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Land Resource Stresses and Degradation in the Arid Environment of Kuwait: An Overview

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ABSTRACT: Arid environments are dry for most of the year. The present article identifies some of the major land resource stress in the arid environment specific to Kuwait. In addition to aridity, Kuwait faces additional stress from erosion, poor quality soils, consequences of the Gulf war (oil contamination of land resources, compaction, surface disturbance-landmines-bunkers), over-exploitation of land resources and inappropriate land use, overgrazing, insufficient water resources, and salinization. The management strategies to either reduce or moderate the affects of land resource stress are also presented.

INTRODUCTION

Kuwait is situated in the northeastern corner of the Arabian Peninsula. It covers approximately 17,818 km^2 area and is characterized by a desert type environment. The mean total precipitation is approximately 100 mm yr^{-1} (Al-Kulaib, 1984). The rate of evaporation exceeds precipitation and is approximately 16.6 mm day^{-1}. Dust and dust storms, locally known as *toze*, are common throughout the year, but are more frequent during the spring and summer months (March to August). However a toze also occurred on February 8, 2000 when it blocked out the sun completely for a whole day.

Kuwait's land resources are threatened by nature (long hot dry period) and human activities. Aridity itself is a significant factor that affects the potential of land resources in a desert type environment so that it is difficult to exploit them to their potential. The combined effect of natural stresses and those related to mismanaged human activity then leads to further degradation of land resources. The degradation reduces the land quality and its productivity. Land quality can be assessed by looking at the soil resilience, which is a qualitative assessment to identify the ability of land to regenerate its capability after sustaining a shock (Blaikie and Brookfield, 1987). Land begins to degrade when its resilience is impaired. It is a major concern to arid land resources, when the land uses do not match the land quality. Kuwait, being a small country, cannot sustain such pressures. Therefore, the stresses on the land resources need to be reduced, or moderated and controlled.

An inventory of Land Resources is the first step for determining the "state of land". The second step using the soil survey identifies areas vulnerable to desertification. Recently, a soil survey of Kuwait has been completed at a reconnaissance scale- 1:100,000 (Soil Survey of Kuwait, 1999) that describes and classifies the soil types at the family level (USDA, 1993; 1994). The survey also describes the suitability of land resources for a number of uses (agriculture, sand and gravel sources, camping, shows potential sites for shallow excavations, septic tank absorption fields, sewage lagoons, sanitary landfill, seedling mortality and desert plant habitat etc). The results from the reconnaissance survey were also used to identify 200,000 ha area having potential for irrigated agriculture, which was later surveyed at a semi-detailed level at scale of 1:25,000 (2nd order survey standards of USDA).

Land use mapping of the State of Kuwait has been compiled at a scale of 1:100,000 (Soil Survey of Kuwait, 1999). It identifies some 19 types of land use in Kuwait. The major land uses are; rangeland (75.12%), oil field (6.78%), military area (3.96%), agriculture (3.08%) and gravel quarrying (2.21%). Minor land uses cover the remaining areas and include communications, cemetries, refuse disposal areas, water reservoirs, parkland, encampment, scrap yards, power stations, racetracks etc. (8.85%). This shows that the land use in Kuwait is dominated by rangeland, which is used for traditional grazing activities by flocks and herds of domestic sheep, goats and camels.

The United Nations Convention to Combat Desertification (CCD) was adopted on 17 June 1994. Kuwait signed and ratified the Convention in 1995. The Convention defines desertification as "land degradation" in arid, semi-arid and subhumid areas resulting from various factors, including climatic variations and

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human activities. The CCD encourages the establishment of National Action Programs (NAPs) to combat desertification and to mitigate the effects of drought (Sourang and Ahmad, 1995) for natural resource management.

Overgrazing, land clearance, overexploitation of natural lands and, using land in a way that is inappropriate to local conditions-each of these can advance the process of desertification. This paper identifies land resource stresses, the processes of land resources degradation in Kuwait and highlights possible management strategies.

TYPES OF LAND RESOURCE STRESSES AND DEGRADATION IN KUWAIT

Land resource stresses in Kuwait can be grouped into four major groups; 1) Physical – compaction and hardsetting, wind and water erosion; 2) Chemical – fertility depletion, oil contamination, salinization and sodication; 3) Biological – decline in, soil organic matter, macro and micro fauna and in land biodiversity; 4) Soil types – soils of Kuwait are not in the best category for agricultural purpose. In addition, the environment is very fragile and the management of the soil resource is of paramount importance.

In Kuwait the stress due to wind erosion appears to be the most widespread. A combination of wind erosion and vegetation degradation pervades the rangelands that occupy a major part in Kuwait. Salinity is confined to Bubyan Island and to the coastal area. The water erosion is more prevalent in areas of slopes (Jal Az-zor). Surface crusting and hardsetting are prevalent under off road heavy traffic and areas susceptible to rain drop splash action. Oil pollution is more evident in areas near to oil lakes. However, oil soot occurs in an extensive area, caused through oil well fires during the Gulf war, when more than 700 oil wells were set ablaze (Al-Awadhi et al., 1996). The consequences of the above and their possible management are described below.

Soils of Kuwait

The soils of Kuwait at reconnaissance scale (1:100,000) are classified into eight great soil groups (petrogypsids, petrocalcids, aquisalids, torripsamments, haplocalcids, calcigypsids, haplogypsids and torriorthents) (USDA, 1994), and a generalized soil map at scale 1:250,000 is available. The mapping of great soil groups through reconnaissance soil survey of Kuwait is presented elsewhere (KISR, 1999). The petrogypsids and petrocalcids occupy 44% of the area in Kuwait. These soils are underlain by hardpan within 1 m from the soil surface, and therefore, cannot be exploited for irrigated agriculture. Aquisalids (7%) are soils with high salinity levels, not conducive for agricultural uses. However, they could be used for wildlife habitat. This shows that 51% soils of Kuwait have limited use and require comprehensive management plans. Torripsamment soils are loose sandy, less developed soils, and are highly susceptible to wind erosion. It is estimated that, including torripsamments (27%), a total of 78% soils of Kuwait are in the severe grip of natural stresses. Only the haplocalcids, calcigypsids and haplogypsids (15%) have some potential for agriculture, subject to their optimal management. Other areas are under miscellaneous uses (6%).

Erosion

As mentioned above, loose sandy soils are prone to wind erosion. The aeolian deposits are the most predominant and account for 50% of the surface deposits (Khalaf, 1989). Khalaf et al. (1984) estimated that mean monthly fallout of soil deposition is 191.3 t km^{-2}, while the mean monthly maxima and minima were recorded in July with 1002.7 t km^{-2} and November with 9.8 t km^{-2} respectively.

There are three distinct phases of wind erosion: 1) Movement; 2) Transportation and, 3) Deposition. Figure 1 shows significant signs of the transportation

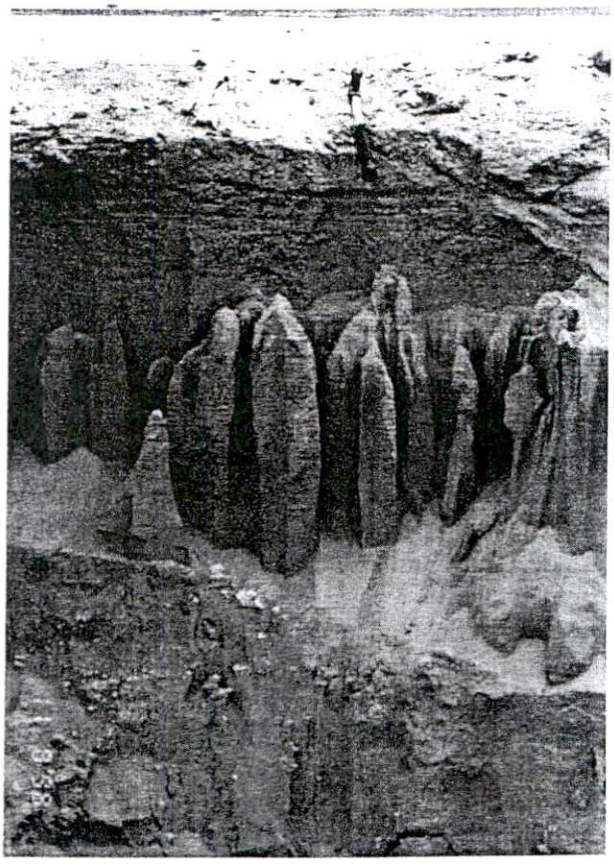

Figure 1 Sandy pyramids showing the signs of wind erosion.

of soil material through wind action, leaving behind false sandy pyramids (Figure 1). Deposition of soil particles occurs when the gravitational force is greater than the forces holding the particles in the air. This occurs when vegetation or a rough soil surface causes a decrease in wind speed, leaving the particles deposited as sand dunes.

Mechanism of soil particle movement

Wind erosion causes serious problems in Kuwait, where loose, dry, sandy soils, poor vegetation protection of the soil, and periods of strong winds prevail. In the wind erosion process, three different modes of transport can be distinguished: creep, saltation, and suspension (Bagnold, 1973). However, particles of a particular size may be moved by one or more modes, depending on differences in density and wind speed. The mechanisms of particle movement in the deserts of Kuwait have been evaluated as a function of particle size analyses of recently wind deposited sediments (Shahid et al., 1999, 2000). The mechanism is presented in Figure 2, and described below.

Surface creep: Particles (>500 μm) are usually set in motion by the impact of saltating particles. They are large and generally cannot be lifted up by the wind, and tend to roll or slide and creep along the surface. During the rolling process they lose their sharp edges and become rounded (Shahid et al., 1992). The roundness of the soil particles is a clear indicator that the soil material is subjected to severe wind erosion (aeolian movement).

Saltation: Particles (63–500 μm diameter) are rolled on the surface, a vacuum is created at the rear of the moving particles whereas in the front the air is co-pressed below the particles (Figure 2). The lifted particles follow distinct trajectories under the influence of air resistance and gravity. The bounce of these particles over the surface reaches maximum heights of about 1 m but the bulk of the saltation particles move just over the soil surface. On reaching the soil surface, they may rebound or become embedded when impacting the surface, or induce creep and suspension (the raising of fine particles). The saltation moves the main mass of wind blown particles (Chepil, 1945).

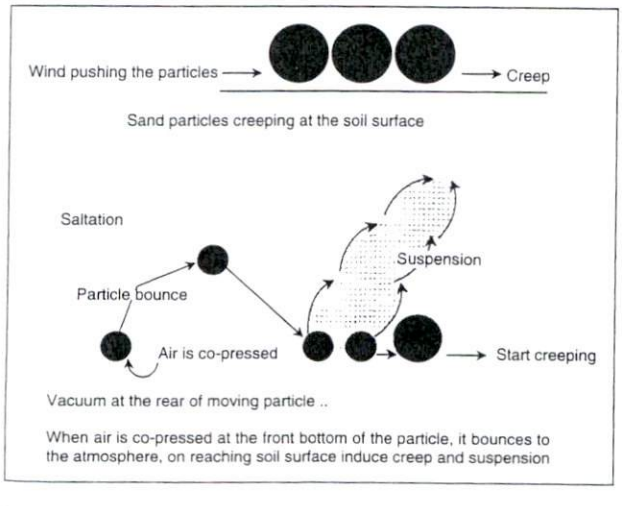

Figure 2 Mechanism of aeolian soil particles movement in deserts.

Suspension: Saltation particles on reaching the surface can dislodge the soil particles (<63 μm diameter) and lift them into the air. They remain in the atmosphere for a longer period, cause dust storms and reach the soil surface with rain and clog the soil surface to form a surface crust. In Kuwait the suspension movement of particles causes dust storms called "toze".

Shahid et al. (2000) evaluated aeolian soil movement mechanisms from a number of soil samples collected from recently wind born deposits. They analysed the samples for particle size distribution. They deduced from the data that soil particles range between 15.1–46.5% (>500 μm), 50.5–80.8% (500–63 μm) and 1.5–12.7% (<63 μm). This illustrates that the deserts of Kuwait are in the size range which is susceptible dominantly for saltation movement, and therefore, saltation moves the main mass of wind blown particles (Chepil, 1945). Fewer particles are moved by creep and the least by suspension.

Future strategies of wind erosion management in Kuwait

The very fragile natural land resource in Kuwait needs to be conserved to enhance environment quality. Practice, which maintains soil structure and conserves moisture, should be followed. The vegetation used to vegetate Kuwait should flourish on sandy soils, withstand the wind, and remain hardy in a harsh environment. The use of mulches is another option. These can be organic or inorganic, the main objective of adding mulch material being to conserve the soil moisture and protect the soil surface from erosion. The use of synthetic "hydrophilic polymers" is another option.

They effectively increase soil stabilization, decrease both wind and water erosion of soil, increase final infiltration rate and water holding capacity and also act as "Soil Conditioner" (Ben-Hur and Keren, 1997).

Water erosion

Water erosion in Kuwait is active only during the wet season (October to March), when intensive rainfall causes severe water erosion by runoff flow. Misak and Dousari (1997) reported water erosion to take place on the slopes of watersheds in Jal Az-Zour (+145 m),

Al-Ahmadi-Adan (+100 m) and Wadi Al-Batin (+265 m). Moreover, accelerated erosion prevails in grazing and camping areas e.g., Mesherif (Kuwait City), Ras Al-Sabiyah (northeastern portion of Kuwait Bay) and northwest Al-Jahra city. Runoff scouring and deposition are the most significant indicators.

Salinity

Salinity is common in the coastal areas. However, it is also a feature of some farming areas where brackish water offsets the water requirement of plants. The effects are evident in the farming areas in the north (Abdali) and south (Wafra) of Kuwait. Recently salinization was presented as an early warning of land degradation in Kuwait (Shahid et al., 1998). It occupies about 209,000 ha (Hamdallah, 1997) which is 11.7% of the area in Kuwait, mainly confined to Bubyan island and to the coastal areas.

In Kuwait, good quality water is limited and the seasonal water balance, i.e. the difference between rainfall and evaporation, is invariably negative, imposing severe stresses on the utilization of land resources in Kuwait, particularly for agriculture. The groundwater in Kuwait is mostly saline with some limited amounts of fresh and brackish water (Al-Sulaimi et al., 1996). The total dissolved solids (TDS) in the groundwater mainly range between 2000 and 5000 mg l^{-1}, and may be even higher in places. The concentration of TDS in the municipal waters is reported as 2500 mg l^{-1} (Akbar and Puskas, 1992). The utilization of these waters for irrigation purposes, when not properly managed, may intensify the salinity further, and hence degrade the land resources.

To manage the salinity problem, research needs to be undertaken to determine the best practices of soil reclamation and management, such as the best mix of plants and possibly subsurface drainage to achieve salinity control. The following are suggested as the prerequisites for research on salt-affected soils in Kuwait: 1) identification, mapping and characterization of salt-affected soils; 2) identification of causes and sources of salts and 3) solution measures.

Salinity control strategy

The strategy should aim at greatly reducing the future effects of salinity. The main emphasis should be on providing further encouragement, assistance and technical support to the scientists to identify the areas where most efforts should be directed. These areas once identified should be considered as "*hot spots*". To achieve success on apparent salinity, the following targets need to be met: 1) revegetation of saline lands with salt-tolerant species and; 2) installation of subsurface drainage and proper disposal of saline water, or blending of drainage and fresh water in suitable ratios prior to irrigating the crops, and conjunctive use of brackish and fresh water; 3) integrated land reclamation programs (including physical, chemical and biological methods).

Crusting/hardsetting and soil structure impairment

In Kuwait, off route trafficking, intensive camping, and raindrop impact have contributed to the compaction and structural problems, resulting in surface sealing and crusting. At least 65% of the degraded Kuwaiti lands are affected to different levels of compaction. Compaction hinders plant growth, infiltration rate and enhances erosion. Crusting and hardsetting (15–40 cm) significantly degrade the land in Kuwait. The impact is evident in severely degraded rangelands at Sulaibiya, Umm El-Eish and Meshrif. It has been observed that once the crusting/hardsetting is established, it promotes water runoff and erosion, reduces infiltration rates, and leads to loss of fertility, organic matter, etc.. Another form of crusting includes the hard black layer of hydrocarbons in the oil contaminated lands (tarmat), formed through oil spillage and subsequent drying.

Mining construction material

Local activities produce gravels for roads, landscaping and concrete from the Quaternary Dibdibba Formation (Kwarteng and Al-Ajmi, 1997). The Dibdibba occurs only in the northern deserts of Kuwait and consists of northeast-southwest, subparallel, elongated ridges parallel to Wadi Al-Batin (Khalaf et al., 1984). Mining operations introduce dust into the atmosphere, and create surface crusting when brought to the soil surface. The tailing from the gravel mines appears as northeast-southwest trending artificial sand dunes (Kwarteng and Al-Ajmi, 1997). Gravel quarrying and military activities affect some 30% of degraded lands.

Military activities

Over two million land and marine mines along the coast of Kuwait and its land borders were planted during the Iraqi invasion and occupation. These mines were laid at the rate of 92.4 mines/km^2 (Al-Ghunaim, 1999). These activities have tremendously disturbed the Kuwaiti lands. Although the landmines were cleared, peoples are still hesitant to utilize these areas. Part of Kuwaiti land forms a buffer zone between

Kuwait and Iraq, under United Nations control, and has restricted use. The National Park of Kuwait (330 km^2) was under severe military stresses during the Iraqi occupation.

Loss of vegetation and organic matter

Kuwait's terrestrial ecosystem is being subjected to various stresses e.g., low rainfall, high temperature, insufficient good quality water, salinity, oil pollution, natural and anthropic stresses on land, collectively reducing vegetation. The rangelands of Kuwait are in poor condition due to the Gulf war crisis and subsequent activities. Plant cover was destroyed due to mechanical activities and plant communities were altered and subjected to pollution due to oil spills and the explosion and ignition of over 700 oil wells (Omar and Zaman, 1995).

Loss of vegetation cover and particularly the soil organic matter present a formidable and unique research challenge. The natural vegetation cover in the Kuwait desert is almost completely denuded and overgrazed (Figure 3) except in those areas which have restricted access, such as military, petroleum and scientific sites. In these areas vegetative cover is still maintained (Khalaf and Al-Ajmi, 1993). Studies (Halwagy et al., 1982; Omar, 1990) have shown that vegetation within protected areas may attain a potential ground cover of about 25–50% under normal climatic conditions. However, under present grazing pressure and land use, vegetation ground cover outside protected areas rarely exceeds 5%. Furthermore, of the perennial species within the rangelands, the most common plants are "invader" species that are indicators of heavy grazing pressure (Omar, 1990). The strategy should be to maintain soil cover and soil organic matter levels, which in turn improves soil structure and aggregate stability. Controlled grazing is suggested to tackle this issue of great environmental concern.

Oil pollution

During the Iraqi invasion and occupation of Kuwait, the land resources were subjected to oil pollution (Al-Awadhi et al., 1996), when more than 732 oil wells and some oil refineries were set on fire to create one of the world's worst environmental disasters. At the Burgan oil field 365 oil wells were set ablaze (Kwarteng and Bader, 1993). Since then the surface of the oil fields and the surrounding productive soils have turned into pools of oil lakes (Figure 4a), tar mats (Figure 4b) and soot which eventually turned into black soil, and degraded it for further uses (Al-Awadhi et al., 1996; Shahid et al., 1999). The effect of tar mats on vegetation is also evident in Figure 4b. The tar mats varied in thickness from a few millimeters to about 2 centimeters. In some areas the tar mat is underlain by soil contaminated to varying levels of oil (Figure 5a, b). The crude oil spills accumulated in shallow depressions resulting in about 70 oil lakes. Recent estimates show the total area occupied by oil lakes to be 49.13 km^2, whereas the volume of oil has been estimated to be 22652.5 (M^3) × 1000

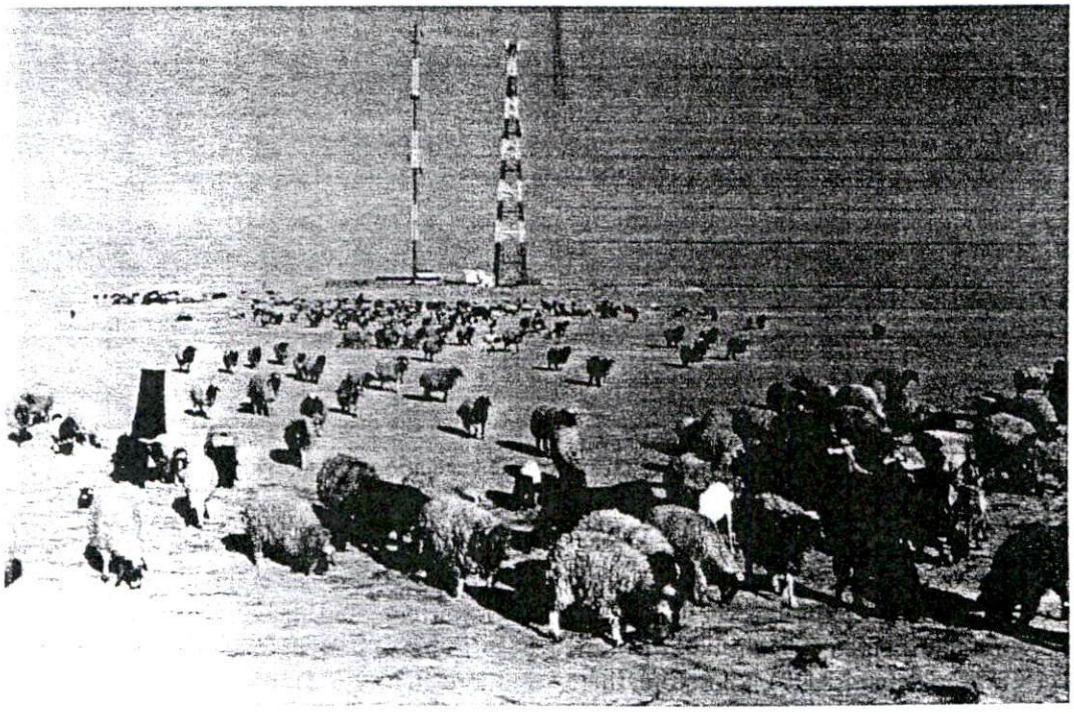

Figure 3 Denuded desert of Kuwait and grazing activity.

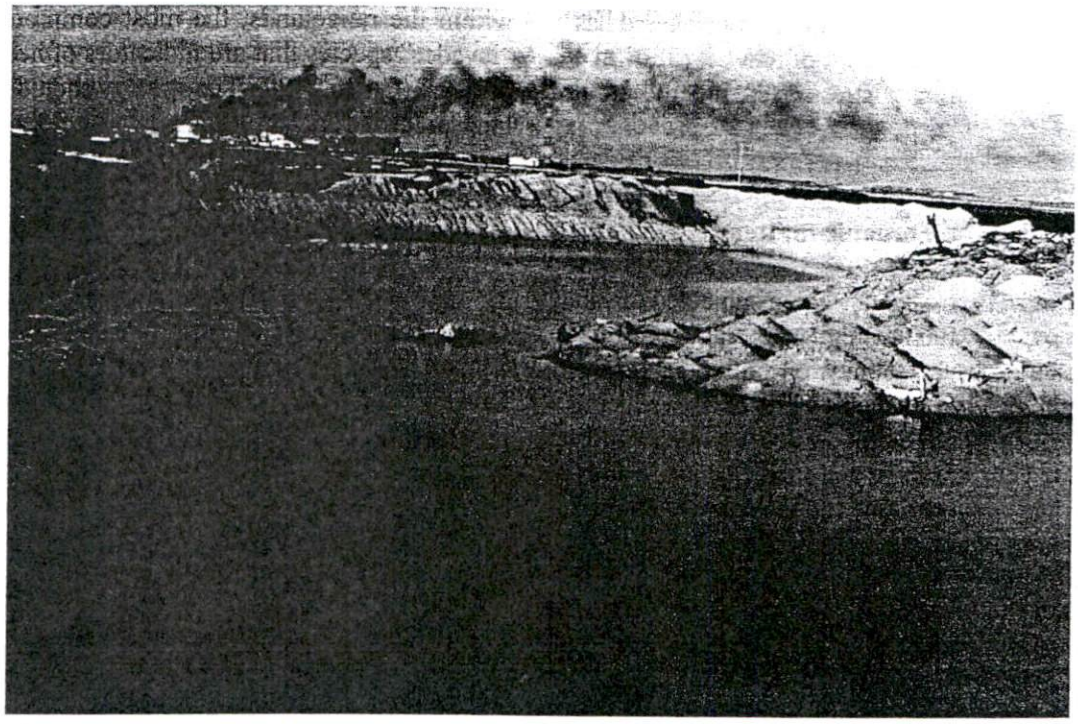

Figure 4a An oil lake in the Burgan oil field.

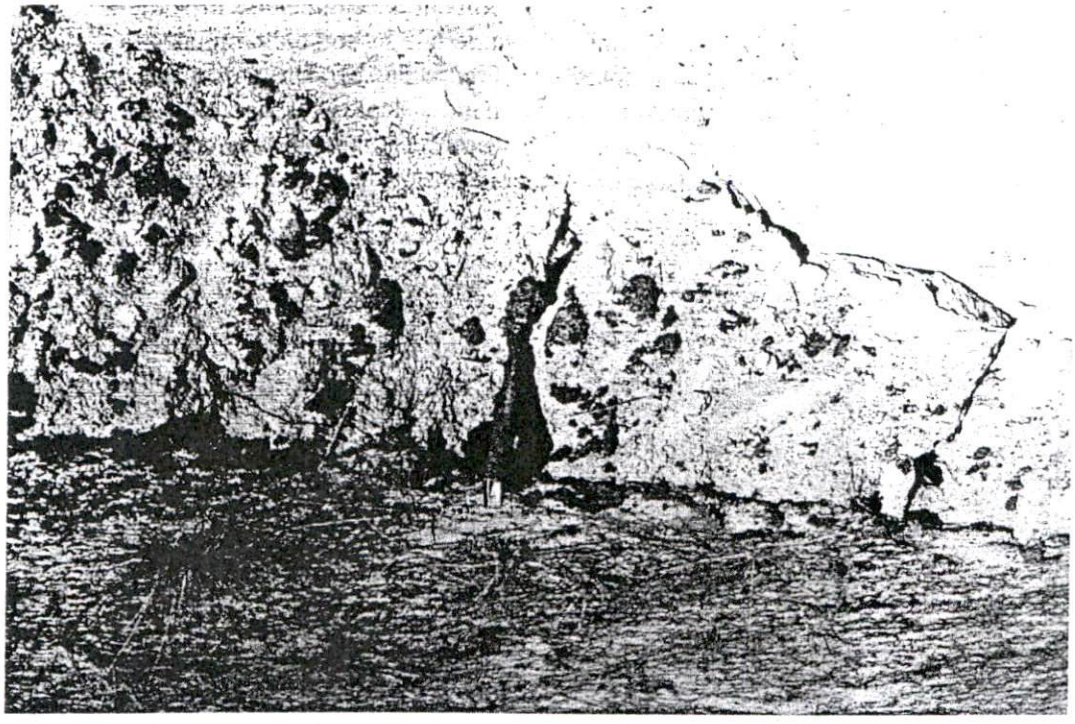

Figure 4b Tarmat overlying clean soil, the effect of tarmat on the vegetation is also evident.

(Salam, 1996). Approximately 96% of the oil from the lakes was recovered and exported. However the remaining 4% of unrecoverable oil is stuck to the bottom of the oil lake beds (Kwarteng et al., 1999). Therefore, there is a need to monitor continuously the oil lakes and polluted surfaces, as they are part of Kuwait's desert, and may pose several hazards to the environment (Kwarteng et al., 1999; Kwarteng, 1999).

The soil contaminated by soot is estimated to be more than 1722 km^2, representing 10% of the total land surface of Kuwait (Kwarteng, 1999). These areas are in the north and in the south of Kuwait. These

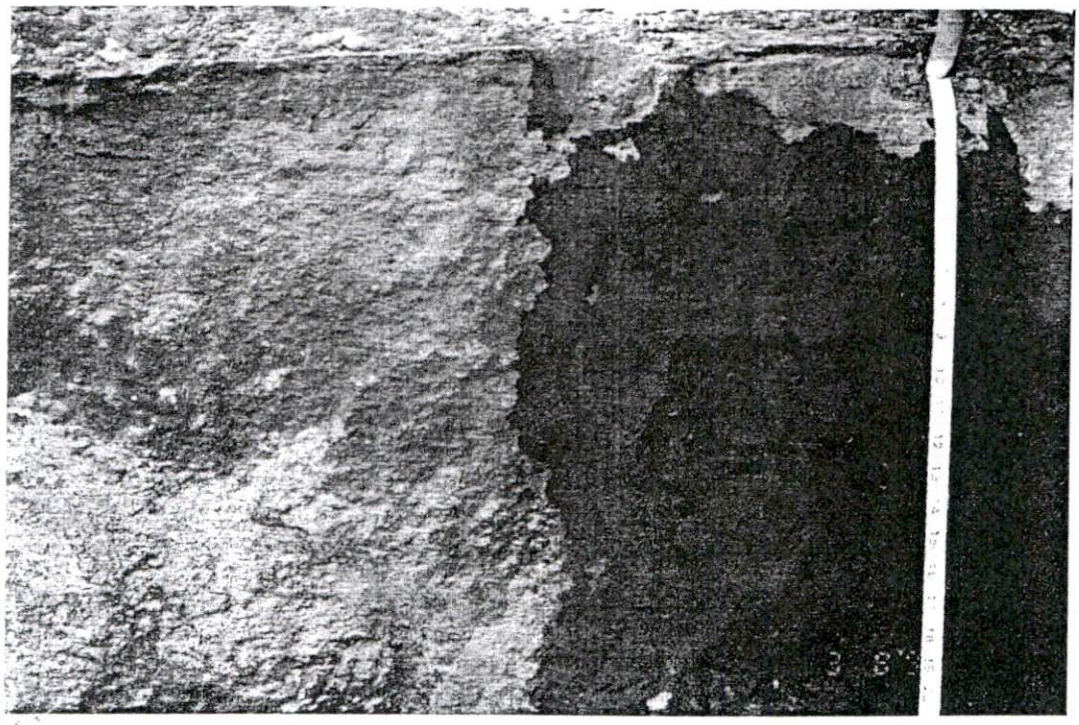

Figure 5a Surface tarmat and slightly oil contaminated subsoil.

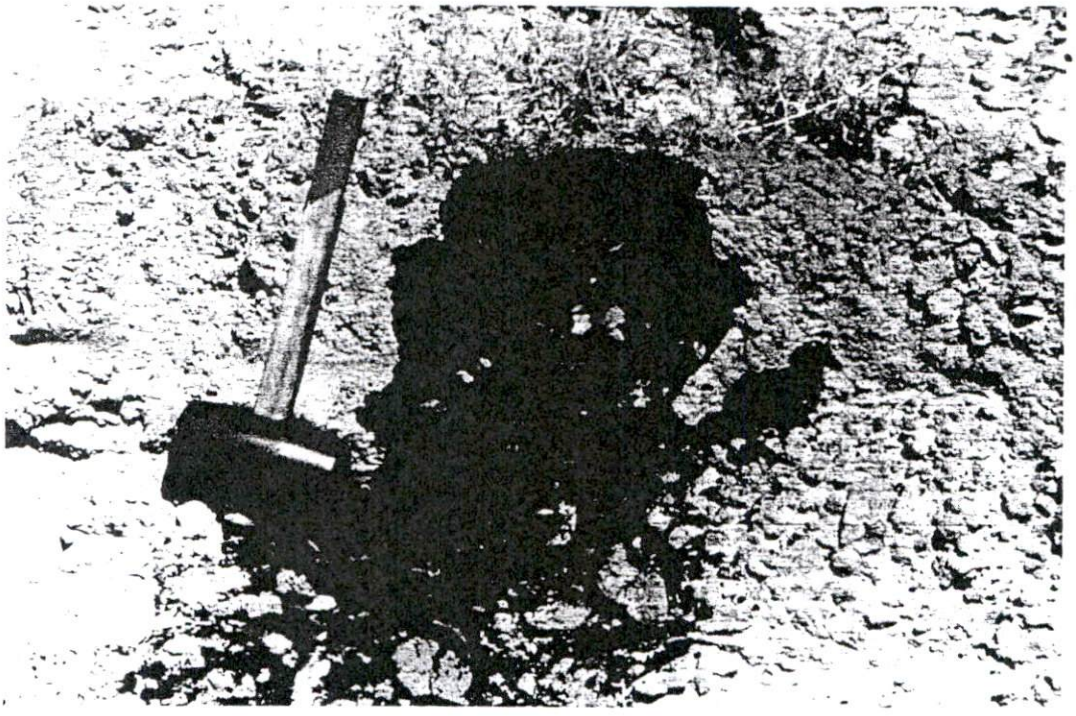

Figure 5b Strongly oil contaminated soil.

activities have greatly modified the chemical, physical and biological characteristics of Kuwait's land resources and the environment.

During the Iraqi invasion and occupation of Kuwait oil trenches were also established over a distance totaling 220 km. These trenches are 4–5 m wide and 2–3 m deep at the southern part of Kuwait, 10–15 km from the Saudi Arabian border. The trenches were filled with oil through pipelines from oil fields in Az-Zor, Al-Wafrah and Minagish. The amount of oil poured into the trenches is estimated as 3.5×10^6 barrels (Al-Ajmi et al., 1998). The amount of soil contaminated with oil in these trenches is estimated as $5.23 \times 10^6 m^3$. This activity damaged $2.21 \times 10^6 m^2$

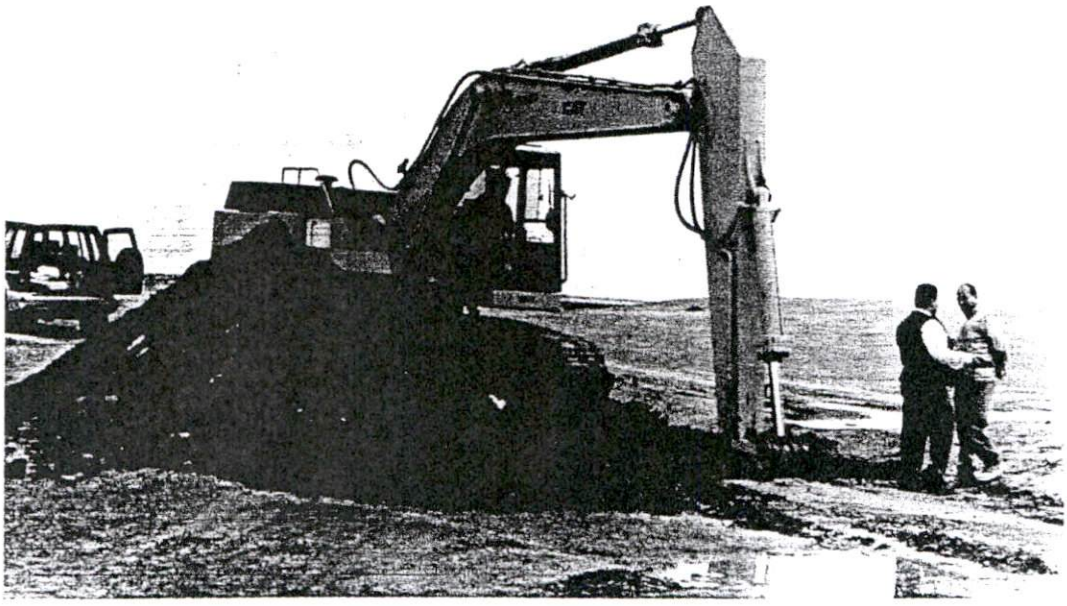

Figure 6a Excavation of an oil trench in the desert of Kuwait.

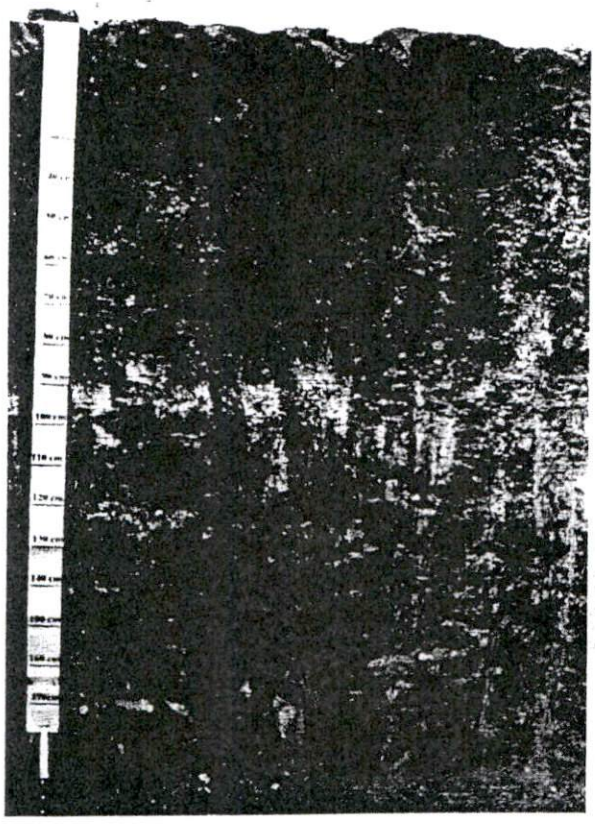

Figure 6b Face of the excavated oil trench showing different levels of oil contamination.

of the surface soil (Al-Ajmi et al., 1998). After nine years of Kuwait liberation, these trenches still exist (Figure 6a) and are causing contamination to the terrestrial environment (Figure 6b), needing a careful action of cleaning and rehabilitation. They lie between the Arabian Gulf, on the east, to Wadi Al-Batan on the west.

CONCLUSIONS AND RECOMMENDATIONS

Land resources of Kuwait are in a severe grip of stress from natural and human activities. This problem should be addressed as a priority. A Landcare strategy should be adopted. They need to involve the whole community caring for their land, government agencies, the farming community, and awareness in schools and among interested individuals. Working together to tackle such land degradation problems is sensible, especially when the cause may not necessarily be confined to one property. Grants and incentives should be made available to enhance awareness of the land degradation problem and to protect natural livelihood. In order to sustain the land resources of Kuwait this environmental trend must be counteracted with action as a matter of urgency. Therefore, the threat to lands must be accorded much greater significance on the environmental agenda, and an improved legal framework must be created for lands as an environmental asset.

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