... Leading to Groundwater Bust

Number of Wells in Mexico

GW Irrigation in India
Mexico’s Virtual Water Imports are Rainwater (w supplemental irrigation)

- Corn... despite the ethanol-tortilla debacle
- Wheat
- Grain-fed beef
- Other animal products
- Deciduous fruit
Mexico’s Virtual Water Exports to the U.S. are Groundwater

Mexico's Virtual Water Exports to the U.S.
GW-Based Intensive Ag. Production

- Exports to U.S., Canada, Pacific rim
- Expanding Mexican domestic market
  - Costa de Hermosillo (Sonora) grapes
  - Cuauhtemoc (Chihuahua) apples
- Low water productivity in basic grains (wheat, corn) competing with high productivity horticulture
... But Overall Profits High

U.S/Mexico Fresh Fruit and Vegetable Trade

Source: U.S. Bureau of the Census
Financially, A Losing Proposition?
Shift to Night-time Irrigation
Growth, night ag. power consumption

[Map of Mexico with insets showing power consumption data for Sonora, Chihuahua, and Coahuila Ag. Power Consumption]
2003 – lost the thread? … with lower night-time ag. tariff, but ineffective controls on volume or area irrigated

<table>
<thead>
<tr>
<th>Tarifas ($/kWh)</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Doméstica</td>
<td>0.7496</td>
<td>0.793</td>
<td>0.8356</td>
</tr>
<tr>
<td>Dom. alto consumo</td>
<td>1.728</td>
<td>2.0443</td>
<td>2.1236</td>
</tr>
<tr>
<td>5A. Servicios públicos</td>
<td>1.3353</td>
<td>1.4186</td>
<td>1.4915</td>
</tr>
<tr>
<td>6. Agua Negras y Potables</td>
<td>0.9727</td>
<td>1.041</td>
<td>1.0982</td>
</tr>
<tr>
<td>9. Agrícola baja tension</td>
<td>0.3805</td>
<td>0.4211</td>
<td>0.5357</td>
</tr>
<tr>
<td>9M. Agrícola media tension</td>
<td>0.3933</td>
<td>0.4816</td>
<td>0.6051</td>
</tr>
<tr>
<td>9CU. Agrícola costo unitario</td>
<td>0.3156</td>
<td>0.3928</td>
<td>0.435</td>
</tr>
<tr>
<td>9N. Agrícola nocturna</td>
<td>0.281</td>
<td>0.3409</td>
<td>0.3657</td>
</tr>
</tbody>
</table>

- **Example:** Chihuahua tariffs
- **US$ 1.00 = Mex$ 10.80**

32% difference
GW Titled ≠ GW Pumped

Mex. State Groundwater Titled & Pumped

Pumped = 1.55 * Titled

R^2 = 0.9421

Vol. Titled (m^3/yr)
Ag. GW Share of Total Water Titled
GW Sustainability Initiatives

- 1992 - water rights, titling wells
  - Registro Público de Derechos de Agua (REPDA)
  - annual concessioned volume
  - water meters, but monitoring or compliance inadequate

- Water resource (river basin) master plans
  - bans on new wells in overdrafted aquifers
  - recharge programs (controversial, runoff impacts)
  - groundwater user committees
Aquifer Overdraft
Ag. Groundwater Pumped, 2005
(derived from energy data; national total ≈ 17.6 km³/year)

<table>
<thead>
<tr>
<th>Country</th>
<th>Annual groundwater use (km³)</th>
<th>No. of GW structures (million)</th>
<th>Extraction/structure (m³/year)</th>
<th>% of population dependent on groundwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>150</td>
<td>19</td>
<td>7,900</td>
<td>55-60</td>
</tr>
<tr>
<td>Pakistan-Punjab</td>
<td>45</td>
<td>0.5</td>
<td>90,000</td>
<td>60-65</td>
</tr>
<tr>
<td>China</td>
<td>75</td>
<td>3.5</td>
<td>21,500</td>
<td>22-25</td>
</tr>
<tr>
<td>Iran</td>
<td>45</td>
<td>0.5</td>
<td>58,000</td>
<td>12-18</td>
</tr>
<tr>
<td>Mexico</td>
<td>29</td>
<td>0.1</td>
<td>400,000</td>
<td>5-6</td>
</tr>
</tbody>
</table>
High Energy % for GW Pumping
Increasing Volume, Declining Share

Agricultural Energy Consumption in Mexico

- Ag consumption
- Ag % of total consumption

Source: CFE, 2005.
Groundwater-Energy Supply Nexus

- Groundwater overdraft and multiple impacts are driven by electricity supply and pricing
1. VALLE DE JUAREZ
2. ASCENCION
3. CASAS GRANDES
4. F.M.-V. AHUMADA
5. BAJA BABICORA
6. CUAUHTEMOC
7. CHIHUAHUA-SACRAMENTO
8. TABALAOPA-ALDAMA
9. DELICIAS
10. JIMENEZ-CAMARGO
11. PARRAL-EL VERANO

DISTRIBUCIÓN DE LOS ACUÍFEROS SOBREEXPLORADOS
ACUÍFEROS SOBREEXPLOTADOS

ABATIMIENTO MEDIO EN m/año

ASCENCION  BAJABICORBA  CUATHEMOC  CASAS GRANDES  F.M.-AHUMADA  CHIH.-SACRAMENTO  MEQUIL.-DELICIAS  JIMENEZ-CAMARGO  JUAREZ (URBA)  FARRAL.-DEL.V.  TAB.-ALDAMA
Virtual Water

Figure 3.2: Trade in embodied water in agricultural products / livestock before and after NAFTA

The Virtual Waterfall of NAFTA

Before NAFTA
1993-1994

23.2 Km³
8.4 Km³
20.4 Km³
1.14 Km³

After NAFTA
2001-2002

36.6 Km³
43.5 Km³
16.0 Km³
1.67 Km³

Failure of the Virtual Water Argument: possible explanations using the case study of Mexico and NAFTA – manuscript by Jorge Ramirez-Vallejo and Peter Rogers