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Objective

The major objective of the present research is

• To assess the climate change impact on long term water budget for Maitland catchment for 2071-2100 period using CanRCM4 climate model
Methodology

- Hydrological modeling using Soil and Water Assessment Tool (SWAT) 2012 is done for Maitland River catchment.
- Model is calibrated and validated using observed daily flows.
- Climate change impact assessment on catchment water budget is carried out.
- Canadian Regional Climate model (CanRCM4) nested in CanESM2 GCM for CORDEX NAM domain with 0.44° grid resolution is used.
Methodology

Climate change impact assessment process

1. Input data
2. Climate model simulation
3. Model output
4. Reading model output
5. Downscaling and Bias correction
6. Hydrological model simulation
7. Impact Assessment

- Climate modeling
- Role of climate scientist
- Climate change impact assessment study
Study Area

• Catchment located in south-western Ontario, Canada
Watershed Description

- Catchment Area: 2455 km²
- Elevation: 235m to 525m
- River: Maitland, ~150km length
- Tributaries: Middle Maitland, Little Maitland, South Maitland
- Outfall: Drains into Lake Huron ~El. 185m (at Goderich)
Watershed Description

- Annual average
  - rainfall : ~1100 mm
  - temperature : ~ 2.6°C (min) to 11.5°C (max.)
  - evapotransp. : ~ 550mm

- Land cover
  - Agriculture : 81%
  - Natural cover : 15%
  - Urban : 3%

- Soils
  - Harriston (silt loam) : 72%
  - Huron (silt loam) : 10%
  - Brookstone (clay) : 7%
Data Collection

- Climate Data – Environment Canada
Data Collection

- Landuse – South Ontario Landuse Resource Information System (SOLRIS)
- Soil – National Soil Data Base, Soil landscapes of Canada (slc)

![Map of land use and soil types](image)

Legend:
- **Agriculture**
- **Natural cover**

Locations:
- LISTOWEL
- BROOKSTON
- HARRISTON
- BURFORD
- DONNYBROOK
- HURON
- PIKE LAKE
- PERTH
Data Collection

- Observed daily flow data at Environment Canada’s 02FE015 gauging station is available from 1989-2013
- 1989 – 2001 data is used
Model Calibration

- Model performance statistics
  - Nash-Sutcliffe Efficiency (NSE)
    \[ \text{NSE} = 1 - \frac{\sum_{i}(Q_m - Q_s)^2}{\sum_{i}(Q_{m,i} - \overline{Q}_m)^2} \]
  - Coefficient of determination, \( R^2 \)
    \[ R^2 = \left[ \frac{\sum_{i}(Q_{m,i} - \overline{Q}_m)(Q_{s,i} - \overline{Q}_s))^2}{\sum_{i}(Q_{m,i} - \overline{Q}_m)^2 \sum_{i}(Q_{s,i} - \overline{Q}_s)^2} \right]^2 \]

where, \( Q_m \) – measured or observed discharge
\( Q_s \) – simulated discharge
Sensitivity Analysis

• Parameter sensitivity

- GWQMN.gw, CN2.mgt, ESCO.hru, GW_REVAP.gw
- SMTMP.bsn

• Most sensitive parameters

GWQMN.gw, CN2.mgt, ESCO.hru, GW_REVAP.gw
SMTMP.bsn
Model Calibration

- Annual water yield calibration
- 1989 - 1996

![Graph showing annual water yield calibration from 1989 to 1996 with observed and simulated water yield data. The graph includes a trend line with the equation \( y = 0.92x + 55.98 \) and an \( R^2 = 0.85 \).]
Model Calibration

- Monthly water yield calibration
- 1989 - 1996

\[ y = 0.64x + 18.95 \]
\[ R^2 = 0.68 \]
Model Calibration

- Daily flow calibration
- 1989 - 1996

\[ y = 0.97x + 5.15 \]
\[ R^2 = 0.41 \]

Daily stream flows
Model Validation

- Annual and monthly water yield calibration
- 1997 - 2001

![Graph showing annual water yield calibration with equation $y = 0.98x + 29.40$, $R^2 = 0.82$.]

![Graph showing monthly water yield calibration with equation $y = 0.73x + 11.56$, $R^2 = 0.77$.]
Model Validation

Daily stream flows

\[ y = 1.09x + 2.60 \]

\[ R^2 = 0.57 \]
Climate Change Impact Assessment Study

- Weather input data for SWAT has been extracted from the climate model outputs
- Climate Model : CanRCM4
- Parent GCM : CanESM2
- Grid resolution : 0.44 deg ~ 50 km
- CORDEX Domain : NAM (North America)
- Modeling Agency : Canadian Center for Climate Modeling and Analysis (CCCma)
- Experiments : Historical r1i1p1 (1971-2000) - Baseline
  : RCP 4.5 r1i1p1 (2071-2100) - Future

- Land use pattern is considered same for the future scenario
Climate model – Salient Features

CORDEX NAM-44 Grid over Maitland Catchment

Legend
(11.00°, - 2.2°) : (rlat, rlon)
[44.21°N, 81.57°W] : (Lat, Lon)
- : Grid point
- : Climate station
Climate Change Study - Inputs

- Comparison of observed and baseline period precipitation

- Bias in the two precipitations is removed using Bias correction factor
Climate Change Study – Bias Correction

• Bias correction factor for precipitation

\[ \delta_m = \frac{\sum_{i=1}^{n} P_{\text{Obs},i}}{\sum_{i=1}^{n} P_{\text{RCM},i}} \]

where, \( P_{\text{RCM}} \) – model precipitation in base period
\( P_{\text{obs}} \) – observed precipitation in base period

• Bias correction factor for minimum and maximum temperature

\[ \delta_m = \frac{1}{n} \sum_{i=1}^{n} T_{\text{Obs},i} - \frac{1}{n} \sum_{i=1}^{n} T_{\text{RCM},i} \]

where, \( P_{\text{RCM}} \) – model temperature in base period
\( P_{\text{obs}} \) – observed temperature in base period
\( n \) – no. of years in base period

• Monthly bias correction factor are computed
Climate Change Study - Bias Correction

- Bias correction factor for precipitation

![Graph showing bias correction factor for different locations over the year. Each location has a line representing its bias factor. The x-axis represents the months from January to December, and the y-axis represents the bias factor ranging from 0.0 to 2.4. The locations include Goderich, Blyth, Wroxeter, Newton, and MtForest. The graph shows variations in bias factors across different months and locations.]
Climate Change Study - Inputs

- Comparison of average monthly minimum temperature

Baseline

Future scenario RCP 4.5
Climate Change Study - Inputs

• Comparison of average monthly maximum temperature

Baseline

Future scenario RCP 4.5
SWAT Model Results

- Monthly precipitation

- Variation in precipitation in different periods:
  - Winter (Oct-Feb) - increase by **17%**
  - Spring (Mar-May) – decrease by **3%**
  - Summer (Jun-Sep) – decrease by **10%**
SWAT Model Results

- Monthly Evapotranspiration (ET)

Variation in ET in different periods:
- Winter (Oct-Feb) - increase by 96%
- Spring (Mar-May) – increase by 86%
- Summer (Jun-Sep) – decrease by 3%
- Peak ET shifts by 1-2 month
SWAT Model Results

• Monthly total water yield

• Variation in total water yield in different periods:
  Winter (Oct-Feb) – increase by 28%
  Spring (Mar-May) – decrease by 28%
  Summer (Jun-Sep) – decrease by 50%
SWAT Model Results

- Variation in water budget w.r.t Baseline period (% change)

<table>
<thead>
<tr>
<th>Period</th>
<th>Precipitation</th>
<th>ET</th>
<th>Surface Water</th>
<th>Ground Water</th>
<th>Water Yield</th>
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</thead>
<tbody>
<tr>
<td>All year</td>
<td>2.4</td>
<td>16.8</td>
<td>-33.6</td>
<td>15.0</td>
<td>-10.3</td>
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<tr>
<td>Winter (Oct-Feb)</td>
<td>17.0</td>
<td>96.2</td>
<td>13.4</td>
<td>55.6</td>
<td>28.4</td>
</tr>
<tr>
<td>Spring (Mar-Apr)</td>
<td>-2.9</td>
<td>86.9</td>
<td>-51.4</td>
<td>44.1</td>
<td>-28.3</td>
</tr>
<tr>
<td>Summer (May-Sep)</td>
<td>-10.6</td>
<td>-2.6</td>
<td>-31.9</td>
<td>-70.5</td>
<td>-50.0</td>
</tr>
</tbody>
</table>

- Overall water yield of the watershed reduces
- Winter period shows increase in water yield
- Spring period shows equal decrease in water yield
- Summer period has significant reduction in water yield
Conclusions and Future Work

• SWAT hydrological model for Maitland catchment when forced with CanRCM4 climate model result, predicts:
  - Severely strained summer months with ~50% reduced water availability w.r.t. baseline
  - Considerably reduced surface water yield during spring period
  - Peak evapotranspiration (ET) is advanced by a month period with increased peak

• Change in hydrological regime has strong implications to agriculture

Future Work

• We proposed to perform SWAT simulation using ensemble of climate model outputs
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