The Impact of Climate Change on Streamflow in a Boreal Watershed: A Case Study of the Upper Humber River Watershed in Newfoundland, Canada.

Kamal Ziaul Islam

Transdisciplinary Sustainability(TRSU) doctoral candidate

Grenfell Campus, Memorial University of Newfoundland & Labrador

Email: kzislam@grenfell.mun.ca

Canada - climate change impacts

Reduced reliability of ice roads threatens access to northern communities and remote mine sites

Reduced sea ice cover affects traditional ways of life and economic development

Degrading permafrost affects infrastructure

Ecosystem changes in species distribution affecting country food supply and species at risk

Increased pest (e.g. pine beetle) and fire activity threaten wildlife

Increased frequency of drought affects agriculture and forests

Sea level rise and increased coastal erosion affecting coastal communities, property value, and insurance

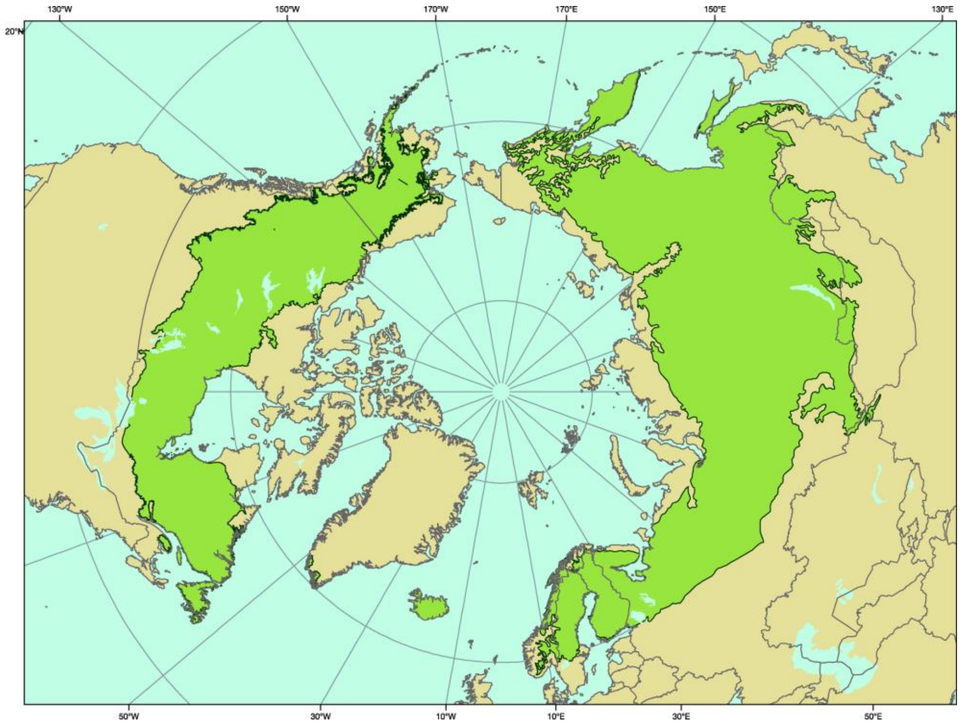
Reduced glacier cover and precipitation affecting hydro electric power resources

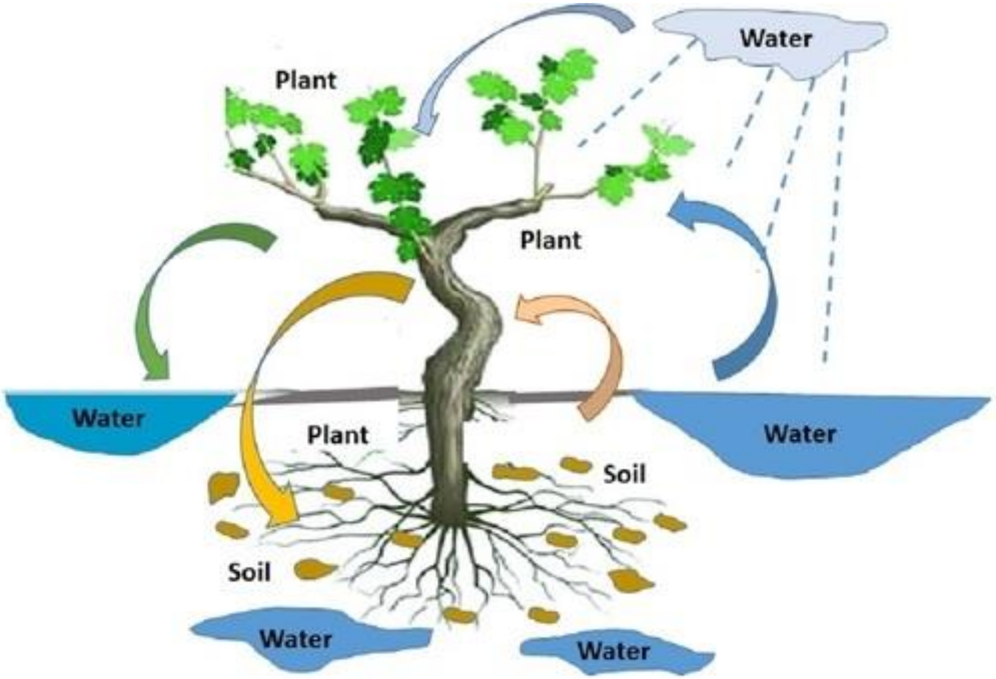
Heat stress and vector-borne diseases cause health issues

Introduction

Concerns over the impact of environmental change on the boreal ecosystem.

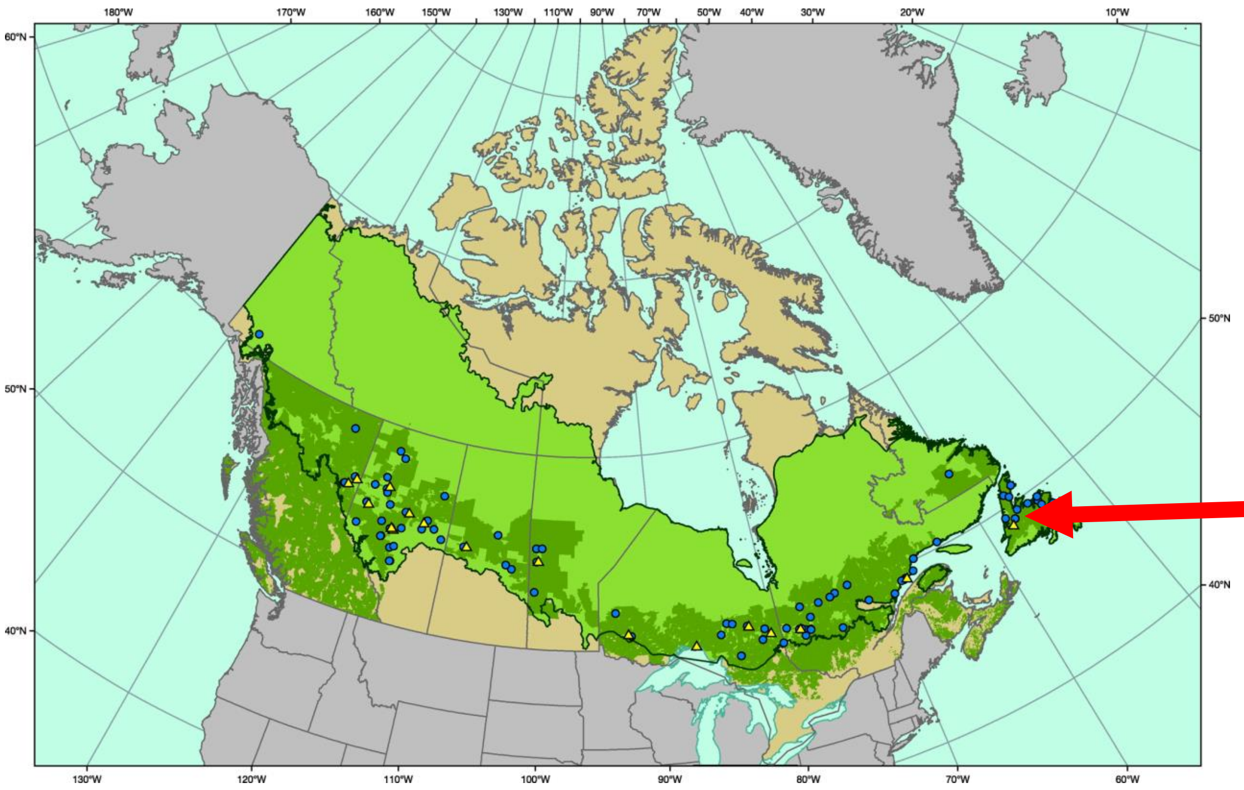
Variations in hydrological processes affecting agriculture, land, and water resources.

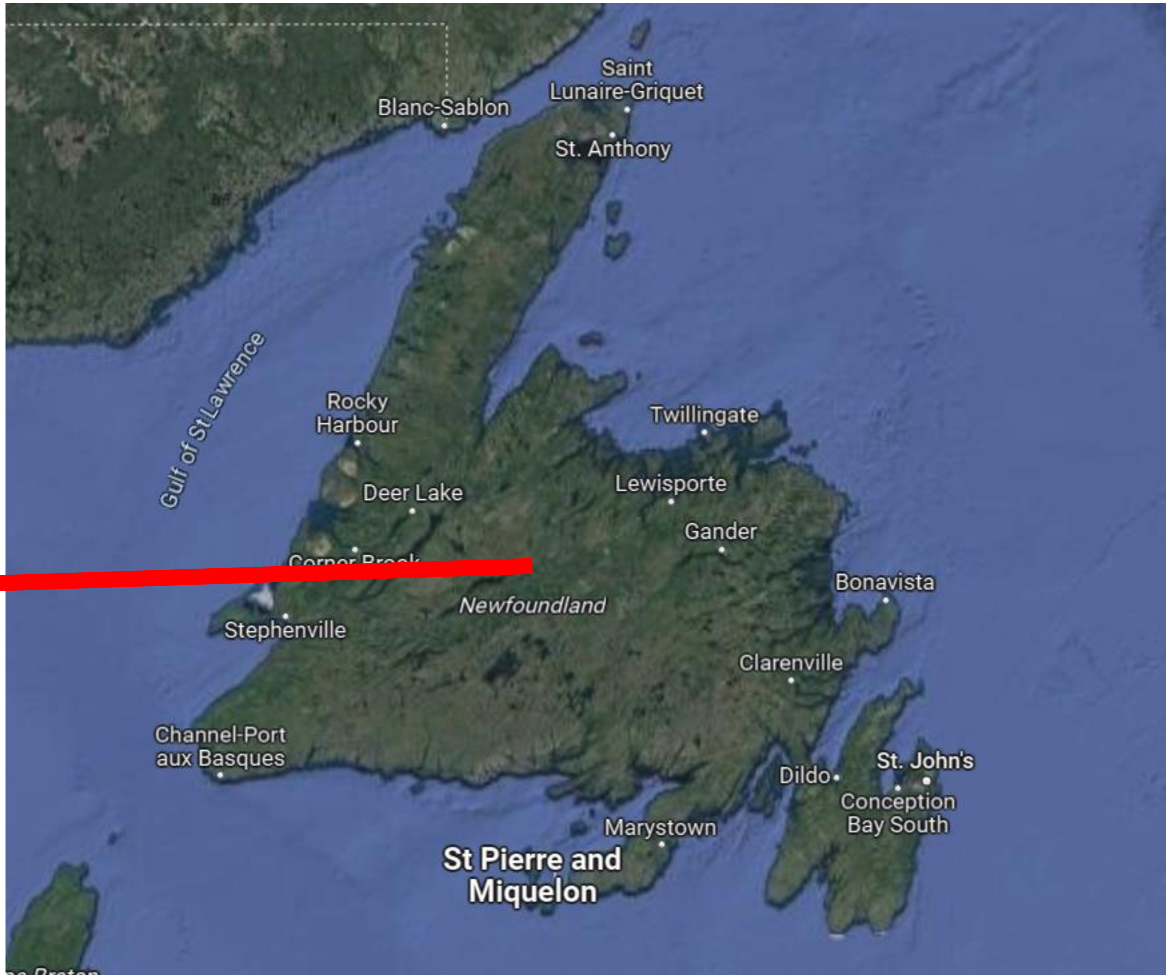




(Brandt et al., 2013; Shrestha et al., 2017; Wells et al., 2020).

Climate Change impacts on hydrological processes leading to water excess or scarcity. Significant challenges to sustainable management in Western Newfoundland.

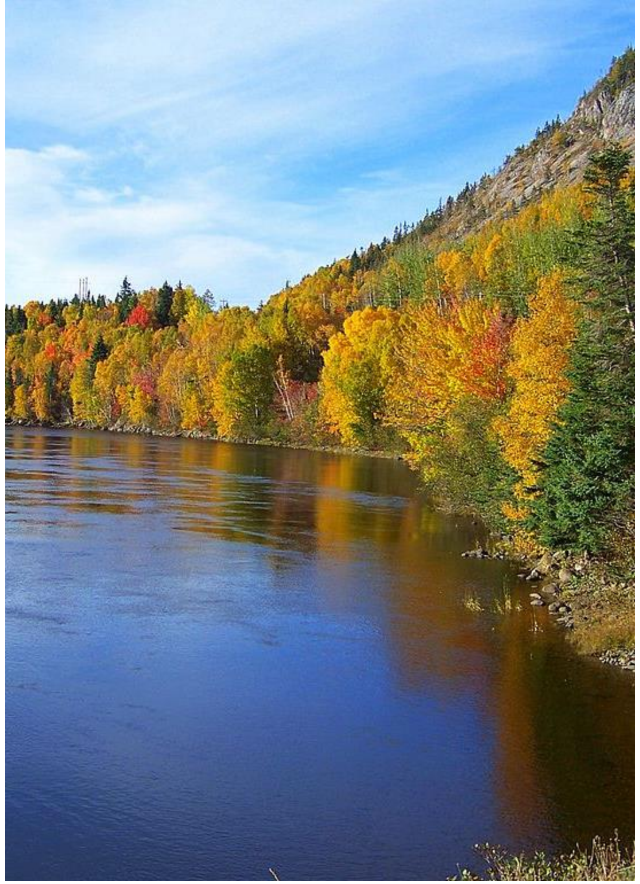


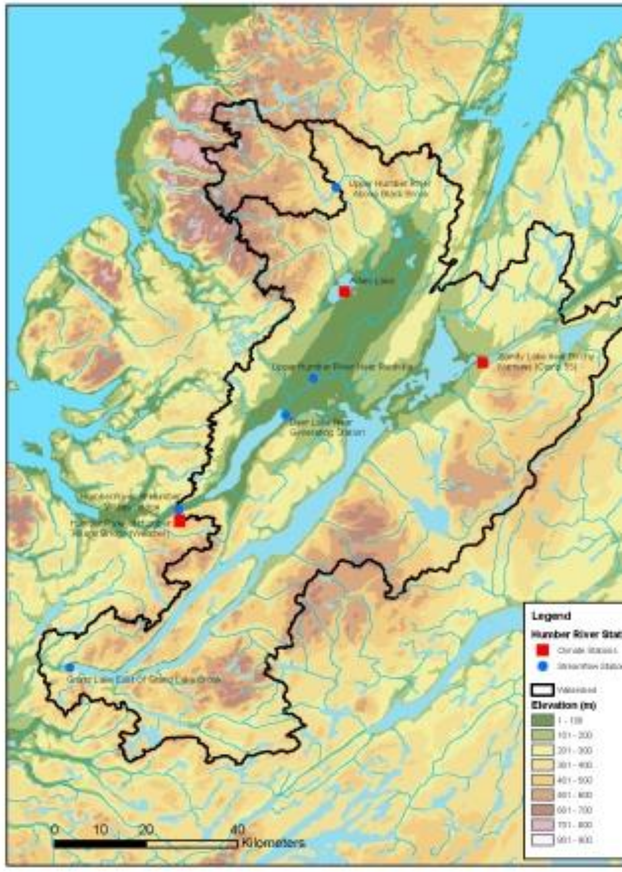


Humber River

- The Humber River is approximately 153 kilometres long; it flows through the long-range mountains, southeast then southwest, through Deer Lake, to the Bay of Island at Corner Brook. It begins near the town of Hampden. Taylor's Brook, Aidies Stream and Dead Water Brook run into the upper Humber. The Humber is one of Newfoundland's longest rivers.
- James Cook first charted the Humber in the summer of 1767. It was named for its English counterpart the Humber (estuary).
- The Humber is rich in Atlantic Salmon and was from the 1800s used as a waterway for European trappers and loggers. It is one of the world's best recreational salmon fishing rivers.

(www.gov.nl.ca)

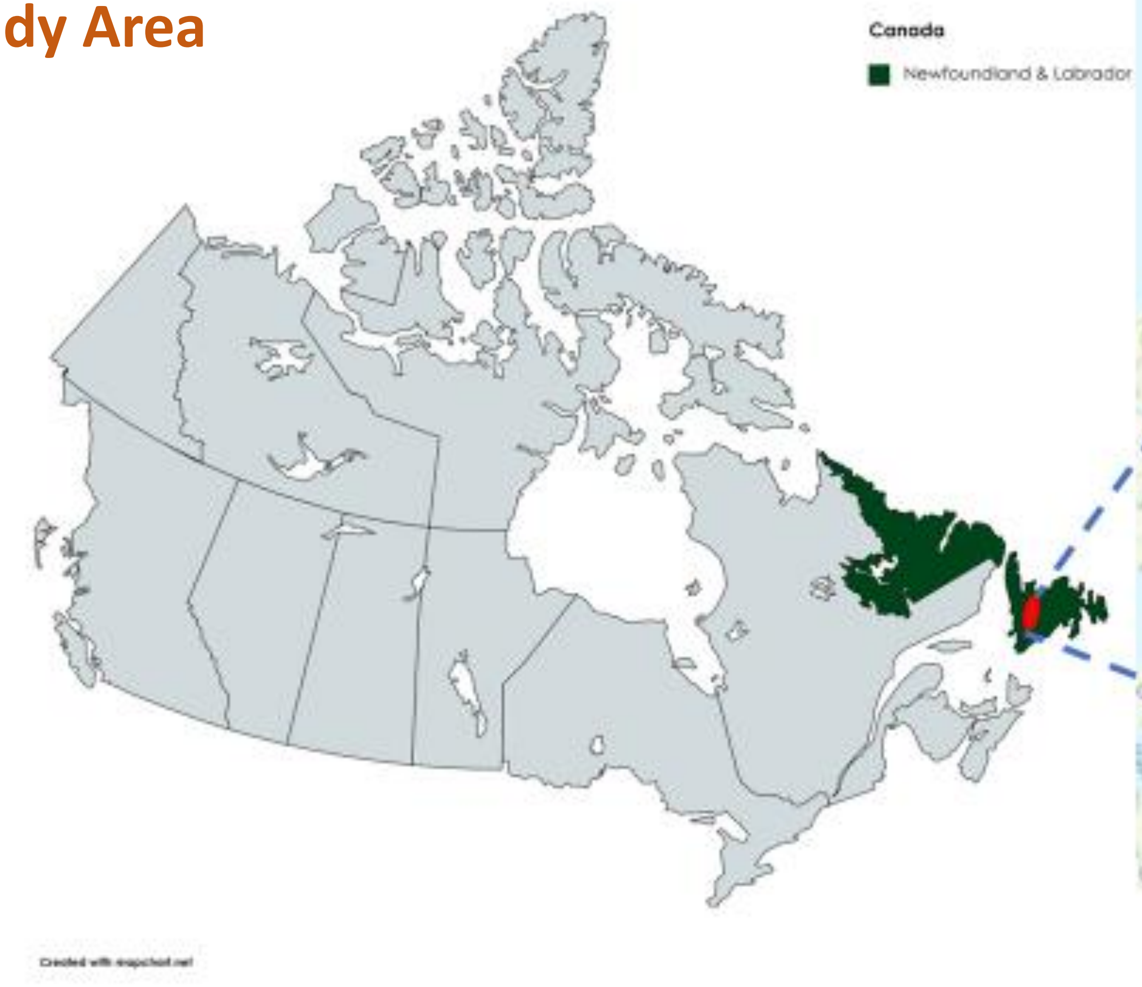




Objective

- Evaluate the projected changes in streamflow within the Upper Humber River Watershed.

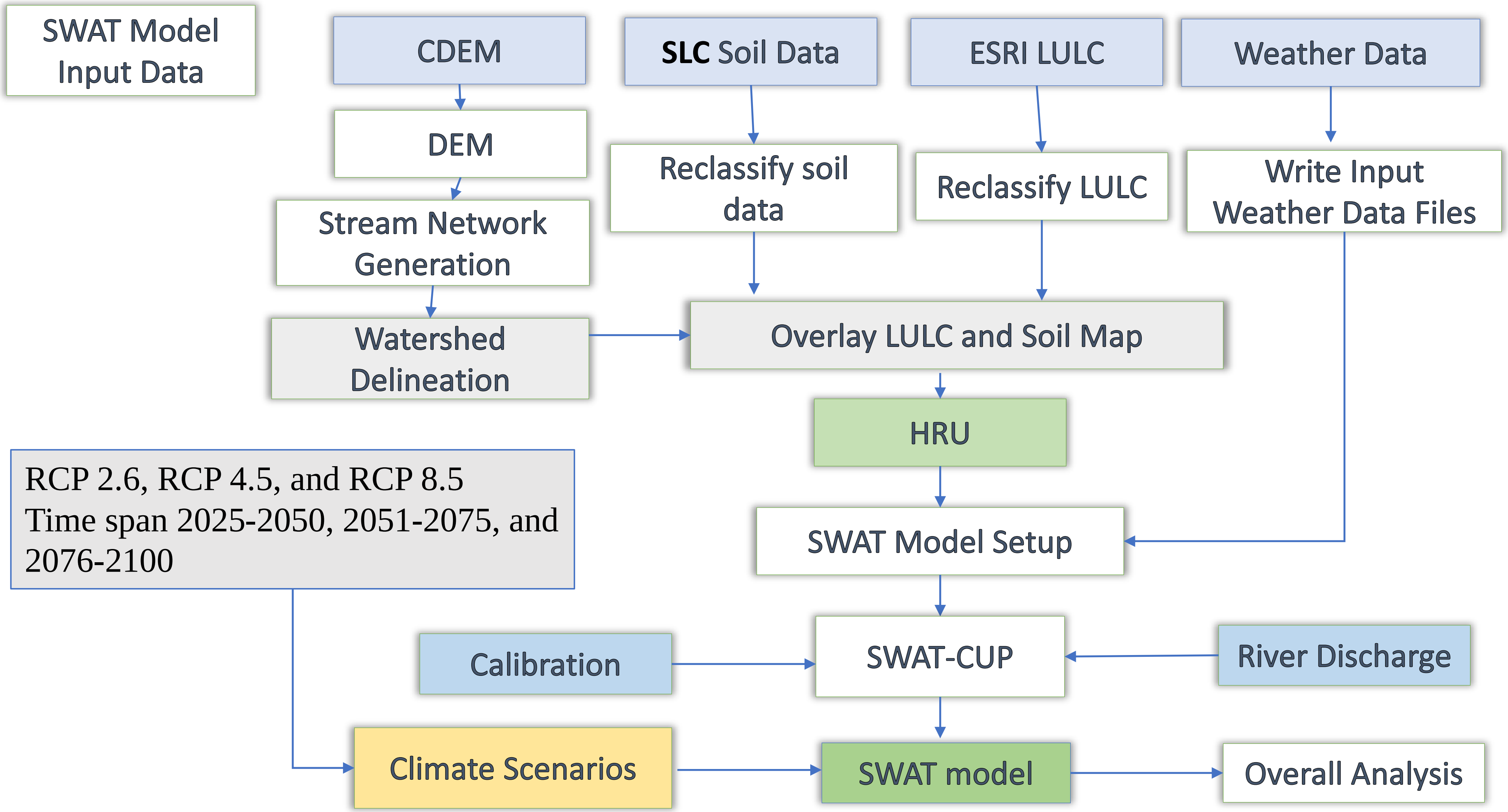
Study Area



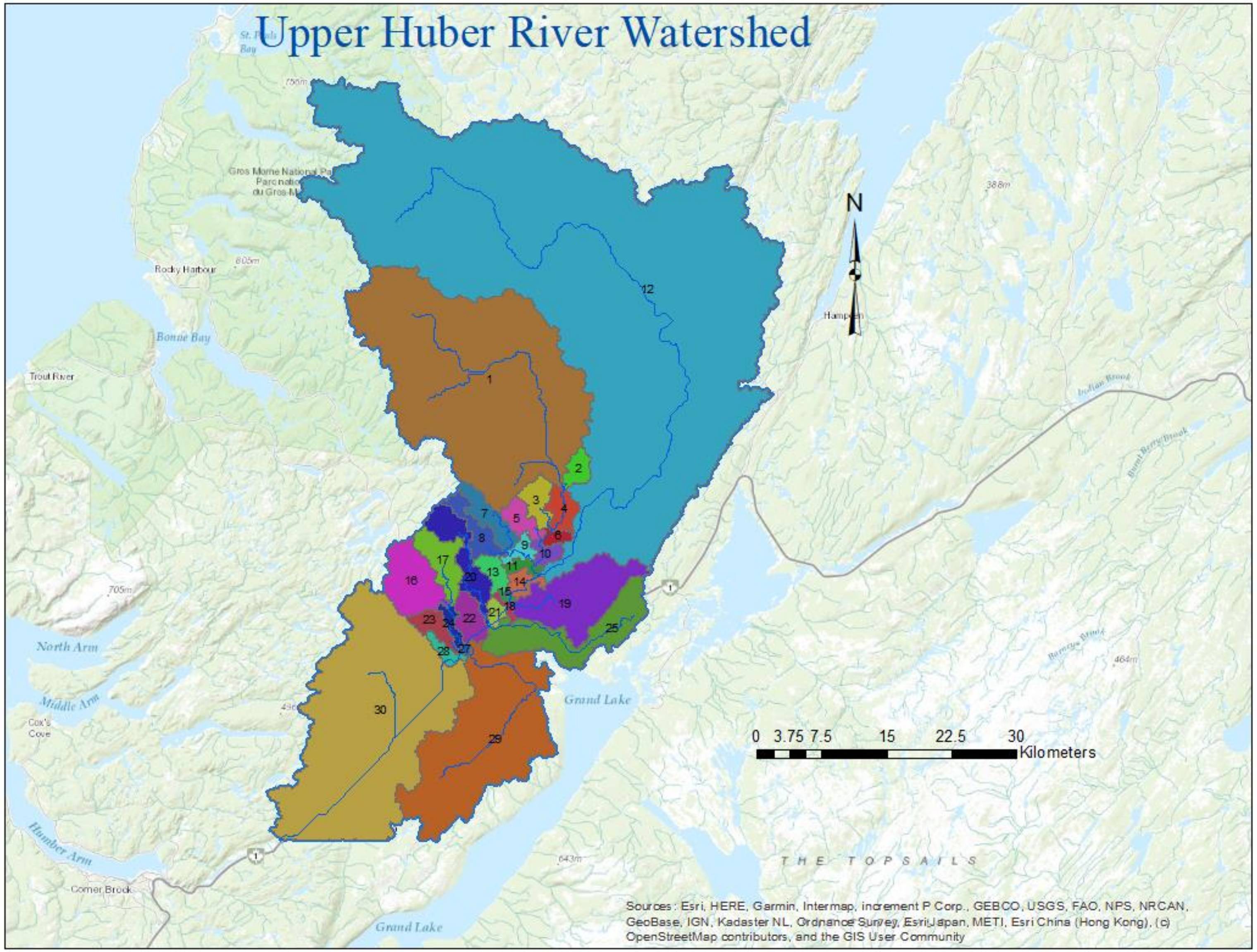
- Gros Morne National Park before reaching the Bay of Islands in Corner Brook.
- Total basin area of 7860 km^2, making it the second-largest river basin on the island

(ECC, 2023)

Workflow


SWAT Model Input Data
CDEM
SLC Soil Data
ESRI LULC
Weather Data
DEM
Reclassify soil data
Reclassify LULC
Write Input Weather Data Files
Stream Network Generation
Watershed Delineation
Overlay LULC and Soil Map
HRU
RCP 2.6, RCP 4.5, and RCP 8.5
Time span 2025-2050, 2051-2075, and 2076-2100
SWAT Model Setup
Calibration
SWAT-CUP
River Discharge
Climate Scenarios
SWAT model
Overall Analysis

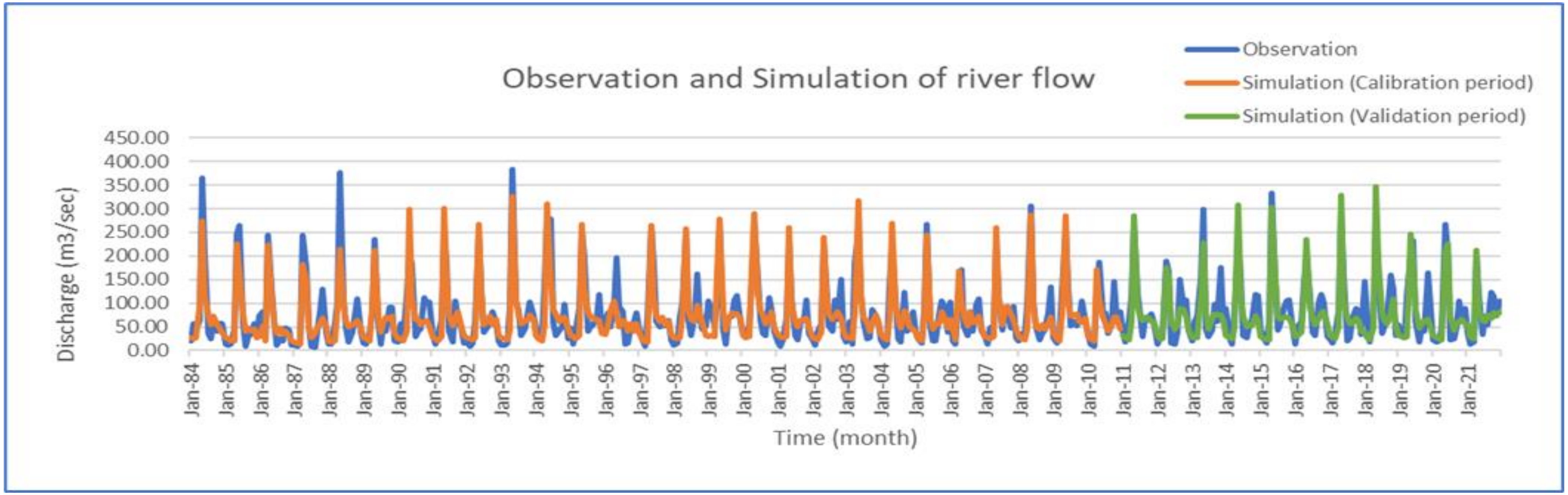
SWAT Model



Set up	SWAT
Sub Basin	30
HRU	251
Watershed area	2,890.59 Km^2
Simulation length	37 Year (1981-2022)
Warm up period	3 Year
Output timesteps	Monthly

Model calibration and Performance

Sequential Uncertainty Fitting 2 (SUFI-2)

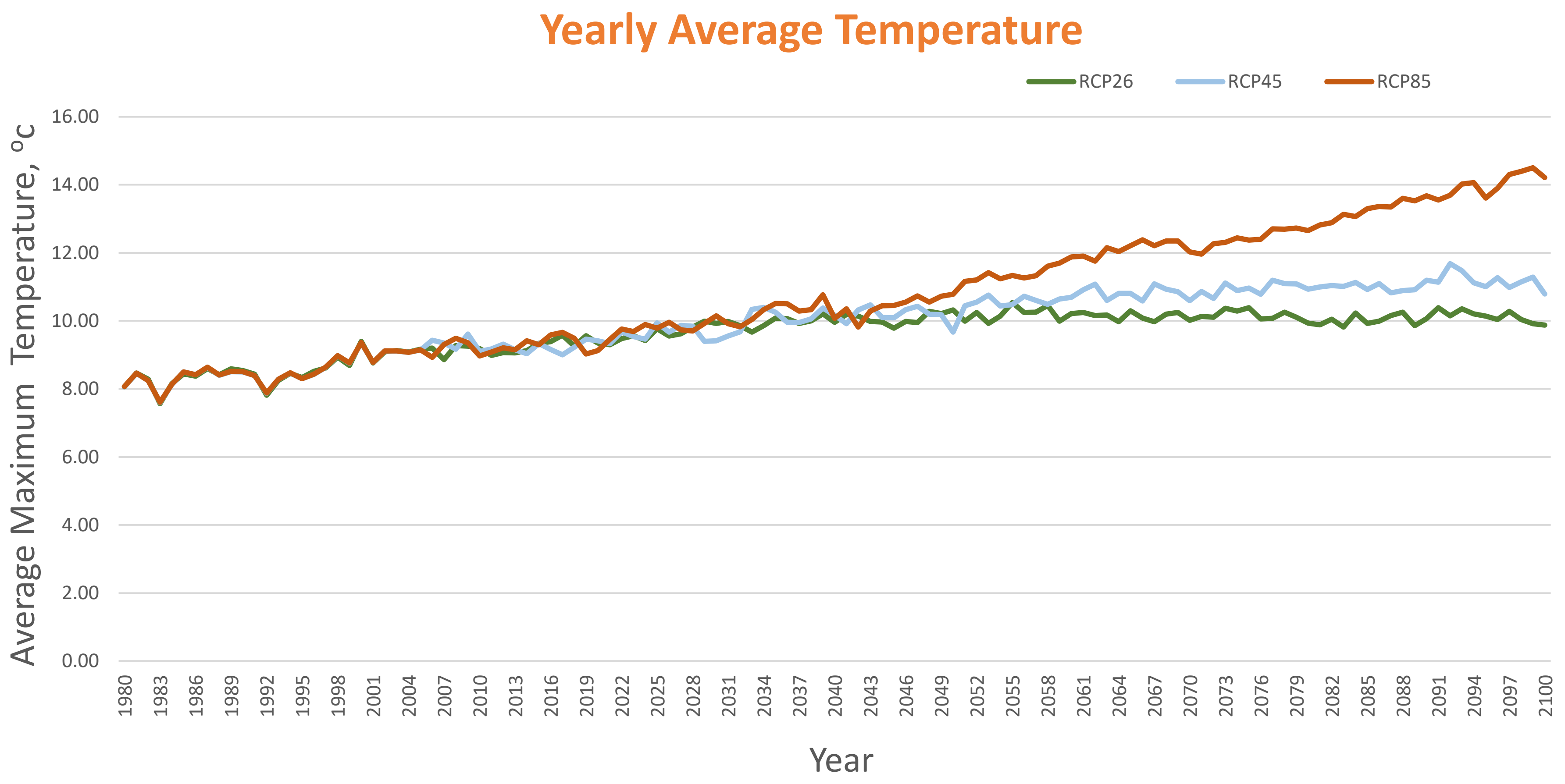


Period	Year	Statistical analysis of model performance		
		R^2	PBIAS	NSE
Calibration	1984-2010	0.79	6.9	0.79
Validation	2011- 2022	0.81	7.9	0.78

Calibration Parameters with Fitted Values

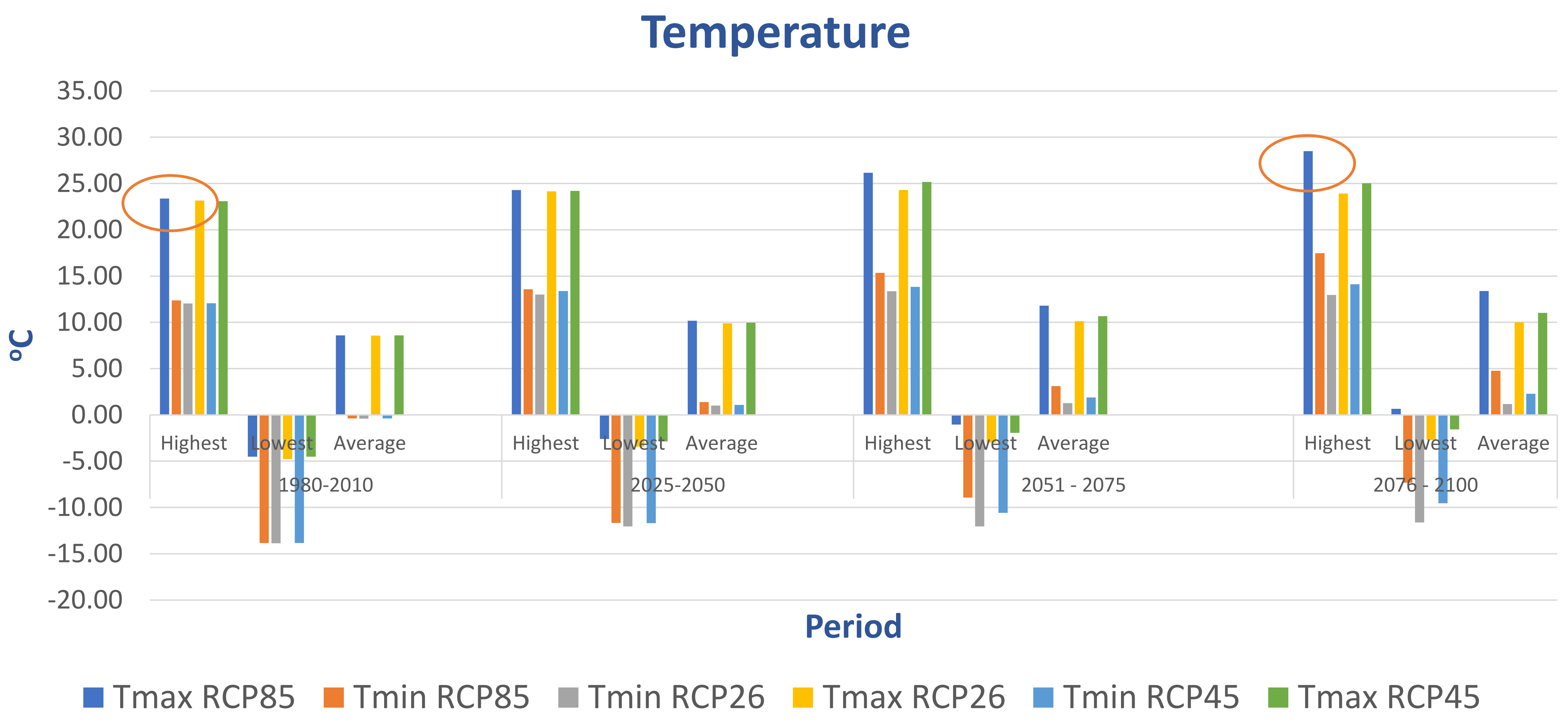
Parameters Ranks for the Upper Humber River Watershed Model

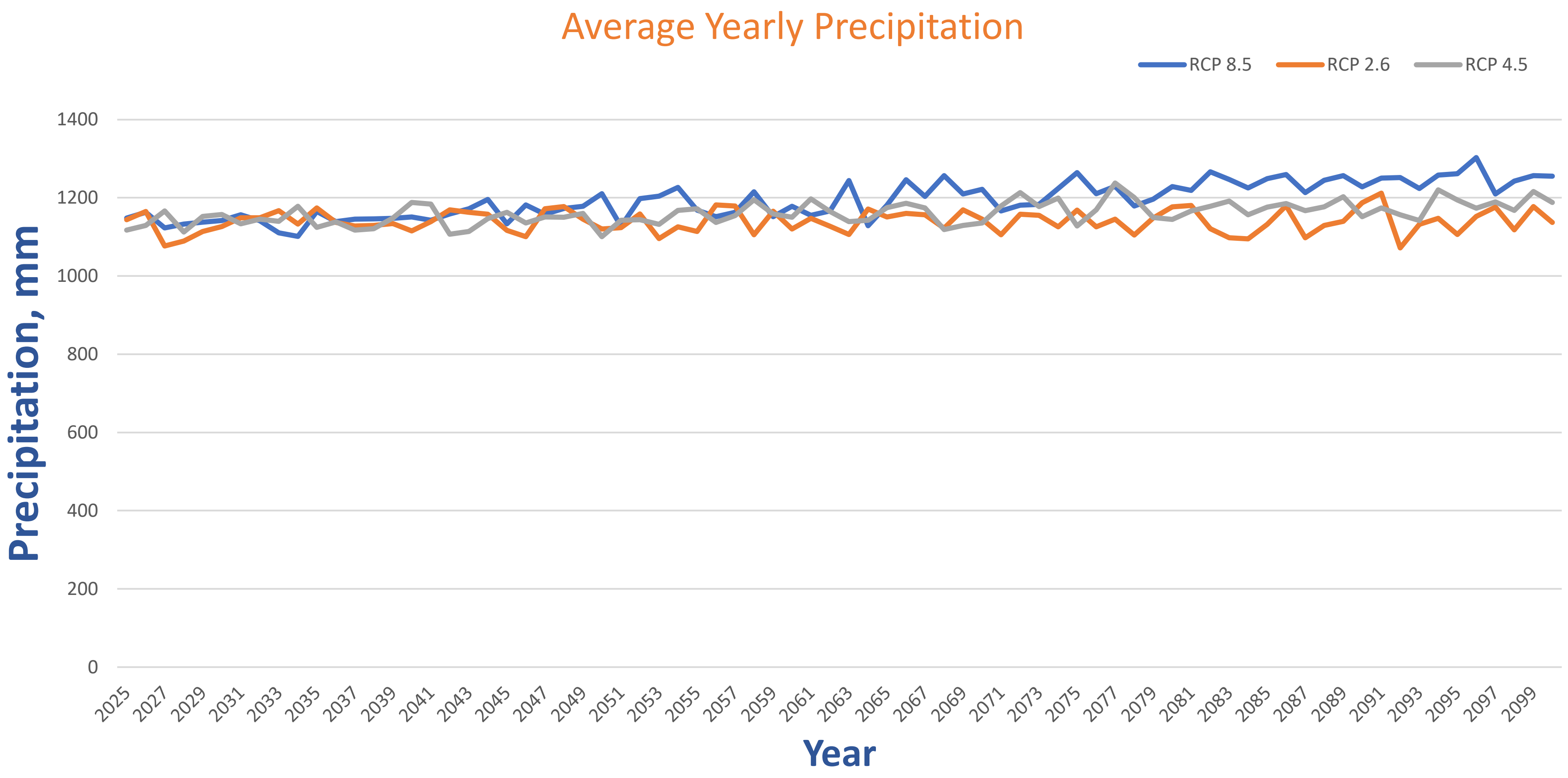
Parameter	Description	Type	Initial range	Fitted value	Rank
r_CN2.mgt	SCS runoff curve number	R	-0.2-0.2	0.0996	1
v_CH_K2.rte	Effective hydraulic conductivity in main channel alluvium(mm/h)	V	5.0-130.0	63.625	2
v_TLAPS.sub	Temperature lapse rate	V	-10-10	9.860	3
v_ESCO.hru	Soil evaporation compensation factor	V	0-1	0.913	4
v_EPCO.hru	Plant uptake compensation factor	V	0-1	0.899	5
v_SURLAG.bsn	Surface runoff lag time	V	0.05-24	3.427	6
r_SOL_AWC.sol	Available water capacity of the soil layer	R	-0.2-0.4	-0.089	7
v_SFTMP.bsn	Snowfall temperature	V	-5.0-5.0	4.670	8
v_GWQMN.gw	Treshold depth of water in the shallow aquifer required for return flow to occur (mm)	V	0-5000	715	9
v_GW_REVAP.gw	Groundwater "revap" coefficient	V	0.0-0.2	0.081	10
r_SOL_BD.sol	Moist bulk density	R	-0.5-0.6	-0.179	11
r_SOL_K.sol	Saturated hydraulic conductivity(mm/h)	R	-0.8-0.8	0.738	12
GW_DELAY.gw	Groundwater delay (days)	V	0-500	305	13
v_CH_N2.rte	Manning's "n" value for the main channel	V	0.0-0.3	0.234	14
v_ALPHA_BF.gw	Baseflow alpha factor (days)	V	0-1	0.111	15



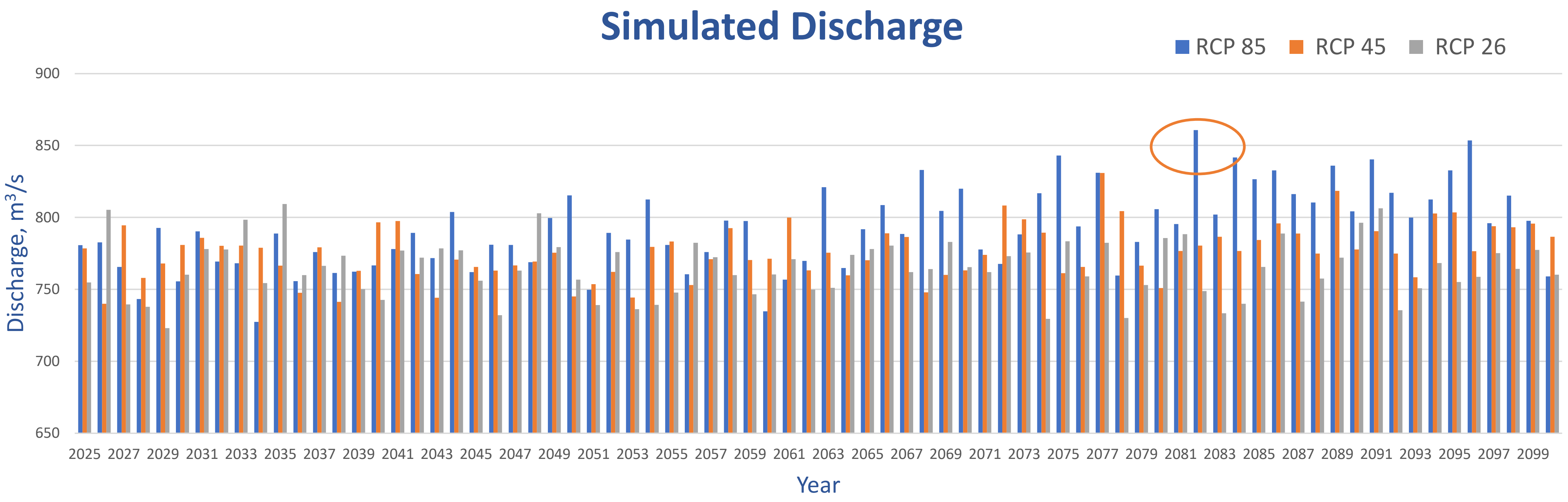
This graph was produced from an *ensemble* of 19 different climate models that have been developed by research groups from around the world and then run for 3 different scenarios represented by the shaded areas (green : RCP 2.6; blue : RCP 4.5; red: RCP 8.5).

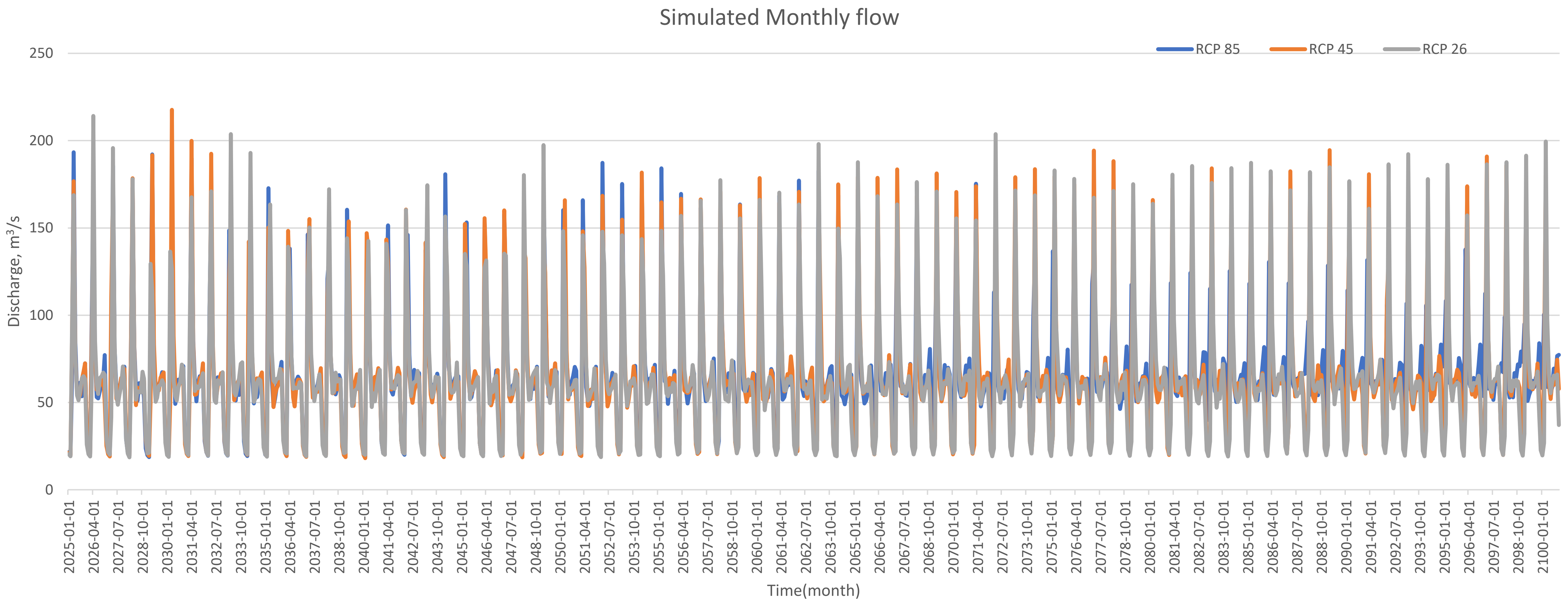
(climatedata.ca)


Temperature
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
ºC
Highest
Lowest
Average
1980-2010
2025-2050
2051 - 2075
2076 - 2100
Period
Tmax RCP85
Tmin RCP85
Tmin RCP26
Tmax RCP26
Tmin RCP45
Tmax RCP45



Year	RCP 8.5	RCP 4.5	RCP 2.6
1980-2010	1151.99	1138.16	1141.56
2025-2050	1151.99	1141.56	1138.16
2051-2075	1192.59	1160.45	1141.45
2076-2100	1238.56	1179.02	1139.56


Simulated Discharge
RCP 85
RCP 45
RCP 26
Discharge, m³/s
900
850
800
750
700
650
2025 2027 2029 2031 2033 2035 2037 2039 2041 2043 2045 2047 2049 2051 2053 2055 2057 2059 2061 2063 2065 2067 2069 2071 2073 2075 2077 2079 2081 2083 2085 2087 2089 2091 2093 2095 2097 2099
Year



The maximum values of high flows, average flow, and low flow -
RCP 8.5 are projected to be 193.3 m^3/s, 111.1 m^3/s, and 18.7 m^3/s, respectively.
RCP 4.5, the values are estimated to be 217.6 m^3/s, 120.4 m^3/s, and 18.6 m^3/s.
RCP 2.6, they are projected to be 214.2 m^3/s, 120.4 m^3/s, and 18.6 m^3/s.

Conclusions

- The study estimates temperature increases of 4.2°C, precipitation increases of 8%, and a decrease in average annual streamflow of 5% under RCP 8.5 until 2100.
- For RCP 4.5, the maximum increases in these hydro-meteorological variables are projected to be 1°C temperature increases, 8% in precipitation, and an 11% decrease in streamflow until 2100.
- Under RCP 2.6, a decrease of 0.2°C in temperature is projected, while precipitation and average yearly streamflow remain unchanged.
- Based on modeling results, it is expected that the Upper Humber River Watershed will experience more frequent extreme flow events in the future due to climate change.
- The significance of examining the influence of climate change on watershed hydrology becomes evident in light of these findings, highlighting the necessity for effective water resource management in agriculture.
- Moreover, the study's results reveal the potential of the study area to foster improved agricultural conditions.

Future Directions for the SWAT Model in the UHRW

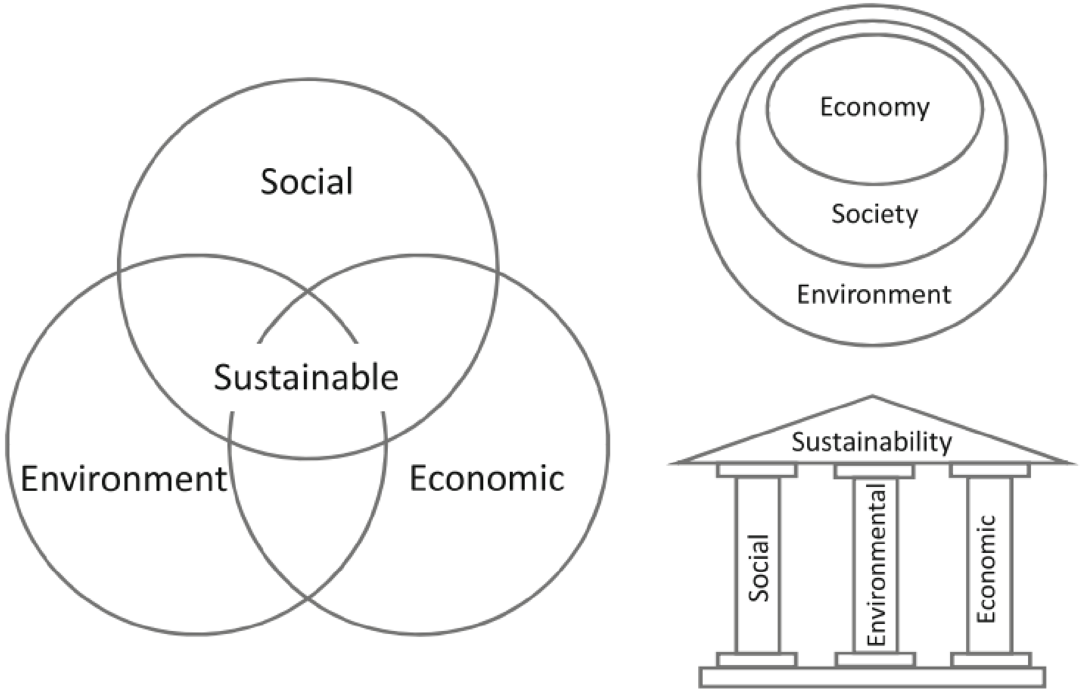
Soil & Water Assessment Tool SWAT

\+

Social science studies

=

Agricultural Sustainability



- Integrate SWAT model with social science studies.
- Economic, environment, social sustainability for overall **agricultural sustainability**.

(Purvis et al. 2019)

References

Akoko, G., Le, T.H., Gomi, T., Kato, T., 2021. A review of SWAT model application in Africa. Water 13, 1313.

Arnold, J.G., Moriasi, D.N., Gassman, P.W., Abbaspour, K.C., White, M.J., Srinivasan, R., Santhi, C., Harmel, R.D., Van Griensven, A., Van Liew, M.W., 2012. SWAT: Model use, calibration, and validation. Transactions of the ASABE 55, 1491–1508.

Brandt, J., Flannigan, M., Maynard, D., Thompson, I.D., Volney, W.J.A., 2013. An introduction to Canada's boreal zone: ecosystem processes, health, sustainability, and environmental issues INTRODUCTION. Environmental Reviews 21, 207–226. https://doi.org/10.1139/er-2013-0040

https://climatedata.ca

Shrestha, N.K., Du, X., Wang, J., 2017. Assessing climate change impacts on freshwater resources of the Athabasca River Basin, Canada. Science of the total environment 601, 425–440.

ECC, 2023a. Humber Water Level Information [WWW Document]. Environment and Climate Change, Newfoundland. URL https://www.gov.nl.ca/ecc/waterres/flooding/humber/ (accessed 1.24.23)

Ebi, K., 2016. Ontario Climate Change and Health Vulnerability and Adaptation Assessment Guidelines.

Evapotranspiration and Crop Water Use, n.d. . Student Materials. URL https://serc.carleton.edu/integrate/teaching_materials/food_supply/student_materials/1091 (accessed 6.22.23).

Martin, N., 2021. Watershed-Scale, Probabilistic Risk Assessment of Water Resources Impacts from Climate Change. Water 13, 40. https://doi.org/10.3390/w13010040

SLC, A. and A.-F., 2021. Soil Landscapes of Canada (SLC) [WWW Document]. URL https://sis.agr.gc.ca/cansis/nsdb/slc/index.html (accessed 4.6.23).

Wells, J.V., Dawson, N., Culver, N., Reid, F.A., Morgan Siegers, S., 2020. The State of Conservation in North America's Boreal Forest: Issues and Opportunities. Frontiers in Forests and Global Change 3.

https://serc.carleton.edu/

Purvis, B., Mao, Y., & Robinson, D.. (2019). Three pillars of sustainability: in search of conceptual origins. *Sustainability Science*, *14*(3), 681–695. https://doi.org/10.1007/s11625-018-0627-5

GRENFELL CAMPUS | MEMORIAL UNIVERSITY

TRSU

Acknowledgment

- **Supervisor:** Lakshman Galagedara
- **Co-authors :** Joseph Daraio, Gabriela Sabau, Mumtaz Cheema, Lakshman Galagedara.
- **Funding:** Industry, Energy and Technology of the Government of NL (**IET Grant**: 5404-1962-102) and Memorial University of Newfoundland and Labrador.
- **Collaborators:** Department of Fisheries, Forestry and Agriculture, Government of Newfoundland and Labrador.

MEMORIAL UNIVERSITY

Newfoundland Labrador

Thank You!

GRENFELL CAMPUS | MEMORIAL UNIVERSITY

TRSU

Question /Feedback/ Comments