Evaluation of climate and land use changes on hydrologic processes in the Salt River Basin, Missouri, United States

Quang Phung\textsuperscript{a}, Thompson Allen\textsuperscript{a*}, Claire Baffaut\textsuperscript{b}, Christine Costello\textsuperscript{a}, John Sadler\textsuperscript{b}, Anthony Lupo\textsuperscript{c}, Bohumil M. Svoma\textsuperscript{c}, Sagar Gautam\textsuperscript{a}

\textsuperscript{a}Department of Bioengineering, University of Missouri, Columbia, MO 65211.
\textsuperscript{b}USDA–ARS, Cropping Systems and Water Quality Research Unit, Columbia, MO 65211
\textsuperscript{c}Department of Soil, Environmental and Atmospheric Sciences, University of Missouri, Columbia, MO 65211

*Corresponding author. E-mail: ThompsonA@missouri.edu  Tel: +1 (573) 882-4004
1. Introduction

- Around the world, many regions are struggling to effectively manage and allocate their freshwater.

- Competition and conflicts over water resource are rising among different sectors.

- Essential for regions with limited water supplies as water resources becoming scarcer.
2. Objective

Assess impacts of climate and land use changes on hydrologic processes and estimate future water availability of the Salt River Basin

- Projecting changes in land use and climate patterns
- Define scenarios
- Estimate changes with help from SWAT
3. Site Description

Salt River Basin:

- Located in Northeast Missouri
- Flows into the Mississippi River
- Total drainage area $6,417 \text{ km}^2$ at Mark Twain Lake outlet
- Predominant soil – high surface runoff and erosion potential
- Average annual precipitation of 1000 mm.
3. Site Description (cont.)

Original LU 2001

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Original %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1.8</td>
</tr>
<tr>
<td>Urban</td>
<td>5.2</td>
</tr>
<tr>
<td>Forest</td>
<td>15.3</td>
</tr>
<tr>
<td>Pasture</td>
<td>35.2</td>
</tr>
<tr>
<td>Agriculture</td>
<td>39.7</td>
</tr>
<tr>
<td>Wetland</td>
<td>2.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
3. Model Setup - Climate

Climate data
- Daily totals of precipitation,
- Daily means of maximum & minimum air temperature

- **Historical data:**
  Observed data (1965-2013) - Climate Data Online (CDO) system of NOAA’s National Climatic Data Center (NCDC)

- **Projected data:**
  Future climate data (2014-2060) - daily bias-correction and constructed analogs (BCCA) from Downscaled CMIP5 Climate Projections. Resolution about 12 km x 12 km
  Representative concentration pathway (RCP):
  - RCP 8.5
  - RCP 4.5
Climate Model

- Community Earth System Model (CESM) has been chosen

- We will be adding additional models to create an ensemble dataset
3. Model Setup – Climate (Cont.)

Quantile Mapping Result for Precipitation

*Precipitation (mm)*

![Graph showing annual precipitation for RCP 8.5 and RCP 4.5 CESM scenarios from 1965 to 2055. The blue line represents observation data, the orange dashed line represents simulated historical data, and the red dashed line represents simulated future data.](image)
3. Model Setup – Climate (Cont.)

Delta Method for Temperature

RCP 8.5 CESM
Annual Average Temperature

RCP 4.5 CESM
Annual Average Temperature
3. Model setup – Land Use

Landuse/Land Cover
Landuse map was obtained from Missouri Spatial Data Information Service for 2001 and 2011.

Project land use change

First Projection:
Forest land with less than 5% slope converted to agricultural land.
16% Increase in Agricultural Land

Second Projection:
Forest with less than 15% slope converted to agriculture land.
36% Increase in Agricultural Land

Third Projection:
Agriculture land with more than 5% slope will be converted back to forest
28% Decrease in Agricultural Land
3. Model Setup – Land Use (Cont.)

Original LU 2001

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Original</th>
<th>First Projection</th>
<th>Second Projection</th>
<th>Third Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>15.2</td>
<td>8.8</td>
<td>0.9</td>
<td>26.7</td>
</tr>
<tr>
<td>Agriculture</td>
<td>39.7</td>
<td>46.2</td>
<td>54.1</td>
<td>28.4</td>
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Legend

LUSwat
- WATR
- URBN
- FRST
- PAST
- AGRR
- WETL

16% Increase in Agr Land - 1st projection
36% Increase in Agr Land - 2nd projection
28% Decrease in Agr Land - 3rd projection
3. Model Setup – Other Parameters

**Digital Elevation Model (DEM)**
30 m (1 arc second) DEM - U.S. Geological Survey (USGS)

**Soils**
Soil Survey Geographic Database (SSURGO) - National Cooperative Soil Survey

**Slope**
5 slope classes

**HRU Threshold**
10% for land use
20% for soil
20% for slope
### 3. Model Setup - Scenarios

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<tr>
<td>Scenario 1</td>
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<tr>
<td>Scenario 2</td>
<td>RCP 8.5 CESM &amp; 16% Increase in Agriculture Land</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>RCP 8.5 CESM &amp; 36% Increase in Agriculture Land</td>
</tr>
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<td>RCP 4.5 CESM &amp; No Land Use Change</td>
</tr>
<tr>
<td>Scenario 5</td>
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</tr>
<tr>
<td>Scenario 6</td>
<td>RCP 4.5 CESM &amp; 28% Decrease in Agriculture Land</td>
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4. Results and Discussion

**Mean Annual Precipitation Change**

- RCP 8.5 CESM: 12%
- RCP 4.5 CESM: 7%

**Mean Maximum Temperature Change**

- RCP 8.5 CESM: 27°C
- RCP 4.5 CESM: 18°C

**Mean Minimum Temperature Change**

- RCP 8.5 CESM: 8°C
- RCP 4.5 CESM: 6°C
4. Results and Discussion (Cont.)

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- **Change in Surface Runoff**
  - Scenario 1: [Change Value]
  - Scenario 2: [Change Value]
  - Scenario 3: [Change Value]

- **Change in Water Yield**
  - Scenario 1: [Change Value]
  - Scenario 2: [Change Value]
  - Scenario 3: [Change Value]

- **Change in Groundwater Shallow Aquifer Flow**
  - Scenario 1: [Change Value]
  - Scenario 2: [Change Value]
  - Scenario 3: [Change Value]

- **Change in Sediment Yield**
  - Scenario 1: [Change Value]
  - Scenario 2: [Change Value]
  - Scenario 3: [Change Value]
4. Results and Discussion (Cont.)

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**Change in Water Yield**

**Change in Surface Runoff**

**Change in Groundwater Shallow Aquifer Flow**

**Change in Sediment Yield**
5. Conclusion

With the projection of climate and land use change for RCP 8.5 and RCP 4.5 for the CESM model

- Changes in climate and increase agriculture land
  - Increase in precipitation ~10%
  - More runoff, less groundwater flow
  - Increase in sediment yield

- Reforestation could help mitigate some of the effect from climate change
  - Reduce surface runoff
  - Reduce sediment yield

- Future Work
  - Include additional CMIP5 datasets for each RCP and generate SWAT output.
  - Refine land use scenarios and link them to future population scenarios.
  - Estimating water availability, and water allocation for future