182	very large	A, B &D	1,2,3& 4
42	90.955	very large	A&B	1, 2,3 &4
43	92.079	very large	A & B	1,2 &3
44	92.462	very large	A&B	1,2, 3 &4
45	98.347	very large	A&B	1, 2,3 &4
46	100.291	very large	A&B	1, 2 &3

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47	105.963	very large	C &A	1,2,3 & 4
48	112.811	very large	A, B &C	1,2,3& 4
49	114.737	very large	A & B	1, 2,4& 4
50	142.594	very large	A & B	1,2 & 4
51	148.576	very large	A, B & C	1,2 & 4
52	157.174	very large	A,B& F	1&2
53	538.521	very large	A, B& E	1,2, 3&4
54	631.221	very large	C, A& B	1,2, 3&4
55	664.746	very large	C &A	1, 2, 3 & 4
56	1136.735	very large	A, B & E	1, 2, 3 & 4
57	2000.669	very large	F, A, B, C & E	1, 2, 3 & 4
58	13.4	Small	C	1,2, 3 &4

Land use*

A: Rangelands grazing, B: Encampment (Temporary accommodation in the desert), C: Quarries and landfills, D: Oil, E: Water pipelines and wells & F: military maneuvers

Land degradation indicators**

1: Vegetation degradation & loss of biodiversity, 2: Soil losses (both by wind and water), 3: Soil crusting, sealing and compaction & 4: Soil mining

a) very small (less than 10 km^2)

b) small (10 – 20 km^2)

c) medium (20-40 km^2)

d) large (40-60 km^2)

e) very large (more than 60 km^2)

Large and very large hot spots are distributed in the northern and western parts of the country. Coalescence of two or more small to medium hot spots results in large to huge spots (in the case of northern and western parts of Kuwait. Table 3 brief on the land use and land degradation indicators for the 58 hotspots. Rangeland grazing and encampment comprises 98% of land uses of the hotspots, Both the land uses are connected to each other. These main land uses were mainly concentrated in the hotspots 1 to 57 which covers a total area of 7575.9 km^2. Hotspot 58 that covered an area of 13.4 km^2 recorded no indicators of rangeland grazing and encampment due to this hot spot is located in a protected area where these activity is prohibited. As for the land degradation indicators such as vegetation deterioration, and soil losses (both by wind and water) were recorded in all the 58 hot spots (Table 3) [17-28].

Soil Degradation

The results of the present study indicate that the area of soil degradation is 7590.3 Km^2 (47% of the terrestrial environment) (Figure 8) and (Table 4).

Table 4: Degraded soil types.

Degraded Soil Types				
Soil Type	**Soil Type Area (km^2) (Omar et al. 2001)**	**Percentage of Soil Type Area (Omar et al. 2001)**	**Degraded Area 2017 (km^2) (Current Study)**	**Percentage of Degraded Area 2017 (Current Study)**
Aquisalids	1,211.8	7%	21	1.7%
Calcigypsids	1,065.2	6%	359.3	33.7%
Haplocalcids	1,350.95	8%	295.5	21.9%
Haplogypsids	8.1	0.05%	?	?
Petrocalcids	1,928.3	11%	1,259	65.3%
Petrogypsids	5,735.6	33%	3,830	67.0%
Torriorthents	135.5	0.08%	2.1	1.5%
Torripsamments	4,728.3	27%	1,810	38.3%
Total	16,163.8	92.1%	7576.9	46.9%

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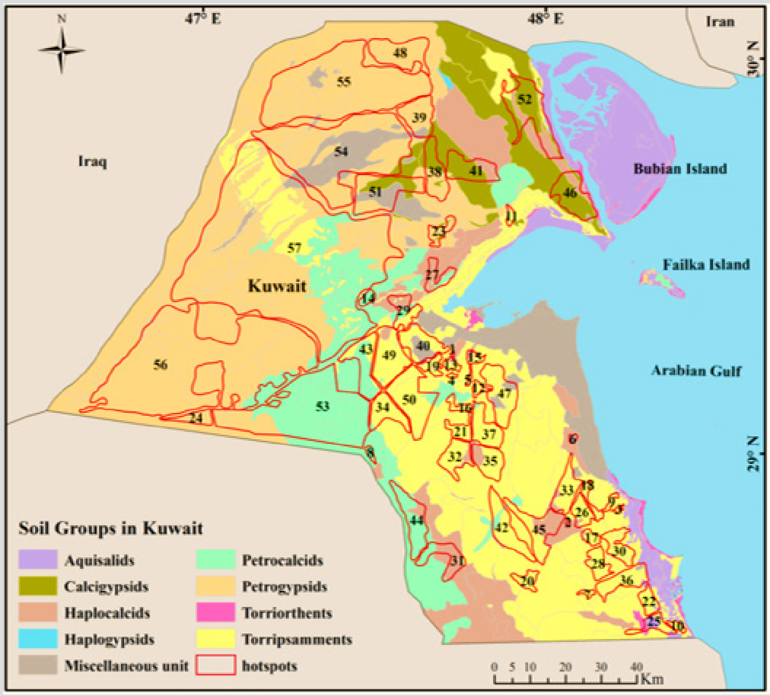

Figure 8: Hotspots on Soil Type Layer.

The highest vulnerable soil type to the deterioration of soil type were Petrogypsids (3.830 Km^2, 67%) and Petrocalcids (1.259 Km^2, 65.3%) and the lowest types were Aquisalids (21 Km^2, 1.7%) and Torriorthents (2.1 Km^2, 1.5%) (Table 4).

Vegetation Degradation

The results of the present study indicate that the area of vegetation degradation is 7590.3 Km^2 (48.7% of the total vegetation cover) (Figure 9) and (Table 5). The highest vulnerable vegetation type to the deterioration was Stipagrastietum (3.688 Km^2, 58%), then Cyperetum (2.198 Km^2, 50.4%) and the lowest types were Rhanterietum (36 Km^2, 11%), Centropodietum (22.2 Km^2, 14.1%), and Panicetum (12 Km^2, 14.1%) (Table 5).

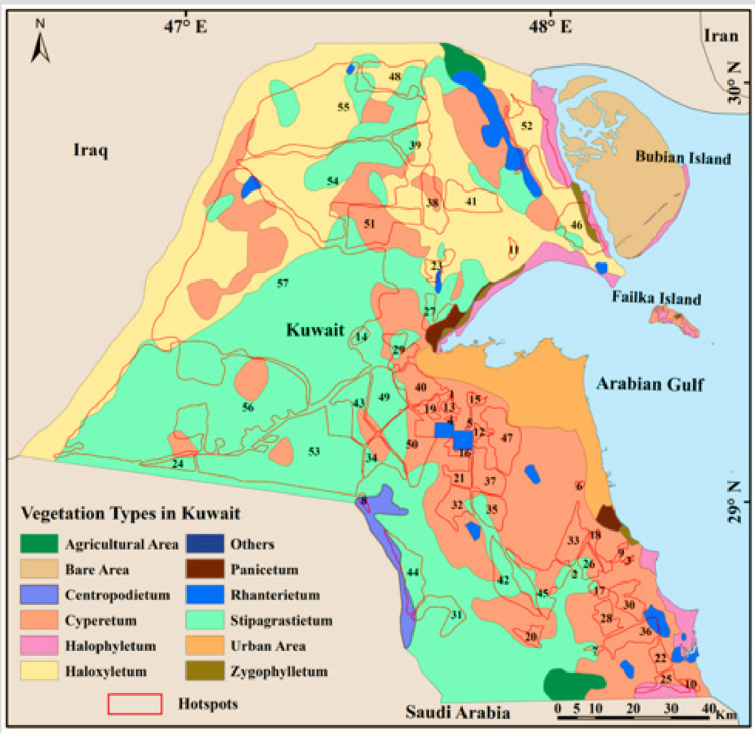

Figure 9: Hotspots on Vegetation Cover Layer.

Table 5: Degraded vegetation types.

Degraded Vegetation Types				
Vegetation Type	Area Covered by Plant (km²) (Omar 2001)	Percentage of Area Covered by Plant (Omar 2001)	Degraded Vegetation 2017 (km²) (Current Study)	Percentage of Degraded Vegetation 2017 (Current Study)
Haloxyletum	3,765	22.70%	1,485.3	39.4%
Rhanterietum	327	2.10%	36	11.0%
Cyperetum	4,394	26.90%	2,198.2	50.4%
Stipagrastietum	6,360	39.30%	3,688	58.0%
Zygophylletum	58	0.30%	25.2	43.4%
Centropodietum	158	1%	22.2	14.1%
Panicetum	85	0.70%	12	14.1%
Halophyletum	450	1.90%	110	24.4%
Total	15,597	94.90%	7,576.9	48.6%

Land Degradation Neutrality (LDN)

Land Degradation Neutrality (LDN) in arid, semi-arid and dry sub-humid areas is a state whereby the amount of healthy land resources remains stable or increases within specified temporal and spatial scales (UNCCD, 2014). Based on analyses of information on the nature, extent, and magnitude of land degradation in the terrestrial ecosystem of Kuwait, a strategic LDN target is defined. It aims to reduce land degradation from 50 % in the year 2019 to 10-15 % in the year 2030. A twelve-year roadmap (2019-2030) is proposed. It consists of four programs:

a) GIS-based knowledge support system (2019 -2023),

b) Public awareness and capacity building (2019-2023),

c) Sustainable land use program (2020-2023) and

d) Restoration/rehabilitation program (2023-2030).

7. Conclusions & Recommendations

Vegetation and soil degradation affects about 50% of the terrestrial environment of Kuwait which covers about 15.130 km2 (85 % of Kuwait). The main objective of this study was to detect and assess degraded areas in the terrestrial environment of Kuwait. A qualitative and quantitative approach was adopted through integrating remote sensing (Landsat 8, September 2017), Geographic Information System (ArcGIS S/W 10.5) and field investigations. The vegetation map [1] showing eight vegetation units was used as a baseline data for comparison with the vegetation conditions of the year 2017. On the other side, the soil map (KISR, 1999) showing eight soil units was used as a reference for comparison with the soil conditions of the year 2017. The study mapped and characterized some 58 land degradation hotspots with a total area of about 7590.3 Km2. Significant variations were observed concerning the sizes, land use and land degradation indicators of the 58 hot spots. Seven land use types were recorded. The most significant of which were rangelands grazing, encampment (temporary accommodation in the desert), military maneuvers and quarries and landfills.

Four mainland degradation indicators were reported. These are vegetation degradation & loss of biodiversity, soil losses (both by wind and water), soil crusting, sealing and compaction & soil mining. It is indicated that for 98 % of the hot spots, rangelands grazing and encampment are the main land uses. Both land uses are connected to each other. They were recorded in hotspots 1-57 (7,576.9 4 km²). The only hot spot where no rangeland grazing, is hot spot 58 (13.4 km²).Concerning land degradation indicators, vegetation degradation and soil losses (both by wind and water) were recorded in the 58 hot spots. Currently, most of the hotspots act as anthropogenic sources for sand and dust. Compared to the baseline data, some 48.7% of the vegetation and 47% of the soils were degraded during the period between 2001 to 2017. it is strongly recommended to develop a 12-year roadmap (2019-2030) to reverse land degradation.

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References

1. Omar S, Misak R, King P, Shabbir S, Abo Rizq H, et al. (2001a) Mapping the vegetation of Kuwait through reconnaissance soil survey. Journal of Arid Environment 48(3): 341-355.
2. Omar S, Misak R, Minkarah H, King P, Kwarting A, et al. (2001) Land-use mapping for the State of Kuwait using the Geographical Information System (GIS). Arab Gulf Journal of Scientific Research 19(2): 59-65.
3. Khalaf FI, Misak RF, Al Awadi J (2013) Land use Planning for Controlling Land degradation in Kuwait Developments in Soil Classification. Land use planning and Policy Implications, Springer, pp. 609-689.
4. Misak RF (2003) Classes of land degradation in the Terrestrial Environment of Kuwait. In Application of New Technology for Improvement of Desert Environment, Kuwait-Japan Symposium, State of Kuwait.
5. Khalaf FI (1989) Desertification and Aeolian processes in the Kuwait desert. Journal of Arid Environment 16(2): 125-145.
6. Omar S (1991) Dynamics of range plants following 10 years of protection in arid rangelands of Kuwait. Journal of Arid Environments 21(1): 99-111.

7. Zaman S (1997) Effects of rainfall and grazing on vegetation yield and cover of two arid rangelands in Kuwait. Environmental Conservation. 24(4): 344-350.
8. Misak R, Al Awadhi J, Al Sudairawi M (1999) Assessment and controlling land degradation in Kuwaiti desert ecosystem. In: Proc. Conf. on the Impact of Environmental Pollution on the Development in the Gulf Region, Kuwait, p. 15-17.
9. Brown G (2003) Factors maintaining plant diversity in degraded areas of northern Kuwait. Journal of Arid Environ 54(1): 183-194.
10. Brown G, Porembski S (1998) Flora and vegetational aspects of miniature dunes in a sand-depleted Haloxylon salicornicum community in the Kuwait desert. Flora 193(2): 133-140.
11. Brown G, Porembski S (2000) Phytogenic hillocks and blow-outs as 'safe sites' for plants in an oil-contaminated area of northern Kuwait. Environmental Conservation 27(3): 242-249.
12. Al Awadhi J, Misak R, Omar S (2003) Causes and consequences of desertification in Kuwait. A case study of land degradation. Bulletin of Engineering Geology and the Environment 62(2): 107-115.
13. Al-Awadhi J, Omar S, Misak R (2005) Land degradation indicators in Kuwait. Land Degradation and Development 16 (2): 163-176.
14. Omar S, Bhat NR, Shahid SA, Assem A (2005) Land and vegetation degradation in war-affected areas in the Sabah Al-Ahmad nature reserve of Kuwait: a case study of Umm Ar Rimam. Journal of Arid Environ 62(3): 475-490.
15. Misak R, Khalaf F, Omar S (2013) Managing the hazards of drought and shifting sands in drylands (the case study of Kuwait), Developments in Soil Classification, land use planning and Policy Implications. Springer pp703-729.
16. Lanfredi, M, Coppola R, Simoniello T, Coluzzi R, D'Emilio M, et al. (2015) Early Identification of Land Degradation Hotspots in Complex Bio-Geographic Regions. Remote Sens 7(6): 8154-8179.
17. Al Dousari A, Misak R, Shahid S (2000) Soil compaction and sealing in Al Salmi area. Journal of Land Degradation & Development 11(5): 401-418.
18. Al Dousari A (2005) Causes and indicators of land degradation in northwestern part of Kuwait. Arab Gulf Journal of Scientific Research 23(2): 69-79.
19. KISR (1999) Soil Survey for the State of Kuwait. AACM International, Adelaide, Australia. 1: 270.
20. Kobayashi C, Oki K (2015) Mapping of land degradation and its factors using landsat and DEM in the Western Australian wheatbelt. 2015 IEEE International Geoscience and Remote Sensing Symposium (IGARSS).
21. Misak R, Al Ghazali F (2017) Causes and indictors of land degradation in the Terrestrial Environment of Kuwait. Journal of the Gulf and Arabian Peninsula, University of Kuwait. No 165-vol.43
22. Misak R, Suleiman M (2014) Controlling land degradation using environmentally friendly materials (the Case of Kuwait). Journal of Arid Land Studies 24(1): 73 -76.
23. Misak R, Al Dousari A (2013) Prolonged Drought Issues and DLDD (Desertification, Land Degradation, and Drought) in Kuwait. Invited paper, Kubuqi International Desert Forum (KIDF), China.
24. Misak R, Kwarteng A, Al Sudairawi, M Omar S, Al Obaid, et al. (2000) Controlling land degradation in several areas in Kuwait. Final Report. KISR6002 pp. 234.
25. Misak RF (2003) Military Operations as a Major Cause of Soil Degradation and Sand Encroachment in Arid Regions (the Case of Kuwait). Proceeding of Desert Technology. 7th International Conference, Jodhpur, India, 14: 25-28.
26. (2015) National Committee for Combating Desertification in Kuwait 2015: Strategy of land degradation control in Kuwait-technical report EPA.
27. Omar S, Misak R, Shahid SA, Malik R, Madouh H, et al. (2001b) Rehabilitation of Kuwait's Rangelands for Sustainable Yield, Final Report. KISR6087 pp. 210.
28. Vågen TG, Winowiecki LA, Abegaz A, Hadgu KM (2013) Landsat-based approaches for mapping of land degradation prevalence and soil functional properties in Ethiopia. Remote Sensing of Environment 134: 266-275.

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