Water Management With Wastewater Treatment and Reuse, Desalination, and Conveyance to Counteract Climate Change in the Gaza Strip

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Outline

- Study area and problems
- Predicted climate change
- Research questions
- Methods
- Results and discussion
- Institutional framework
- Conclusions

Untreated wastewater in Wadi Gaza
Gaza Strip, Palestine

- Total area: 365 km²
- Population 1.55 million
- Population growth rate: 3.2%
- More than 3500 agricultural wells

<table>
<thead>
<tr>
<th>Sector</th>
<th>Water Demand (MCM/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010</td>
</tr>
<tr>
<td>Urban</td>
<td>74</td>
</tr>
<tr>
<td>Industrial</td>
<td>7.5</td>
</tr>
<tr>
<td>Agricultural</td>
<td>88</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Quantity (MCM/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>50.0</td>
</tr>
<tr>
<td>Lateral inflows</td>
<td>36.0</td>
</tr>
<tr>
<td>Irrigation return flows</td>
<td>28.0</td>
</tr>
<tr>
<td>Water system leaks</td>
<td>18.0</td>
</tr>
<tr>
<td>Wastewater return flows</td>
<td>15.0</td>
</tr>
</tbody>
</table>
Gaza Water Problems

- Inefficient water use by the agricultural sector
- Limited fresh water supply and high water demand
- Groundwater contamination
  - Over abstraction
  - Seawater intrusion
  - Wastewater disposal

Palestinian Water Authority, 2005; Abu Madi, 2004
Predicted Climate Changes

- Up to 4°C warmer
- 20% less precipitation
- 15% reductions in stream flow and groundwater recharge
  - PWA and CDM, 2007
  - Abdulla and Al-Omari, 2008
  - Abu-Taleb, 2000
  - Oroud, 2008

- We consider a 15% reduction in annual water availability from the Gaza aquifer
  - 147 to 125 MCM/year
Research Objectives

1) Economic effects of reduced water availability on Gaza water system
2) Infrastructure to mitigate and counteract effects
3) Infrastructure sizing
4) Institutional changes to facilitate response
Methodology

- Water Allocation Systems model (Fisher et al., 2005)
  - Single year deterministic optimization program
  - Economic benefits of water use
  - Costs of supply, conveyance, treatment, and reuse
  - Net benefit
  - Shadow value of water
- Analyze system behavior under different scenarios
  - Water availability
  - Infrastructure
**Water Allocation System Analysis**

**Objective function**

\[
\text{Max (Net Benefits)} = \sum_i \frac{b_i}{\alpha_i + 1} (\text{Service Demand}_i)^{\alpha_i + 1} - \text{Costs}
\]

- Local Sources, Imports
- Exports, Wastewater
- Treatment, Desalination

**Demand Curve**

\[
P = b \left( Q_{\text{Fresh}} + Q_{\text{Recycled}} \right)^{\alpha}
\]

**Cost function**

\[
\text{Price (S/unit)}
\]

\[
\text{Quantity (units)}
\]

\[
Q^* \quad P^*
\]
Continuity Constraint (Inputs = Outputs)

\[
\text{Water Use}_i = \left( \text{Local Sources}_i + \text{Imports}_i \right) \cdot \left( 1 - \text{Loss Rate}_i \right), \ \forall i
\]

Imports from other districts

Shared sources

Local sources

Leakage

Exports to other districts

Use to meet demands

A. Freshwater

B. Recycled water
Shadow values outputs

Marginal willingness to pay to obtain 1 additional unit of water

\[ SV_1 \text{ @ District } 1 \]

\[ CC_{12} \text{ From District } 1 \text{ to District } 2 \]

\[ SV_2 \text{ @ District } 2 \]

\[ SV_2 - SV_1 \geq CC_{12} \]

Interpretation:
- Build conveyance when difference in shadow values between districts is larger than conveyance cost
- Build a desalination plant when shadow value in district on a seacoast is greater than desalination cost
## Model Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Water Availability (MCM/year)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Base case</td>
<td>147</td>
<td>Demand in 2030 with existing infrastructure</td>
</tr>
<tr>
<td>2. Base case with climate change</td>
<td>125</td>
<td>Groundwater availability reduced by 15%</td>
</tr>
<tr>
<td>3. Base case with optimal infrastructure</td>
<td>125</td>
<td>Very large infrastructure capacities for desalination, WWTPs, conveyance</td>
</tr>
</tbody>
</table>
## Results

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Water availability (MCM/yr)</th>
<th>Annual net benefits ($ Mill/yr)</th>
<th>WWTP capacity (MCM/yr)</th>
<th>Desal. capacity (MCM/yr)</th>
<th>Convey. capacity (MCM/yr)</th>
<th>Capital costs ($ Mill)</th>
<th>Present value benefits ($ billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Base case</td>
<td>147</td>
<td>478</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6.7</td>
</tr>
<tr>
<td>2. Base case with climate change</td>
<td>125</td>
<td>377</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5.2</td>
</tr>
<tr>
<td>3. Climate change with optimal infrastructure</td>
<td>125</td>
<td>824</td>
<td>136</td>
<td>96.4</td>
<td>30.2</td>
<td>130.4</td>
<td>12.1</td>
</tr>
</tbody>
</table>
Shadow Value Results

![Graph showing shadow value results for different locations and scenarios.]

- **Base case**
- **Base case with climate change**
- **Climate change with optimal infrastructure**
Institutional Framework

- MOLG: Ministry of Local Governorate
- MoH: Ministry of Health
- EQA: Environmental Quality Authority
- PSI: Palestinian Standards Institute
- MoPIC: Ministry of Planning and International Cooperation
- MoA: Ministry of Agriculture
- PARC: Palestinian Agricultural Relief Committees
- PCBS: Palestinian Central Bureau of Statistics
- PWA: Palestinian Water Authority

Data source
Institution
Infrastructure
Conclusions

- Climate change will impose significant costs on Gaza water system
- New infrastructure can mitigate impacts and increase benefits
- Recommended infrastructure sizes
  - 136 MCM/year WWTs
  - 96 MCM/year Desalination
  - 30 MCM/year conveyance from Gaza to Khan-Younis and Rafah
- Benefits far exceed costs to restructure institutions
References


Questions

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