Rehabilitation Soils with Date Palm Mulching Treatments

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Abstract: Kuwait is located in hyper arid desert environment. This geographical location and irrational human activities accelerate the expansion of land degradation problem. In order to rehabilitate the degraded areas it is necessary to use soil and water resources in sustainable manner. Owing to these reasons it is essential to use appropriate methods based on the scientific diagnostics of the problem. It is compulsory to identify, specify and test different efficient, cost-effective and environment friendly sound sustainable sand control measures such as, semi-circular bunds, square micro catchment and checker board palm leaves to rehabilitate degraded lands in Liyah refilled quarries. To evaluate the impact of rehabilitation method through mulching with date palm leaves soil samples were collected (control and rehabilitation sites with square micro catchment) prior to the implementation plan and post completion of the project (three years). In this study will be highlighted on detail the results of using square micro catchment and with short brief descriptions on other water harvesting techniques. The results showed an improvement of physical soil properties after the application of these techniques. Soil fertility increased through increasing the quantity of fine and very fine sand. The soil moisture at the surface soil increased from 0.085% to 1.62% after the treatment. The untreated soil has high bulk density about 2 g/cm^3 and low porosity about 27%. However, after the soil was ploughed and mulched the bulk density decreased to 0.03 g/cm^3. And porosity improved 98%. This study conserved the irrigation water through reducing the proportion of soil evaporation, in addition to the creation of optimum condition for plant growth. The aim of this study was to analyze the effect of using organic mulch date palm leaves with water harvesting techniques on the physical and biological properties of degraded soil in Liyah area.

Key words: Control measures, degraded lands, rehabilitation, mulching.

1. Introduction

Restoration of desert ecosystem is difficult but possible to re-establish desert ecosystem to become productive system. Ecological restoration means the activity that accelerates and assists the recovery of an ecosystem. The Society for Ecological Restoration (SER) defines ecological restoration as “the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed” [1]. The desert ecosystem in Kuwait is fragile and suffers from natural and anthropogenic factors including drought, scarcity of rainfall, poor soil, high wind speed and miss land use and human pressure. These factors accelerate soil erosion that makes possible serious environmental economic problem to occur.

Liyah area located in the northern part of Kuwait. It is about 199.89 km^2. The area is rich with aeolian and gravel deposits where it is place of gravel extraction activities in early sixties of the last century [2]. Environmental Public Authority (EPA) took initiative to address the eland degradation due to quarrying by forming a national committee for the rehabilitation of quarry site (Decision No. 441.1997). The committee succeeds in developing a proposal showing the stages required to rehabilitate the gravel quarries. The council of Ministers General Secretariat accepted EPA committee’s recommendation in October 1997 and issued Decision No. 973/1997 with a decree to organize quarrying activities and protect the natural resources of Kuwait. Another decision from the council of ministers was issued in August 2001 to refill quarries sites and level the surface irregularities in order to rehabilitate the natural vegetation and wildlife to its original shape. The restoration process is tremendously leisurely in the refilled areas in Liyah.
This positive process enlarges the usability of the degraded land for growing more plants and developing greenery in Kuwait as well as improving the biodiversity within the desert environment.

Date palm tree is *Phonix dactylifera* which belongs to the palm family. It is a flowering plant species large, compound, green and made up of several leaves arranged at the top of unbranched stem. It is one of the most economically important plants to humans throughout history. Many common products, edible sweet fruit and foods are derived from palms. The species is widely cultivated, available and is naturalized in many habitats from rainforest to desert.

Each date palm produces 20-30 leaves (fronds) per year. The leaves are 4-6 m long, with spines on the petiole, and pinnate, with about 150 leaflets; the leaflets are 30 cm long and 2 cm wide. One palm tree produces an average of about 50-100 kg/year depending on the age and size of the tree. This statistics shows the vast amount of palm leaves produced every year especially on the gulf country and Arabic states [3]. This huge amount if not used will cause many health and environmental problem for both human and environments. There are a lot of dead fronds lying around out of garden that ended in the bin. It is necessary to take advantage of the recycling residue in the production of what is useful and profitable (Fig. 1). The aim of this study was to analyze the effect of using ecofriendly organic mulch of date palm leaves on the physical and biological properties of degraded soil in Liyah area.

2. Materials and Methods

2.1 Study Area

The study area located in Liyah is rich with gravel. The area of pilot site for square micro catchment was playa with an area of 2,500 m². The other pilot sites were scattered in many locations for example, playas, wadis and uphill. The soils of such areas were sandy soil rich with calcium carbonate, gypsum and gravel. There are a number of indicators of land degradation such as soil compaction, disappearance wild flora and fauna (Fig. 2).

2.2 Main Steps to Rehabilitate Degraded Soil

The main steps taken to rehabilitate degraded soil are as follows:
Fig. 2  The soil of pilot area.

(1) Assessment of the mechanism and magnitude of land degradation;

(2) Identification of physical and chemical characteristics of the soil by collecting soil samples before and after treatment at three depths (0-20, 20-40 and 40-60 cm);

(3) Surface cultivation of soil about 25-30 cm for enhancing storage of precipitation, aeration of soil and rapid and deeper development of the roots, and increasing the water retention capacity;

(4) Applying water harvesting techniques to store more water such as semi-circular bunds, square micro-catchment and checker board system (Fig. 3);

(5) Plantation of drought resistant native plants inside each bund such as *Lycium shawii*, *Calligonum comosum*, *Haloxylon salicornicum*;

(6) Mulching over the surface of degraded soil with date palm leaves.

Site information is determined through field examination, soil sampling and their analysis in the laboratory. A total of 25 soil samples were collected at three depths (0-20, 20-40 and 40-60 cm). Site investigation included determination of soil moisture using gravimetric method [4], bulk density using standard core method and porosity (%) [5]. Laboratory analysis included the grain size distribution of all soil samples using sieves with diameter openings ranging between 2-0.063 mm. The volumetric properties of the granules of sand and extract were calculated by the graphical method [6]. The organic matter was measured using oxidation method by Walkley and Black [4].

2.3 Examples of Different Applications Used for the Rehabilitation of Degraded Soil in Al-Liyah Area

2.3.1 Semi-circular Micro Catchment

Its rain water harvesting techniques consist of a number of half-moon designed bunds arranged on the area as rows. 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 [7]. Bunds height is between 30-50 cm and the width between 1-5 m. This technique is used to maximize the usefulness of rainwater through reducing the evaporation of explosives and cashed out border of the field by stored within soil.
2.3.1.1 Study Area

The area of interest is an artificial degraded playa around 100 m² (Fig. 4). This playa formed after dumping gravel quarries in Kuwait in December 2003. Playa is a depression in which rainwater collects. The soil is rich in sand (84.5%) and gravel (15%) with a lower amount of mud (0.5%). The study area has been degraded and lost total vegetation cover, and gradually reptiles and insects have been extinct. The area is almost flat interrupted with group of hills, dry valleys.

2.3.1.2 Methodology

The major steps involved in designing the water harvesting system called semicircular micro catchments are: before and after applying harvesting system, the density and type of flora and fauna that existed and morphologic characteristics of planted plant, physical and chemical parameters for treated and untreated soil must be identified; construction of 10 semicircular runoff basins in each row; surface plowing of the compacted soil from 15 cm to 25 cm depths to increase soil porosity and infiltration, and to reduce external runoff; covering the bund surface with date palm leaves; plantation of native plant inside each bund (Fig. 5); improvement of soil after rehabilitation process (Fig. 6).

2.3.2 Checker Board System

It is rain water harvesting technology implemented at the top of the hill used to protect down crop area from flood and wind erosion. This system consists of a series of small square bunds made from palm leaves and arranged as checker board design as well as two permeable palm barriers were constructed to reduce wind speed and to block the water flow to spread it on the adjacent plain and enhance infiltration rate.

2.3.2.1 Study Area

It is located at the top of hills. The area is almost flat (400 m²) and has hard compacted sandy soil (Fig. 7).

2.3.2.2 Methodology

Before applying harvesting system, the mechanism and magnitude of land degradation at pilot site
measured; arrange rows of palm leaves as checkerboard design to mulch the soil surface; construct first defense palm wall with 50 cm high and 20 m wide; construct second defense palm wall with 1 m high and 20 m wide (Fig. 8). After treatment, there was improvement in soil and vegetation cover (Fig. 9).

Fig. 4  The degraded pilot area before applying semicircular micro catchment.

Fig. 5  Preparation of semicircular micro catchment mulched with palm leaves (2011).
(A) Construction of semicircular bunds and plowing of the compacted soil; (B) mulched the bunds with palm leaves and stones; (C) & (D) plantation of drought resistance native plants inside each bund [8].
Fig. 6  After five years of applying semicircular micro catchment.

Fig. 7  The degraded pilot area before applying checker board system.
2.3.3 Square Micro Catchment

This water harvesting system consists of series square large bunds within area 25 m² constructed along the study area. These square bunds covered completely with organic mulch to trap blowing slit, seed and micro flora and to increase soil moisture.

2.3.3.1 Study Area

The concerned area is an artificial playa (2,500 m²)
formed after dumping gravel quarries (Fig. 10). The soil is hard, compacted sandy rich with carbonate calcium and gypsum.

2.3.3.2 Methodology

Before and after applying harvesting system, the biological, physical and chemical parameters must be measured; surface plowing of the compacted soil from 15 cm to 25 cm deep; construction of square bunds with an area of 5 m × 5 m and the height between 30 cm and 50 cm; construction of 10 square runoff basins in each row; covering the soil’s surface completely with date palm leaves (Fig. 11). It must be applied properly to give landscape decorative finish; plantation of drought-resistant shrubs inside each bund such as *Lycium shawii* (Fig. 12).

3. Results and Discussion

It was noticed that all the pervious eco-friendly applications had significant improvement in the physical and chemical characteristics of the soil structure. The most successful application for the rehabilitation of degraded soil according to the result studied was the use of square micro catchment that completely covered with palm leaves from March 2013 to March 2016.

The area of pilot site was 2,500 m² (Fig. 10). Dead palm leaves used as main mulch materials covered the upper layer of soil. There were a number of physical improvements after three years of treated soil. For example, the soil moisture at the surface soil increased from 0.085% to 1.62% after the treatment. Palm leaves preserved the soil moisture by reducing the water loss through evaporation. The percentage of soil moisture of treated soil increased with depth. For instance, at depth 40 cm for treated soil the moisture was 2.3% while untreated soil was 1.4% (Table 1).

The compaction of the soil and the presence of calcium carbonate and gypsum, operates as a carnivorous for pore in the soil. It was noticed that the untreated soil has high bulk density about 2 g/cm³ and low porosity about 27%. However, after the soil was ploughed and mulched the bulk density decreased to

Fig. 10 Degraded study area before rehabilitation.
0.03 g/cm$^3$, as well porosity was improved to 98% (Table 2). Organic mulch acts as an insulator that maintains a uniform soil temperature during the year. The treated soil was cooler than untreated soil with depth (Table 3).

The construction of short bunds about 20 cm high trapped more sand and dust to deposit over mulched soil by the wind action (Fig. 13). Therefore, new layer of soil was formed with a thickness about 15 cm. This layer was rich with fine sand, very fine sand and mud particles; as well it has stronger ability to absorb organic carbon since it has large surface area that maintains organic matter accordingly the soil fertility increases [10]. The average percentage of grain size distribution for untreated soil was 41% very coarse sand, 8% fine sand, 1.4% very fine sand and 0% mud while the treated soil was 17.2% very coarse sand, 20% fine sand, 13% very fine sand and 1% mud (Table 4).
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Table 1  In-depth percent variation of soil characteristics for untreated and treated soil.

| Soil section (cm) | Soil moisture (%) | Organic (%) |
|-------------------|-------------------|-------------|
|                   | Untreated | Treated | Untreated | Treated |
| 0                 | 0         | 0.55    | 1.12      | 0.57    |
| 20                | 7.03      | 1.63    | 1.11      | 2.32    |
| 40                | 3.59      | 1.68    | 1.48      | 2.5     |
| 60                | 3.59      | 1.95    | 2.29      | 3.6     |

Table 2  The variation in soil characteristics for untreated and treated soil.

| Soil sample | Bulk density (g/cm³) | Porosity (%) | Soil moisture (%) |
|-------------|----------------------|--------------|------------------|
|             | Untreated | Treated | Untreated | Treated | Untreated | Treated |
| 1           | 1.97      | 0.03    | 26.9      | 98.8    | 0.08      | 1.82    |
| 2           | 1.8       | 0.04    | 29.4      | 98.6    | 0.02      | 2.23    |
| 3           | 2         | 0.01    | 22.6      | 99.4    | 0.15      | 0.79    |
| Average     | 1.9       | 0.02    | 26.3      | 99      | 0.085     | 1.161   |

Table 3  Soil temperature of untreated and treated soil at depths of 0, 20, 40 and 60 cm.

| Sample | Temperature (°C) |
|--------|------------------|
|        | Surface | 20 cm | 40 cm | 60 cm |
| U-1    | 35      | 35    | 34    | 34    |
| U-2    | 35      | 35    | 34    | 33.5  |
| U-3    | 35      | 35    | 35    | 34.5  |
| T-4    | 34      | 33.5  | 33.5  | 33.5  |
| T-5    | 33.5    | 33    | 33    | 33    |
| T-6    | 34      | 33.5  | 33.5  | 33.5  |

U: untreated soil; T: treatment soil.

Fig. 13  New soil accumulates above mulched soil.
Table 4  Grain size distribution for untreated and treated soil.

| Sample          | Very coarse sand (%) | Coarse sand (%) | Medium sand (%) | Fine sand (%) | Very fine sand (%) | Mud (%) |
|-----------------|----------------------|-----------------|-----------------|---------------|--------------------|---------|
| Untreated soil  | 37.2                 | 15.8            | 38.4            | 7.3           | 1.3                | 0       |
|                 | 40.2                 | 14.1            | 31.7            | 12.3          | 1.8                | 0       |
|                 | 44.9                 | 19.8            | 29.6            | 4.5           | 1.3                | 0       |
| Average of      | 40.7                 | 16.5            | 33.2            | 8.0           | 1.4                | 0       |
| untreated soil  |                      |                 |                 |               |                    |         |
| Treated soil    | 9                    | 42.5            | 20              | 18            | 10                 | 0.5     |
|                 | 2.8                  | 22.3            | 32              | 27.5          | 14.8               | 0.8     |
|                 | 40                   | 13              | 14.8            | 16.3          | 14.3               | 1.8     |
| Average of      | 17.2                 | 25.9            | 22.2            | 20.6          | 13.0               | 1.0     |
| treated soil    |                      |                 |                 |               |                    |         |

Fig. 14  The growth of *Lycium shawii*.

(A) at cultivation the seedling length was between 30-40 cm; (B) after three years, the length of plants became more than 1 m.

Table 5  Average physical measurement for *Lycium shawii*.

| Treatment       | Length of main stem (cm) | Width of canopy (cm) |
|-----------------|--------------------------|----------------------|
| At beginning    | 30-40                    | 5-8                  |
| After three years| 135-165                  | 170-230              |

Table 6  The percentage of mineral content (based on dry matter) of date palm leaves [3].

| Mineral content of date palm |          |
|-----------------------------|----------|
| Humidity (%)                | 15.9%    |
| Nitrogen (%)                | 0.7725%  |
| Organic matter (%)          | 92.99%   |
| Organic carbon (%)          | 53.94%   |
| Ash (%)                     | 7.01%    |
| C:N (%)                     | 1:69.8%  |
| Total phosphorus (%)        | 0.3655%  |
| Total potassium (%)         | 0.2190%  |
| Iron (mg/kg)                | 685.6    |
| Manganese (mg/kg)           | 77.1     |
| Copper (mg/kg)              | 10.1     |
| Zinc (mg/kg)                | 12.7     |
The application of such technique improved the growth of cultivated native plant and vegetation cover. It was noticed that the length of the seedlings *Lycuim shawii* (drought resistant plant) at the beginning of cultivation was 30-40 cm after three years and becomes more than 1 m with better health and vigor (Table 5). Moreover, the density of vegetation cover for 600 plant species in area 25 m$^2$ was 24 plants species/m$^2$. Examples of plant species come into sight of treated soil were *Fagonia indica*, *Fagonia bruiguieri*, *Stipagrostis plumose*, *Plantago coronípus*, *Plantago ciliate*, *Plantago boissieri*, *Rumex vesicarius*, *Savignya praviflor*, *Launae mucronata*, *Picris babylonica* and *Diplotaxis harra* (Fig. 14).

During decomposition, leaves of date palm were used as organic mulched materials by microorganism. These microorganisms secrete a sticky substance that plays an important role in soil granulation and stabilization. The palm adds organic matter and nutrient mainly, N, P, K and little amount of Mn, Zn and Fe to the soil (Table 6). These nutrients serve as food to worms and beetles which turn raw matter into humus. Moreover, the wild animal such as ants, lizards and uromastyx (Fig. 15), used the mulched material as shelter to protect themselves from hot temperature in the desert as well as utilize uncompacted soil to build easily their houses. It was noticed that there are 44 burrows for uromastyx, 11 burrows for lizards and 11 houses for ants. So, these tiny animals added their manure into the soil as well they aerated soil through consistent digging. The percentage of organic content at depth 60 cm in treated soil was 3.6% more than the untreated soil which was 2% (Table 1).

4. Conclusions

Using organic mulching with water harvesting techniques has gained importance which was used in the present rehabilitation program. The quality of the soil properties was positively improved after using such program in many approaches as follows: the soil moisture increased with depth; the formation of new layer of soil that is rich with fine, very fine sand and mud; the porosity of soil improved allowing more
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water to penetrate into soil pore; the content of organic matter increased; the stabilization of soil through useful microorganisms; the density of vegetative cover increased; the health and growth rate of cultivated native plant improved; favorable soil microbial activity and worms activated into the treated soil.

This study will open new horizons to work through the recycling plant waste. The rehabilitation of degraded soil in arid lands and changed to productive green lands is not possible. The application of eco-friendly techniques can be used a lot in projects concerned with the rehabilitation of the desert.

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