Economic and Engineering Optimization for Groundwater Assessment, Use and Management in Agriculture Sector in GCC Countries

Dr. Mohamed A. Dawoud and Ahmed H. Al Muaini
Water Resources Department
Environment Agency – Abu Dhabi
United Arab Emirates
1. General Background (Aridity)
## Increase in water use in agriculture sector in GCC countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Water Use (MCM)</th>
<th>Ration of increase % (1995-2025)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1995</td>
<td>2000</td>
</tr>
<tr>
<td>Bahrain</td>
<td>115</td>
<td>124</td>
</tr>
<tr>
<td>Kuwait</td>
<td>74</td>
<td>110</td>
</tr>
<tr>
<td>Oman</td>
<td>1129</td>
<td>1270</td>
</tr>
<tr>
<td>Qatar</td>
<td>98</td>
<td>185</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>1489</td>
<td>15000</td>
</tr>
<tr>
<td>UAE</td>
<td>943</td>
<td>1400</td>
</tr>
<tr>
<td>Total</td>
<td>17254</td>
<td>18089</td>
</tr>
</tbody>
</table>
### Agriculture Sector share in GDP.

<table>
<thead>
<tr>
<th>Country</th>
<th>2005 Irrigation Water (MCM/Year)</th>
<th>2005 Total Groundwater Abstraction (MCM/Year)</th>
<th>2005 Agriculture GDP share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bahrain</td>
<td>251</td>
<td>258</td>
<td>0.85</td>
</tr>
<tr>
<td>Kuwait</td>
<td>521</td>
<td>405</td>
<td>0.40</td>
</tr>
<tr>
<td>Oman</td>
<td>1325</td>
<td>1690</td>
<td>2.81</td>
</tr>
<tr>
<td>Qatar</td>
<td>245</td>
<td>185</td>
<td>0.85</td>
</tr>
<tr>
<td>KSA</td>
<td>15854</td>
<td>14430</td>
<td>6.23</td>
</tr>
<tr>
<td>UAE</td>
<td>2547</td>
<td>2650</td>
<td>3.34</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20743</strong></td>
<td><strong>19618</strong></td>
<td></td>
</tr>
</tbody>
</table>
Increase in groundwater deficit (1985-2005).
Measuring the costs of groundwater use

<table>
<thead>
<tr>
<th>Cost of Groundwater Abstraction</th>
<th>Water Supply Costs</th>
<th>Social Opportunities Costs</th>
<th>External Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Economics</td>
<td>Capital Costs (Fixed Costs)</td>
<td>Operation and Maintenance Costs (O&amp;M Costs)</td>
<td>Foregone Value of Alternative Uses (Present/Future)</td>
</tr>
<tr>
<td>Paid by Users</td>
<td>Capital Costs (Credit sometimes subsidized)</td>
<td>Operation and Maintenance (Energy Often subsidized)</td>
<td>Resources Administration Costs</td>
</tr>
</tbody>
</table>
The economic feasibility of groundwater irrigation is mainly conditioned by the crop value.

High value crops can usually be developed even using low permeability or deep aquifers.

In most normal aquifers the cost of abstracting groundwater is usually affordable to grow any type of crops.

These data explain why, in the last decades, the farmers in most arid and semiarid countries have intensively developed groundwater irrigation.
CAUSES OF THIS SPECTACULAR DEVELOPMENT

DRIVING FORCE: ECONOMICS.

- Mostly private initiative, although the initial steps governmental action.
- The full direct cost of abstracting groundwater for irrigation is only a small fraction of the value of the crops grown using groundwater.
- The externalities or the decrease of the in situ value of groundwater are rarely taken into account.

- Scientific and technological factors.
Schematic Diagram for the Optimization Process.

- Groundwater Aquifer System (Hydrogeology)
- Infrastructure/Facilities and Capabilities
- Environmental Constrains
- Agriculture Values of Water
- Groundwater Pumping/Operational Cost

**Economic/Engineering Optimization Model**

- Groundwater Model
  - Database of Input Meta Data

- Economic Benefits
- Other Water Resources Alternatives
- Willingness to pay for water and reliability
- Value of flexible operation
- Value of increasing Capacities
Framework for Economic Analysis

- Economic considerations
- Equity considerations
- Intergenerational effects
- Sustainability of resource systems
- Social risk aversion
  - Economic analysis is used to help organize available information
  - Economic analysis should not be the sole determinant of choices
Groundwater mining

- Essential issue for GCC countries. It must be analyzed in the context of these countries.
- The long-term sustainability: a complex concept.
- Under certain circumstances groundwater mining may be a reasonable option, not necessarily against ethical principles. The following factors should be considered:
  - The mining can be technically and economically maintained for some time (e.g. more than 50 years).
  - The ecological costs are compensated by its socio-economic benefits.
  - To give appropriate information to the users about the present and future situation.
Optimization Model Development

- Management Requirements (Available groundwater resources in terms of quality and quantity, groundwater abstraction cost, aquifer deterioration, ....etc)

- Agricultural Economic Values for Water Use

Example set of agricultural water value functions
Schematic Diagram for the simulated aquifer system

Groundwater Abstraction

Irrigation application

Evapotranspiration

Water Table

Irrigation surplus

Quaternary Aquifer System
(Storage = 30 million m³)

Deep Aquifer System

Lateral Inflow

Lateral Outflow

Lateral Inflow

Lateral Outflow
There is not a *blue print*.

Transfer of new technology is relevant.

The driving force of the intensive development of groundwater for irrigation is the low economic cost of its abstraction in relation to the value of crops.

Reduction of perverse subsidies is also relevant, but requires time, education, transparency and public participation.

Institutions for collective surface water management have a long tradition in the region. This may facilitate the set up of similar institutions for groundwater management.
Water Use Efficiency Improvement Measures

Increasing the Re-use of Treated Wastewater

Achieving Sustainable Aquifer Management

Water Laws, Regulation and Legal Reform
Thanks