Status of the Agricultural land, Soil and ground water in Bahrain

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Overview

- Introduction
- Structure Geology
- Topography
- Physiography
- Water Resources
- Groundwater
- Status of the existing Agricultural land in Bahrain
- Status of soil Resources in Bahrain
- Treated Sewage Effluent (TSE)
- Agricultural Drainage
- Priorities for sustainable management for soil resources
- Recommendations
Introduction

- Location (Arid Region)
- Area (712 Km²)
- Population (~ million)
- High population density
- Accelerated development growth since early 1960s
- Rapid population growth associated with rapid urbanization and industrialization
Introduction

- Bahrain has an arid to extremely arid climate
- High summer temperature (38°C)
- Rainfall is low and irregular, average annual is about 75 mm
- High evaporation rate, 1840 mm/y
- No surface water
- Groundwater is the only natural available source for freshwater supply
Generalized surface geology of Bahrain (modified after GDC, 1980).

Explanations:
- Sand & Sand dunes
- Quaternary
- Miocene-Oligocene
- Orange Marl
- Khob
- Sharks Tooth
- RuShale Formation
- Fold Traces
Water Resources

- **Groundwater**
  - Dammam aquifer system: safe yield is between 90 - 112 Mm³ year⁻¹ – average abstraction per year (last 30 years) is about 190 Mm³ – normal salinity distribution varies from 2,300 – 4,800 ppm TDS.
  - Bahrain depends principally on the Dammam aquifer system (70% of total consumption as a natural resource).
  - Recharged by the Eastern Arabian Aquifer System.
  - Rus – Umm Er Radhuma aquifer: lens type aquifer virtually non-renewable – average abstraction per year is 39 Mm³ - normal salinity distribution varies from 7,000 – 15,000 ppm TDS.
Aquifer System in Bahrain

Geological Units

- Neogene Formation + Recent deposits
  - Alat Member
  - Orange Marl Member
  - Khobar Member
  - Sharks Tooth Shale M.

- Rus Formation (+anhydrite & shales)
- Umm Er Radhuma Formation

Bahrain main island

Sitra island

Limestone (Aquifer)

Shale and marl (Aquitard)

Anhydrite (Aquitard)

Underflow from Saudi Arabia aquifers

A

A'

meters below sea level

0

20

40

60

80

100

120

140

160

180

200

220

240

260

280

300

320
Groundwater Resources (Bahrain)

- Bahrain depends principally on the Dammam aquifer system (70% of total consumption)
- Recharged by the Eastern Arabian Aquifer System
- Renewable at local scale (Bahrain), conceptualized

The Eastern Arabian Aquifer System (Eastern Saudi Arabia – Bahrain)

GDC, 1980
Groundwater

Hydrogeological cross section showing the C aquifer

- C aquifer
- Shale and marl
- Anhydrite and gypsum
- Main fractured zone
- Salinity contour

Depth in meters

- BNLD
- Dammam Formation
- Rus - Umm Er Radhuma Formations
- Aruma Formation

Salinity contour
Water demands in Bahrain are met by three sources:

- Groundwater (Agricultural and Domestic Sector)
- Desalination (Domestic sector)
- Wastewater treatment (Agricultural and municipality)

Water uses in Bahrain by sources year 2009 in Mm3

<table>
<thead>
<tr>
<th>Source</th>
<th>Abstraction Mm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater</td>
<td>151.5</td>
</tr>
<tr>
<td>Desalinated water</td>
<td>203</td>
</tr>
<tr>
<td>TSE</td>
<td>36</td>
</tr>
<tr>
<td>Total</td>
<td>390.5</td>
</tr>
</tbody>
</table>
Significant increase in the country’s water demands in the past four decades (Municipal & Agricultural competition)

<table>
<thead>
<tr>
<th>year</th>
<th>Groundwater</th>
<th>Desalinated water</th>
<th>TSE</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>213</td>
<td>44.1</td>
<td>0.7</td>
<td>257.8</td>
</tr>
<tr>
<td>1988</td>
<td>202.9</td>
<td>49.2</td>
<td>1.5</td>
<td>253.6</td>
</tr>
<tr>
<td>1989</td>
<td>213.4</td>
<td>48.6</td>
<td>2.3</td>
<td>264.3</td>
</tr>
<tr>
<td>1990</td>
<td>219.5</td>
<td>54.2</td>
<td>4.4</td>
<td>278.1</td>
</tr>
<tr>
<td>1991</td>
<td>214.8</td>
<td>56</td>
<td>5.9</td>
<td>276.7</td>
</tr>
<tr>
<td>1992</td>
<td>231.1</td>
<td>61.3</td>
<td>7.5</td>
<td>299.9</td>
</tr>
<tr>
<td>1993</td>
<td>243</td>
<td>58.3</td>
<td>8.3</td>
<td>309.6</td>
</tr>
<tr>
<td>1994</td>
<td>256.3</td>
<td>59.8</td>
<td>12.9</td>
<td>329</td>
</tr>
<tr>
<td>1995</td>
<td>266.9</td>
<td>52.7</td>
<td>11.9</td>
<td>331.5</td>
</tr>
<tr>
<td>1996</td>
<td>274.6</td>
<td>60.6</td>
<td>13.2</td>
<td>348.4</td>
</tr>
<tr>
<td>1997</td>
<td>287.9</td>
<td>58.9</td>
<td>12.8</td>
<td>359.6</td>
</tr>
<tr>
<td>1998</td>
<td>293.4</td>
<td>61.4</td>
<td>12.2</td>
<td>367</td>
</tr>
<tr>
<td>1999</td>
<td>272.3</td>
<td>62.7</td>
<td>14</td>
<td>349</td>
</tr>
<tr>
<td>2000</td>
<td>262.8</td>
<td>89.2</td>
<td>14.6</td>
<td>366.6</td>
</tr>
<tr>
<td>2001</td>
<td>231.9</td>
<td>93.9</td>
<td>15.4</td>
<td>341.2</td>
</tr>
<tr>
<td>2002</td>
<td>244.9</td>
<td>93.7</td>
<td>14.1</td>
<td>352.7</td>
</tr>
<tr>
<td>2003</td>
<td>239.5</td>
<td>102.4</td>
<td>18.8</td>
<td>360.7</td>
</tr>
<tr>
<td>2004</td>
<td>231.6</td>
<td>105.5</td>
<td>22.6</td>
<td>359.7</td>
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<tr>
<td>2005</td>
<td>208.5</td>
<td>109</td>
<td>24</td>
<td>341.5</td>
</tr>
<tr>
<td>2006</td>
<td>216.5</td>
<td>118.6</td>
<td>29.5</td>
<td>364.6</td>
</tr>
<tr>
<td>2007</td>
<td>176.1</td>
<td>132.3</td>
<td>36</td>
<td>344.4</td>
</tr>
<tr>
<td>2008</td>
<td>163.9</td>
<td>167.8</td>
<td>36</td>
<td>367.7</td>
</tr>
<tr>
<td>2009</td>
<td>151.5</td>
<td>203</td>
<td>36</td>
<td>390.5</td>
</tr>
</tbody>
</table>
Total Water Requirements Bahrain 1987-2009
Aquifers Potentiometric Level and Observation Network

Water Observation
Aquifers Salinity and Observation Network

Salinity Contour Map of the Khobar Aquifer, 2008

5000 ppm TDS Contour line
Heavy reliance on groundwater and unplanned utilization

- Over-exploitation (more than the safe yield)
- Potentiometric level decline
- Quality deterioration
- Loss of agricultural lands due to salinization
- Loss of environmental resources (Loss of natural springs and surrounding environment, habitats destruction, loss of biodiversity, etc..)
- Sea water intrusion
The existing desalination plants and their annual production capacities

<table>
<thead>
<tr>
<th>Desalination plant</th>
<th>Type of desalination</th>
<th>Production capacity (Mm$^3$/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitra Power and Water Station</td>
<td>Multistage flash</td>
<td>25.2</td>
</tr>
<tr>
<td>Ras Abu-Jarjur Desalination Plant</td>
<td>Brackish groundwater RO</td>
<td>26.9</td>
</tr>
<tr>
<td>Ad - Dur Desalination Plant</td>
<td>Seawater reverse osmosis</td>
<td>4.85</td>
</tr>
<tr>
<td>Hidd Power and Water Plant</td>
<td>Multistage flash</td>
<td>137.4</td>
</tr>
<tr>
<td>Alba Coke Calcining Desalination Plant</td>
<td>Multistage flash</td>
<td>8.5</td>
</tr>
<tr>
<td><strong>Total output</strong></td>
<td></td>
<td><strong>203</strong></td>
</tr>
</tbody>
</table>
### Status of the existing Agricultural land in Kingdom of Bahrain (2000 – 2011)

<table>
<thead>
<tr>
<th>Serial</th>
<th>Period</th>
<th>Gross Area contains (hac)</th>
<th>Number of The Farms Approx.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Before 2000</td>
<td>4672.334</td>
<td>726</td>
<td>Approximately</td>
</tr>
<tr>
<td>2</td>
<td>2000 - 2002</td>
<td>4631.354</td>
<td>714</td>
<td>Based on actual Reconnaissance Survey</td>
</tr>
<tr>
<td>3</td>
<td>2003 - 2005</td>
<td>4457.436</td>
<td>674</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2006 - 2008</td>
<td>4070.480</td>
<td>546</td>
<td>Excluded (Buhair, Tubli Royale C. and 1301)</td>
</tr>
<tr>
<td>5</td>
<td>2009</td>
<td>3995.090</td>
<td>540</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2010</td>
<td>3731.500</td>
<td>527</td>
<td>Excluded (Safiyya, Euro university and Zayed Twn)</td>
</tr>
<tr>
<td>7</td>
<td>Up to 31/12/2011</td>
<td>3742.33</td>
<td>642</td>
<td>New Cultivation Included at Shakhoora and Sanad (Awqaf)</td>
</tr>
</tbody>
</table>

- The above mentioned status based on our records
- Take in consideration that some farms are partially deleted
Contour map salinity of Alat and Khobar Aquifer 2008
Loss of agricultural lands

Agricultural Lands 1956
Aquifer Salinity 1965
Total Agricultural Lands Area 64.6 sq. km
Actually Cultivated Lands Area 32.3 sq. km

Agricultural Lands 1977
Aquifer Salinity 1978
Total Agricultural Lands Area 41.0 sq. km
Actually Cultivated Lands Area 17.5 sq. km

Agricultural Lands 1992
Aquifer Salinity 1992
Total Agricultural Lands Area 42.0 sq. km
Actually Cultivated Lands Area 31.0 sq. km
Loss of agricultural lands due to salinization

Loss of natural springs and their surrounding habitats (biodiversity, migratory birds, etc..)
Treated Sewage Effluent (TSE)

- **Major Treatment Plant:** Tubli
- **TSE Utilization:** Started since 1987-88.
- **Production capacity (2005):** 160,000 m³ day⁻¹ of secondary effluent
- **Present TSE Production:** 101,000 m³/day (Tubli)
- **TSE Quality:** As per WHO standard for irrigation
- **Primary User:** Agriculture (85-90%)
- **Secondary User:** Municipal Landscaping, others
- **Coverage under TSE:** ~3,000 hectares (out of 4200 ha).
- **Projection for 2015:** 390,000 m³/day
- **Projection for 2030:** 500,000 m³/day
Treated sewerage effluent
Treated sewerage effluent

<table>
<thead>
<tr>
<th>No. of connected farms</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13</td>
<td>165</td>
<td>112</td>
<td>6</td>
<td>21</td>
<td>74</td>
<td>7</td>
<td>398</td>
</tr>
</tbody>
</table>

The chart shows the number of connected farms from 2004 to 2010, with a total of 398 farms in 2010. The pie chart indicates that the majority of farms are from the second phase, followed by the first phase, and a smaller portion are non-connected farms.

Legend:
- 13: 2004
- 165: 2005
- 112: 2006
- 6: 2007
- 21: 2008
- 74: 2009
- 7: 2010
The Extent of the TSE scheme (Irrigated Farms)

Legend:

- EXISTING TSE RESERVOIRS
- EXISTING TRANSMISSION LINES
- EXIST. AGRICULTURAL AREAS SUPPLIED WITH TSE
- TSE RESERVOIRS
- TRANSMISSION LINES - 1
- TRANSMISSION LINES – 2
- TRANSMISSION LINES - 3
- DISTRIBUTION LINES - 1
- DISTRIBUTION LINES - 2
- DISTRIBUTION LINES - 3
- DISTRIBUTION LINES - 4

EXISTING TRANSMISSION LINES
EXISTING TSE RESERVOIRS
EXIST. AGRICULTURAL AREAS SUPPLIED WITH TSE
TSE RESERVOIRS
TRANSMISSION LINES - 1
TRANSMISSION LINES – 2
TRANSMISSION LINES - 3
DISTRIBUTION LINES - 1
DISTRIBUTION LINES - 2
DISTRIBUTION LINES - 3
DISTRIBUTION LINES - 4

Tubli WPCC
Soil

According to the soil taxonomy system devised by USDA (1975), MOST OF Bahrain soils belong to the Aridisol and Entisol orders:

- **Aridisol Order**: three great group namely, Salorthids, Gypsiorthids and Paleorthids are defined:
  
  - Salorthids Great Group: Salorthids soils mainly have a salic horizon within 75 cm of the surface above any calcic or gypsic horizon.
  
  - Gypsiorthids Great group: Gypsiorthid soils have gypsic horizon whose upper surface is within 100 cm of the surface
  
  - Paleorthids Great Group: These soils have a petrocalcic horizon usually the upper boundary of this horizon is close to the soil surface and it is thick. The upper boundary of the petrocalcic horizon occurs within the upper 100 cm of the soil profile. The soils also have a salic horizon within 75 cm of the surface if the soil is saturated with water within 1m. Oh the surface for a month or more in most years
Soil

According to the soil taxonomy system devised by USDA (1975), MOST OF Bahrain soils belong to the Aridisol and Entisol orders:

- **Entisol Order**: Three great group namely, Psammaquent, and are defined:
  
  - Psammaquent Great Group: These soils are saturated with water for all or most of the year. They usually occur in recent sediments (silicious sandy marine alluvium.
  
  - Torripsamment Great group: These soils are predominantly of aeolian origin. They occupy stable aeolian sand sheets and the occasional stable dune.
  
  - Torriorthent Great Group: Torriorthents are usually dry and on recent erosional surfaces. They are slightly to moderately saline and differ from the Torripsamments by having either a finer than sandy particle size class, or gravelly layers.
Characteristics of Bahrain soil

Physical Characteristics:

- Generally the soils of Bahrain are moderate to shallow in depth.
- The topsoil texture ranges from sand to loamy sand whereas the sub soil texture varies from loamy sand to sandy loam.
- Occasionally the subsoil texture is silty clay loam.
- Most of the deeper soils are underlain by sand and/or a cemented layer of gypsic or calcic horizon.
- Soil structure in most cases is poorly defined.
- In general, the soils have high infiltration rate up to more than 120 mm/hr particularly in coarse textured soil, while the fine-textured soils have a low rate of water movement.
- Also the presence of shallow water table, salt crusting or cemented layers have an effect in reducing the rate of the water movement.
- Regarding to the soil moisture retention, the field capacity ranges between 5-60% v/v whereas the wilting percentage varies between 1-30% v/v the available water content correspondingly ranging from 4-30% v/v.
- The bulk density varies between 0.82-1.61 gm/cm³ in most soils.
- The soil surface color varies widely, from dark greyish brown to light brown in moist cases.
- While the subsoil color ranges from olive grey to light grey and white.
Characteristics of Bahrain soil

Chemical Characteristics:

- Regarding to the agricultural land deterioration, salinity is a major soil problem throughout Bahrain.
- Agricultural lands are affected by salts due to high salinity of the irrigation water (TDS 2500-10000)
- Waterlogging due to over irrigation intruding sea water, as well as from the shallow saline water table in the absence of adequate drainage and soil-water management
- The salinity of the soil is very variable in general, the electrical conductivity (Ec) in irrigated soil lie within the range of 4-15 mmhos/cm. Non irrigated sites have a higher range of Ec
- The dominant cation is sodium, is value generally exceeds the sum of calcium and magnesium.
- The dominant anion is chloride which exceed sulfate
- Bicarbonate is present in very small concentration
Characteristics of Bahrain soil

Chemical Characteristics:

- The PH values usually range between 7-8.
- Most of the soils contain moderate amount of gypsum mainly in the upper 75 cm of the soil profile.
- The gypsum content of most soils range from 8-24%.
- In general, the soils of Bahrain are calcareous to highly calcareous.
- The calcium carbonate content in most soils range from 15-30%. Calcium carbonate value increase with depth and exceed 80% in the sub soil.
- The cation exchange capacity of the soil is very variable, varying between 1-25 me/100gm.
Fertility Characteristics

- Bahrain soils have low fertility potential.
- Organic matter content is low (<1%) and its build up in the soil is very slow because of the prevailing high oxidizing conditions.
- The nitrogen content is very low, soluble nitrate ranges from 1-5 ppm in the saturation extract of the topsoil.
- Phosphorus availability is relatively low and this is commonly associated with highly calcareous soils.
- In general, the available phosphorus content is very much variable (3-50 ppm).
- The soils of Bahrain seem well supplied with potassium. The available potassium content ranges from 100-360 ppm.
- In general, most of Bahrain soils are deficient in the micronutrient elements, while boron is satisfactory for most crops.
- Other nutritional elements are more likely to be found in amounts in the soil.
Problems of the soil

- Taken into consideration that the quality of the irrigation water is low, in general the soils of Bahrain have low potential for agriculture due to the following:
  - The soil are moderately saline to saline.
  - High gypsum and calcium carbonate content of most soils.
  - The PH values are moderately alkaline.
  - The soil texture mainly sandy and the soils generally have low water and nutrient holding capacities.
  - The soil have low fertility potential. Organic matter contents is very low and the soils are deficient in most of macro and micro nutrient elements.
  - The presence of shallow and saline water table.
  - Soil profiles depths are limited by the presence of petrocalcic horizons at variant depth. Also the presence of compacted or cemented layers of gypsum and lime at shallow depths acts as a barrier to maximum root penetration and water movement which creat a severe limitations for agriculture.
### Land Capability for Agriculture

With regard to land capability for agriculture, the soils of Bahrain could be classified as follows:

<table>
<thead>
<tr>
<th>Class No.</th>
<th>Class</th>
<th>Area, ha</th>
<th>% of the soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Good</td>
<td>1055</td>
<td>1.49</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>350</td>
<td>.50</td>
</tr>
<tr>
<td>3 &amp; 3D</td>
<td>Moderate, liable to salinization</td>
<td>3100</td>
<td>4.39</td>
</tr>
<tr>
<td>4 &amp; 4D</td>
<td>Moderately Low salt tolerant crops only</td>
<td>6250</td>
<td>8.85</td>
</tr>
<tr>
<td>5</td>
<td>Low</td>
<td>17540</td>
<td>24.82</td>
</tr>
<tr>
<td>6</td>
<td>Unsuitable</td>
<td>22473</td>
<td>31.8</td>
</tr>
<tr>
<td>7</td>
<td>Urban/Industrial</td>
<td>19892</td>
<td>28.15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>****</td>
<td><strong>70660</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
Land Use for Agriculture

- The total cultivable land is about 4762 ha in 1997.
- Bahrain main crops are dates, vegetable and fodder crops.
- Dates are the most traditional food crop.
- In addition to date palms, various kinds of fruit are grown in Bahrain.
- These includes citrus, mango, guava, chiku .. etc.
- The total area of dates and fruit is about 51% of total cultivable area.
- Vegetable are the most important cash crop, 80 percent of vegetable are grown during the winter time when temperature is favorable.
- The total area of vegetable is about 23% of the total cultivable land.
- Tomato is the most important vegetable, other vegetable are cucumber, lettuce, okra, onion …etc.
- Alfalfa is the main fodder crop but sudan grass, rhodes grass, bermuda grass and others are also grown.
- The area of the green fodder is about 16% of total cultivable area.
## Land Use Pattern

<table>
<thead>
<tr>
<th>Cultivated Land</th>
<th>Area in ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetables</td>
<td>1110</td>
</tr>
<tr>
<td>Fodder and Others</td>
<td>780</td>
</tr>
<tr>
<td>Dates and Fruit trees</td>
<td>2410</td>
</tr>
<tr>
<td>Landscaping</td>
<td>308</td>
</tr>
<tr>
<td>Fallow and Abandoned</td>
<td>154</td>
</tr>
<tr>
<td><strong>Total cultivated area</strong></td>
<td><strong>4762</strong></td>
</tr>
</tbody>
</table>
Soil Improvement

- Drainage of leached salt is necessary for optimum growth of crop.
- In area along the coastal strip, calcareous impermeable layers are found at varying depth between 1,2 and 3 meters and these have caused localized waterlogging and impeded leaching. Establishment of drainage system necessary.
- Etc…..
Recommendation

- Enhance the quality and availability of soil data and information
- Activate laws and regulations (Regulations should consider soil as a valuable none renewable resource)
- Increase farmer supporting
- Increase programs and projects which sport the agriculture and agricultural affairs.
- Training
- Alternative water resources for irrigation (TSE)
- Alternative lands for development
- Encourage Agri_investments by private sector
Thank You for your attention