Drought and Climate Change in Jordan

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RESEARCH OBJECTIVE

• Examine the impact of drought on Jordan and how climate change may affect drought afflicted areas.
OUTLINE

I. Context
II. Analysis and Results
III. Research Limitations
IV. Conclusions
V. Further Research
JORDAN BACKGROUND

- Small arid country in heart of the Middle East
- 7.6 million people
- Upper-Middle Income country
- Key U.S. Ally
- Severe water scarcity
WATER INSECURITY

- Jordan has the 10th lowest per capita renewable freshwater resources in the world.

The population of Jordan is expected to increase by 85% over the next 70 years.

In order to meet the consumption needs of its population, Jordan imports 95% of its cereals.


Source: Arab Organization for Agricultural Development, Arab Agricultural Statistical Yearbook, 2014
CLIMATE CHANGE IMPACT IN THE MIDDLE EAST

- Climate Change Model predict the Middle East region will become hotter, drier, less predictable (IPCC, 2014).

- Climate change may already be causing extreme drought in the Middle East

### Drought Tops Climate Change Concerns across All Regions

*Regional medians of most concerning effects of global climate change*

<table>
<thead>
<tr>
<th>Region</th>
<th>Droughts or Water Shortages</th>
<th>Severe Weather, Like Floods or Intense Storms</th>
<th>Long Periods of Unusually Hot Weather</th>
<th>Rising Sea Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latin America</td>
<td>59%</td>
<td>21%</td>
<td>12%</td>
<td>5%</td>
</tr>
<tr>
<td>Africa</td>
<td>59%</td>
<td>18%</td>
<td>16%</td>
<td>3%</td>
</tr>
<tr>
<td>U.S.</td>
<td>50%</td>
<td>16%</td>
<td>11%</td>
<td>17%</td>
</tr>
<tr>
<td>Asia/Pacific</td>
<td>41%</td>
<td>34%</td>
<td>13%</td>
<td>6%</td>
</tr>
<tr>
<td>Middle East</td>
<td>38%</td>
<td>24%</td>
<td>19%</td>
<td>5%</td>
</tr>
<tr>
<td>Europe</td>
<td>35%</td>
<td>27%</td>
<td>8%</td>
<td>15%</td>
</tr>
<tr>
<td>Global</td>
<td>44%</td>
<td>25%</td>
<td>14%</td>
<td>6%</td>
</tr>
</tbody>
</table>

Source: Stokes et al. 2015
2007-2010 REGIONAL DROUGHT

- Severe drought in 2007-2010 caused widespread water and food insecurity in Syria
- Syria forced to import wheat
- Rural-Urban Migration

Source: United States Department of Agriculture, 2015
RESEARCH APPROACH

• Assessed Climate in Jordan past to present to identify drought years

• Used composite drought index to measure drought severity

• Measured population affected and impact on agricultural production.

• Identified how climate change will impact drought afflicted areas in 2050.
<table>
<thead>
<tr>
<th>Data</th>
<th>Timeframe</th>
<th>Description</th>
<th>Spatial Resolution</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly Precipitation</td>
<td>1901-2012</td>
<td>Monthly Average precipitation data. Used data for November to April</td>
<td>Non-spatial</td>
<td>World Bank Climate Hub</td>
</tr>
<tr>
<td>Composite Drought Index</td>
<td>November 2008 to April 2009</td>
<td>Index of drought severity based on NDVI, SPI, surface temperature anomaly, and soil moisture.</td>
<td>.05 degree</td>
<td>International Center for Biosaline Agriculture</td>
</tr>
<tr>
<td>Landcover</td>
<td>2009</td>
<td>Landcover data used to identify cropland</td>
<td>.5km</td>
<td>Global Landcover Facility</td>
</tr>
<tr>
<td>Normalized Difference Vegetation Index Anomaly</td>
<td>November 2008 to April 2009</td>
<td>Input Variable for CDI, used in measuring cropland affected</td>
<td>.05 degree</td>
<td>International Center for Biosaline Agriculture</td>
</tr>
<tr>
<td>Wheat Yield, Production</td>
<td>2000-2014</td>
<td>Annual production figures for agricultural products</td>
<td>Non-spatial</td>
<td>Food and Agriculture Organization (FAO)</td>
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<td>Barley Yield, Production</td>
<td>2000-2014</td>
<td>Annual production figures for agricultural products</td>
<td>Non-spatial</td>
<td>Food and Agriculture Organization (FAO)</td>
</tr>
<tr>
<td>Landscan</td>
<td>2010</td>
<td>Gridded Population Dataset</td>
<td>1km</td>
<td>Oak Ridge National Library</td>
</tr>
<tr>
<td>Future Climate - Monthly Precipitation - January</td>
<td>2040-2060</td>
<td>Average values from six GCMS in rcp 4.5 and 8.5 scenarios</td>
<td>30 seconds</td>
<td>WorldClim</td>
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<td>2040-2061</td>
<td>Average values from six GCMS in rcp 4.5 and 8.5 scenarios</td>
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<td>Interpolations of observed climate data</td>
<td>30 seconds</td>
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ASSESSMENT OF HISTORIC CLIMATE AND DROUGHT CONDITIONS

- Monthly Precipitation data from World Bank Climate Hub
- Calculated Standard Precipitation Index for winter wet months
RESULTS – HISTORIC DROUGHT ANALYSIS

SPI < -0.5 = Drought years

6-month SPI (November to April)

Number of Droughts

1901-1960
1961-2010
RECENT DROUGHT
2006-2009

Total Precipitation November to April (mm)
Average Winter Precipitation 1970-2012

2008-2009, 62.7
CASE STUDY OF 2008-2009 WINTER DROUGHT

- Composite Drought Index (CDI) used to map drought severity

Equation:

\[ \text{CDI} = 0.40 \times \text{SPI}_{a} + 0.2 \times \text{SM}_{a} + 0.2 \times \text{LST}_{a} + 0.2 \times \text{NDVI}_{a} \]

- Where SPI\(_{a}\) = precipitation anomaly, SM\(_{a}\) = soil moisture anomaly, LST\(_{a}\) = land surface temperature anomaly, and NDVI\(_{a}\) = vegetation anomaly.

<table>
<thead>
<tr>
<th>Values</th>
<th>Percentiles</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5</td>
<td>0 to 2%</td>
<td>Exceptional Drought</td>
</tr>
<tr>
<td>-4</td>
<td>2 to 5%</td>
<td>Extreme Drought</td>
</tr>
<tr>
<td>-3</td>
<td>5 to 10%</td>
<td>Severe Drought</td>
</tr>
<tr>
<td>-2</td>
<td>10 to 20%</td>
<td>Moderate Drought</td>
</tr>
<tr>
<td>-1</td>
<td>20 to 30%</td>
<td>Abnormally Dry</td>
</tr>
<tr>
<td>0</td>
<td>30 to 70%</td>
<td>Normal</td>
</tr>
<tr>
<td>1</td>
<td>70 to 80%</td>
<td>Unusually Wet</td>
</tr>
<tr>
<td>2</td>
<td>80 to 90%</td>
<td>Very Wet</td>
</tr>
<tr>
<td>3</td>
<td>90 to 95%</td>
<td>Severely Wet</td>
</tr>
<tr>
<td>4</td>
<td>95 to 98%</td>
<td>Extremely Wet</td>
</tr>
<tr>
<td>5</td>
<td>98 to 100%</td>
<td>Exceptionally Wet</td>
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</table>
JANUARY ANOMALY DATASETS

- All four anomaly datasets show drought conditions.
- Precipitation Anomaly (top left) and soil moisture (bottom right) were exceptionally low in northwest Jordan.
Approximately 4.7 million people, or 73% of Jordan’s population resides in areas that were impacted by the drought.
Cropland in Jordan is concentrated in northwest which overlaps with some of the areas affected by drought.

Approximately 52% of cropland affected.
WHEAT AND BARLEY PRODUCTION

- Historical decrease in wheat and barley production
- Makes measuring the impact of drought challenging
WHEAT AND BARLEY PRODUCTION

- Not a clear relationship between barley and wheat production with drought severity
- 2008-2009 winter had a lower SPI than 2007-2008, but production and yield
CLIMATE CHANGE ANALYSIS

- Used publicly available downscaled climate change data from WorldClim
- Average of 6 Global Climate Models
- Focused on precipitation and temperature in January to identify conditions that could affect drought
- Current climate data 1960-1990 used as baseline

## Data Table

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<th>Purpose</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>2040-2060</td>
<td>Average January Precipitation</td>
<td>30 seconds</td>
<td>Measures average monthly precipitation under future climate conditions</td>
<td>WorldClim</td>
</tr>
<tr>
<td>Max Temperature</td>
<td>2040-2060</td>
<td>Average Max Temperature in January</td>
<td>30 seconds</td>
<td>Measures max monthly temperature under future climate conditions</td>
<td>WorldClim</td>
</tr>
<tr>
<td>Current Conditions</td>
<td>1960-1990</td>
<td>Current conditions data for max temp</td>
<td>30 seconds</td>
<td>Used for comparison with future climate conditions</td>
<td>WorldClim</td>
</tr>
</tbody>
</table>

### Model and Source

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<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCSM4</td>
<td>National Center for Atmospheric Research</td>
</tr>
<tr>
<td>CNRM-CM5</td>
<td>National Center for Meteorological Research</td>
</tr>
<tr>
<td>GFDL-CM3</td>
<td>Geophysical Fluids Dynamics Lab</td>
</tr>
<tr>
<td>HADGEM2-ES</td>
<td>Met Office Hadley Centre</td>
</tr>
<tr>
<td>GISS-E2-R</td>
<td>National Aeronautics and Space Administration - Goddard Institute for Space Studies</td>
</tr>
<tr>
<td>MRI-CGCM3</td>
<td>Meteorological Research Institute</td>
</tr>
</tbody>
</table>
PRECIPITATION CHANGE IN JANUARY

- Under low emission scenario, can expect to see an average decrease of 6-10% in precipitation in January.
- Under high emissions scenario, decrease will be closer to 16-20%.

Change in Average January Monthly Precipitation 1960-1990 to 2040-2060

Data Source: Worldclim.org
MAX TEMPERATURE CHANGE IN JANUARY

- Max temperatures in January will increase by 2 to 3 degrees Celsius.
- Current climate average max temperature in January is 21.2 degrees.
- Increase in 2 to 3 degrees is unlikely to have major effects.

Change in Max Temperature in January 1960-1990 to 2040-2060

Data Source: Worldclim.org
RESEARCH LIMITATIONS

• Composite drought index relies on satellite sensor data that is not available for long term historic analysis

• Unable to distinguish between rainfed and irrigated cropland

• Research doesn’t capture the effect of drought on groundwater resources
CONCLUSIONS

• Drought frequency and severity has increased
• Climate change data suggests that this trend is likely to continue
• Drought primarily affects northwest Jordan where majority of Jordan’s population and cropland are located.
• More difficult than expected to measure the relationship between drought and crop production.
FURTHER RESEARCH

• Examine why winter crop production was worse in 2008 than in 2009

• More granular analysis of cropland affected (i.e. rainfed vs irrigated, barley, wheat fields)

• Comparison study with impact in Syria
QUESTIONS?
REFERENCES


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