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Land and Vegetation Degradation Caused by Military Activities: A Case Study of the Sabah Al-Ahmad Nature Reserve of Kuwait

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Abstract

The invasion and occupation of Kuwait by Iraq and the liberation war during 1990-91 caused severe damage to the land and native vegetation in the Sabah Al-Ahmad Nature Reserve. During 1999-2001, studies were conducted to assess the damage and ascertain natural recovery of land and vegetation resources to design strategies to restore them to their pre-disturbance status. Based on a reconnaissance survey, a site measuring 135,000 m^2 in the desert flat sub-habitat of the reserve (At. Talhah) was selected for the study. On-site assessment of this site was severely impacted by military activities, such as refilled bunkers (65.6%), refilled foxholes (0.3%), compacted area between foxholes (9.4%), sandy low lying area (21.3%) and compacted road tracks (3.4%). The physical and chemical characterization of soil samples from different damage types indicated serious disruption of pedogenic processes in the soil profile and alterations in a number of soil properties. The composition, abundance and coverage of vegetation were also negatively impacted by military activities. Impact of different damage types on soil and vegetation properties was scored on an impact rating scale of 0 (no impact) to 4 (severely impacted). Areas covered by refilled foxholes, refilled ridges and compacted areas between foxholes and under road tracts were severely damaged, whereas the low-lying sandy areas created by erosion of loosened top soil was moderately damaged. The assessment of the present status of soil and vegetation also confirmed that natural recovery did not restore these resources to their predisturbance status.

Key words: Protected areas; soil assessment; damage assessment; vegetation cover.

Introduction

The Sabah Al-Ahmad Nature Reserve (formerly called Kuwait National Park/ Nature Reserve) was the first protected area established to preserve the natural heritage of Kuwait and to provide opportunities for education, research and outdoor recreation. The reserve comprises diverse landscape features and plant and animal life forms from both coastal and terrestrial ecosystems. *Rhanterium epapposum* Oliv. (60%), *Haloxylon salicornicum* (Moq.) Bunge ex Bioss. (30%), *Nitraria retusa* (Forssk.) Asch. and *Zygophyllum qatarense* Hadidi. (10%) (Omar et al., 1986) were the dominant plant communities in the reserve during the predisturbance period (i.e., prior to the Iraqi invasion). Similarly, the main wildlife habitats were the coastal plain, debris slope, escarpment and the desert plain. A number of studies were conducted between 1980 and 1986 to generate baseline information on the reserve's resources and an action plan was prepared to conserve and enrich the native biodiversity (Omar, 1982; Omar and Taha, 1984; Omar and Shuaibi, 1986; Taha and Omar, 1982; Omar, et al., 1998). The invasion and subsequent occupation by Iraqi military during 1990-91 disrupted all planned activities in the reserve and severely damaged its infrastructure, land, native vegetation and wildlife habitats. Specifically, numerous bunkers and foxholes were constructed all over the area and mines were laid from the coastal front of the park to the wadis and gullies in the Jal Az Zor escarpment. Heavy equipment and personnel carriers were used during occupation and liberation war. In the post war period, foxholes and bunkers were refilled with excavated and transported soils. Preliminary results showed severe negative impact of these war activities on vegetation structure and species composition, wildlife population and soil throughout the country (Al-Houty et al., 1993; Omar et al., 1998; Zaman and Al-Sdirawi 1993 and Omar et al., 1999).

With extreme temperatures, low and erratic rainfall and high evaporation rates, soil and plant recovery under arid environments is inherently slow (Kockelman, 1983; Prose and Wilshire, 2000). While majority of research done in areas affected by military activities have indicated that natural recovery of severely disturbed and compacted desert soil to be extremely slow, some have even suggested that the subsurface compaction may not recover at all. The establishment and growth of desert plants may be significantly retarded in compacted soils (Adams et al., 1982). Using a logarithmic model, Webb (2002) estimated that the time required for 85% compaction recovery ranges from 105 to 124 years. Prose and Metzger (1985) estimated that it requires eight to 112 years for vegetation to recover to predisturbance conditions on moderately compacted desert sites, and 100 to 3,000 years on heavily compacted sites. In view of these observations, the study reported in this paper was undertaken during 1999-2001 to examine the type and magnitude of damage to soil and native plants and the natural recovery of soil and vegetation ten years after the severe damage caused by military activities in the At. Talhah area of the Sabah Al-Ahmad Nature Reserve of Kuwait. The reserve was protected from human activities during the post-invasion period and immediately after the clearance of mines and ammunitions in 1994.

Materials and Methods

Climate and Geomorphology of Experimental Area

Geographically, Kuwait occupies approximately 17,800 km^2 of the northwestern part of the Arabian Gulf, between latitudes 28°30' and 30°05'N and longitudes 30°05' and 46° 33'E. Kuwait's climate is characterized by harsh summers and mild winters. Temperature extremes are high, with means during the warmest and coolest months ranging between 46.2°C and 6.9°C (Annual Statistical Abstract, 1998). Winter brings occasional frost. Rainfall is minimal; not exceeding 115 mm.y^{-1}, but evaporation is very high, ranging from 3.0 to 14.1 mm.d^{-1}. The relative humidity is low, and strong, dry and hot northwesterly winds prevail during summer, particularly in June and July.

The study site (At. Talhah) is in the desert flat habitat of the reserve and consists of a long stretch of relatively flat areas. The area slopes gently in the north-westerly direction with a slope angle $< 5^0$. The soil depth in this habitat varies from very shallow to deep sandy soil in the depression. The undisturbed soil in the study site contained 94 – 96 % sand, 11.3 – 13.6 % gravels and 3.6 – 5 % silt. The soil is slightly to moderately saline with ECe ranging between 2.4 and 6.9 mS/ cm with moderately high levels of chlorides (10.6 – 15.4 meq/ l) and sulfates (10.2 to 17.5 meq/ l). The soil is low in organic matter and most plant nutrients (Omar et al., 1986).

Pre-invasion Vegetation in the At. Talhah Area

During the preinvasion period, the desert flat sub-habitat, which includes the study site hosted a wide range of plant species. *Haloxylon salicornicum* (in the northeast) and *Rhanterium epapposum* (in the west) were the major perennial shrub communities, with a high density, but low coverage (5 – 45 %). The annual species, *Stipa capensis* Thunb. covered a large area, especially in the *Haloxylon* community (Omar et al., 1986). Other common species in this area were *Arnebia decumbens* Vent. Coss & Kral., *Asphoedelus tenuifolius* Cav. Baker, *A. viscidulus* Boiss., *Astragalus shimpera* Boiss., *Brassica tournifortii* Gouan, *Cakile Arabica* Velen. & Bornm., *Cardus pycnocephalus* L., *Cutandia memphitica* (Spreng.) Benth., *Cynodon dactylon* (L.) Pers., *Emex spinosus* (L.) Campd., *Filago spathulata* L., *Hippocrepis bicontorta* , *Iflago spicata* (Forssk.) Sch.Bip., *Launaea capitata* (Spreng.) Dandy, *Lotus pusillus, Plantago boissieri* Hausskn. & Bornm., *Reseda Arabica* Boiss., *Silene arabica* Boiss., *Schismus barbatus* (L.) Thell. and *Schimpera arabica* Hochst et. Steud. Some of these plants were identified as rare. A lonely native tree, Acacia pachyceras O. Schwartz and a number of naturalized trees of *Prosopis juliflora* and *Zizyphus spina-christi* (L.) Willd. also existed near the study area.

Selection of Study Site

Based on the biophysical features the reserve was previously divided into five sections (coastal area, coastal sand dune area, escarpment, back slope and depressions). The site selected for this study is located in the desert plain habitat (desert flat sub-habitat) of the reserve. For selecting the study site, several potential sites in this habitat were individually assessed by a multidisciplinary team consisting of experts in range management, horticulture, environmental science and soil science. Indicators, such as nature and extent of damage, resemblance of damage to other areas in the reserve, importance of the area to the aim's of reserve and need for undertaking immediate rehabilitation measures were used in the selection of the study site (Omar et al., 2002). A 135,000 m^2 site that contained major damage types was selected for this study.

Damage Assessment

The study area contained five main types of disturbances (refilled bunkers, refilled foxholes, compacted area between foxholes, low-lying sandy area and off-road vehicle tracts). Semiquantitative field survey supported by laboratory analyses of soil samples was employed for assessing the nature and extent of damage caused by various war-related activities (Omar et al., 2002). The study area was thoroughly assessed by a multidisciplinary team, who systematically traversed the site and recorded the relevant observations on the ground (presence of munitions materials and *gatch* (a hard to very hard lime or lime silica hardpan) pieces, erosion of top soil, exposure of *gatch* layer and uneven topography) These information was later used in developing impact rating for various damage types.

The nature of the soil in the study area was examined by augering and collecting soil samples from identifiable horizons of the profile. A number of soil profiles were dug and total of representative soil samples were collected. In addition, a soil core of a known volume was collected from each area and oven dried to determine the bulk density according to the procedure described by Page et al., (1982). Porosity was calculated using bulk density values and standard particle size density of 2.65 g/ cm^3.

Soil samples were air-dried at around 30°C until they were fully dry and were sieved through a 2-mm sieve to separate fine (< 2 mm) and coarse fractions (> 2 mm) according to the United States Department of Agriculture (USDA) specifications (Soil Survey Division Staff, 1993). The course fraction was discarded after recording its weight. The fine soil fraction was analyzed for various physical (color and saturation percentage) and chemical (electrical conductivity, pH of saturated paste and $CaCO_3$ levels) parameters. Soil color was determined by the Munsell® Color Chart (Munsell, 1998). pH and EC of saturated soil paste were estimated using USDA 1996 method (method 8a). Saturation percentage was calculated based on the amount of water required to prepare the saturated soil paste. $CaCO_3$ content was measured using calcimeter (USDA, 1996).

Infiltration Rate and Penetration Resistance

Infiltration rates were measured in refilled bunkers, refilled foxholes, compacted area between foxholes, low-lying sandy area and off-road vehicle tracts. Fall of water head (level) in the double-ring infiltrometer at fixed time intervals was used to calculate the rate of movement of water through the soil profile.

The penetration resistance was measured using the Bush soil penetrometer (model SP 1000). Specifications used for the test included sample type (2:25 readings per insertion at 2-cm depth intervals), cone diameter (12.83 mm) and pressure (Pressure (kg cm^{-2}) = Cone resistance/ (∏ i) $radius^{-2}$). The data from three insertions were averaged for each depth and entered into a computer. Penetration curves were prepared by plotting cone resistance against depth of insertion (i). The interpretation of these curves allowed the identification of location of soil compaction in the profile. Eight penetration tests were carried out in each disturbance type and an average values were computed.

Vegetation Assessment

The technique developed by Stohlgren et al. (1998) based on modified-Whittaker multiscale vegetation plot was used for assessing the vegetation cover. The percentage of ground cover was measured in ten (0.5 x 2 m) subplots, replicated four times. Plant species in each plot and subplot were identified and the percent ground cover determined visually for gravel, litter, bare ground and total vegetation. The vegetation assessment covered 5000 m^2. The data was statistically analyzed using the one-way ANOVA to compare means (Bonham, 1989). These results were compared with the previously reported data for this area of the reserve.

Impact Rating

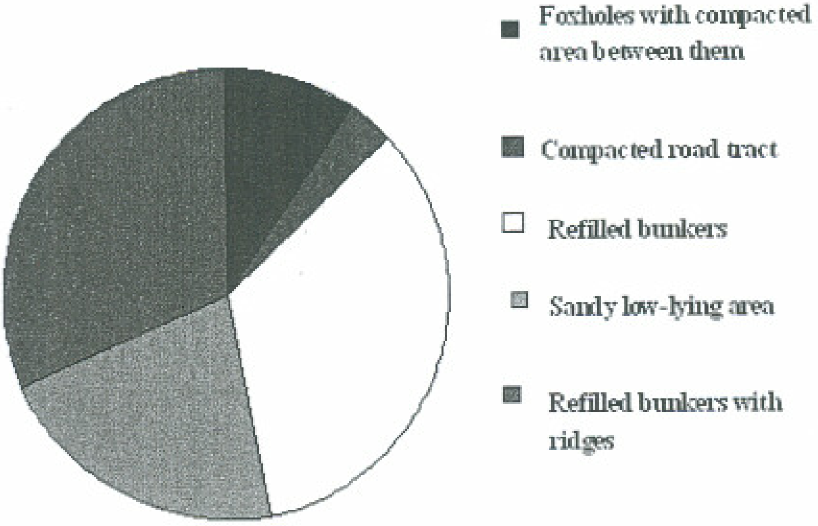
Various features observed on the ground (such as loss of top soil, accelerated water erosion, exposure of *gatch*, uneven topography, compacted road tracts, mixing of broken pieces in soil profile, loss of vegetation, altered infiltration rates and altered penetration resistance) and the laboratory characterization of the soil (changes in physical and chemical properties) were rated on a scale of zero (no disturbance) to four (severely disturbed). A cumulative score was computed for each disturbance type to determine the severity of damage. This information have been used in the planning of a pilot rehabilitation study to restore the degraded land and vegetation to their pre-disturbance levels.

Results

Field Assessment of Damage

Over 65% of the total area of the study site was impacted by refilled bunkers and their surrounding ridges (Fig. 1). Excavation of refilled bunkers by shovel supplemented with hand augering revealed an average soil depth ranging from 40 to 50 cm (calcrete layer appeared at this depth), below which hand augering was difficult. The refilled bunkers had uneven topography and were highly impacted by military activities. The refilled bunkers with slightly raised ridges were covered with shattered gatch pieces.

Fig. 1: Damage types in the study site.



The sandy low-lying area accounted for 21.3% of the total study area. This low-lying area was created due to compaction of refilled soils and subsequent accumulation of eroded soils on the surface. Excavation and hand augering revealed a soil depth ranging from 75 cm to 90 cm, below which calcrete layer (*gatch*) occurred. The soil profile had a 5 cm thick layer of loose, eroded sand at the surface followed by a 5 cm thick layer of silt and clay indicating that the surface materials was deposited recently indicating that the surface materials was deposited recently. The soil in the 10 – 90 cm layer was relatively stable.

The foxholes and the compacted area between them accounted for approximately 10% of the study area. These foxholes, which measured 1.5 X 1.5 m, were refilled with excavated soil containing calcareous (calcrete) *gatch* pieces of different sizes (2 x 5 to 4 x 6 cm). Excavated *gatch* pieces were also scattered nearly uniformly on the surface through out the area between foxholes.

The area under road tracks, which accounted for 3.4% of the total study area, was highly compacted and contained mostly micropores.

Physical and Chemical Properties of Soil in the Impacted Areas

The occurrence of distinct layers in soil profiles and soil properties were influenced by the nature of damage and the type of soil material used for refilling. For example, the profile in the refilled foxholes, refilled bunkers and stabilized ridges contained only two layers of varying depths compared to three layers in areas between foxholes and sandy low-lying areas (Table 1). Soils from all layers in refilled foxholes and areas between foxholes, and deeper layers in the sandy low-lying area (10 – 30 cm and 30 cm plus layers) and stabilized ridges (40 – 100 cm layer) had greater amounts of coarse fractions (10.2 to 56.0%) compared to those from all layers in refilled bunkers (0 – 0.8%) and the top layer (0 – 10 cm) in the sandy low lying area (5%). These observations indicate an interruption in the ongoing soil-forming processes caused by excavation and refilling operations.

Table 1: Selected Physical and Chemical Soil Properties in Area Impacted by Various Kinds damage

Damage Type	Depth (cm)	pHs	ECe(dS/m)	SP	$CaCO_3$(%eq)	Munsell Color	% Coarse Fraction
Foxholes	0-20	7.45	8.1	32.0	18.0	Pale brown	56.00
	20-50	7.66	21.6	34	16.6	Pale brown	22.00
Area between foxholes	0-20	7.35	2.8	23	13.9	Pale brown	15.4
	10-40	7.60	10.2	26	14.10	Pale brown	16.10
	40+	7.90	9.5	45	21.0	Pale brown	*Gatch*
Sandy low-lying area	0-10	7.64	0.8	24	12.7	Pale brown	5.00
	10-30	7.53	1.6	32	14.6	Pale brown	10.20
	30+	7.57	5.3	33	14.1	Pale brown	14.10
Refilled bunkers	0-10	7.68	1.2	26	13.8	Pale brown	0.80
	10- 40	7.66	1.5	27	8.0	Pale brown	Nil
Stabilized ridge	0-40	7.13	19.6	25.5	15.54	Very pale brown	1.08
	40-100	7.70	12.50	29.0	16.24	Very pale brown	13.18

SP = Saturation percentage; Munsell color according to Munsell chart (1998), pale brown and very pale brown corresponds to 10YR 6/3 and 10 YR 7/3, respectively.

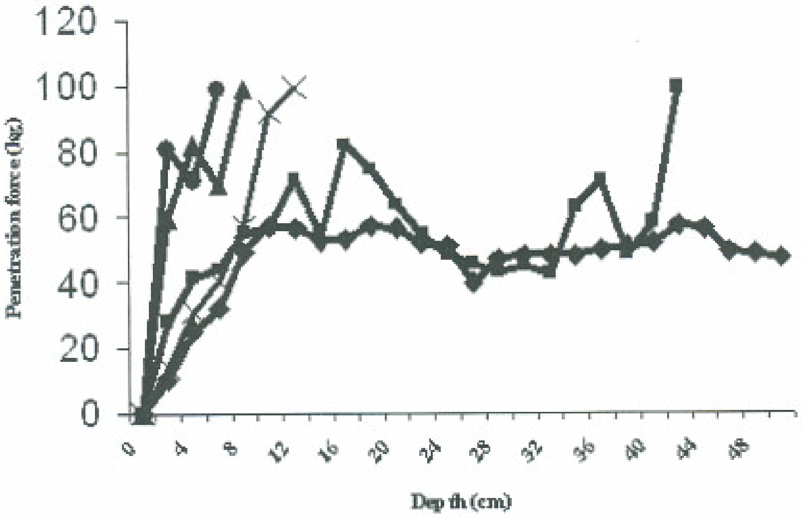
The pH of the saturated soil (pHs) ranged between 7.13 and 7.90. Deeper layers of profiles in foxholes, areas between foxholes and stabilized ridges were more alkaline than the shallow layers. The soils in the 0-10 cm layer in the sandy low-lying area had the lowest (0.8 dS/ m) ECe, whereas the 20-50 cm layer in the refilled foxholes had the highest (21.6 dS/ m) ECe. Excavation and refilling of foxholes also increased the saturation percentage.

The undisturbed soil the in the study site contained 94 – 96 % sand, 11.3 – 13.6 % gravels and 3.6 – 5 % silt. The soil is slightly to moderately saline with ECe ranging between 2.4 and 6.9 mS/ cm with moderately high levels of chlorides (10.6 – 15.4 meq/ l) and sulfates (10.2 to 17.5 meq/ l).

Penetration Resistance

The penetrometer was able to enter up to a depth of 42 cm in refilled foxholes, 50-70 cm in refilled bunkers and 12 cm in the sandy low-lying area (Fig. 2). Areas covered by road tracks, stabilized ridges and between foxholes offered maximum resistance, where penetrometer could only enter to depth ranging from 0 – 8 cm. The higher resistance observed in the low lying area was due to the deposition of silt and clay in the upper layers. Considerable variations in penetration resistance were observed in areas between the foxholes. The differences in force required at various depths reflected the degree of compaction.

Fig. 2: Penetration Resistance (Kg) in areas under various damage types: 1). foxholes refilled will *gatch* (!), 2). area between foxholes () 3). sandy low-lying area (3), 4). refilled bunkers (◆), 5). road tracts (✸).



Infiltration Rate

The rate of infiltration of water through the soil profiles expressed in terms of fall-of-water-head in the double-ring infiltrometer (DRI) as a function of time lapsed from the start of the test was influenced by both the nature and the extent of damage. The water level in the DRI decreased at the rate of 4.8 cm/h in compacted road tracts compared to 65.2 cm/ h in refilled foxholes, 41.6 cm/ h in foxholes refilled with gatch pieces, 32.0 cm/l in areas between foxholes, 64.0 cm/h in sandy low-lying area, 58.0 cm/ h in refilled bunkers and 42.0 cm/ h in stabilized ridges (Fig. 3). The wetting zone ranged from 80 mm in the road tract to 270-350 mm in the sandy low-lying areas. The soils that offered resistance to water movement also had higher bulk density and less total pore space (Table 2).

Fig. 3: Infiltration rate (cm/ hr) and wetting zone in areas under various damage types: 1). foxholes refilled will gatch, 2). foxholes refilled with eroded sand, 3). area between foxholes, 4). sandy low-lying area, 5). refilled bunkers, 6). Refilled bunkers with ridges, 7). road tracts.

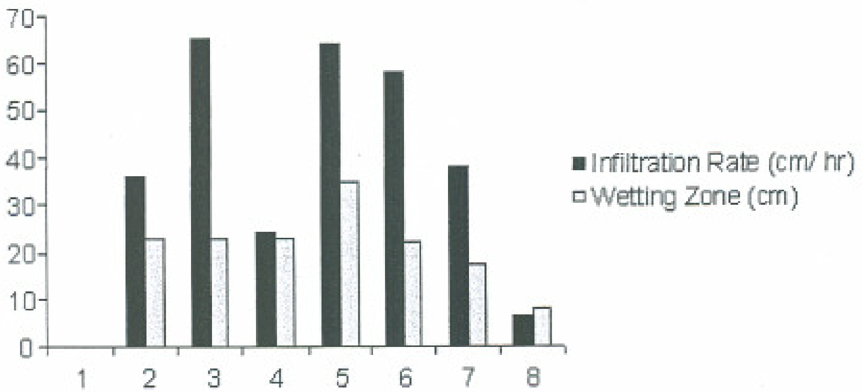


Table 2: Bulk Density of Soils in Areas affected by Various Military Activities

Military Impact	Bulk Density (Dry) ($g.cm^{-3}$)	Bulk Density (wet) ($g.cm^{-3}$)
Foxhole refilled with gatch pieces	1.71	2.04
Foxhole refilled with eroded sand	1.59	2.07
Area between foxholes	1.59	1.97
Sandy low lying area	1.59	1.88
Refilled bunkers	1.40	1.79
Refilled bunkers with stabilized ridge	1.58	1.89
Road track	1.77	2.04
Undisturbed control in the reserve	1.66	1.96

Vegetation Assessment

The comparison of vegetation before and after the occurrence of disturbance shows that military activities significantly altered the vegetation composition and increased variability within a small area (Table 3). The number of species recorded in plots 1, 2, 3, and 4 were 20, 21, 12 and 6, respectively. The number of species also varied among quadrates of different sizes. The dominant species were annual forbs, *Plantago boissieri* and *Ifloga spicata* and the annual grass, *Stipa capensis*. These three species showed highest percentage of cover. *Plantago boissieri* scored 21.8%, followed by *Stipa capensis* (11.1%) and *Ifloga spicata* (7.1%). Other species such as *Filago pyramidata*, and *Schismus barbatus* were moderately abundant (16-30% frequency). The mean total vegetation, litter, gravel and bare ground were 49, 12.5, 17.9 and 19.9 %, respectively; however, there were significant difference among the plots (Table 3). While the vegetation cover ranged between 35 and 64 %, the extent of bare ground varied between 0 and 41 %. This suggests that alterations in soil properties due to the damage caused by military activities are reflected in species distribution, abundance and percentage of native vegetation cover.

Table 3: Vegetation Assessment in the At. Talhah Study Area

Parameters	Mean	SD*	Plot 1	Plot 2	Plot 3	Plot 4	Predisturbance Frequency (%)**
Gravel	17.9	23.3	0.0b	0.0b	30.8a	40.7a	
Litter	12.5	10.2	9.0b	23.5a	8.2b	9.3b	
Bare	19.9	23.2	27.0ab	41.0a	11.5bc	0.0c	
Total Vegetation	49.8	20.6	64.0a	35.5b	49.5ab	50.0ab	
Anthemis deserti	0.0	0.2	0.1a	0.0a	0.0a	0.0a	3
Carduus pycnocephalus	0.0	0.0	0.0a	0.0a	0.0a	0.0a	57
Crucianella membranacea	0.0	0.0	0.0a	0.0a	0.0a	0.0a	3
Erodium sp.	0.4	1.3	1.6a	0.0b	0.0b	0.0b	11
Filago pyramidata	5.1	5.0	7.1a	7.2a	3.0a	3.1a	34
Gymnarrhena micrantha	0.0	0.2	0.1a	0.0a	0.0a	0.0a	7
Ifloga spicata	7.1	10.4	13.9a	6.8ab	5.8ab	1.7b	57
Lotus halophilus	0.1	0.8	0.0a	0.5a	0.0a	0.0a	6
Oligomeris sp.	0.0	0.0	0.0a	0.0a	0.0a	0.0a	3
Picris sp.	0.1	0.8	0.0a	0.5a	0.0a	0.0a	3
Plantago boissieri	21.8	22.7	35.50a	16.0ab	29.2ab	6.40a	17
Schismus barbatus	4.1	3.9	3.6a	5.0a	2.8a	4.8a	26
Stipa capensis	11.1	17.0	2.1b	0.0b	8.2b	34.0a	3

*SD = Standard deviation, The data were analyzed using one-way ANOVA and Tukey's mean separation procedures. Figures followed by the same letter within the row are not statistically different at P = 0.05

** The predisturbance plant frequency was taken from a previous study in the nature reserve.

The studies conducted by El-Sheikh and Abbadi (2004) during the spring of 2001 showed that the undisturbed (control) areas in this habitat contained the highest number of species (98) and had a plant coverage of 51.6%. Major contribution to the plant cover was made by annual herbs and grasses like *Plantago boissieri* Hausskn. & Bornum., *Picris babylonica* Hand. Mazz., *Schimpera arabica* Hochst., *Erodium laciniatum* (Cav.) wild, *Cutandia dichotoma* (Boiss.), *Neurada procumbens* L., *Schismus barbatus* (L.), *Stipagrostis ciliate* (Desf.) de Winter and *Stipa capensis* Thunb. *Haloxylon salicornicum* (Moq.) Bunge ex Boiss. was scattered throughout the undisturbed areas. Prior to the invasion, this habitat was dominated by *Haloxylon salicornicum* (Moq.) Bunge ex Boiss., *Calligonum polygonoides* L., *Arnebia decumbens* Vent. Coss & Kralik, *Cardus pycnocephalus* L., *Cutandia memphitica* (Forssk.) Trabut in Batt. & Trab., *Ifloga spicata* (Forssk.) Sch.Bip., *Ochradenus baccatus* Delile, *Pennisetum divisum* (Gmel) Henrard., *Launaea mucronata* (Forssk.) Muschl., *Lycium shawii* Roem & Schult. and *Gynandriris sisyrinchium* Parl. (Omar etal., 1986). These observations clearly indicate that the disturbance resulted in the loss of species diversity and increase in the number of species that are either rare or endangered.

Impact Rating

Overall, the land and native vegetation in the study site was severely degraded by military activities. The cumulative impact score ranged between 16 (low impact) in the sandy low lying area and 36 (severe impact) in areas that contained refilled bunkers and their surrounding ridges (Table 4). The areas that were covered by refilled bunkers (cumulative impact score of 33), refilled foxholes (cumulative score of 34) and off-road vehicle tracts (according to visual observations) were also severely damaged.

Table 4: Impact Rating of Damaged Areas in the Study Site

Damage Indicators	Damage Type*			
	Areas covered by refilled foxholes	Areas covered by refilled bunkers	Areas covered by bunkers with surrounding ridges	Low lying sandy area
Loss of top soil	4*	4	4	2
Accelerated water erosion	1	3	3	1
Exposure of gatch	4	3	3	1
Uneven topography	3	4	4	1
Soil compaction	4	1	4	1
Mixing of broken gatch pieces in soil profile	4	4	4	1
Loss of vegetation	4	4	4	4
Altered infiltration rate	2	2	2	1
Altered physical properties	4	4	4	2
Altered chemical soil properties	4	4	4	2
Cumulative scores	34	33	36	16
Damage magnitude**	Very Severe	Very severe	Very severe	Low

* Impact rating: 0 – no damage; 1- low and recoverable impact; 2 – moderate impact, recoverable with less intensive rehabilitation measures; 3 – severely impacted, needs active rehabilitation; 4- very severe impact, rehabilitation is essential, but may be expensive.

** Damage magnitude is based on cumulative score; Very Severe = 31- 40; Moderate = 21 - 30; low = 11 - 20; insignificant or no damage = 0 - 10.

Discussion

In Kuwait, harsh climatic conditions, increased human pressure, overgrazing and Gulf war activities have led to significant loss of biological diversity and desertification (Omar, 1990). The inherent fragility of soils and loss of native vegetation cover have accelerated land degradation further (Al-Awadhi *et al.*, 2003). A number of plant communities in the nature reserve have become either rare or endangered by the Gulf war crisis (Omar, 2000; El-Sheikh and Abbadi, 2004). Under these circumstances, enforcement of protection measures and restoration of plant diversity to their original status assume greater importance now than ever before.

The present study showed more than two-thirds of the study area has been severely degraded to the extent that the identity and the original soil class have been changed. Excavation and refilling operations during occupation destroyed established natural soil horizons and natural pedogenic sequence of soil horizons, and altered a number of their properties. The variations noticed in some properties (pHs, ECe, infiltration rate and compactness) may be related to altered soil texture and the integrity of *gatch* (calcrete containing $CaCO_3$). The creation of macrospores the by coarse soil fractions was probably the main cause of acceleration of percolation of water through soil matrix. This was substantiated by the fact that the refilled soil materials had lower bulk density and higher porosity. In contrast, the fine-textured soil materials eroded from surrounding areas increased the bulk density and reduced the porosity. These conditions, in turn, influenced percolation of water and chemical properties. Although macropores in soil will get blocked with time by fine-textured transported soil material, the slow pedological changes under arid climatic conditions make the natural rehabilitation rather difficult.

Several researchers all over the world have shown that severely disturbed soils are very slow to recover and in turn, have significant effects on ecosystem recovery (Johnson and Sallberg, 1960; Web and Wilshire, 1980; Web, 2002). Soil compaction increases soil's bulk density and changes other soil properties; most notably, the size distribution, strength characteristics, continuity of pores and decreases infiltration rate (Web, 2002). These changes will have considerable long-term influence on root growth, which may affect seedling establishment and restoration of vegetation cover. Subsequent seedling growth rates may also be poor because compaction may limit access to both water and nutrients. In playas or seasonally inundated soils compaction can limit oxygen availability to roots. It may also affect natural succession process by selectively affecting the establishment and/ or growth of certain species.

The assessment of vegetation composition and frequency (Table 3) suggested that currently, the area is inhabited mainly by two forbs (*Plantago boissieri* and *Ifloga spicata*) and one annual grass (*Stipa capensis*), and the frequency of most species have greatly been reduced. The perennial shrubs, particularly *Rhanterium epapposum* have completely disappeared from the area. Because of low productivity, the recovery of native plants from abiotic (drought, high salinity) and biotic (human interference, overgrazing, cutting, off-road vehicles, disruption of soil forming process by excavation and/ or refilling operations) stresses is very slow under Kuwait's environment. The harsh arid climatic conditions combined with the disruption of soil structure made it difficult for natural recovery of vegetation cover and wildlife habitats to predisturbance status.

The changes in soil properties, which have long-term influence on root growth, may have affected seedling establishment and restoration of vegetation cover. Subsequent seedling growth rates may also have been affected because increased compaction limited access of plant roots to water and nutrients. In low-lying areas (playas) or seasonally inundated soils can limit oxygen availability to roots. These changes also affect natural succession process by selectively affecting the establishment and/ or growth of certain species, which might be the case in the present study. Whilst a quick solution for a complete reversal of land degradation and deterioration in ecosystem health under harsh climatic conditions may not be possible, steps can and should be taken to tackle this problem. These measures should include continued enforcement of protection measures, creation of a favorable microclimate through temporary shelter belts and water conservation practices and reintroduction of native plant species.

Conclusions

It is concluded from this study that the major portion of At. Talhah site has been severely damaged due to military activities. The damaged areas, where the soil profiles indicated physical disturbance that can not be reversed by natural soil forming process would require adoption of intensive rehabilitation measures for improving soil properties and restoration of vegetation cover to their preinvasion levels.

Different rehabilitation options should be evaluated for their effectiveness in restoring native vegetation cover and wildlife habitats prior to their large-scale application.

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