# Sustainable Rehabilitation Measures for Degraded Lands in Kuwait

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## ABSTRACT

Located in the northeastern part of the Arabian Peninsula, Kuwait is experiencing hyper-arid environmental conditions in the desert. Due to inadequate arable land, a lack of water supplies and a high rate of land degradation, Kuwait has faced several challenges in the sustainable growth of the agricultural sector. The effective use of the available water and soil resources must therefore be stressed in a sustainable way in order to rehabilitate the degraded land using proper restoration techniques. Different vital control measures attributed for planning experiment in the rehabilitation of degraded playas in quarries refilled in the Liyah area depending on water harvesting, organic mulching (e.g., using date palms) methods such as semi-circular bunds, checker board palm leaves, square micro catchment, deep pit system, protection of the annual community, and plantation on sand accumulation body. This study concentrated on the concept of sustainable rehabilitation of the soil through using simple techniques that are environmentally sound, economically feasible, maintain water resources and improve the quality of the soil, which in turn increases the vegetation cover

**Keywords**
Control measures, Degraded lands, Rehabilitation, Kuwait

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## Introduction

The State of Kuwait occupies 17,818 square kilometers of which 85 percent is occupied by environmental territory in line with the World Desertification Atlas [1]. With an arid climate, Kuwait is classified as hyper-arid. Kuwait is characterized by an unusually hot , dry summer and cool winter with intermittent rain. Evaporation is very strong due to hot temperatures, ranging from 3 mm/d in summer to 16 mm/d in winter. Organic matter is less than 1% and is observed in a rough gypsum pan. The spatial and temporal vegetation changes in Kuwait were described by Al-Dousari et al. [2-4].
A protective cover or boundary between the atmosphere and the soil can be established by vegetation [5-8]. In the Kuwaiti desert, there are several plant species that can be classified as either perennial or annual. However, due to overgrazing and off-road transport, the native plants have been subjected to serious damages. For these factors, in the terrestrial environment of Kuwait, a high rate of land degradation prevails, leading to a rise in dust and mobile sand activity [9-14]. The land degradation in Kuwait is identified in the form of soil erosion (wind and water), loss of vegetation cover, surface sealing and crusting, soil salinization and soil compaction [15-19].

## Study Area

The research area is based in Liyah, northern Kuwait. Al-Liyah reserved area is considered as one of the most important areas for gravel extraction in the State of Kuwait.
The study area is an artificial playas, shaped after dumping gravel quarries as well as to degraded lands. These areas have been lost total vegetation cover and stockpile of seeds at the top. This causes reptiles and insects to become extinct
Methodology
The basic principles of site preparation techniques can be described as follows:

- Conservation of existing vegetation.
- Assessment of land degradation mechanism and magnitude.
- Identification of soil (treated and untreated soil) for physical and chemical characteristics by collecting soil sample at depth 0, 20, 40 and 60 cm. Bulk density (bd) was measured using standard core method and pore space calculating using standard formula (Porosity = 100 (1-bd/pd constant) (gcm-3). Gravimetric soil moisture and the compressive soil strength were determined [20-21] as well as using organic matter was measured using method of oxidation [22-23].
- Approximately 25-30 cm of soil surface cultivation.
- Using water harvesting techniques. [24]
- Planting drought resistant plants.

Different Sustainable Rehabilitation Measures Applied on Degraded Playas and Degraded Lands

*Semi-Circular Bunds*

This measure consisted of a number of large half-moon-shaped bunds with palm leaves and stones arranged on a degraded playa. In each bund, the soil was cultivated and native plants was planted (Fig. 1). Runoff water is collected within the bunds from the area above it and excess water is liberated around the tips and is intercepted by the second row and so on [25]. Bunds height is between 30-50 cm and the width between 1-5 m. These techniques used to maximize the usefulness of rainwater through reducing the evaporation of explosives and cashed out border of the field by stored within soil.

*Palm leaves checker board*

At the top of the hill, this technique brings into effect a set of square bunds arranged as a checker board pattern and the building of two permeable palm barriers. This system consists of a series of small square bunds made of from palm leaves and arranged as checker board design and two permeable palm barriers to reduce wind speed and to block the water flow and spread it on the adjacent plain and enhance infiltration. The wetted area is then used for crop production (Fig. 2).

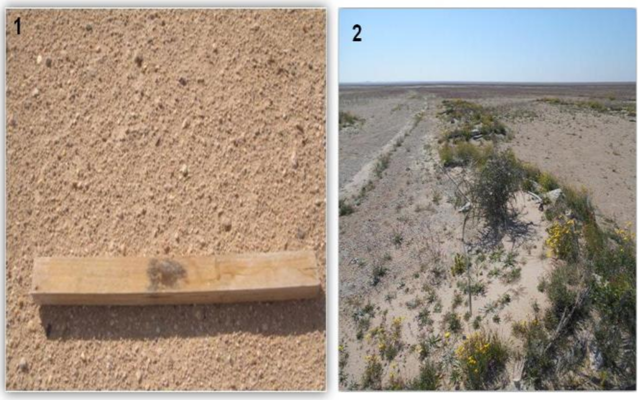


Fig. 1. *Soil before treatment (2) After five years of applying semi-circular micro-catchment with palm leaves.*


Fig. 2.. *Soil before treatment (2) After rehabilitation for two years*

*Square micro catchment*

It consists of a series of square runoff basins arranged along degraded playa. Each square bunds covered 25m$^2$ area and 30 cm height, native plant cultivated in each square and date palm leaves mulched the entire area of micro catchment (Fig. 3). Mulching sheet retain soil moisture and reduced evaporation, thus minimized need of watering. The palm mat acted as insulating blanket. It kept soil cooler in summer and warmer in winter


Fig. 3. *(1) Soil before treatment (2) After three years of rehabilitation.*

*Deep pit system*

For one meter or more, deep pits were drilled deeply to deeply depending on where the soil moisture was rich and high. These pits were filled with 3-4 liters of water. After 24 hours the top soil in the pit was ploughed to allow the penetration of oxygen. Manure was added and mixed with the fresh top soil. Healthy seedlings of *native plant* were cultivated inside the deep pits system (Fig. 4). These pits act as rain catchment areas and amplify soil moisture. The goal of creating deep pits was to allow the seedling to survive from soil moisture that existed in the depths. Majority of the native plants are drought resistant and respond well to limited irrigation.

Fig. 4. *Cultivation of Salvadora persica in pit system*.

*Protection of annual community*

A temporary dominant community type of annual shrub colonizes around > 10 cm thick on smooth sand sheet can play a major role in stabilizing and improving soil quality and creating better microenvironments for growing perennial native plants such as conglomerates of Rhanterium epapposum, Haloxyon salicornicum and Cyperus. For example , the group of Cornulaca is one of the most abundant and dominant shrubs in the rehabilitated area of Liyah. It has the potential to grow around artificial lakes, playas, disturbed land, everywhere. Cornulaca spp is a native plant equipped with a range of physical and behavioral processes to thrive in an arid system. It has the ability to trap mobile aeolian sediments and stabilize soil through forming nabkha. (Fig. 5).

Fig. 5. *Protection of temporary annual community*

*Plantation on sand accumulation body*

The accumulation of sand near the fence for protection issues played a major role to achieve environmental balance. The body of sand acted as shield that protects the plant from sand blowing, provides stocks of rain water and stockpile of seeds. All these factors create a suitable microenvironment for plantation of native plant along the bottom of sand body (Fig. 6).


Fig. 6. *(1) Soil before treatment (2) After plantation.*

Results and Discussion

In semi circular bund the average infiltration capacity of the soil increased from 107.2 $cm^3$/min to 193.5 cm $cm^3$/min. There was 71% average difference in volume of infiltrated water. After ploughing the soil, water infiltrates more rapidly and replacing the air in the pores. Table 1 shows the changes in the soil characteristics before treatment and after treatment.

Table 1**.** Average soil characteristics before treatment

| **Depth (cm)** | **Penetration Force (psi)** | **pH** | **EC (mS/cm)** | **Soil Moisture (%)** | **Bulk Density (%)** | **Porosity (%)** |
|---|---|---|---|---|---|---|
| **Before treatment** | | | | | | |
| 0 | 273 | 7.7 | 2.4 | 1.3 | 2.7 | 0 |
| 20 | - | 7.7 | 3.1 | 1.3 | - | - |
| 40 | - | 7.7 | 3.1 | 1.8 | - | - |
| 60 | - | 7.7 | 3.2 | 1.9 | - | - |
| **After treatment** | | | | | | |
| 0 | 190 | 7.6 | 2 | 2.3 | 2 | 24.5 |
| 20 | - | 7.6 | 2.3 | 2.8 | - | - |
| 40 | - | 7.6 | 2.7 | 3.7 | - | - |
| 60 | - | 7.6 | 2.8 | 3.7 | - | - |

The main results were reached after the application of square micro catchments for one year duration. The average infiltration capacity has increased by 74.418 $cm^3$/min in control soil to 111.8625 $cm^3$/min in the treated soil. The average differences in volume of infiltrated water was 33.5%. Mulching sheet retained soil moisture and reduced evaporation, thus minimizing the need of watering. A new layer of soil with an average height 26.2 cm was trapped above the mulched palm leaves with in an area 2500m$^2$. The volume of new trapped layer of soil was 109.2 m$^3$. The trapped sand accumulated above mulching materials rich in essential elements and organic materials and consider as seed banks played role in the growth and activation of new plant species. (Table 2and 3)

Table 2. The variation in the percentage of soil characteristics results with depth in the treated and untreated areas

| Sample | Depth (cm) | Moisture content % | Organic Carbon % | Organic matter % | pH | EC (µs/cm) |
|---|---|---|---|---|---|---|
| UT-1 | 0 | 1.00 | 0.32 | 0.56 | 7.14 | 4040 |
| UT-2 | 20 | 4.12 | 0.95 | 1.64 | 7.4 | 5560 |
| UT-3 | 40 | 2.59 | 0.98 | 1.69 | 7.51 | 5430 |
| UT-4 | 60 | 3.17 | 1.13 | 1.95 | 7.5 | 5120 |
| T-1 | 0 | 0.64 | 0.36 | 0.62 | 7.48 | 4643 |
| T-2 | 20 | 2.34 | 0.96 | 1.66 | 7.4 | 2116 |
| T-3 | 40 | 6.32 | 1.27 | 2.19 | 7.49 | 3010 |
| T-4 | 60 | 5.78 | 1.34 | 2.30 | 7.57 | 3300 |

Table 3. The temperature of untreated and treated soil

| **Sample** | **Temperature ($^0$C)** | | | |
|---|---|---|---|---|
| | **0 cm** | **20 cm** | **40 cm** | **60 cm** |
| UT-1 | 38 | 38.3 | 37 | 37 |
| UT-2 | 40 | 40 | 39 | 38.5 |
| UT-3 | 39.5 | 39 | 39 | 39 |
| UT-4 | 39 | 39 | 39 | 39 |
| T-1 | 36 | 35.5 | 35.5 | 35 |
| T-2 | 36 | 36 | 35.5 | 35.5 |
| T-3 | 37.5 | 37 | 36 | 35 |
| T-4 | 36.5 | 36.5 | 36 | 36 |

The technology of pit system aims to cultivate desert flora without relying on irrigation methods known, this technique relies on the plant to take advantage of ground soil moisture where there is an available water capacity stored in soil and can be available for growing of plant. Seedling can irrigate them self from soil moisture that exist in the depths. Most native plants are drought resistant respond well to limited irrigation. Examples of native resistant plants are *Ziziphus spina-christi* , *Lycium shawii* , *Salvadora persica*, *Haloxylon salicoricum* and *Nitraria retusa*. little irrigation may be more desirable than continuous irrigation as many desert species are very sensitive to overwatering. (Table 4)
13).

Table 4. The variation of canopy width for Salvadora seelings cultivated in pit and without pit system

| **Salvadora seedling** | | | **Salvadora seedling** | | |
|---|---|---|---|---|---|
| **No** | **6** | **10** | **No** | **6** | **10** |
| 1 | 13 | 40 | 1 | 54 | 63 |
| 2 | 16 | 35 | 2 | 28 | 70 |
| 3 | 43 | 40 | 3 | 53 | 63 |
| 4 | 13 | 40 | 4 | 21 | 50 |
| 5 | 35 | 20 | 5 | 50 | 70 |
| 6 | 37 | 38 | 6 | 49 | 40 |
| 7 | 40 | 55 | 7 | 36 | 40 |
| 8 | 20 | 43 | 8 | 17 | 50 |
| 9 | 57 | 72 | 9 | 10 | 30 |
| 10 | 45 | 52 | 10 | 24 | 50 |
| **Aver** | **31.90** | **43.50** | **Aver** | **34.20** | **52.60** |

Annual community has potential for managing the environment as natural types used in desert areas to restore degraded lands. Plantation on sand accumulation body created a suitable microenvironment for plantation of native plant along the bottom of sand body

## Conclusion

The rehabilitation and restoration of the desert environmental regions is necessary for preserving the existing biodiversity and enhancing the productivity of the soil. The studied rehabilitation methods are economical and can be easily implemented. Several attempts have been made to find sustainable methods of rehabilitation to increase the conservation of soil moisture and preserve desert land productivity. Geological characteristics and socio-economic effects, the analysis of playa is significant, acting as a catchment area close to the groundwater level and suitable for agriculture. In this respect, for the restoration of a deteriorated playa site, different control measures were applied. The key problems for rehabilitation are the following: compacted soil surface plowing is important to achieve better surface soil properties that ultimately lead to improved soil infiltration and moisture conservation; mulching improved soil water and nutrient retention capability, reduced soil erosion, and optimum plant growth temperature created; flourishing of new native and droughts. The maintenance of the site is required regularly for any damages, after wind or rain storm.

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