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Threats to Agriculture Lands at Al-Wafra, Southern Part of Kuwait

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Abstract: The Al-Wafra agricultural area is located at the southern fringes of Kuwait, close to the Saudi Arabia border with an approximate land area of 17,000 hectares. Since 2006, this area faced several environmental impacts in terms of water logging and soil salinization. The soil degradation, depletion of crop yields and loss of productive lands is mainly due to misuse of brackish groundwater. Some 600 large diameter flowing wells with minimum discharge of 30 m^3/hour were developed in the area tapping the Dammam Formation. The water flowed without any control with salinity ranging from 5000 to 7000 mg/l. Drainage systems were not developed and the water accumulated in low lying farms forming water ponds. Due to high temperatures and evaporation in summer, the soils were highly salinized and cultivation abilities were nearly demolished. In 2009 and 2010, about 72% of the flowing wells were controlled by governmental organizations. Consequently, water ponds disappeared and soils were dried up. The main objectives of this study are to: 1) assess the magnitude of soil salinization in representative farms at Al-Wafra area; and 2) propose economically feasible and environmentally sound solutions to overcome the problem. The following field, laboratory and desk investigations were conducted: 1) assessment of the problem through field and remote sensing measurements; 2) examinations of six representative soil profiles; and 3) collecting and analyzing of 36 soil samples. Also, Google Earth images dated 2008 and 2011 were used to monitor affected sites. Finally, scientific solutions such as mixing saline soils with clean sands and soil washing were proposed and evaluated.

Key Words: Dammam formation, Flowing wells, Google Earth, Soil salinization, Water logging

1. Introduction

As stated by the Public Authority of Agriculture Affairs & Fish Resources (2006), soil salinization caused by inappropriate irrigation practices affects 60 Mha, which represent about 24% of all irrigated land worldwide. In Africa, salinization accounts for 50% of irrigated land. Increasing soil salinization is also noticed in India, Pakistan, China, and Central Asia. In Egypt, 35% of the agricultural land suffers from soil salinity. In Kuwait, agricultural areas cover about 2.5% of the country (KISR, 1999) and are geographically distributed in three main areas **(Fig 1**). to include: Abdaly (northern part), Kabd (central part) and Al-Wafra (southern part).

Al-Wafra Agricultural Area (about 17,000 hectares) is located at the southern fringes of Kuwait, close to the Kuwait - Saudi Arabia border. The ground elevation of this area ranges between 33 m above sea level (northeastern side) and 117 m above sea level (southwestern side). This area supplies Kuwait with a wide variety of vegetables and fruits. The soil of Al-Wafra Agricultural Area is dominated by deep sands, which are underlain by a gatch bed (impervious zone) at shallow depths rarely exceeding 2 m (KISR, 1999). The groundwater (main irrigation source before using treated waste water) was exploited from two aquifers. An upper aquifer consists of sands and gravel (Kuwait Group) and a deeper fractured limestone aquifer (Dammam Formation).

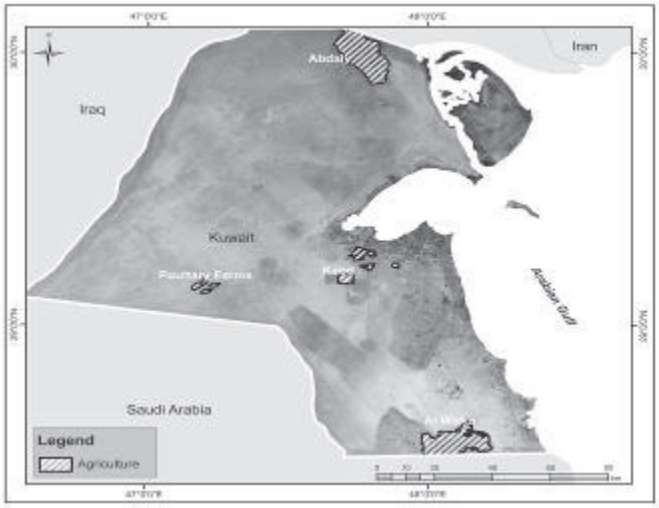

Fig. 1. Satellite image of Kuwait from 2010 showing the location of agriculture areas (Abdaly, Kabd and Al-Wafra).

The total salinity of the groundwater of Kuwait Group ranges from 4,000 to 9,000 ppm, while that of Dammam Formation varies from 3000 to 6000 ppm (Ministry of Electricity and Water, 2011 statistical year book).

As stated in the Water profile of Kuwait (2007), only

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Al-Wafra farmers are allowed to withdraw water from the Kuwait Group Aquifer (4000-9000 ppm). The water used for livestock purposes is pumped by Ministry of Electricity and Water (MEW) from the Dammam fractured limestone aquifer through deep artesian wells (3000-600 ppm). However, farmers illegally drilled about 600 deep artesian wells during the last 15 years so there is no control for water discharge of all artesian wells. Considering the average discharge for an artesian well of 30 m^3/hour (720 m^3/day), the total discharge of the 600 wells will be 432,000 m^3/day (157,680,000 m^3/year).

In 2006, about 45% of the agricultural land was devoted to vegetable production, mainly tomatoes, eggplants, cucumbers and sweet peppers, and 19% used to cultivate cereals, mainly barley and wheat. Date palm trees are the most important fruit trees grown, which occupy about 20 percent of the cultivated land. The remaining crops grown are potatoes and other annual and permanent crops. In 2003, agricultural production included 207,000 tons of vegetables, 18,000 tons of fruits and about 3,300 tons of cereals (Public Authority of Agriculture Affairs & Fish Resources, PAAFR, 2006).

2. Materials and Methods

In the present study, the following field, laboratory and desk investigations were conducted: 1) assessment of the problem through field and remote sensing measurements for the spatial and vertical extent of saline soils; 2) examinations of six representative soil profiles in both affected and non-affected farms; and 3) collection of 36 soil samples for physical and chemical analyses.

In addition, a pilot site (about 2 km^2) was monitored and mapped using high resolution Google Earth images of 2008 (before controlling flowing wells), and 2011 (after controlling flowing wells). The Arcgis software was used to georefrence the satellite images into real world coordinates (Lat/Long) Wgs 84 of the two dates. Also, the contrast stretch was used to enhance the images to be more suitable for visual interpretation and extraction of the needed features. Then, the ArcCatalog was used to create the water ponds and wet lands GIS layer. The ArcMap was then utilized to digitize the water ponds and wet lands. Finally, the attribute data were entered after digitizing the needed features. The topology was run to convert the extracted layers into a GIS ready map.

3. Results and Discussion

3.1. Soil salinization problem

Impervious layers exist at various depths (50-200 cm) of the Al-Wafra Agricultural Area creating water logging in some areas. In 1994, this was estimated at 2,840 ha (Water profile of Kuwait, 2007). Due to misuse of flowing ground water after 1994, areas affected by water logging and soil salinization are expected to be at least two times that of 1994, *i.e.* 5,600 ha.

Since 1995, the Al-Wafra Agricultural Area has faced several environmental hazards, the most significant of which is water logging and soil salinization. This phenomenon that resulted in soil degradation, depletion of crop yields and loss of productive lands is caused by misuse of brackish groundwater. Some 600 large diameter flowing wells were developed by non-professional private drilling companies in several farms at Al-Wafra Agricultural Area. These wells tap the Dammam Formation (fractured limestone aquifer). The water from these wells (salinity varies between 3000-6000 ppm) previously flowed without any control on recharge. Drainage systems were not developed at any level (farm or area levels). So, the water accumulated in low lying farms forming water ponds of different depths and sizes. After time and as a result of high temperatures (exceeding 40ºC in summer) and evaporation (close to 3000 mm/year), the soils were highly salinized and cultivation on affected farms was completely demolished.

Several farms were completely flooded with water and now are abandoned. Some other farms were partially affected depending on their location and ground elevation relative to flowing wells in the surrounding farms. The general geomorphology of the area, where hollows (locally called khabrat) and low ridges alternate, accelerates the seepage of water towards low lying areas. The hollows act as discharging areas for flowing water.

Examination of 6 soil profiles indicates that the EC of the soils of one of the unaffected farm ranges between 0.104 to 0.347 mS/cm. For one of the effected farms, the EC of 0-60 cm interval ranges between 0.784 to 0.986 mS/cm, while from 60-100 cm interval the EC ranges between 14.82 to 15.17 mS/cm.

3.2. Managing soil salinization

In the last few years (2010/2011), the Kuwaiti Government represented by the Ministry of Electricity and Water (MEW) and the Public Authority for Agriculture and Fish Resources (PAAFR) were concerned about soil salinization and water logging in the Al-Wafra Agricultural Area. Some effective measures were taken to control the problem. These measures include blocking (closing) almost all of the flowing wells. However, no measures were adopted for the restoration/remediation of affected soils. Controlling the discharge of water from flowing wells was the most significant step for managing soil salinity problems. The multi-benefits of this measure include:

· Controlling additional damage to soils, cultivations and

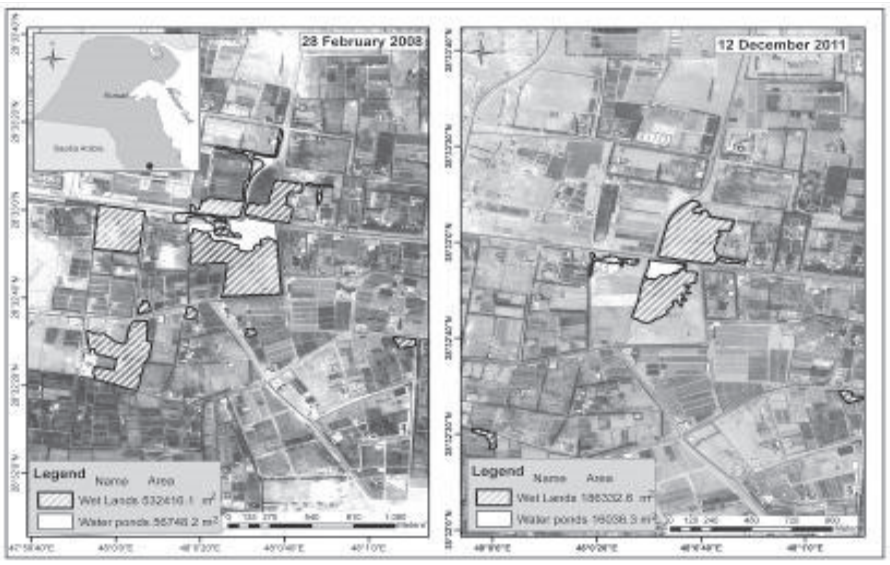

Fig. 2. Images of 2008 and 2011 for a pilot site in Al-Wafra Agricultural area showing the changes in the size of water ponds and wet lands before and after controlling the discharge of flowing wells.

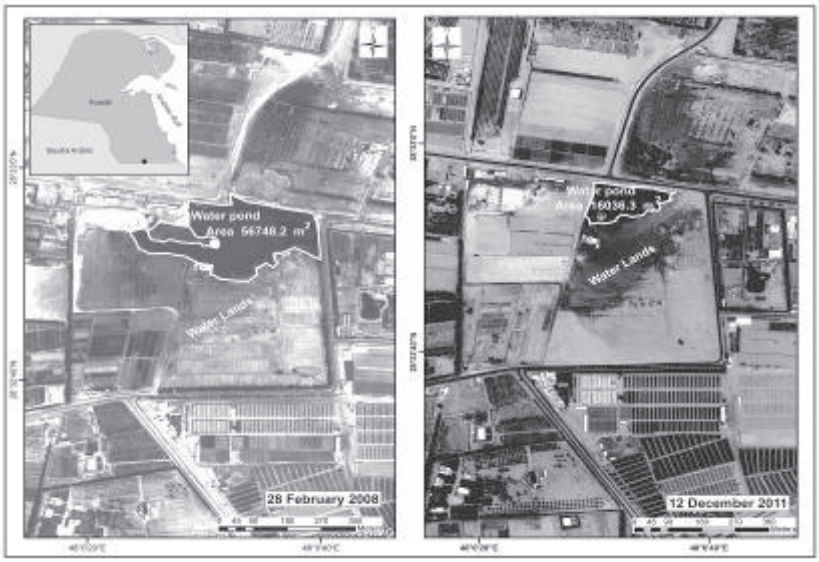

Fig. 3. Google images of 2008 and 2011 showing the difference in size of a water pond before and after controlling the discharge of flowing well.

Fig. 4. Field photos for a farm before and after controlling the discharge of flowing wells.

infrastructures such as roads and fences.

- Preservation of the loss of artesian pressure of the aquifer (Dammam Fractured Limestone).
- Controlling additional loss of groundwater.
- Encouraging the implementation of successful soil treatment plans.

In 2008 (before controlling the discharge of flowing wells), the areal extent of water ponds and wet lands in a pilot site was 56,748.2 m^2 and 532,416.1 m^2 respectively. While in 2011 (after controlling the discharge of flowing wells), the areal extent of the water ponds was 16,036.3 m^2 (72% decrease) and wet land was 186,332.6 m2 (65% decrease). **Figures 2 - 4** show the changes in the size of water ponds and wet lands in 2008 and 2011.

3.3. Cost of land degradation control (Case of saline soils of Al-Wafra agricultural area)

The cost of rehabilitation/reclamation of saline soils through mixing with clean fine sands is KD 0.65 (2US $)/$m^2$ making it an unsustainable approach. The following items

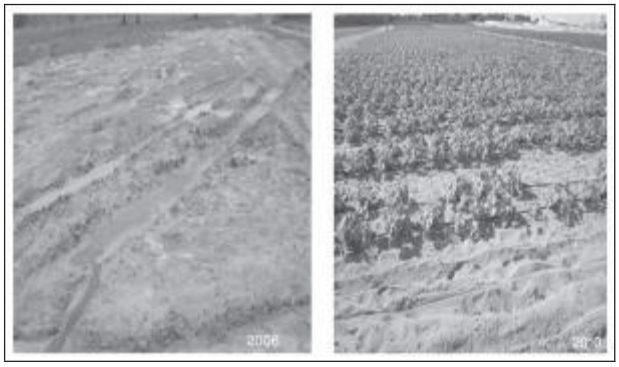

Fig. 5. Saline soil before (2006) and after reclamation (2010).

should be considered in cost estimates of land degradation control of Al-Wafra Agricultural Area:

- Cost of exploited groundwater during 1995-2010.
- Cost of controlling the discharge of flowing wells: KD 600,000 (2,100,000 US$).
- Cost of rainwater losses due to deterioration of its quality by falling on saline soils.
- Cost of control of shallow groundwater pollution.
- Cost of drainage systems.
- Cost of the loss of Ecosystem services.
- Cost of the loss of agricultural production.

4. Conclusion and Recommendations

Soil salinity in the Al-Wafra Agricultural Area (irrigation salinity) developed in the last 15 years as a direct result of misuse of brackish groundwater of Al Dammam Formation (fractured limestone aquifer with TDS ranging from 3000 to 6000 ppm). At the beginning of the problem in mid nineties, the number of flowing wells was several tens increasing over time to about 600 wells in 2010. The ground water was flowing on the ground from 1995 to 2010 without any control on its discharge. As a result, the water percolated into sandy soils (till saturation). After soil saturation, huge amounts (millions of cubic meters) remain on the surface constituting saline wetlands and water ponds. Salinity levels in a number of salt affected farms in Al-Wafra Agricultural Area have reached a point where the long-term productivity is threatened (EC exceeds 15 mS/cm).

Managing irrigation salinity in Al-Wafra Agricultural Area is essential for the sustainability of agricultural production and for land degradation control. The main strategy for controlling irrigation salinity in Al-Wafra Agricultural Area should rely on the following:

- Conducting regular monitoring for soil salinity (four times/year) in representative salt affected farms in Al-Wafra area.
- Implementing efficient water-use programs coupled with good irrigated farming practices and effective surface drainage.
- Establishing and maintaining Eucalyptus trees (for biological drainage) around drains and in discharging areas.
- Implementing drainage systems (80 - 100 cm depth) to reduce the water table below the root zone minimize the upward movement of salts and in turn allow salt-affected land to be brought back into production.
- Developing agro-hydro-salinity models to help calculate the extent and severity of the irrigation salinity in affected farms.
- Using manure and crop residues to provide additional organic matter to the soil (to reduce evaporation, improve water infiltration, water holding capacity and tilth of the soil).
- Establishing forage buffer strips (3 to 5 m wide) on both sides of drains to minimize of soil salinity.
- Selecting crop varieties and forage plants that have a greater tolerance to salt such as Alpla Alpha and Artiplex spp (to reduce evaporation and maximize soil water use).
- Avoiding deep tillage in moderately to slightly affected farms (as it brings salts up to soil surface). Zero tillage should be considered for severely salt affected farms.

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