沙漠研究 **24**-1, 257-260 (2014)
Journal of Arid Land Studies

Application of Water Harvesting System for Rehabilitation of Degraded Land in Liyah in Northern Kuwait

Modi M. AHMED*[1) and Ali M. AL-DOUSARI[1)]

Abstract: The main problem facing sustainable development in Kuwait is the acute shortage of water resources. Rainfall in Kuwait is scarce and irregular with an annual average of about 110 mm. In order to combat rapid desertification, water-harvesting techniques must be used. Rehabilitation of selected degraded playas in the Liyah area at northern Kuwait was accomplished using water harvesting systems which involves the collection and storage of rainwater for productive use. Semicircular bund micro-catchments were developed and were covered with palm leaves and stones. The soil was ploughed and mulched by plant residues before planting. Inside each bund, native plants *Lycium shawii* were planted. Physical and chemical measurements were carried out before and after rehabilitation. The infiltration rates were measured for a water column of 19 cm before treatment taken more than 30 min, while after treatment it takes only 15 to 20 min. The average soil moisture before treatment was 1.5% but increased to 3.5% after treatment. The dominant bulk density of the soil was 2.7% but three months after treatment it was reduced to 2%. The penetration force before treatment was 273 psi, but after treatment it was reduced to 190 psi. The general improvement of soil quality (soil fertility, water content, porosity, content of organic matter) after using rehabilitation methods positively affected the growth of the planted thorny plant. In addition, the trapped sand accumulated on the bunds play a major role in flourishing the desert flora due to richness of mineral and organic content.

Key Words: Micro-catchment, Playa, Semicircular bund

1. Introduction

The largest environmental issues for the 21st century are land degradation (Goudie *et al*., 1999). It is necessary to study the degraded lands and implement practical solutions to control the degradation. In Kuwait, sand encroachment over developed facilities is a serious economic and social problem (Al-Awadhi *et al*., 2005). Human activities and irrational exploitation of natural vegetation directly deteriorate the vegetation cover and accelerate expansion of degraded lands.

Inadequate water supply is a major problem faced by irrigated agriculture in many arid and semi-arid regions of the world. Rainfall in Kuwait is scarce and irregular; the annual rainfall in Kuwait ranges from 70 to 110 mm (**Fig. 1**). The rainfall season is mainly from October to March. When runoff is generated during heavy rainfall, the degraded and compacted soil prevents the water from infiltrating the soil (Al-Dousari *et al*., 2006). Flash flood results when there is heavy and continuous rainfall (between 30-40 mm in one storm). Flooding causes huge amount of soil loss, cutting the roads creating transport problems and other associated socio-economic problems.

Water conservation measures have not been widely applied in Kuwait. Therefore, it is necessary to recharge the ground and surface water by rain. Water harvesting is the process of using and storing rainwater (Misak and Al-Awadhi, 2001).

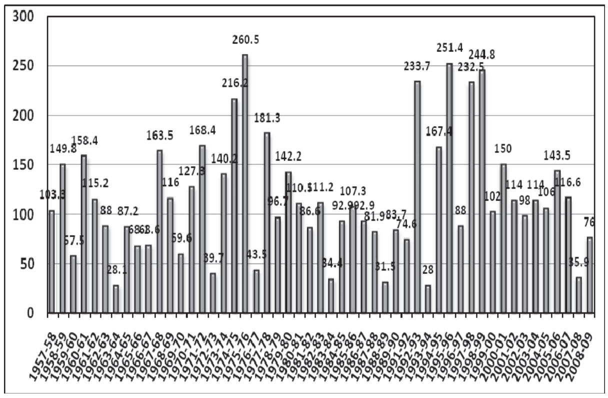

Fig. 1. Amount of rainfall in mm from 1957-2009 (Kuwait Airport).

A key measure in this study is to test one method of water harvesting called semicircular bund, which protects the soil from water erosion and stores more rainwater in the soil.

2. Study Area

The pilot area is located in Liyah area, north of Jahra City

* Corresponding Author: mmahmed@kisr.edu.kw
Kuwait, B.O.Box:24885 Safat 13109
1) Desert Group, Coastal and Air Pollution Department, Kuwait Institute for Scientific Research
(Received, September 15th, 2013; Accepted, March 6th, 2014)

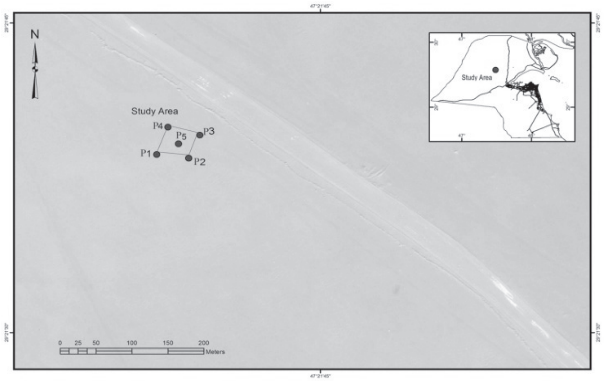

Fig. 2. Map of the study area with sampling sites (P1 to P5).

(**Fig. 2**). The area of focus is a degraded playa around 100 m^2. 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%).

3. Methodology

Field investigations were carried out at five locations (p1, p2, p3, p4 and p5). Five to ten samples were collected from the degraded playa every six months for three years. Infiltration tests, soil moisture, bulk density, porosity, pH, EC, penetration force along with the physical measurements of *Lycium shawii* were carried out before and after rehabilitation. This plant is a desert thorny shrub, genus of flowering plants (*Solanaceae* family). It can reach a height from 90 cm to 1.5 m, their leaves are small, fleshy, and alternately arranged. It has red berry fleshy fruits. It is the dominant plant species in Liyah area. It has high adaptation to degraded areas. Moreover, it has the ability to form sandy mounds around plant forming large nabkha. Therefore, it has high efficiency of trapping sediment. Infiltration rate test is measured as the speed of water entering the soil by using a double-ring infiltrometer. Soil moisture is measured as the quantity of water restricted in a soil and it is calculated on dry basis.

Soil Moisture (%) = (dry oven weight - fresh weight) / dry weight × 100

The bulk density was measured by core method and porosity was calculated using the following equations.

%Bulk density = (dry oven weight) /πr h and … %Porosity = 1 - (Bulk density / Particle density(2.65))

The compressive soil strength was measured using a hand penetrometer. The pH was measured in a saturated soil paste by using a pH meter. EC was measured using an EC meter in extract collected from the soil paste under vacuum after the temperature of the extract was adjusted.

A treatment was introduced by making 50 semicircular bunds by ploughing the area and covering the bunds with palm leaves and stones. The soil is covered with mulching material (plant residues).

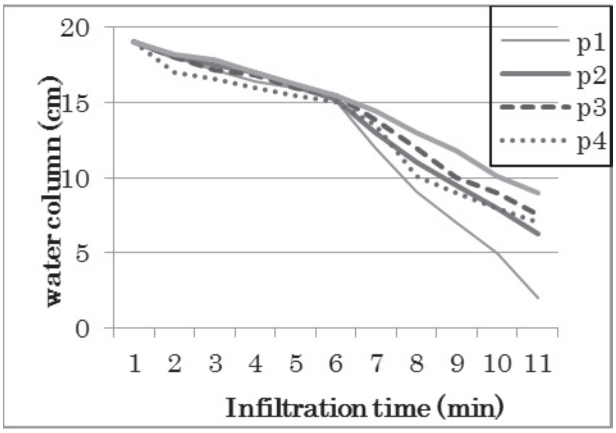

Fig. 3. Infiltration in the study area at five locations (p1, p2, p3, p4 and p5) before treatment.

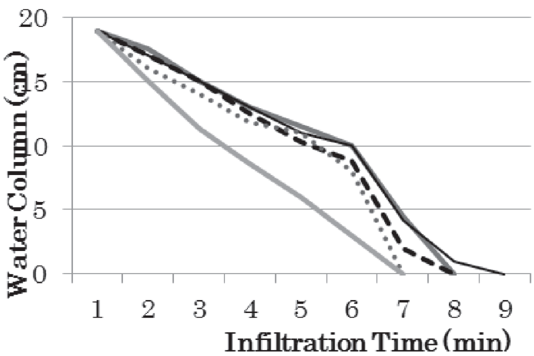

Fig. 4. Infiltration in the study area at five locations (p1, p2, p3, p4 and p5) after treatment.

4. Results and Discussion

In this research, water harvesting techniques were applied to selected artificial playa (100 m^2). Physical and chemical soil tests were carried out before and after treatment to determine the efficiency of the water-harvesting system. The main physical measurements are infiltration test, soil moisture, bulk density, porosity and vegetative survey. The main chemical tests are pH and electrical conductivity (EC). The following results were observed after the application of the treatment for 3 months:

- Before ground treatment, a water column of 19 cm takes more than 30 min to infiltrate, while after treatment; it takes only 15 to 20 min. (**Figs. 3** and **4**).
- The average infiltration capacity was 107.2 cm^3/min in un-treated soil and to 193.5 cm^3/min in the treated soil in comparison with non-treated. The average difference in volume of infiltrated water was 71% (**Fig. 5**).
- The average soil moisture before treatment was 1.5% but increased to 3.5% after treatment (**Tables 1** and **2**).
- Before treatment, the dominant bulk density of the soil was

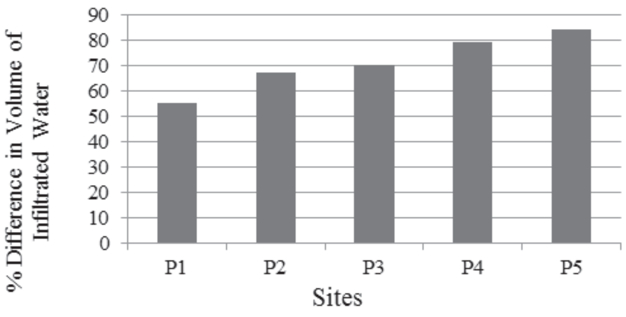

Fig. 5. The % differences in volume of infiltrated water in the study area at five locations (p1, p2, p3, p4 and p5) before and after treatment.

Table 1. Average Soil Characteristics Before Treatment.

Depth (cm)	Penetration Force (psi)	pH	EC* (mS/cm)	Soil Moisture (%)	Bulk Density (%)	Porosity (%)
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		

*EC: Electrical Conductivity

Table 2. Average Soil Characteristics After Treatment.

Depth (cm)	Penetration Force (psi)	pH	EC* (mS/cm)	Soil Moisture (%)	Bulk Density (%)	Porosity (%)
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		

*EC: Electrical Conductivity

Table 3. Average Physical Measurements of *Lycium shawii*.

Treatment	Length of Main Stem (cm)	No of Branches	Length of Large Branches (cm)	Length of Short Branches (cm)
Before	61	3	44	19
After	95	20	77	35

2.7 gm/cm^3 while after the treatment it was reduced to 2.

- The penetration force before treatment was 273 psi, but after treatment it has reduced to 190 psi.
- Researchers observed increase presence of annual plant species around semi-circular bunds.
- Before treatment, the health of *Lycium shawii*, was rather poor. After the treatment the plants health has significantly improved. The average stem length before and after treatment were 61 cm and 95 cm, respectively. The average number of branches before treatment was 3, which was increased to 20 after treatment (**Table 3**).
- The soil of the pilot area was slightly alkaline ranging around 7.3-8 which indicates the presence $CaCO_3$.
- The electrical conductivity is low not exceeding more than 4 mS/cm.

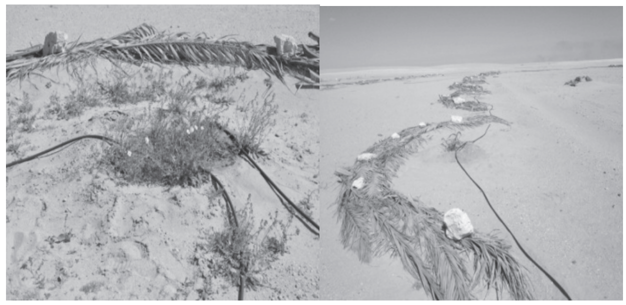

Fig. 6. The appearance of annual plant species around semi-circular bund.

- There was little noticeable variation of pH and EC measurement (pH is basic and EC is less than 4 mS/cm). These conditions are very suitable for growth of *Lycium shawii*. These plants have ability to form large nabkha thus playing important role in controlling sand encroachment.

5. Conclusions

The study of playa area is very important because of their geological features and socio-economic impact. The playa area is considered to be catchment's area, therefore the water infiltrates slowly giving chance for the plant to grow and exploit water.

The soil of the study area is hard and dry. It is covered by a sheet of gravel and coarse sand which acts as a seal preventing and reducing the infiltration of rainwater. So, the soil moisture is very low and the vegetation cover is very poor. The soil is compacted with very low porosity causing the runoff of rain droplets rather than infiltration into the soil. Under these severe environmental conditions, the area is affected by a number of human interventions which caused environmental degradation that damaged the natural resources and micro land forms. The study area suffers from different degrees of water erosion, a number of gullies and rills. In addition, soil crusting, sealing and compaction, deterioration of the vegetation cover and loss of biodiversity are observable.

Applying water harvesting technique using the semicircular bunds is very important to save and rehabilitate the deteriorated area. This will protect the soil from erosion and enhance the storage of water in the soil. The main steps of applications are building of semi-circular bund, ploughing the soil, planting with drought resistant plant and using environmentally friendly materials to cover soil and bunds. This technique will improve the quality of the soil characteristics in desert areas as follows:

- Soil fertility was increased through increasing the quantity of fine and very fine sand.

- The water content was increased thus providing plants sufficient water to grow.
- The content of organic matter was increased, thus affecting soil moisture and the space between the soil grains.
- The porosity of the soil was increased and allowed more water to infiltrate into soil.
- The penetration force was decreased and the loose soil helped the plant root to spread easily.
- The efficiency of catchment aeolian particles was increased.

It is recommended that control measures must have regular maintenance for any damages. The cost of bund construction is very low (about 0.5 KD per bund) and can be implemented very fast, especially when the raw materials (plant residues) are available.

References

Al-Awadhi J.M., Omar S.A., Misak R. (2005): Land degradation indicators in Kuwait: A case study of land degradation. *Bulletin of Engineering Geology and Environment*, **62**: 107-115.

Al-Dousari A.M., Misak R., El-Gamily H., Tharwat N., Ahmed M., Al-Mutairi M., Mehrotras S. (2006): *Integrated system for flood management in Shuaiba area and its vicinities. (EC055C)*. Kuwait Institute for Scientific Research, Report No. KISR 8243, Kuwait.

Al-Dousari A.M., Al-Elaj M., Al-Enezi E., Al-Shareeda A. (2009): Origin and characteristics of Yardangs in the Um Al-Rimam depressions (N Kuwait). *Geomorphology*, **104**: 93-104.

Misak R., Al-Awadhi J. (2001): *Development of the action plan of flash floods control (the case of Al-Jahra City).* Proposal submitted to KFAS.

Misak R., Khalaf F., Omar S. (2013): Managing the Hazards of Drought and Shifting Sands in Dry Lands (the case of Kuwait). *In* Shahid Taha Abdelfatah ed., *Developmens in Soil Classification, Land Use Planning and Policy Implications*, Springer.