2015 SWAT CONFERENCE, PURDUE

Climate Change Impact Assessment on Long Term Water Budget for Maitland Catchment in Southern Ontario

By

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Contents

Objective

The major objective of the present research is

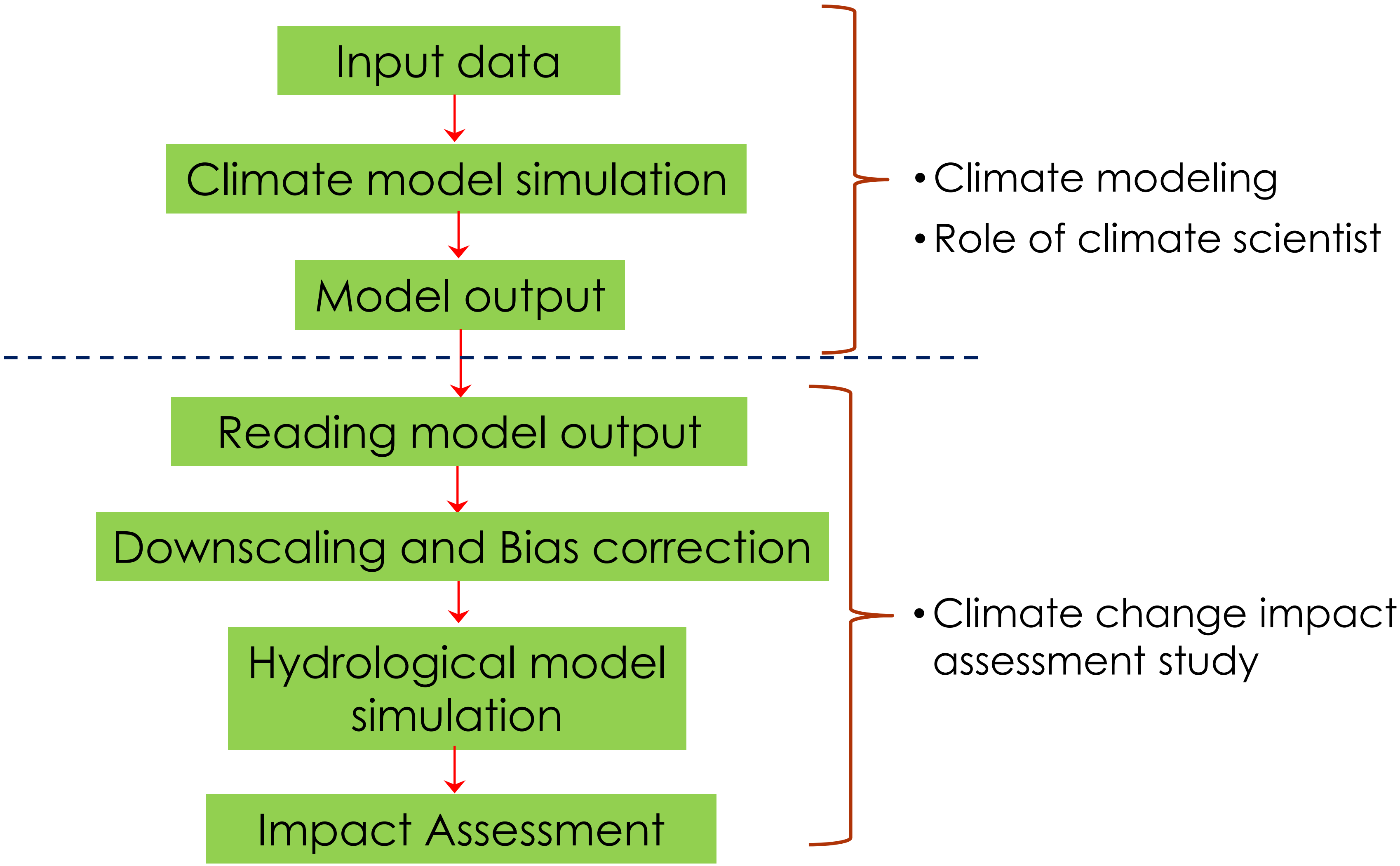
- To assess the climate change impact on long term water budget for Maitland catchment for 2071-2100 period using CanRCM4 climate model

Methodology

- Hydrological modeling using **S**oil and **W**ater **A**ssessment **T**ool (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 0.44^0 grid resolution is used

Methodology

Climate change impact assessment process

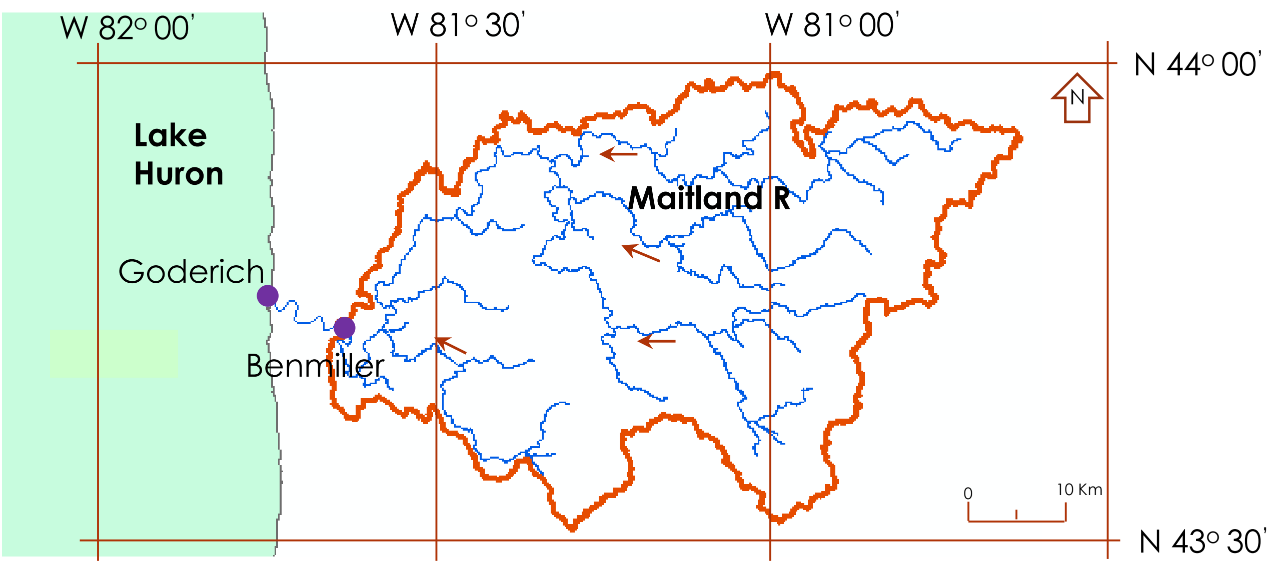


Study Area

- Catchment located in south-western Ontario, Canada

Watershed Description

- Catchment Area : 2455 km^2
- Elevation : 235m to 525m
- River : Maitland, ~150km length
- Tributaries : Middle Maitland, Little Maitland, South Maitland
- Outfall : Drains into Lake Huron ~El. 185m (at Goderich)

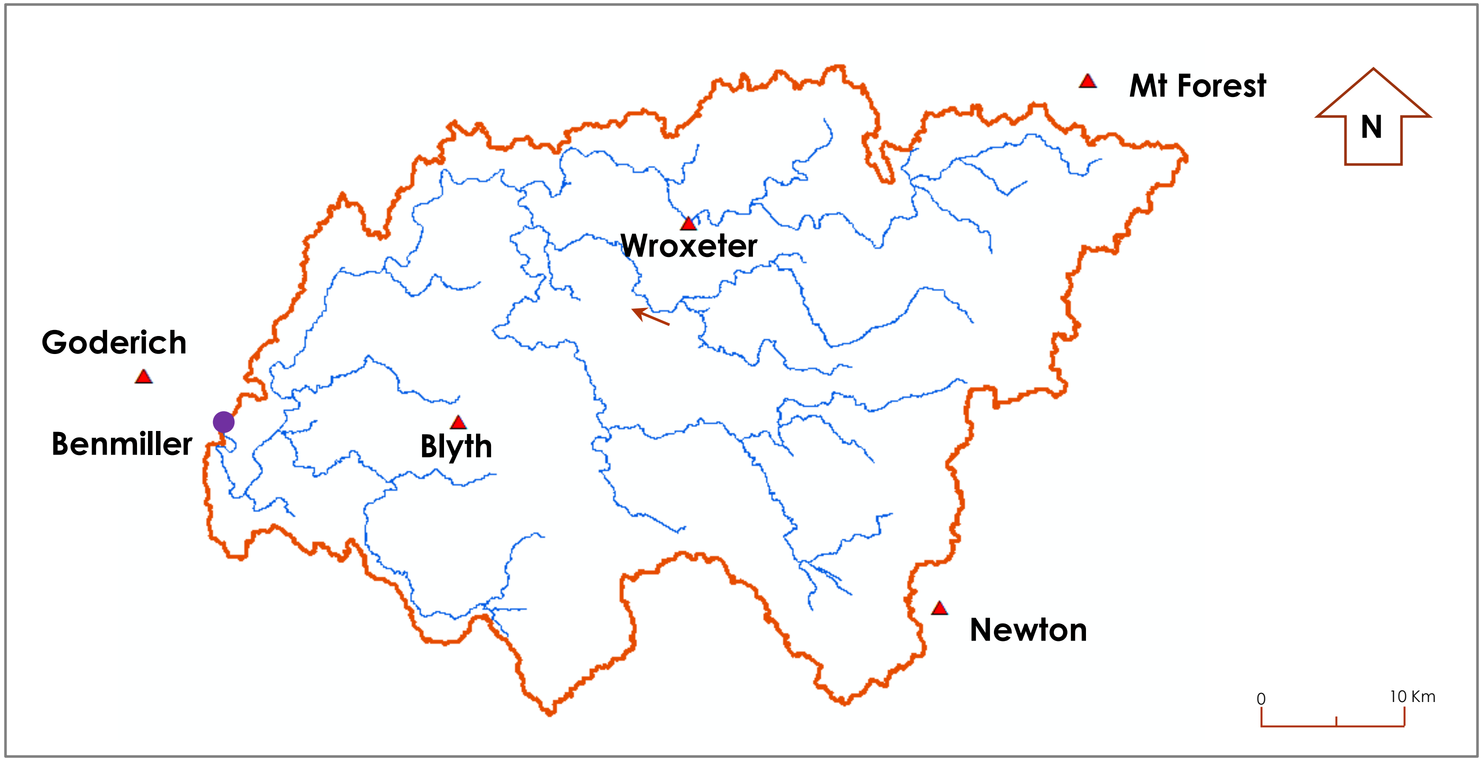


Watershed Description

- Annual average
  - rainfall : ~1100 mm
  - temperature : ~ 2.6°C (min) to11.5°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%

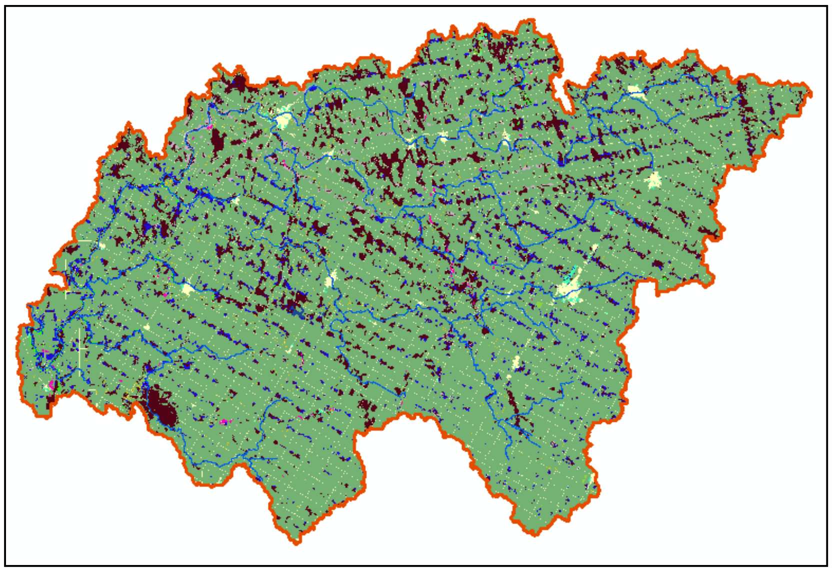
Data Collection

- Climate Data – Environment Canada
- 5 climate station (1970-2015)
- Flow data at Benmiller (1989 – 2013)



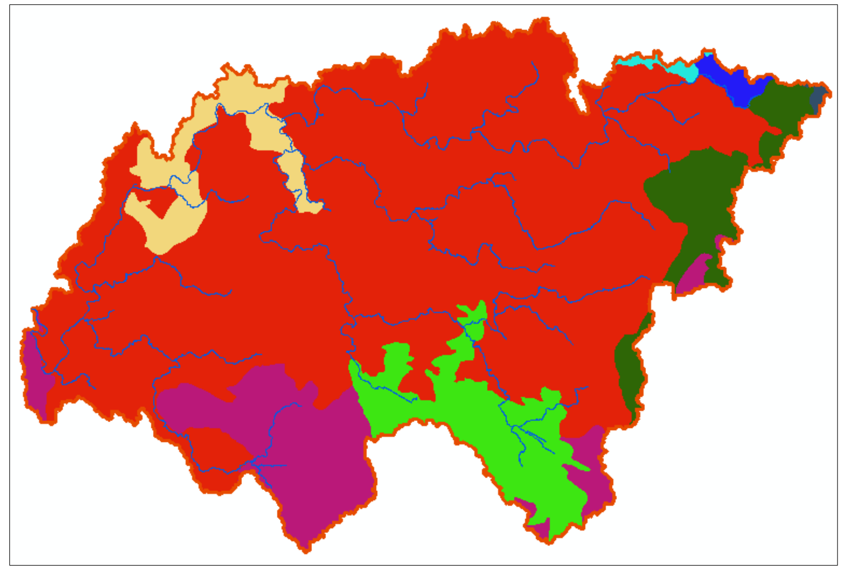
Data Collection

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



Land use

Agriculture
Natural cover

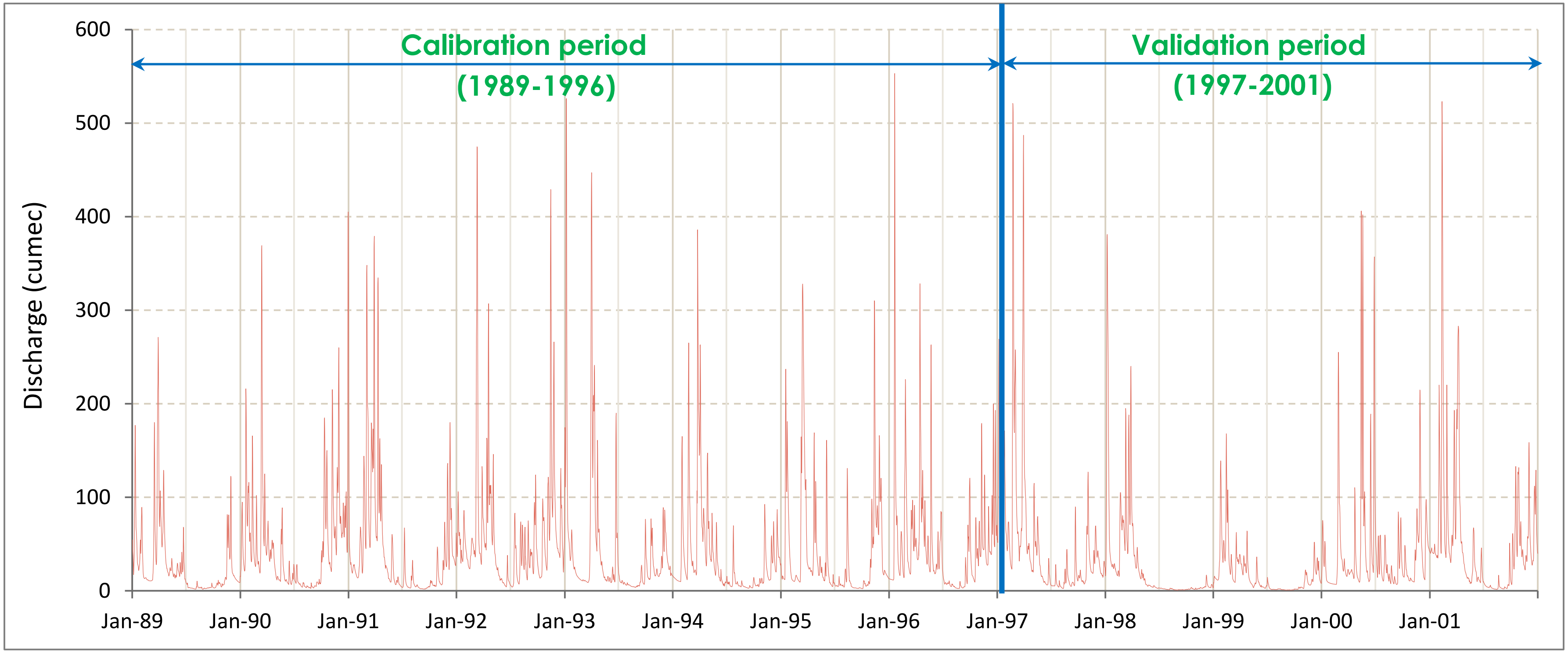


Soil types

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)

$$NSE = 1 - \frac{\sum_i (Q_m - Q_s)_i^2}{\sum_i (Q_{m,i} - \overline{Q}_m)^2}$$

  - Coefficient of determination, R^2

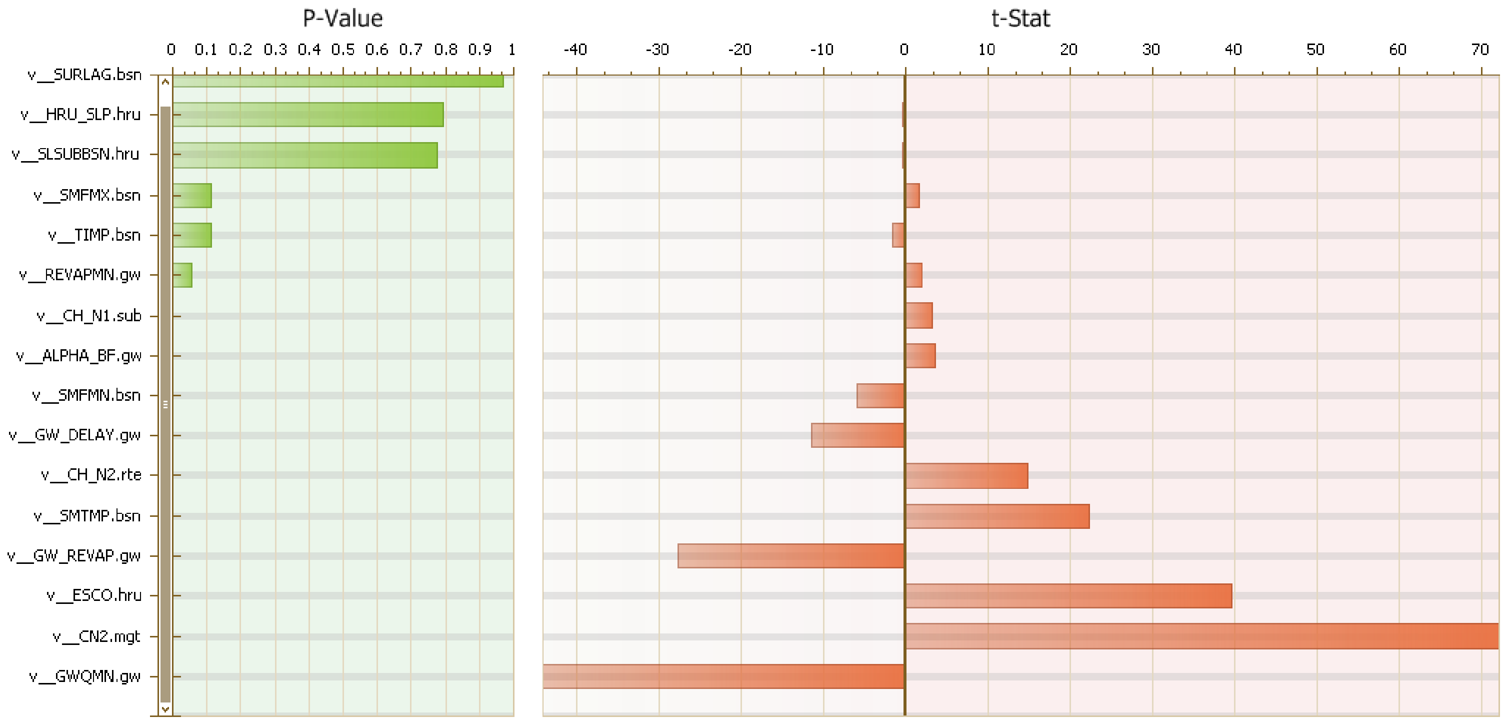
$$R^2 = \frac{\left[\sum_i (Q_{m,i} - \overline{Q}_m)(Q_{s,i} - \overline{Q}_s)\right]^2}{\sum_i (Q_{m,i} - \overline{Q}_m)^2 \sum_i (Q_{s,i} - \overline{Q}_s)^2}$$

where, Q_m – measured or observed discharge

Q_s – simulated discharge

Sensitivity Analysis

- Parameter sensitivity

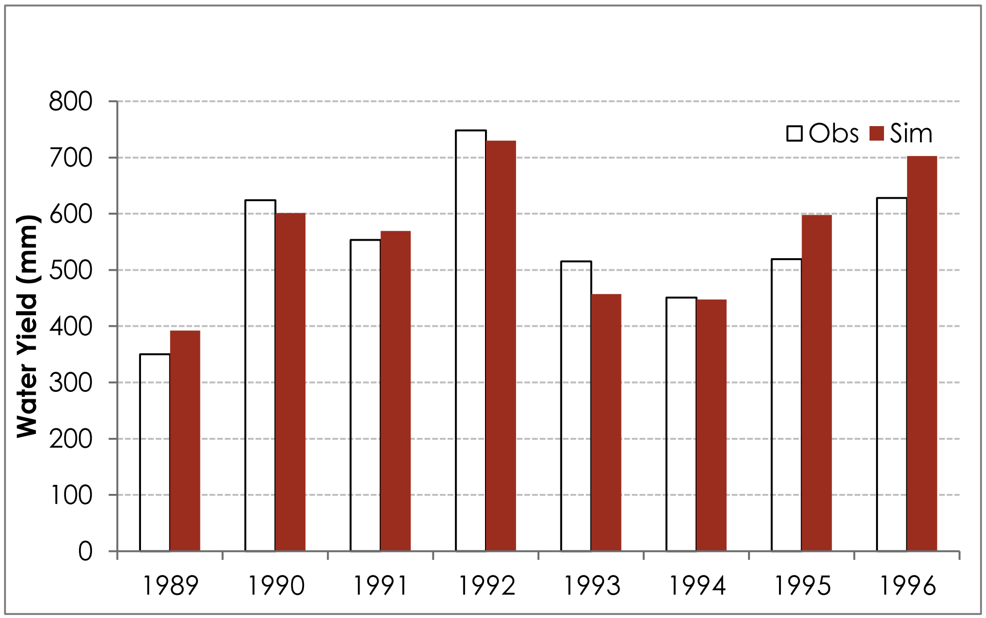


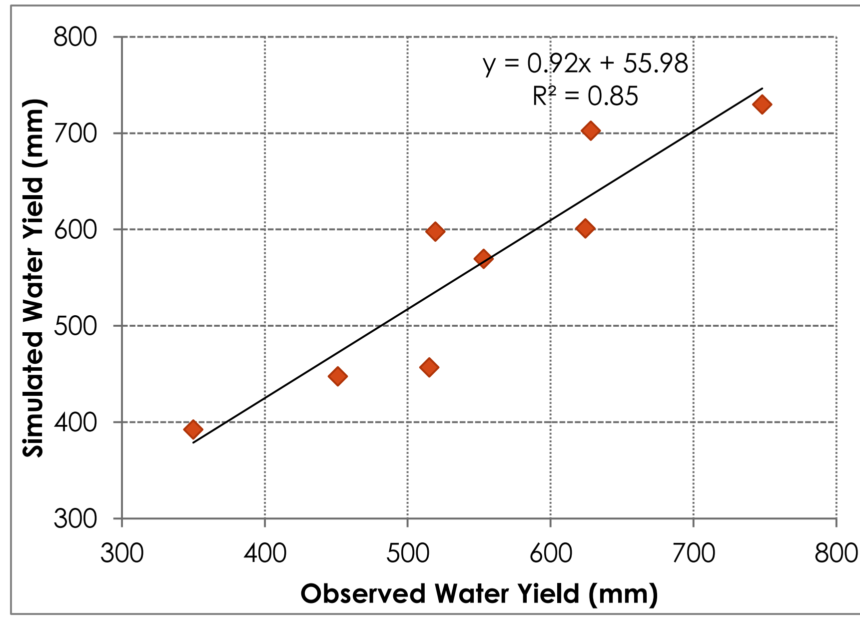
- Most sensitive parameters

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

Model Calibration

- Annual water yield calibration
- 1989 - 1996

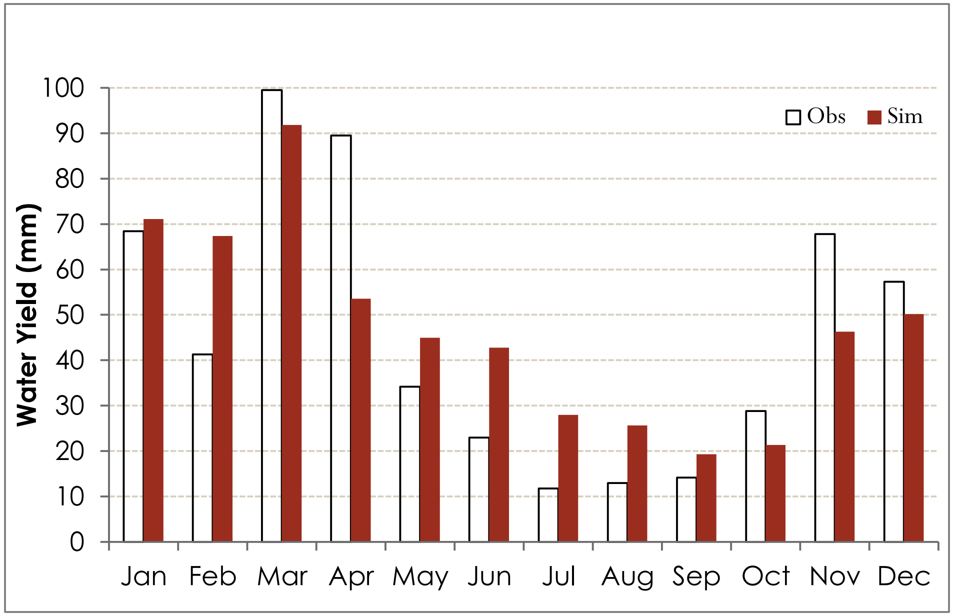


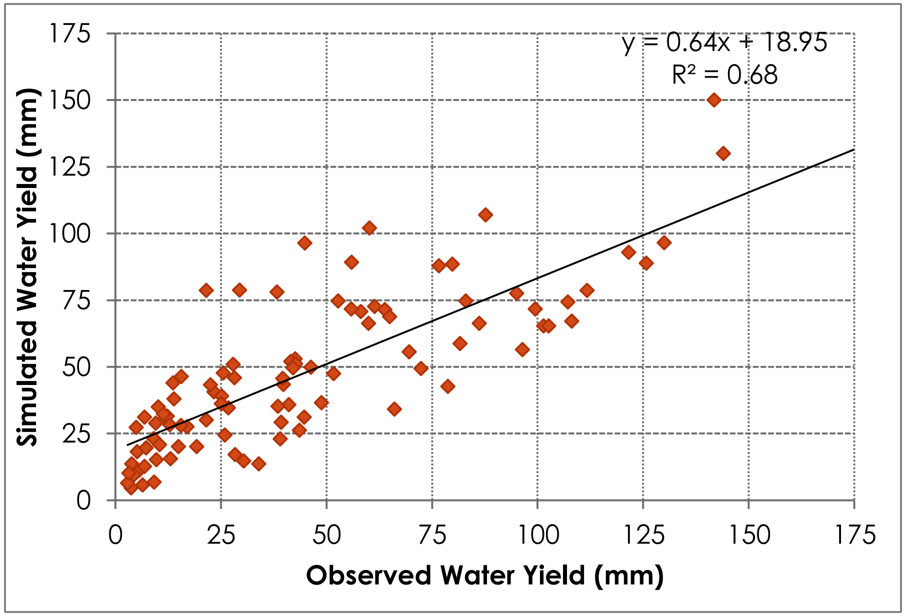


Annual Water Yield

Model Calibration

- Monthly water yield calibration
- 1989 - 1996

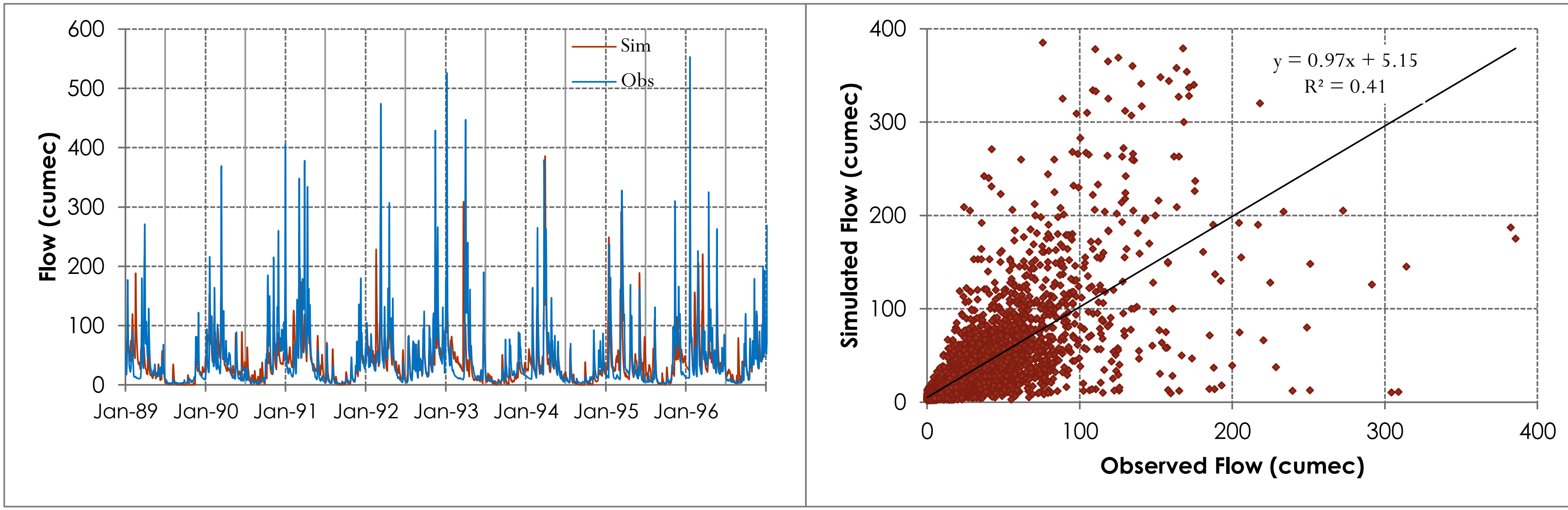




Monthly Water Yield

Model Calibration

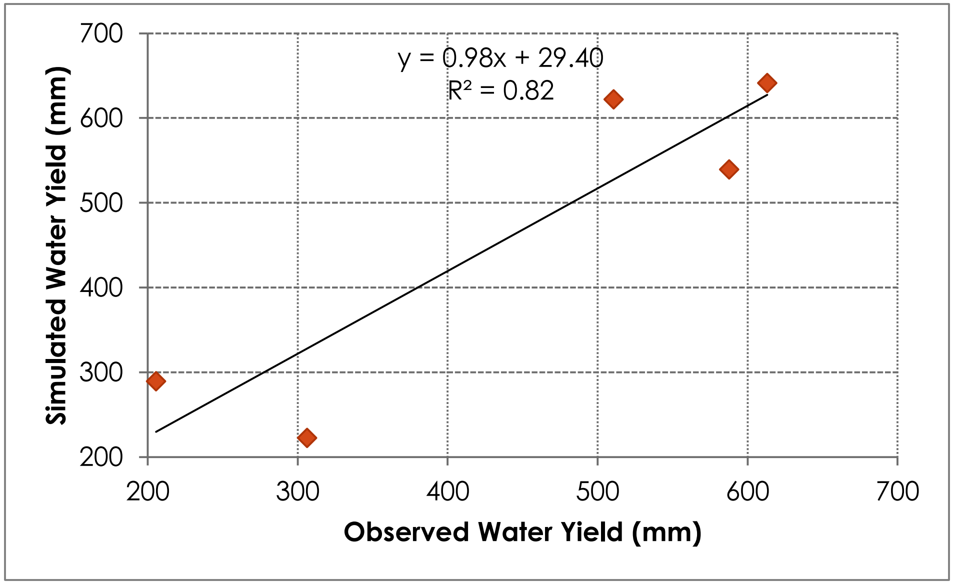
- Daily flow calibration
- 1989 - 1996

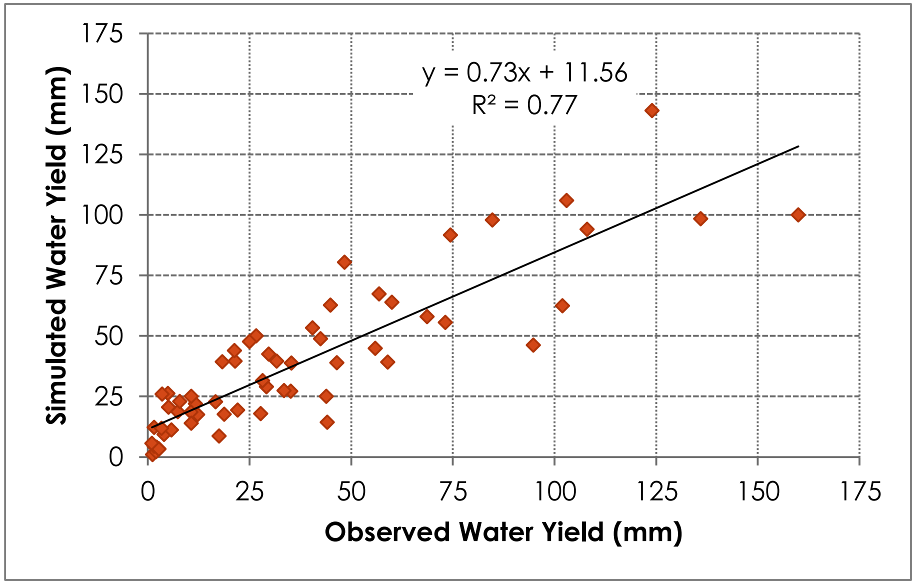


Daily stream flows

Model Validation

- Annual and monthly water yield calibration
- 1997 - 2001

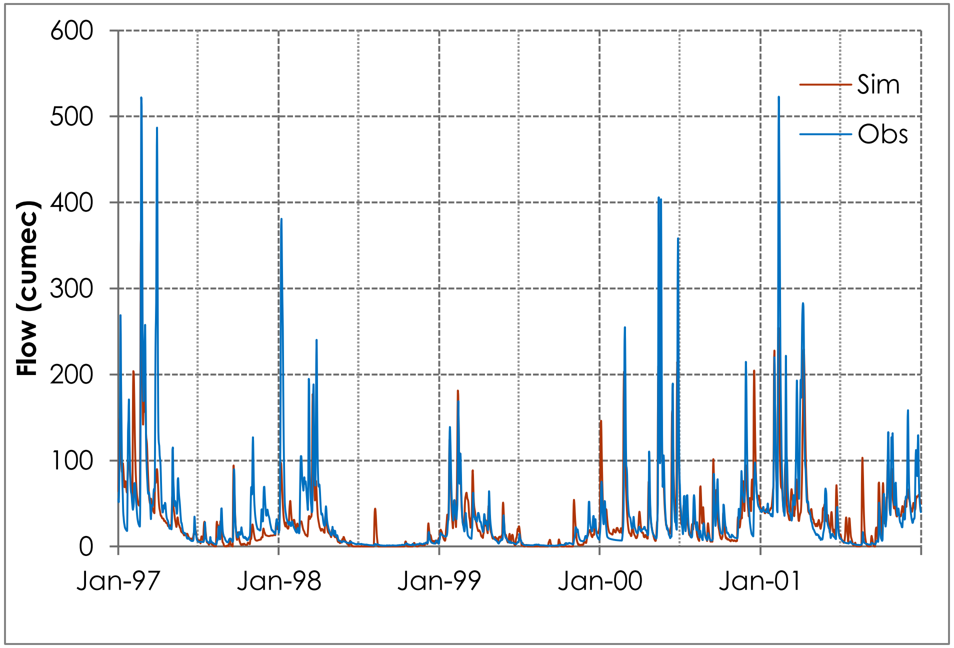


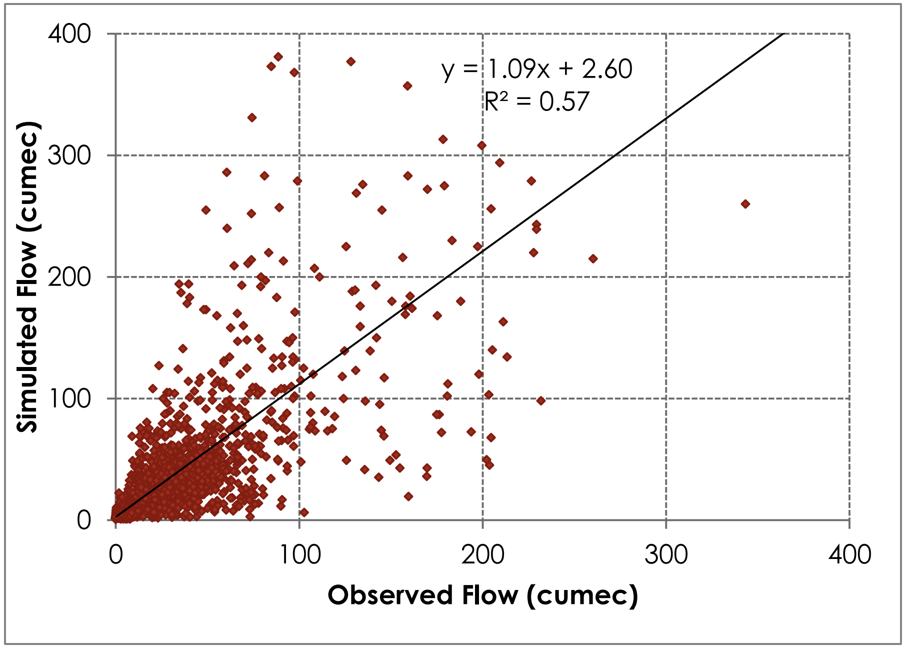


Annual Water Yield

Monthly Water Yield

Model Validation





Daily stream flows

Climate Change Impact Assessment Study

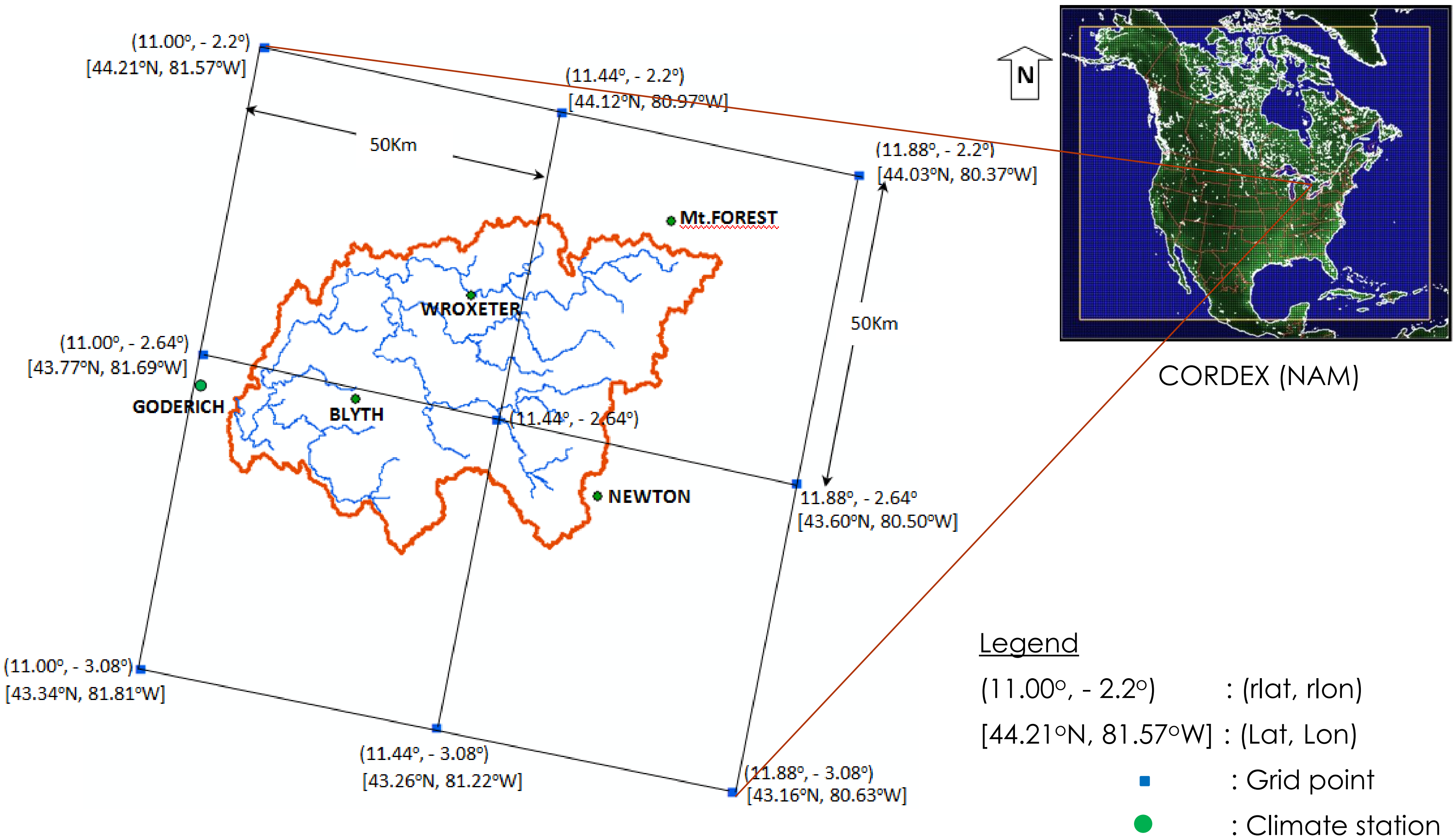
- Weather input data for SWAT has been extracted from the climate model outputs
- Climate Model : CanRCM4
- Parent GCM : CanESM2
- Grid resolution : 0.44 deg ~ 50 km
- CORDEX Domain : NAM (North America)
- Modeling Agency : Canadian Center for Climate Modeling and Analysis (CCCma)
- Experiments : Historical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

  : RCP 4.5 r1i1p1 (2071-2100) - Future

- Land use pattern is considered same for the future scenario

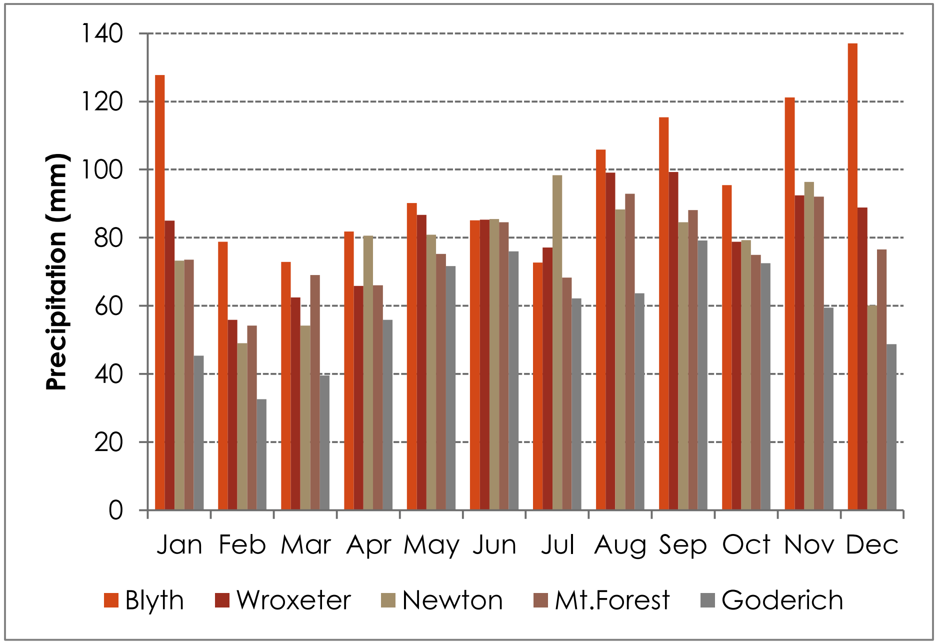
Climate model – Salient Features

CORDEX NAM-44 Grid over Maitland Catchment

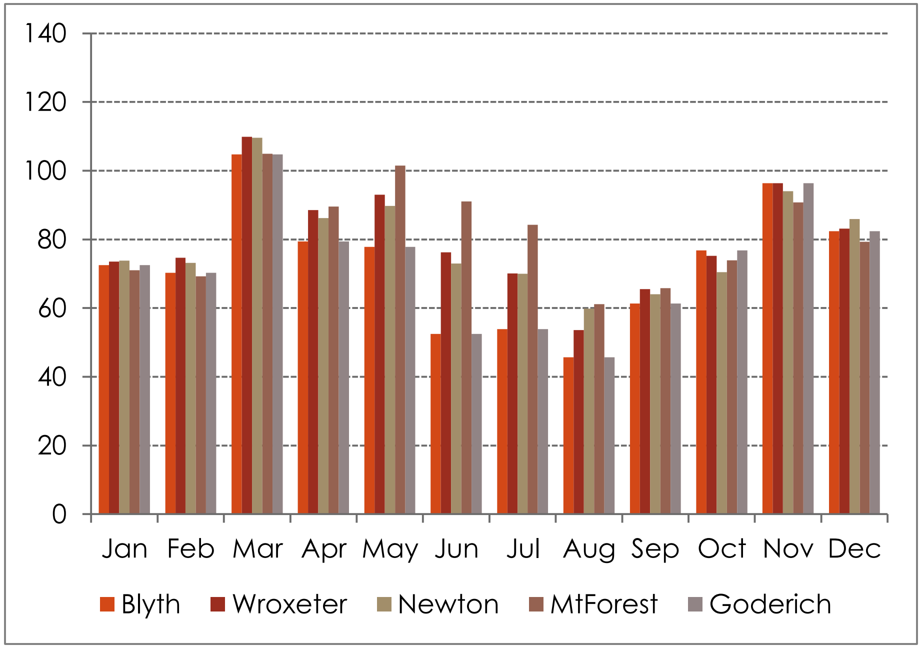


Climate Change Study - Inputs

- Comparison of observed and baseline period precipitation



Observed data



Model baseline data

- Bias in the two precipitations is removed using Bias correction factor

Climate Change Study – Bias Correction

- Bias correction factor for precipitation

$$\delta_m = \frac{\sum_{i=1}^{n} P_{Obs,i}}{\sum_{i=1}^{n} P_{RCM,i}}$$

where, P_{RCM} – model precipitation in base period

P_{obs} – observed precipitation in base period

- Bias correction factor for minimum and maximum temperature

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

where, P_{RCM} – model temperature in base period

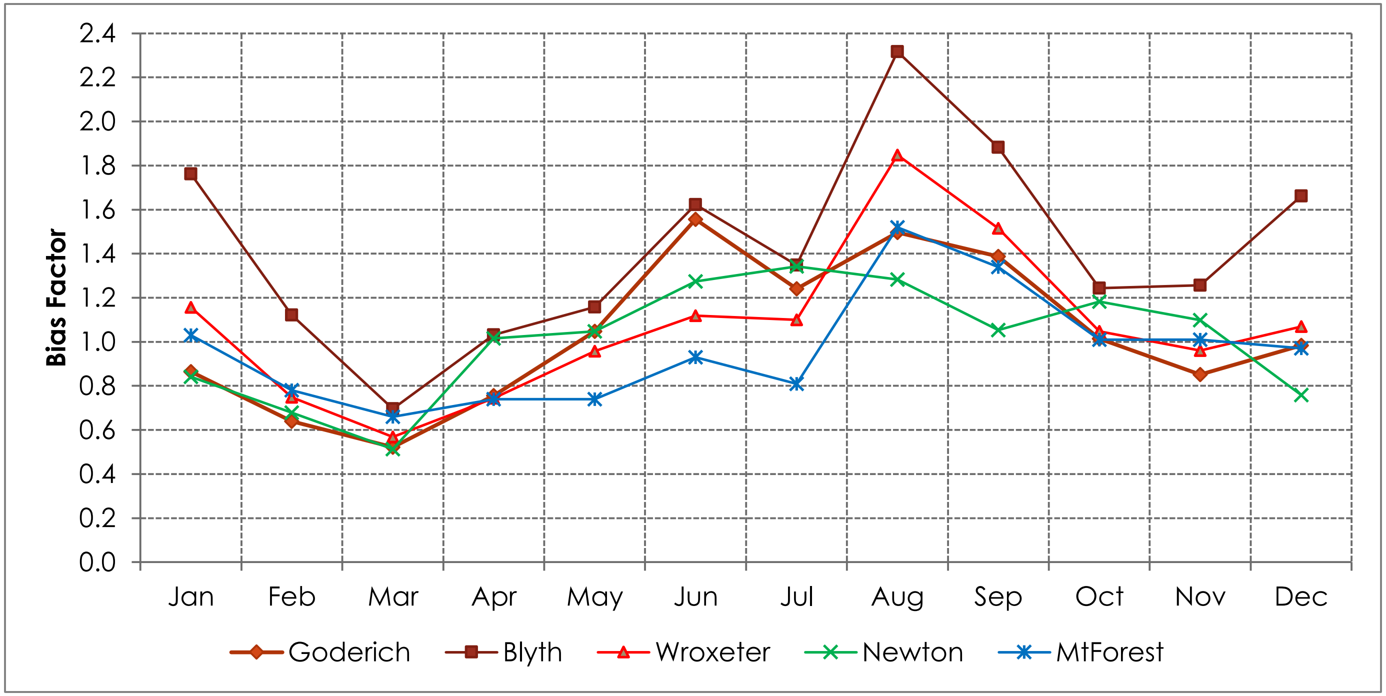
P_{obs} – observed temperature in base period

n – no. of years in base period

- Monthly bias correction factor are computed

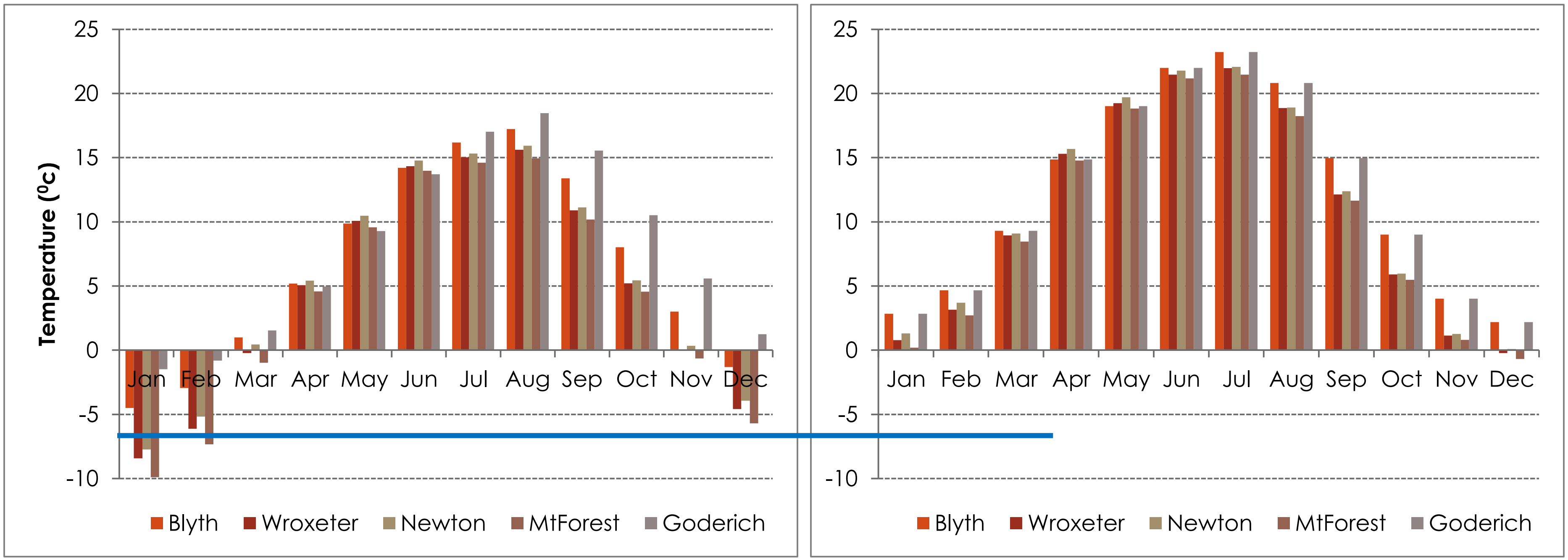
Climate Change Study - Bias Correction

- Bias correction factor for precipitation



Climate Change Study - Inputs

- Comparison of average monthly minimum temperature

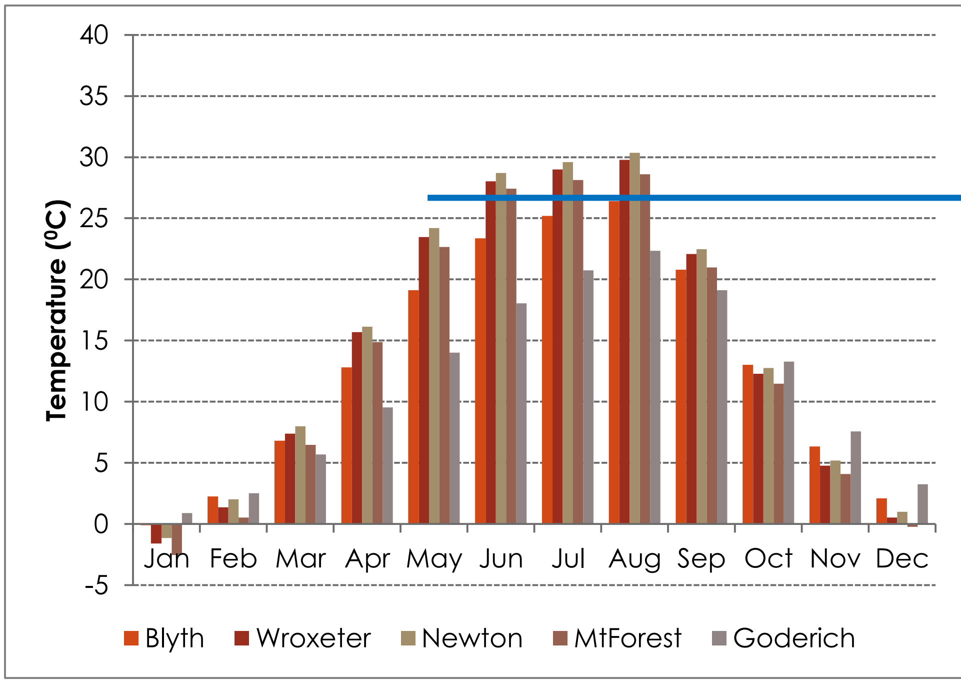


Baseline

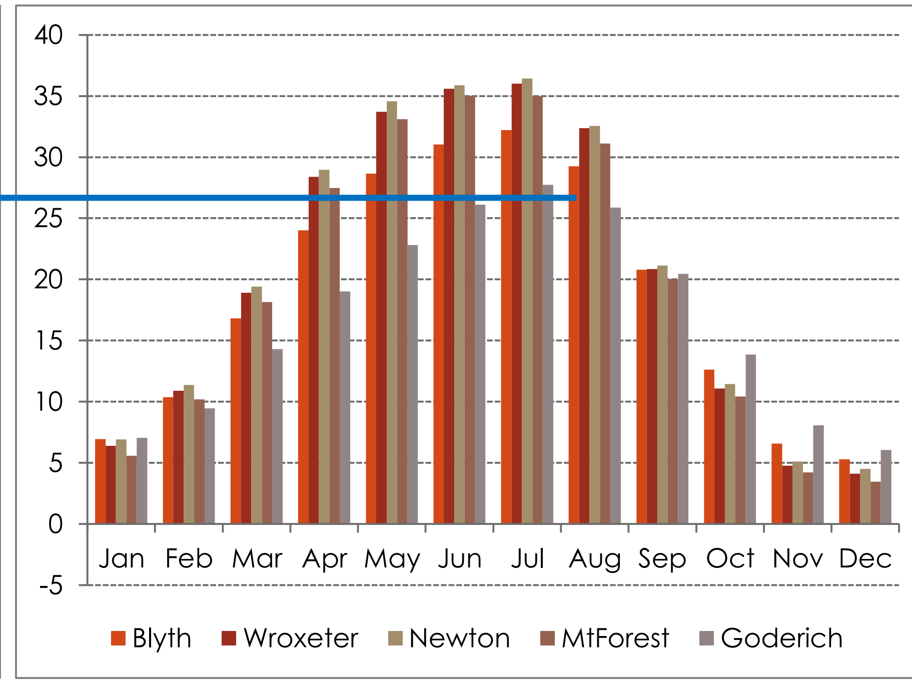
Future scenario RCP 4.5

Climate Change Study - Inputs

- Comparison of average monthly maximum temperature



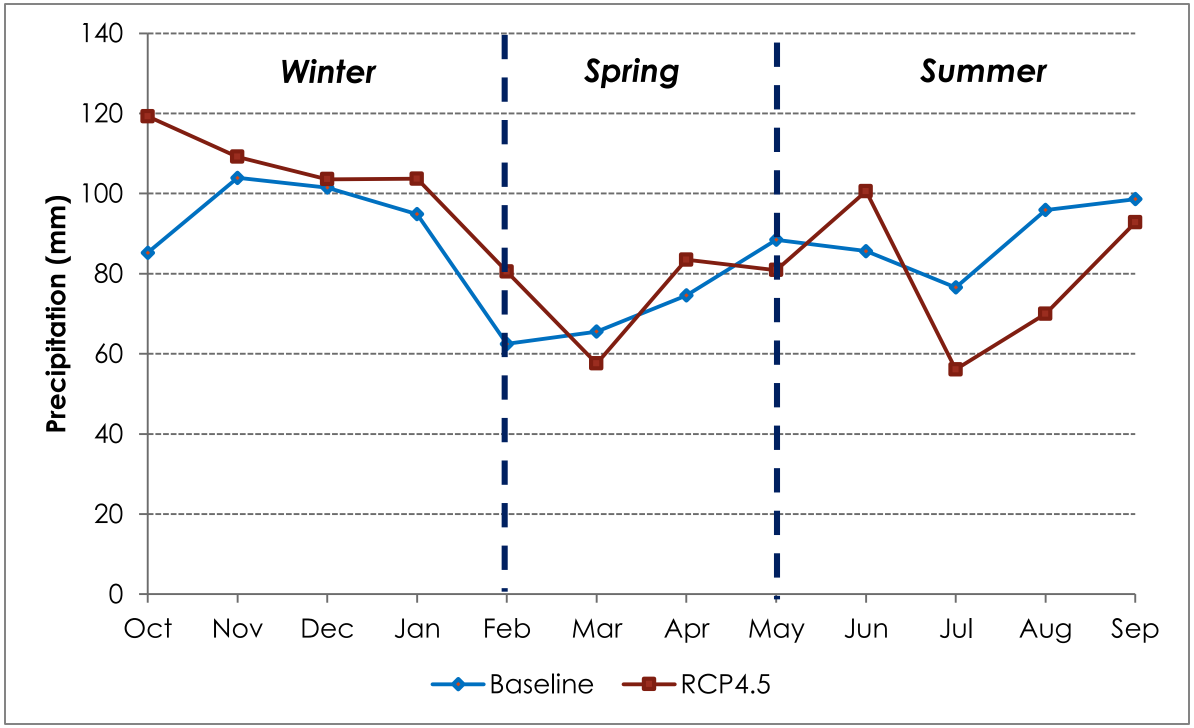
Baseline



Future scenario RCP 4.5

SWAT Model Results

- Monthly precipitation



- Variation in precipitation in different periods:

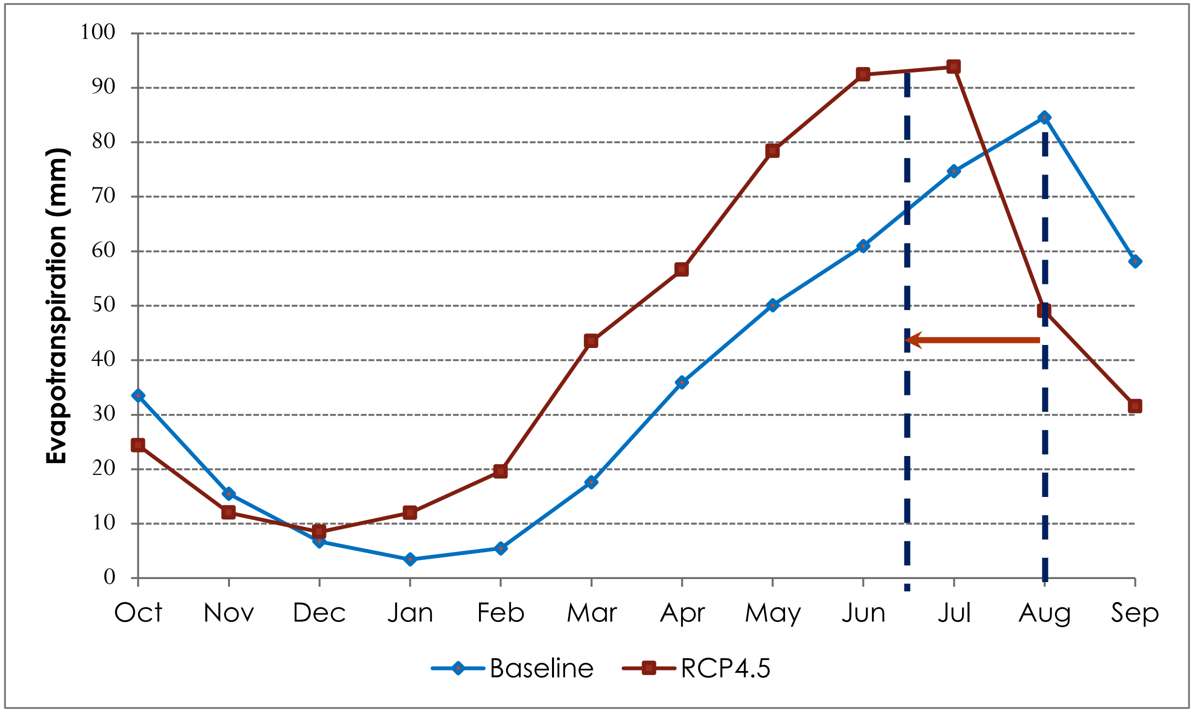
  Winter (Oct-Feb) - increase by **17%**

  Spring (Mar-May) – decrease by **3%**

  Summer (Jun-Sep) – decrease by **10%**

SWAT Model Results

- Monthly Evapotranpiration (ET)



- Variation in ET in different periods:

  Winter (Oct-Feb) - increase by **96%**

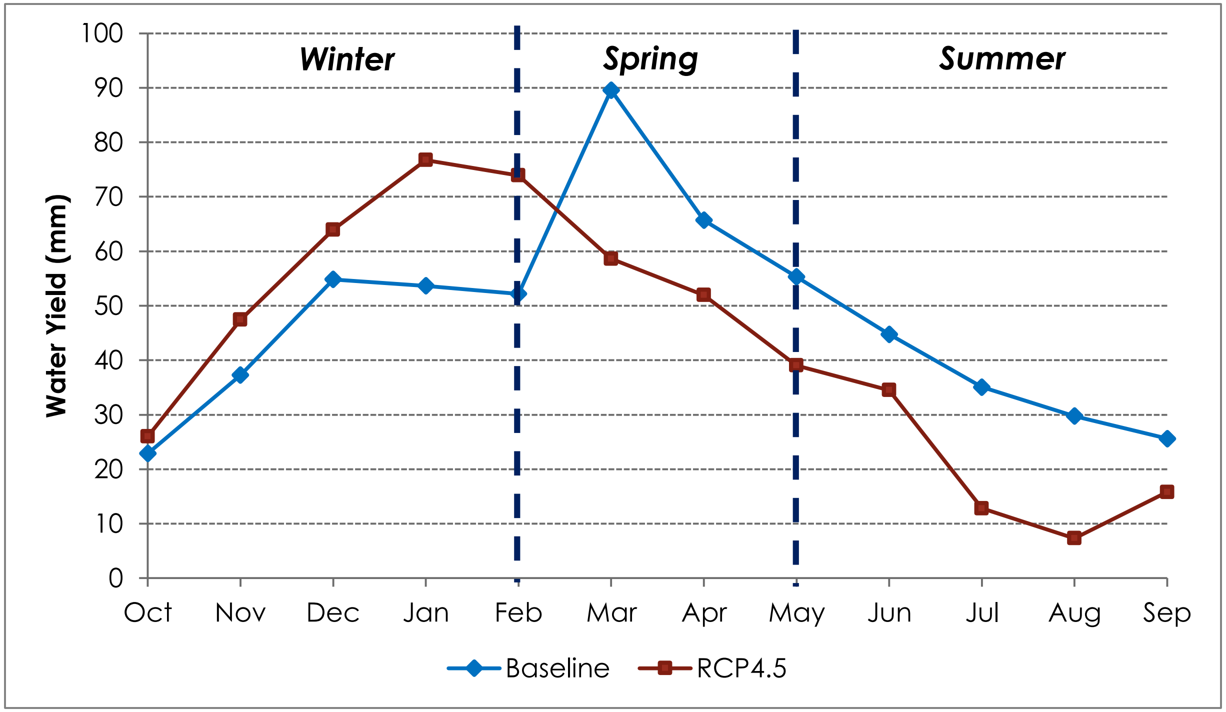
  Spring (Mar-May) – increase by **86%**

  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)

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

- 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

Acknowledgements

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  University of Windsor

THANKYOU