ANALYZING THE EFFECTS OF CLIMATE CHANGE ON CROP WATER REQUIREMENTS IN SAUDI ARABIA

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Saudi Arabia: One of the arid countries in MENA

Limited groundwater reserves; Limited surface RO

Agriculture sector: The highest consumer of GW

Predicted significant change in climate in 2050

Several crops are produced in Saudi Arabia

Needs water conservation
Objective

- Characterize crop productions in Saudi Arabia
- Predict CWR of crops on a regional basis
- Assess seasonal variability of CWR
- Analyze the effects of temperature on CWR
- Analyze the effects of growing seasons on CWR
Obtained data on area and crop productions from SSYB

Used FAO approved CROPWAT 8.0 Software

Applied Penman-Monteith method for predicting $ET_o / ET_c$

Applied climatic conditions of 2011 and 2050 (Predicted)
# Crop productions in Saudi Arabia

<table>
<thead>
<tr>
<th>Crops</th>
<th>Riyadh</th>
<th>Makkah</th>
<th>Madinah</th>
<th>Qaseem</th>
<th>Eastern Region</th>
<th>Aseer</th>
<th>Tabouk</th>
<th>Hail</th>
<th>Jazan</th>
<th>Najran</th>
<th>Al-Baha</th>
<th>Al-Jouf</th>
<th>Total Area</th>
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Crop productions: Wheat, Alfalfa, Dates
Crop productions: Wheat, Alfalfa, Dates
CWR of crops on regional basis

![Chart showing CWR of crops on regional basis]

- **Riyadh**: Case I (3,000 MCM/yr), Case II (2,500 MCM/yr)
- **Makkah**: Case I (1,000 MCM/yr), Case II (500 MCM/yr)
- **Madinah**: Case I (600 MCM/yr), Case II (400 MCM/yr)
- **Qaseem**: Case I (1,500 MCM/yr), Case II (1,200 MCM/yr)
- **Eastern Region**: Case I (800 MCM/yr), Case II (600 MCM/yr)
- **Aseer**: Case I (400 MCM/yr), Case II (300 MCM/yr)
- **Tabouk**: Case I (300 MCM/yr), Case II (200 MCM/yr)
- **Hail**: Case I (500 MCM/yr), Case II (300 MCM/yr)
- **Jazan**: Case I (200 MCM/yr), Case II (100 MCM/yr)
- **Najran**: Case I (100 MCM/yr), Case II (50 MCM/yr)
- **Al-Baha**: Case I (100 MCM/yr), Case II (50 MCM/yr)
- **Al-Jouf**: Case I (50 MCM/yr), Case II (25 MCM/yr)

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CWR on crop basis

a. Case I (2011)  
- Dates: 3492
- Wheat: 1210
- Alfalfa: 1837
- Vegetable: 858
- Other fruits: 925
- Other cereal crops: 388

b. Case II (2050)  
- Dates: 3668
- Wheat: 404
- Alfalfa: 1928
- Vegetable: 974
- Other fruits: 1293
- Other cereal crops: 911

10/28/2014
CWR: crops and regional distributions

<table>
<thead>
<tr>
<th>CWR (MCM/yr)</th>
<th>Dates</th>
<th>Wheat</th>
<th>Alfalfa</th>
</tr>
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<tbody>
<tr>
<td>Riyadh, Qaseem, Madinah, Hail, ER, Makkah</td>
<td>Al-Jouf, Riyadh, Qaseem, ER, Tabouk, Hail</td>
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<tr>
<td>Riyadh, Qaseem, Makkah, Hail</td>
<td>Riyadh, Madinah, Qaseem, Tabouk, Makkah, Hail, Nazran, Al-Jouf</td>
<td>Jazan, Hail</td>
<td></td>
</tr>
</tbody>
</table>

**Diagram:**
- **Dates:** Riyadh, Qaseem, Madinah, Hail, ER, Makkah
- **Wheat:** Al-Jouf, Riyadh, Qaseem, ER, Tabouk, Hail
- **Alfalfa:** Riyadh, Qaseem, Al-Jouf, Tabouk, Hail

**Legend:**
- Riyadh, Qaseem, Madinah, Hail, ER, Makkah
- Al-Jouf, Riyadh, Qaseem, ER, Tabouk, Hail
- Riyadh, Madinah, Qaseem, Tabouk, Makkah, Hail, Nazran, Al-Jouf
- Jazan, Hail
Seasonal variability of CWR

Case I (2011)
Effects of temperature on CWR

- Varied Temperature by 0 – 5°C
- CWR increases from 8713 to 9716 MCM for $\Delta T = 5^\circ$C
- Slope of CWR = 201 MCM/$^\circ$C
- CWR change = 1.9 – 2.9%/$^\circ$C for dates
  = 1.9 – 3.0%/$^\circ$C for alfalfa
  = 2.2 – 3.8%/$^\circ$C for wheat
Effects of temperature on CWR

2011 to 2050: CWR increase: 5.8 (5.0–7.1%)

CWR increase:

- **Wheat:**
  - Riyadh = 5.8%; Al-Jouf: 6.5%

- **Dates:**
  - Riyadh = 5.5%; Qaseem: 5.8%

- **Alfalfa:**
  - Riyadh = 5.5%

Overall: CWR increase = 11.9 MCM/yr ≅ 4900 tons wheat
CWR per ha of cultivation

1 ha land cultivation:

Case I:
- Wheat: 6467 m$^3$/ha
- Dates: 23896 m$^3$/ha
- Alfalfa: 19742 m$^3$/ha

Case II:
- Wheat: 6839 m$^3$/ha
- Dates: 25203 m$^3$/ha
- Alfalfa: 20803 m$^3$/ha

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CWR per ha of cultivation: Riyadh

![Graph showing CWR per ha of cultivation for different crops in Riyadh. The graph compares Case I and Case II for various crops including Wheat, Sorghum, Maize, Barley, Tomato, Potato, Other vegetables, Alfalfa, Dates, Citrus, and Grapes. The x-axis represents the crops, and the y-axis represents the CWR (m3/ha) on a logarithmic scale from 0 to 30,000. The graph indicates a significant difference in CWR between Case I and Case II for Alfalfa and Dates.]
Effects of growing periods on CWR

- Wheat:
  - Exponential decay relationship for a shift of up to 75 days earlier
- Dates: No significant effects
- Alfalfa: No significant effects
- Sorghum: Significant effects

- Total Conservation: 731 MCM/yr: Case I

- Wheat:
  - Shift from Jan 15 to Nov 01: Conserve: 572 MCM/yr

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### Effects of growing periods: Wheat

<table>
<thead>
<tr>
<th>Regions</th>
<th>Current</th>
<th>S₁</th>
<th>S₂</th>
<th>S₃</th>
<th>S₄</th>
<th>S₅</th>
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<td>12.2</td>
<td>11.8</td>
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<td>12.1</td>
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<td>Hail</td>
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<td>108.3</td>
<td>90</td>
<td>77.8</td>
<td>65.2</td>
<td>56.5</td>
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<td>Tabouk</td>
<td>117.1</td>
<td>102.8</td>
<td>85.7</td>
<td>73.3</td>
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<td>58.2</td>
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<td>Jazan</td>
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<td>Najran</td>
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<td><strong>Total</strong></td>
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<td><strong>757</strong></td>
<td><strong>671.5</strong></td>
<td><strong>638.3</strong></td>
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</table>

Current: Jan 15–May 24; S₁: (Jan 01–May 10); S₂: (Dec 15–Apr 23); S₃: (Dec 01–Apr 09); S₄: (Nov 15–Mar 24); S₅: (Nov 01–Mar 10)
Comparing water supplies and CWR

<table>
<thead>
<tr>
<th>Regions</th>
<th>Water Supply</th>
<th>CWR</th>
<th>Water loss</th>
<th>% Loss</th>
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<td>402.3</td>
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Issues on water conservation

- Water losses through percolation
- Irrigation efficiency
- High evapotranspiration
- Water loss through pipeline
- Reuse of treated wastewater
- Crop yields and product quality
- Technical feasibility
- Cost per unit production
Summary, Conclusions, Recommendation

- Understand crop yields for differed growing seasons
- Life cycle analysis for TWW reuse
- Water footprint analysis related to cattle farms
- Technology to minimize water percolation
- Full or partial green-house cultivation
- Leak detection in the pipelines
- Recycling and reuse of TWW
Thanks for listening