Effect of Future Climate Change on Hydrologic Components for Two Watersheds using SWAT

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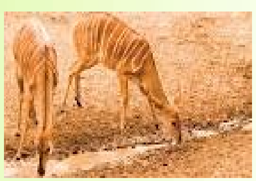



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Outline

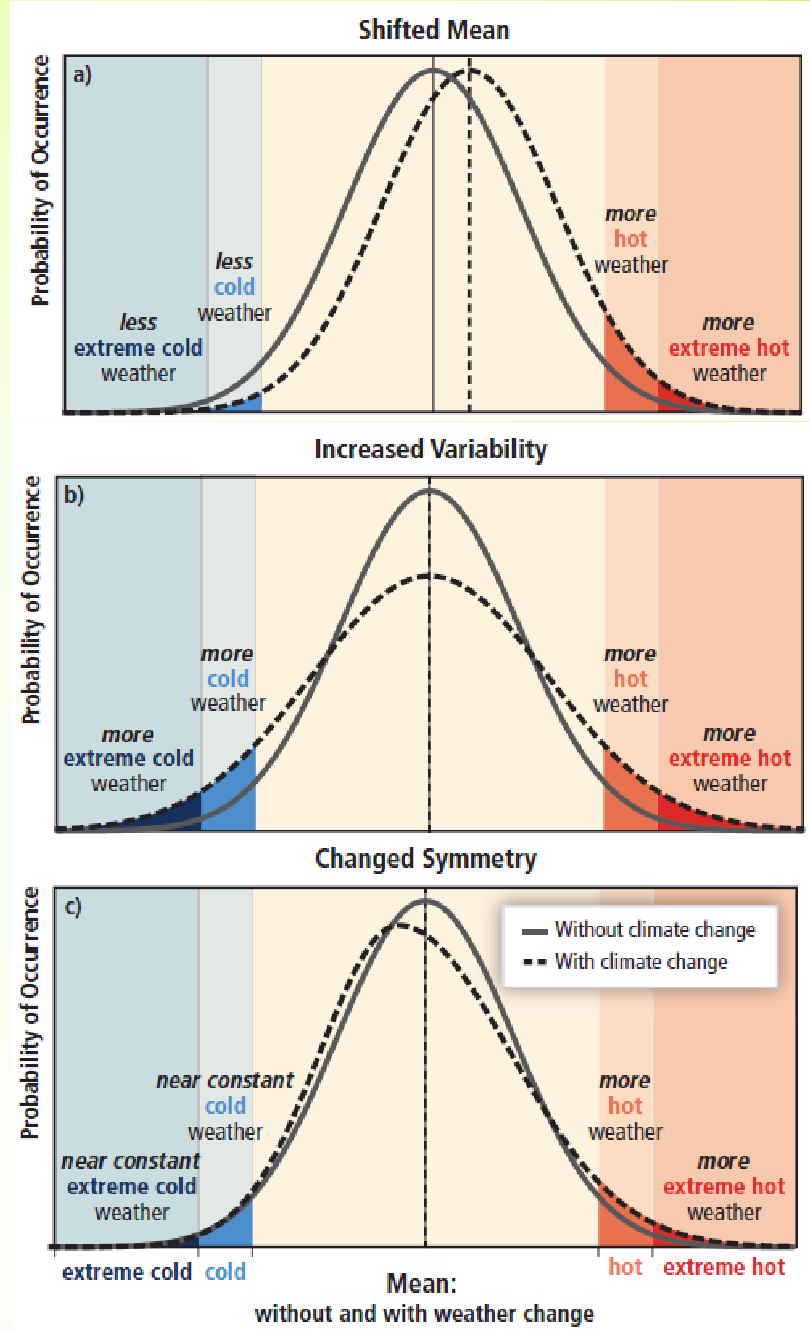
- Introduction to Climate Change
- SWAT Description
- Calibration & application Results
- Water Balance Analysis
- Water Quality Analysis
- Conclusions

Attributes of Climate Change

A changing climate can be attributed to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events, and can result in unprecedented extreme weather and climate events.

These include changes in:

- Mean
- Variance
- Shape of probability distributions



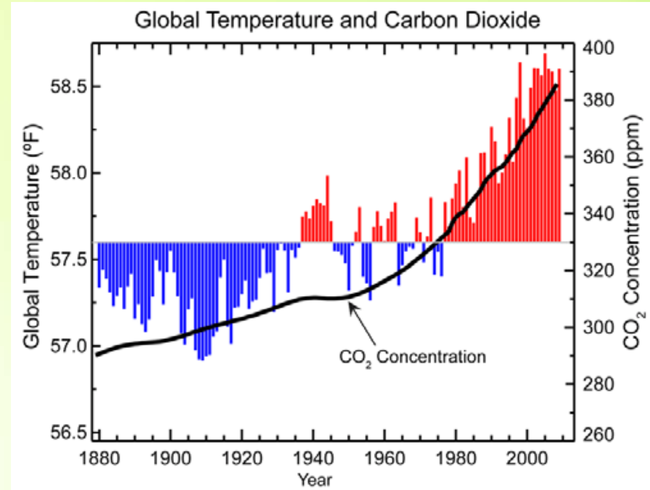
Source: IPCC, 2012

Is it a change in climate?

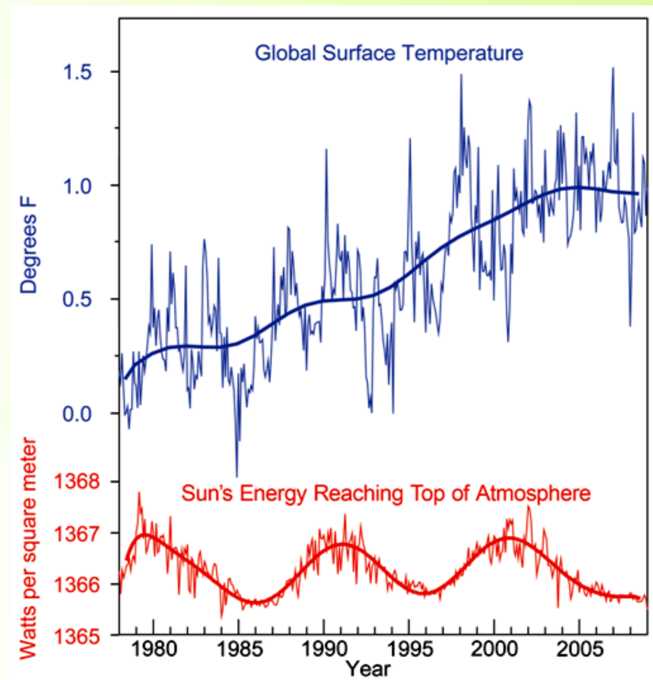
IPCC Fourth Assessment Report:

Some Key facts

- Global temperature has increased over the past 50 years.
- Average rise in global temperature during 1910s to the 1940s and during 1970s to present are estimated at 0.35^{O}C and 0.55^{O}C respectively
- Cold days, cold nights and frost have become less frequent, while hot days, hot nights, and heat waves have become more frequent



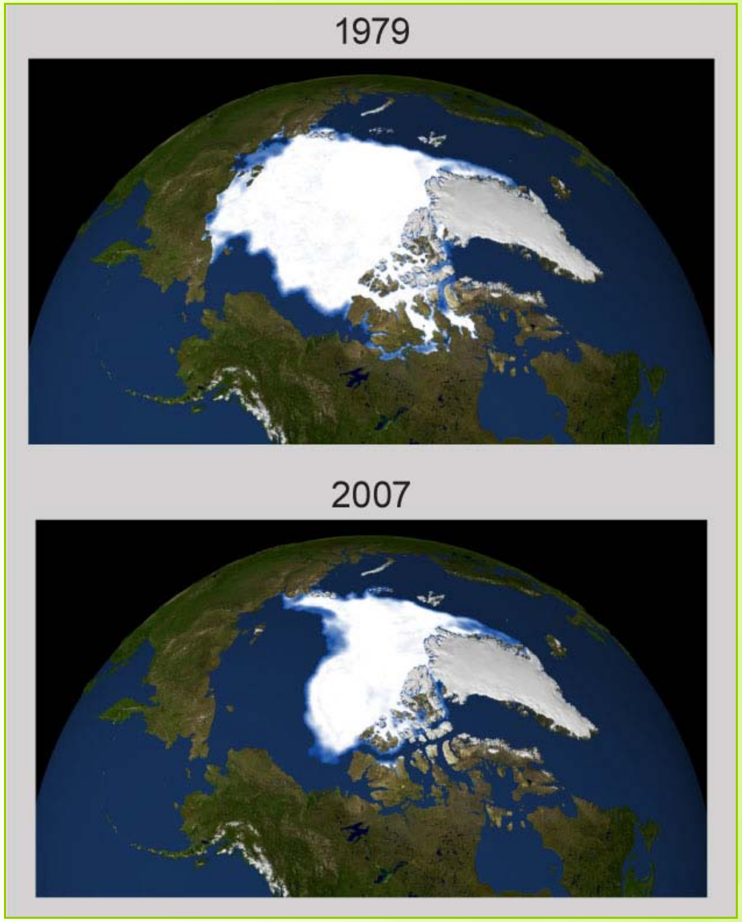
Source: NOAA/NCDC



Source: NOAA/NCDC; Frölich and Lean; Willson and Mordvinov; Dewitte *et al.*

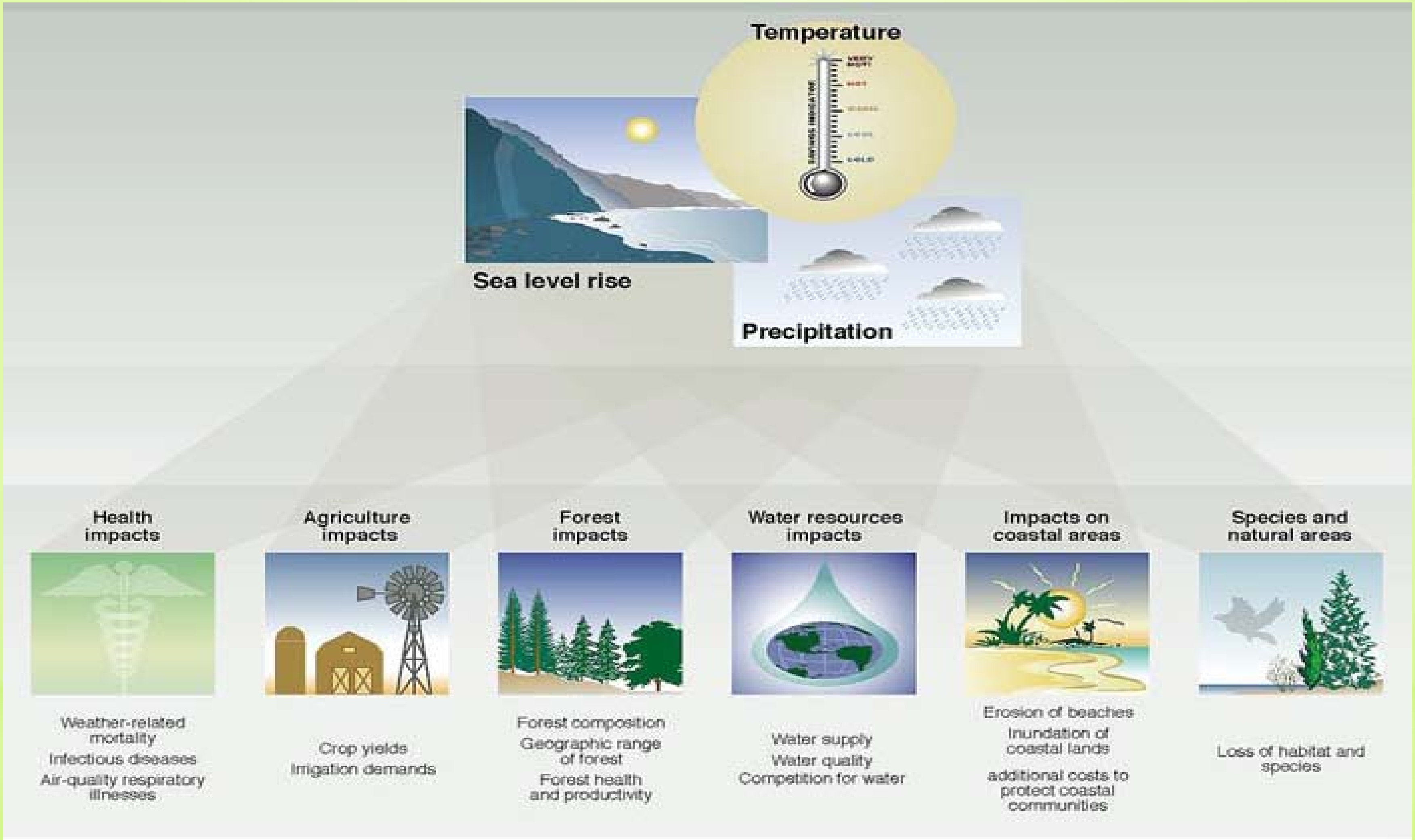
If Answer is Yes what can be the possible consequences of Changing Climate?

- Rising temperatures
- Increase in heavy downpours
- Rising sea level
- Rapidly retreating glaciers
- Thawing permafrost
- Lengthening growing seasons
- Lengthening ice-free seasons in the ocean and on lakes and rivers
- Earlier snowmelt
- Alterations of river flows
- Shifts in the timing of seasons



Source: NASA –GSFC USGCRP 2009

How Climate Change will impact various sectors:



Can Modeling be the answer to Combat the Challenge

- Assessments of hydrology and its impact on water quality at field/watershed scale
- Flow path identification and modeling
- Recharge area identification
- Integration of surface and groundwater models
- Then which model to select?

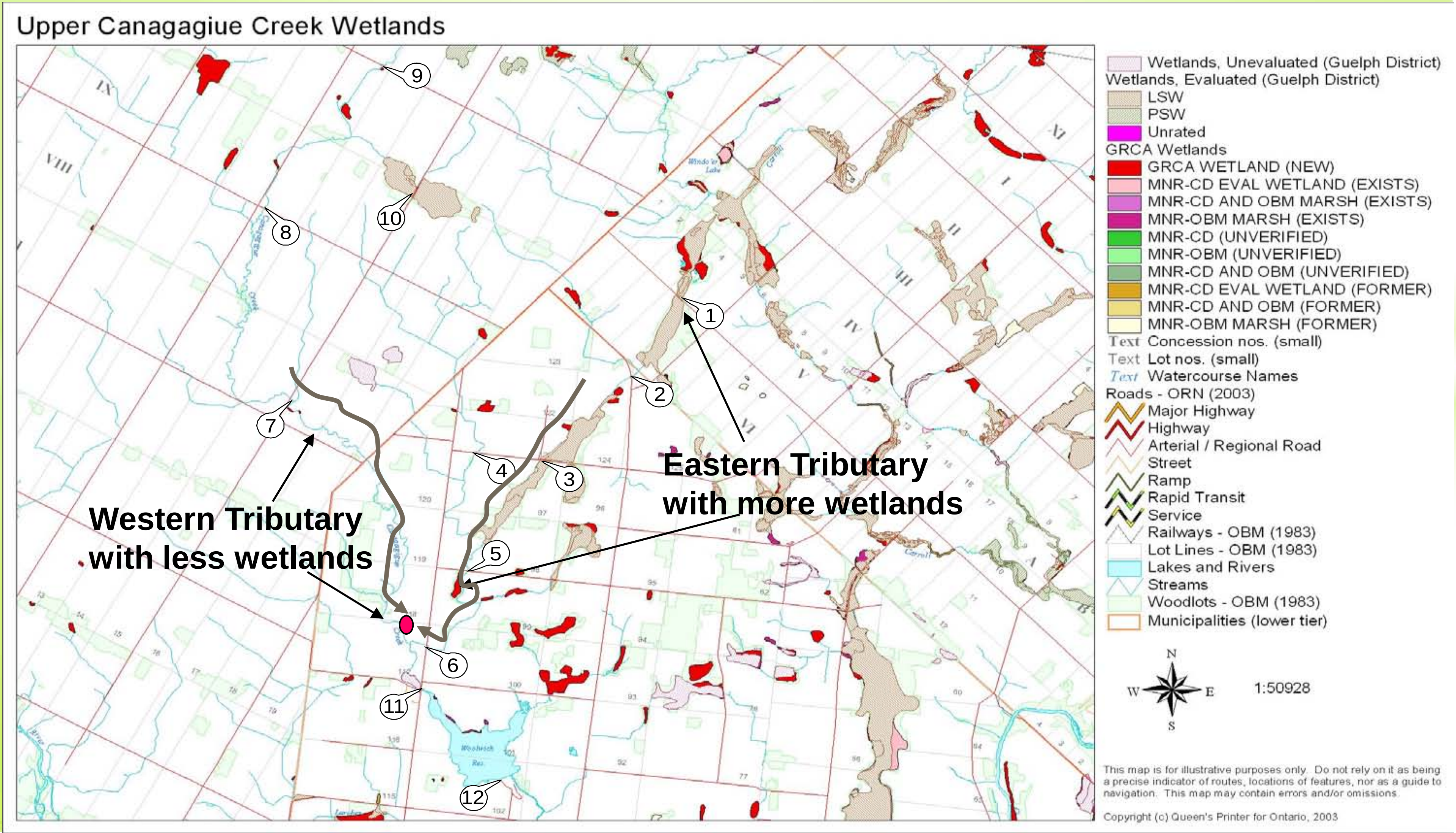
Soil and Water Assessment Tool (SWAT)

- A watershed or river basin scale physically based continuous model, (Developed by Arnold et al., 1998)
- **Data:**
  - Needs basin-specific data for weather, soil properties, topography, vegetation, and land management practices
- **Benefits:**
  - Applicable to large and small watersheds; Ungauged watersheds can also be modeled
  - Sensitivity to different input data can be quantified
  - Determines long-term impacts
- **Output:**
  - Water Balance Components and water quality parameters at Sub-basin and HRU Scale

SWAT Inputs

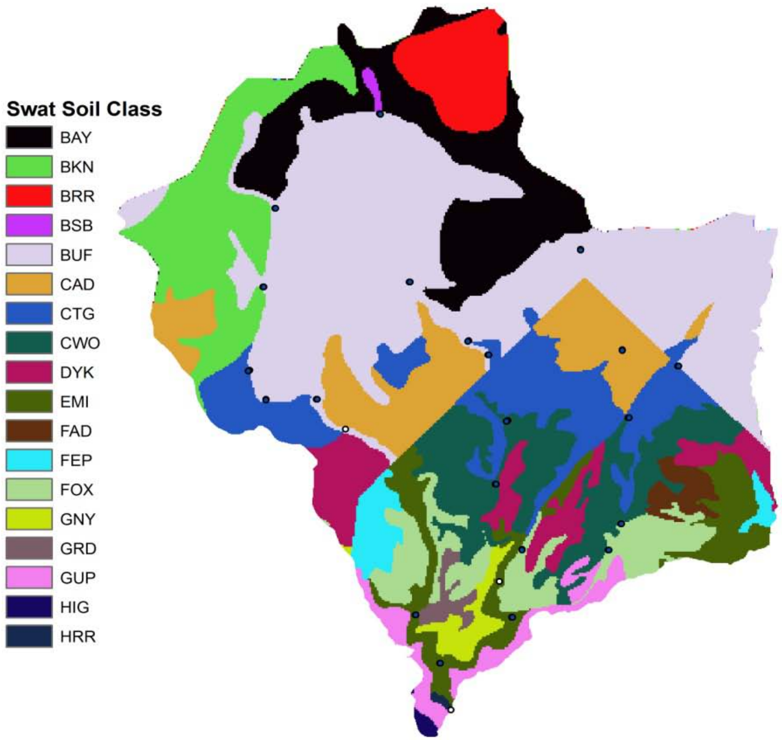
- ✓ **Physical**
  - ✓ Elevation, Land cover, soil
- ✓ **Weather**
  - ✓ Rainfall, air temperature (Min and max), solar radiation, wind speed, and relative humidity
- ✓ **Hydrological**
  - ✓ Stream flow, sediment and nutrient delivery data
  - ✓ Fertilizer and pesticide application data
  - ✓ Point source of pollution

Study Area: Upper Canagagigue Creek Watershed

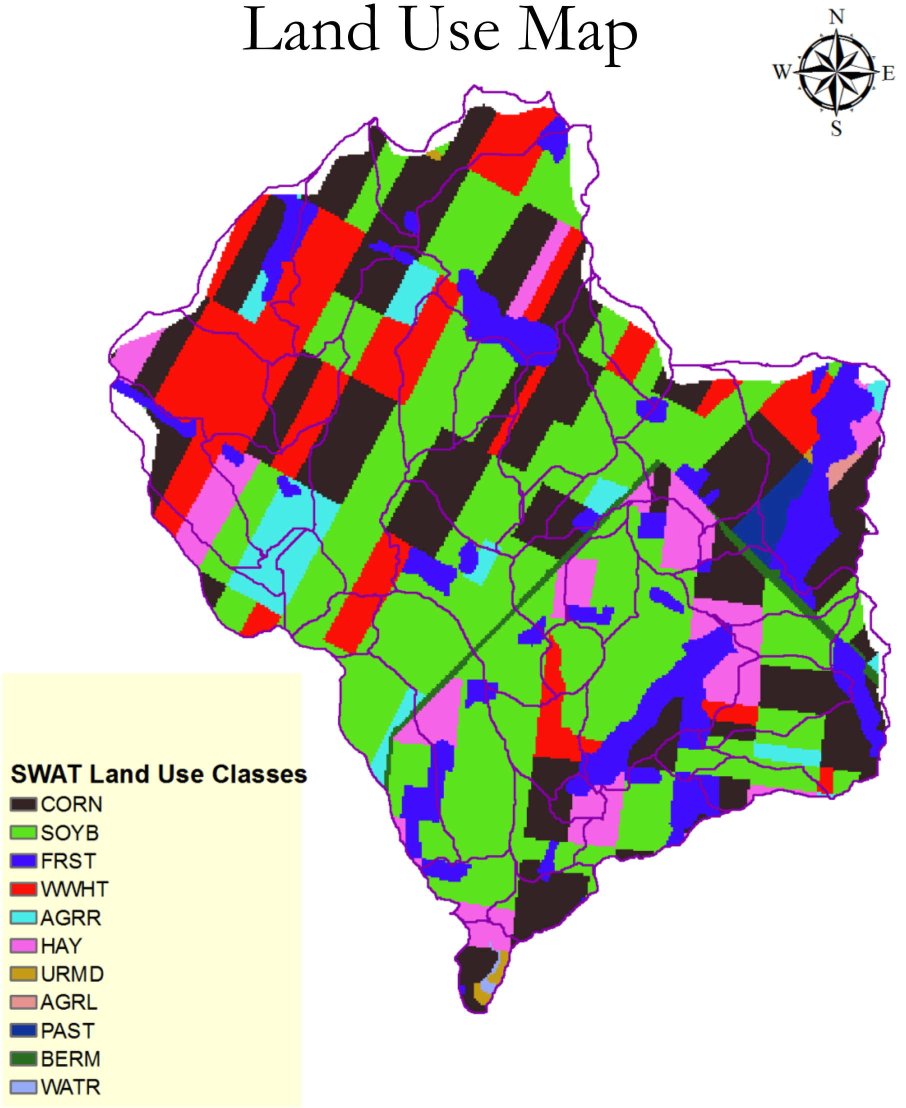


Features of the Study Area

Soil Map

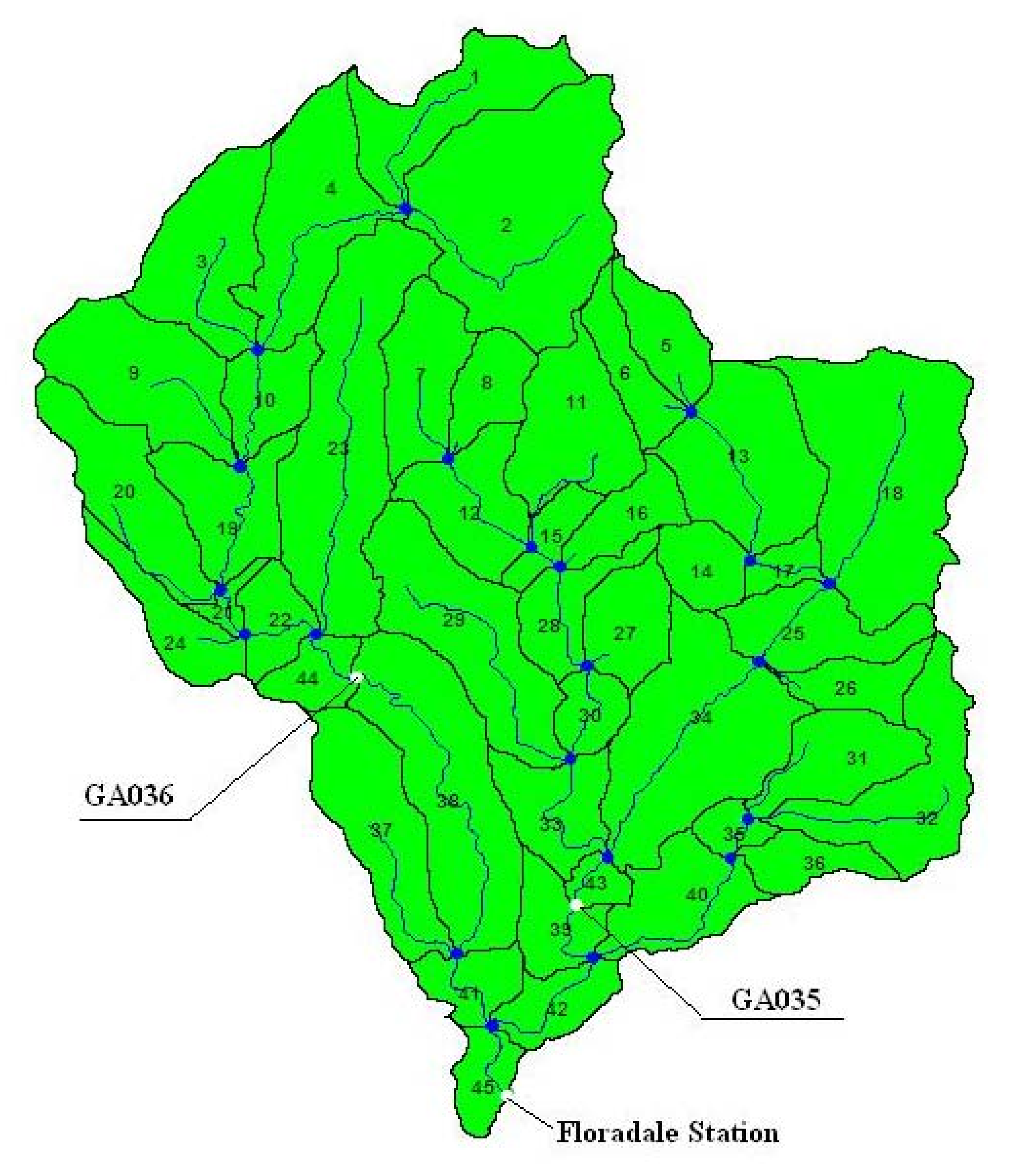


Land Use Map



Data Used during the study

- Precipitation
- Temperature
- Stream flow
- Sediment
- Nitrogen
- Phosphorus



OBJECTIVES

- To calibrate and validate the SWAT model for hydrology, sediment, and nutrients using observed data.

- To simulate developed future climate data by SDSM downscaling for the effect of climate change on water quantity and water quality

Model Calibration – Sensitivity analysis

- **Each parameter was varied individually by a fixed percentage while all other parameters were kept constant**

- **Comparison of predicted (P) and observed (O) stream flow on annual and monthly basis**

- **The percent of relative change was used to determine the relative sensitivity of parameter**

$$Change(percent) = \frac{O - P}{O} * 100$$

Calibration Data & Procedure

- **The period from 1974 to 1979 was used for calibration with four warming up years from 1970 to 1973, and**
- **The period from 1980 to 1984 was used for validation.**

- **Adjusting certain model parameters to obtain a better match (within 10%) between modeled and gauged flows during the calibrated period**

Evaluation of SWAT

* **Calibration and Validation periods** – Hydrology, Water Quality
  * Sediment
  * Phosphorus
  * Nitrogen

Graphical and statistical comparisons

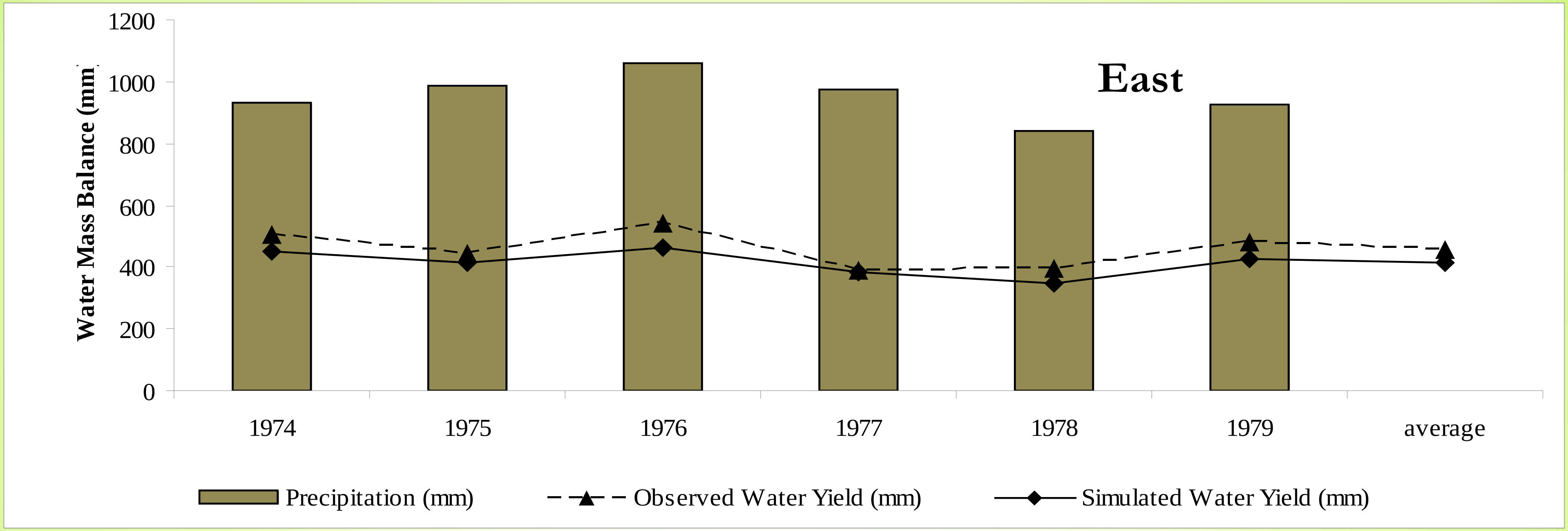
- Time series plot of observed and simulated stream flow and sediment
- Percent error difference (monthly and annual)
- Scatter plot
- Correlation coefficient (R^2)
- Nash-Sutcliff Coefficient (NSE)

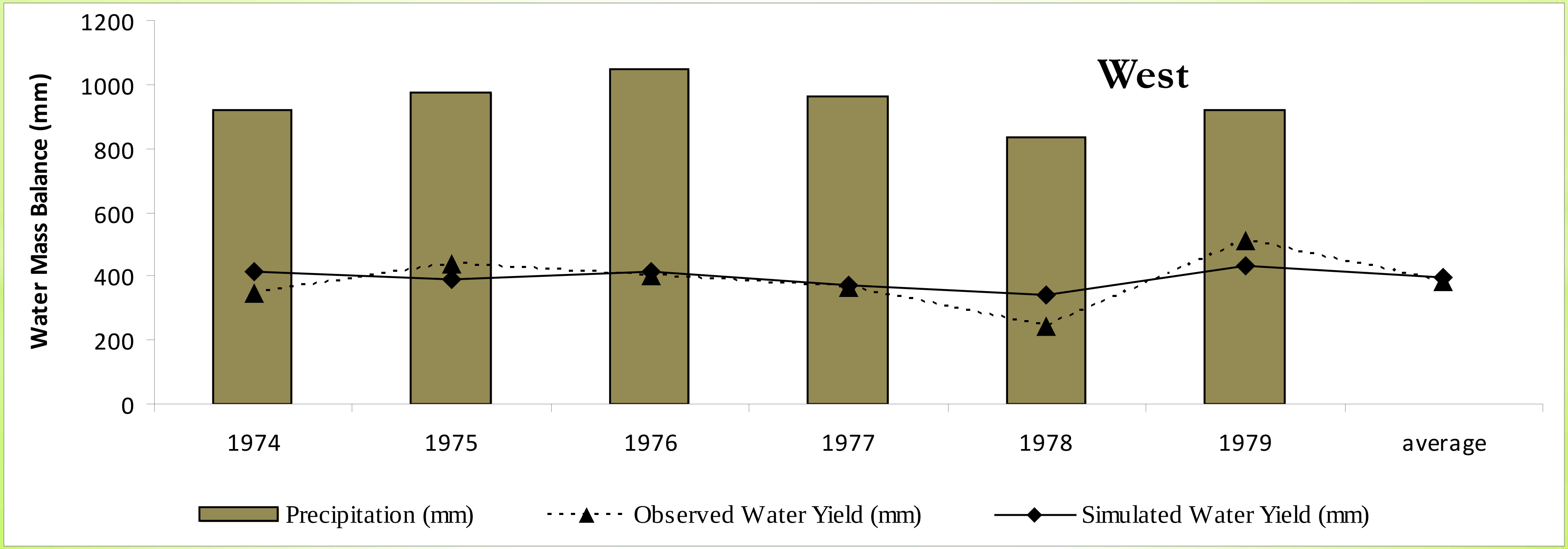
Future Simulation Using SWAT model

- After calibration and validation of the SWAT model, the future weather daily data for A2 scenario, created by the downscaling tool SDSM including mean precipitation and maximum/minimum temperature from 2015 to 2044, were imported as the weather input to the SWAT model

- The data were used for assessment of future conditions for the study area

Annual Calibration

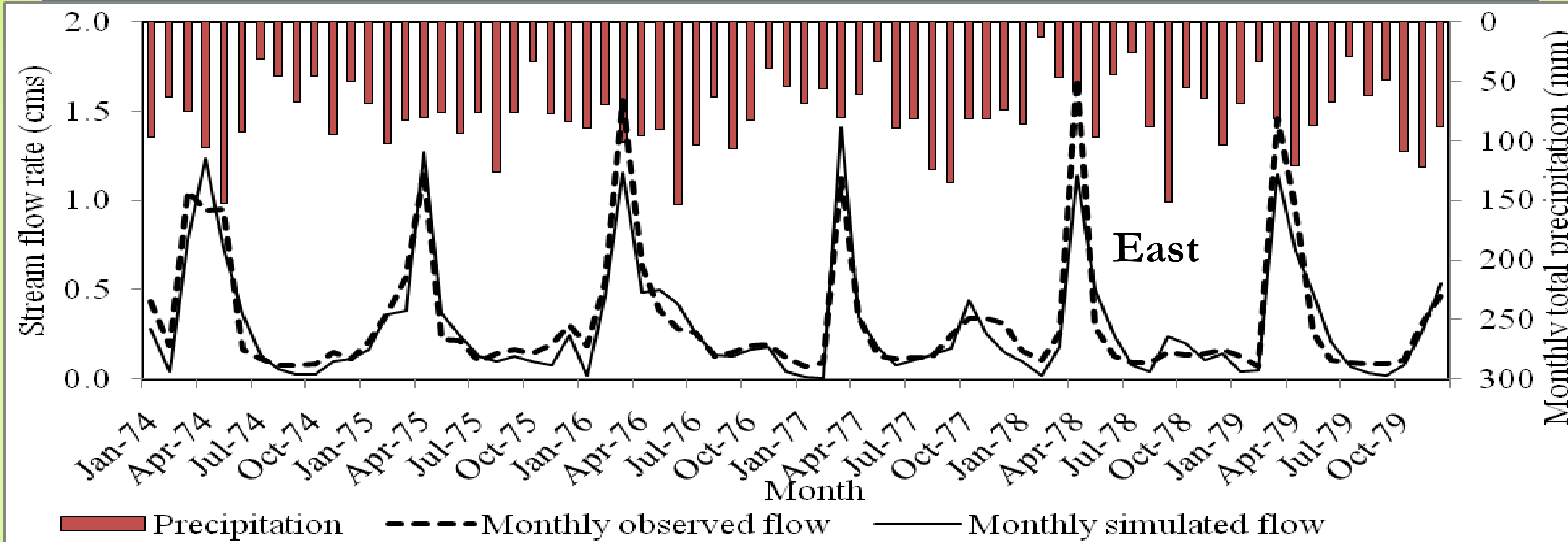


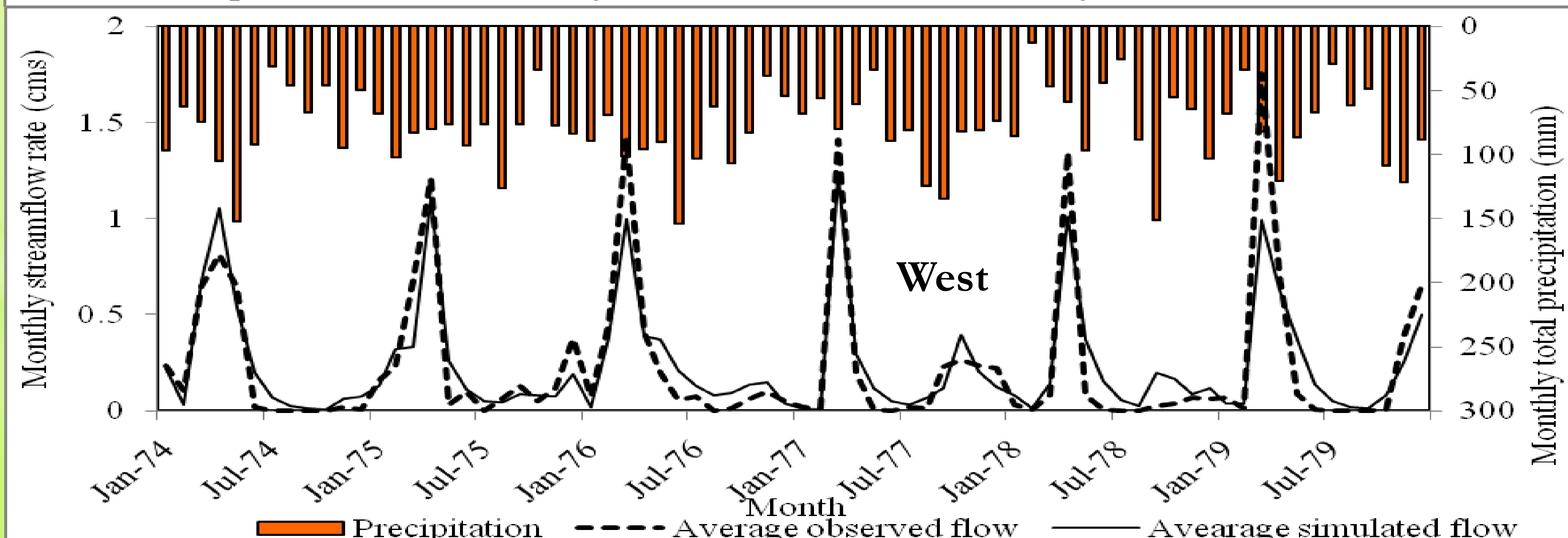


Water Balance (Calibration)

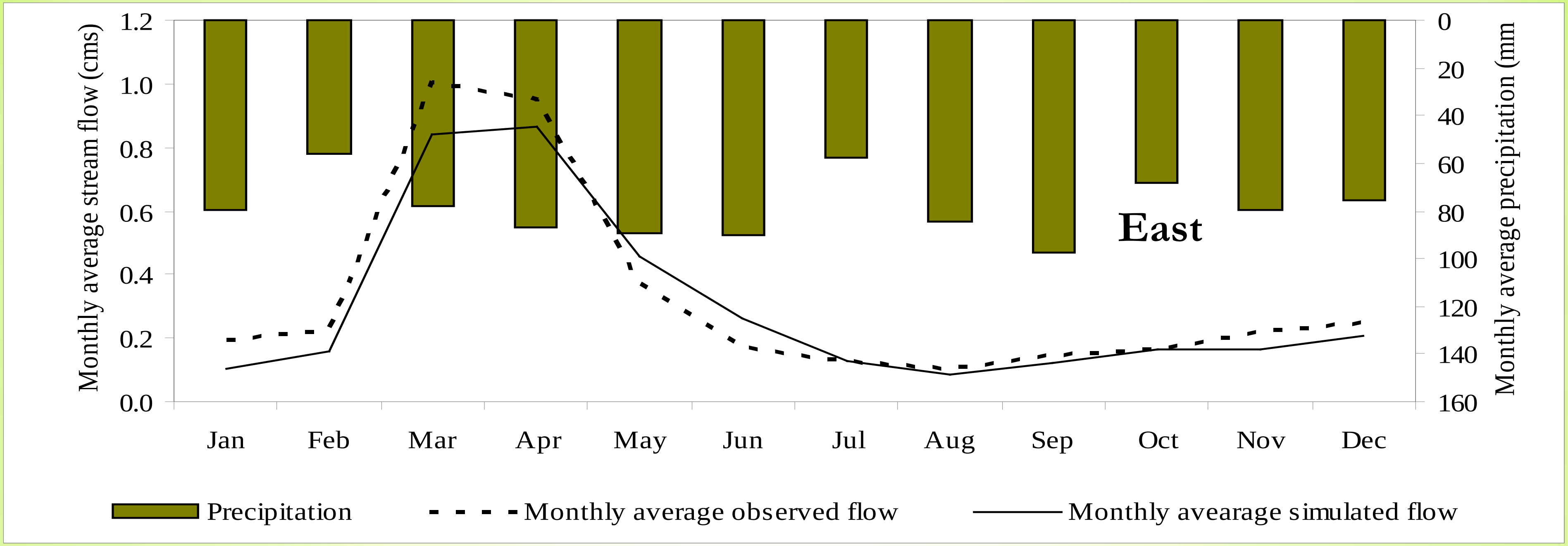
Year	ET[†]/ Precip[±]	SURQ[‡]/ Precip	SURQ/WYLD[α]	GWQ[β]/WYLD
	(Cana-East)			
1974	51%	29%	59%	38%
1975	53%	26%	62%	34%
1976	50%	21%	49%	47%
1977	54%	20%	49%	46%
1978	53%	21%	50%	45%
1979	51%	23%	49%	47%
Average	52%	23%	53%	43%
	(Cana-West)			
1974	56%	30%	65%	32%
1975	57%	28%	68%	29%
1976	55%	21%	51%	45%
1977	56%	20%	49%	46%
1978	54%	22%	51%	45%
1979	50%	24%	48%	49%
Average	55%	24%	55%	41%

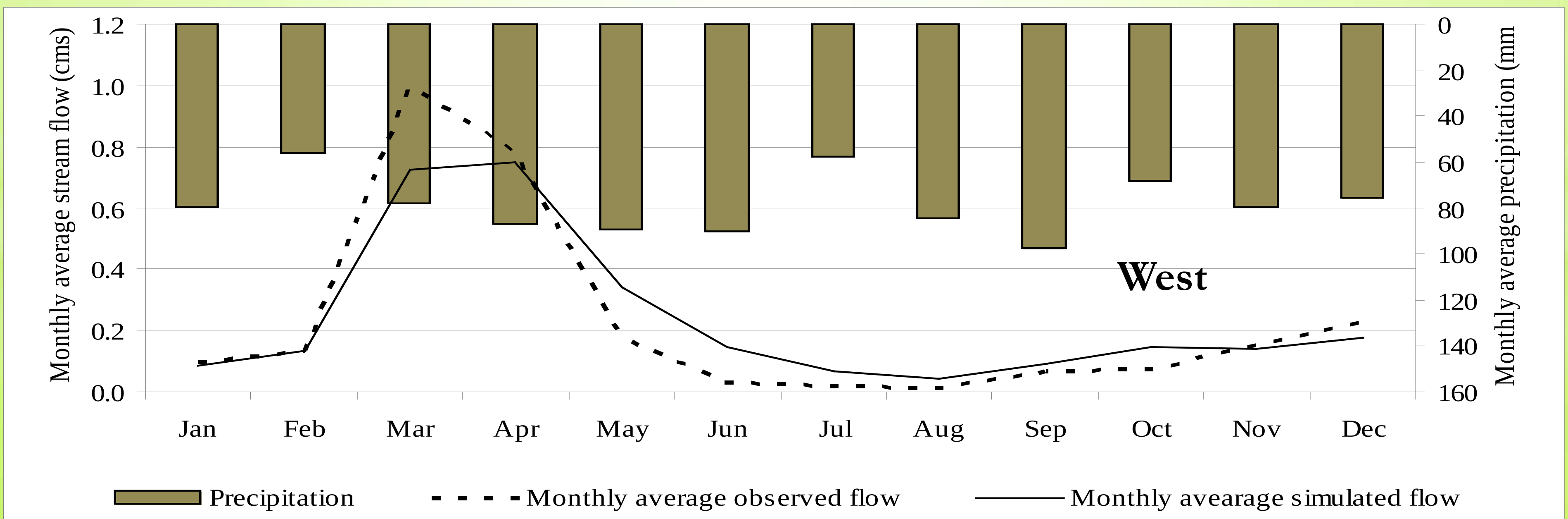
Monthly Calibration





Averaged Monthly Stream flow (Calibration)

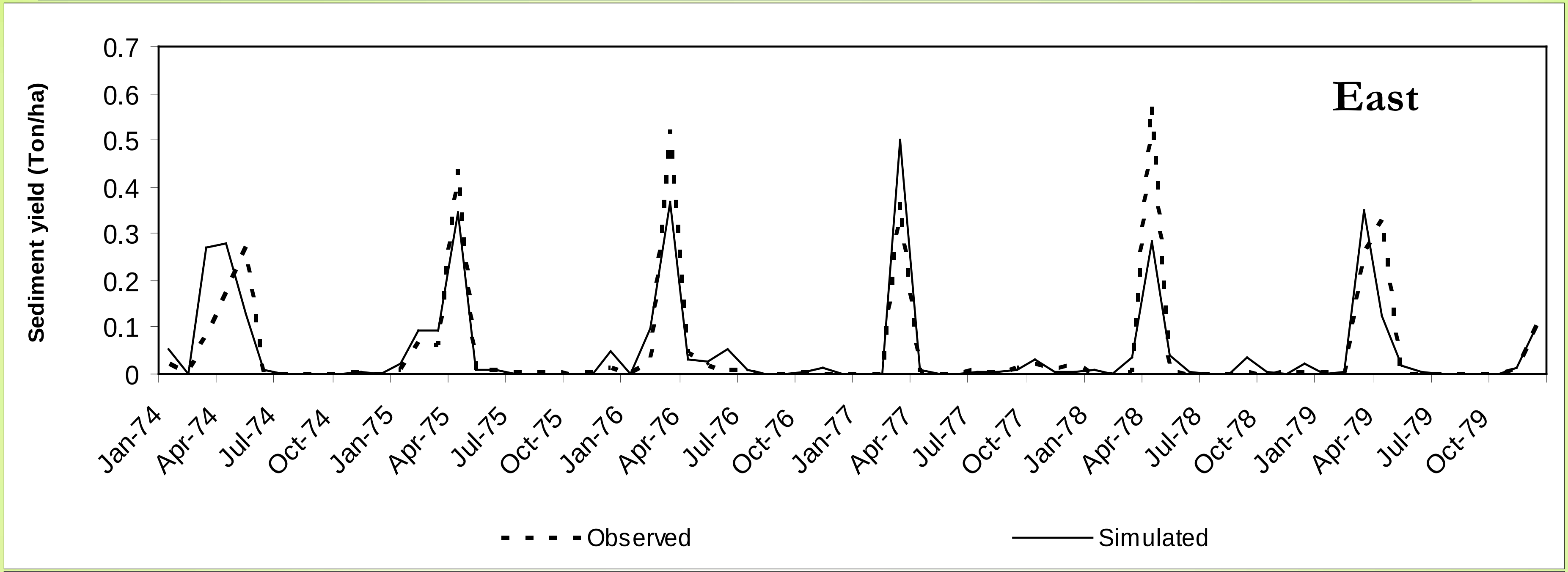


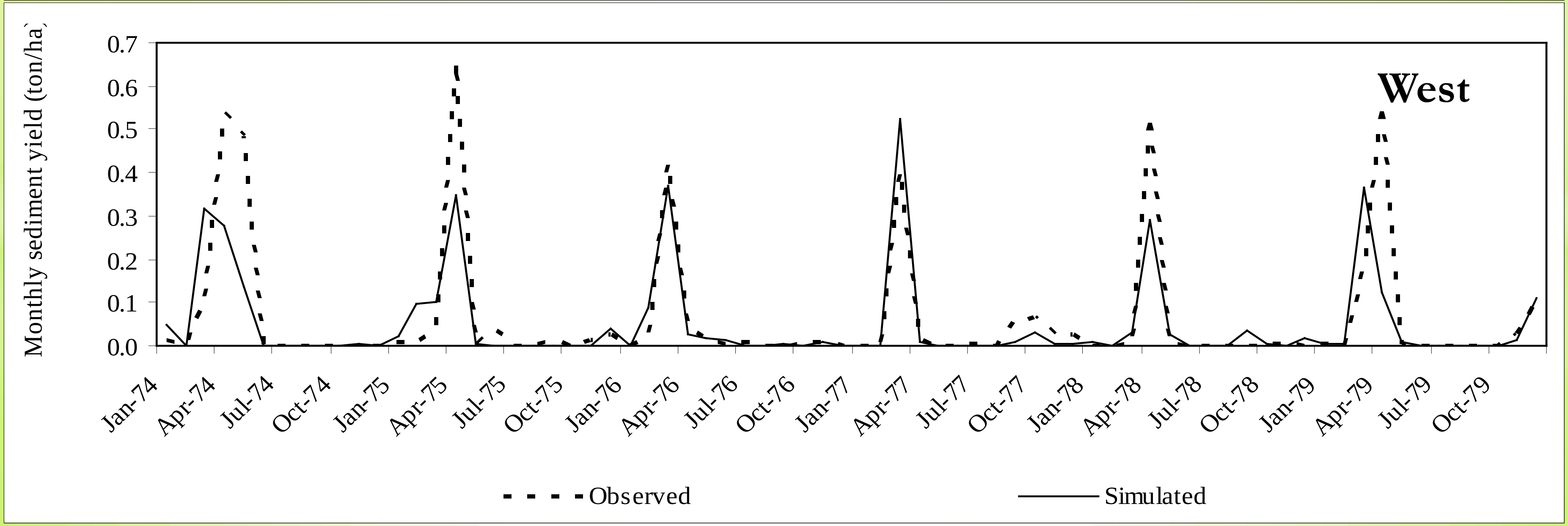


Overall Calibration Results

Analysis	Stream flow	
	Cana-West	Cana-East
Monthly		
NSE	0.84	0.85
R^2	0.87	0.86
Seasonal		
NSE	0.93	0.94
R^2	0.95	0.95
Annual		
NSE	0.46	0.17
R^2	0.64	0.88
%error	-6.02	9.39

Sediment Calibration

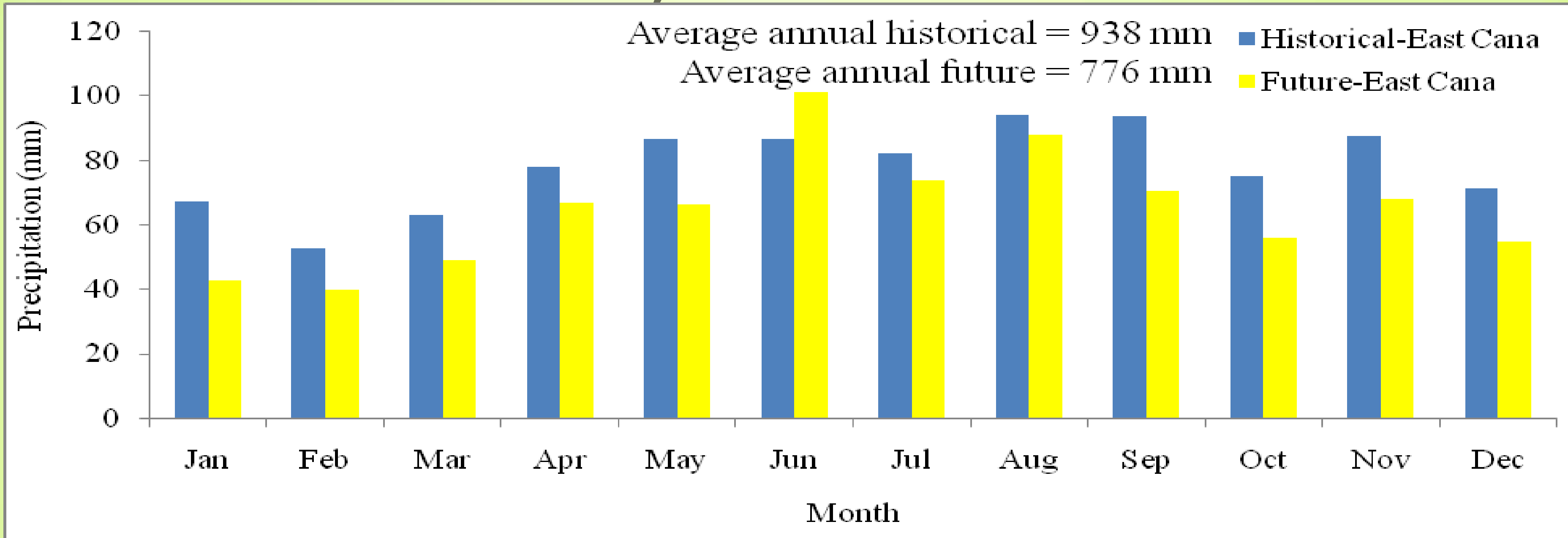


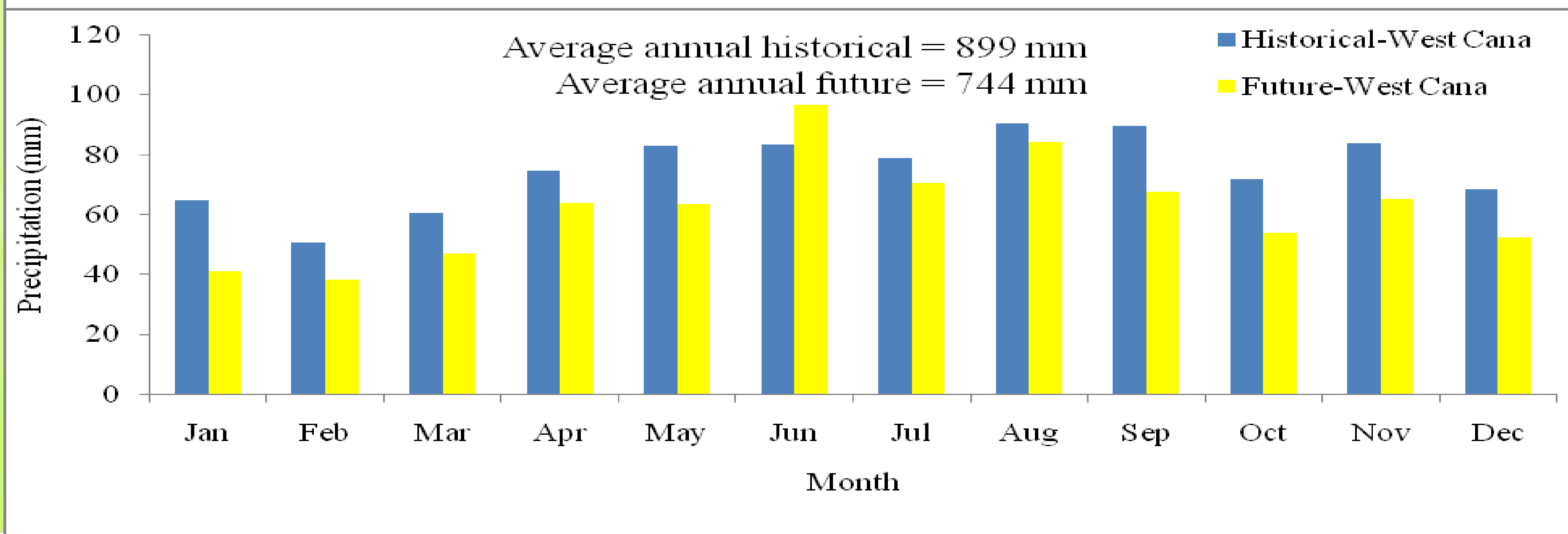


Model Validation

Analysis	Stream flow	
	West	East
Monthly		
NSE	0.58	0.65
R^2	0.67	0.69
Seasonal		
NSE	0.74	0.74
R^2	0.88	0.82
Annual		
NSE	0.25	-0.89
R^2	0.65	0.71
%error	6.27	15.2

Avg. Monthly Precipitation (1974-2003) Vs. (2015-2044) - Scenario A2

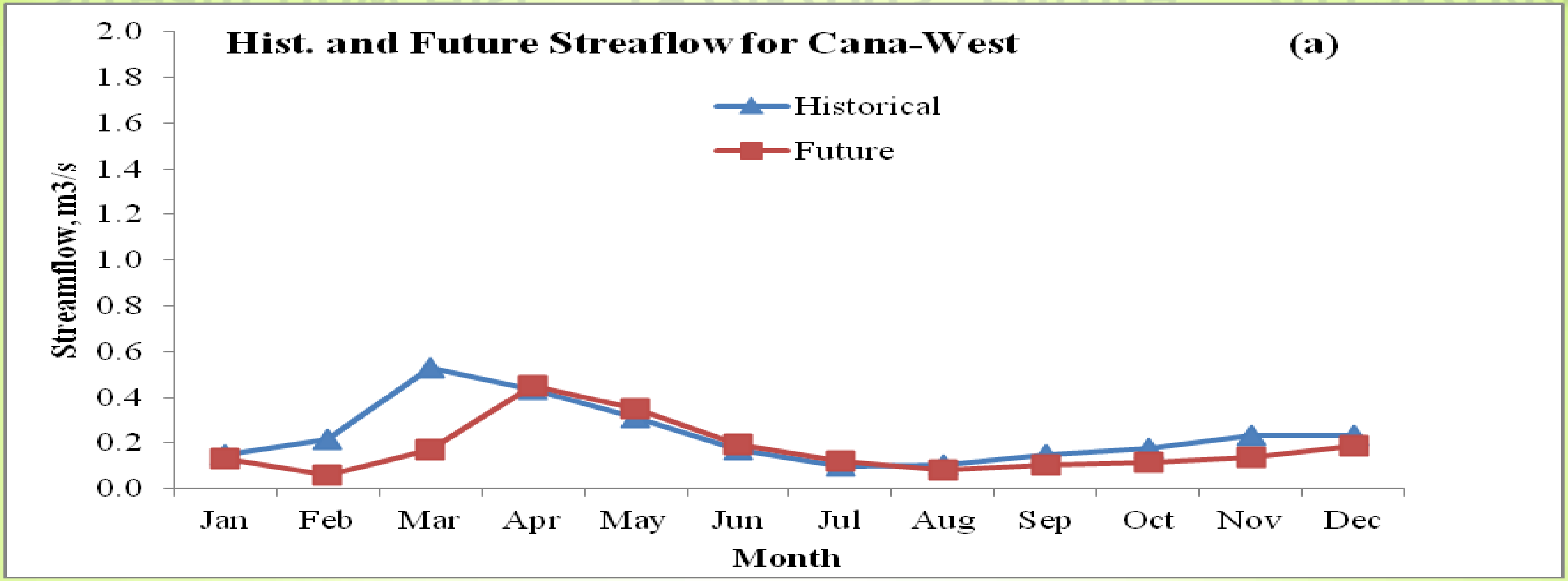


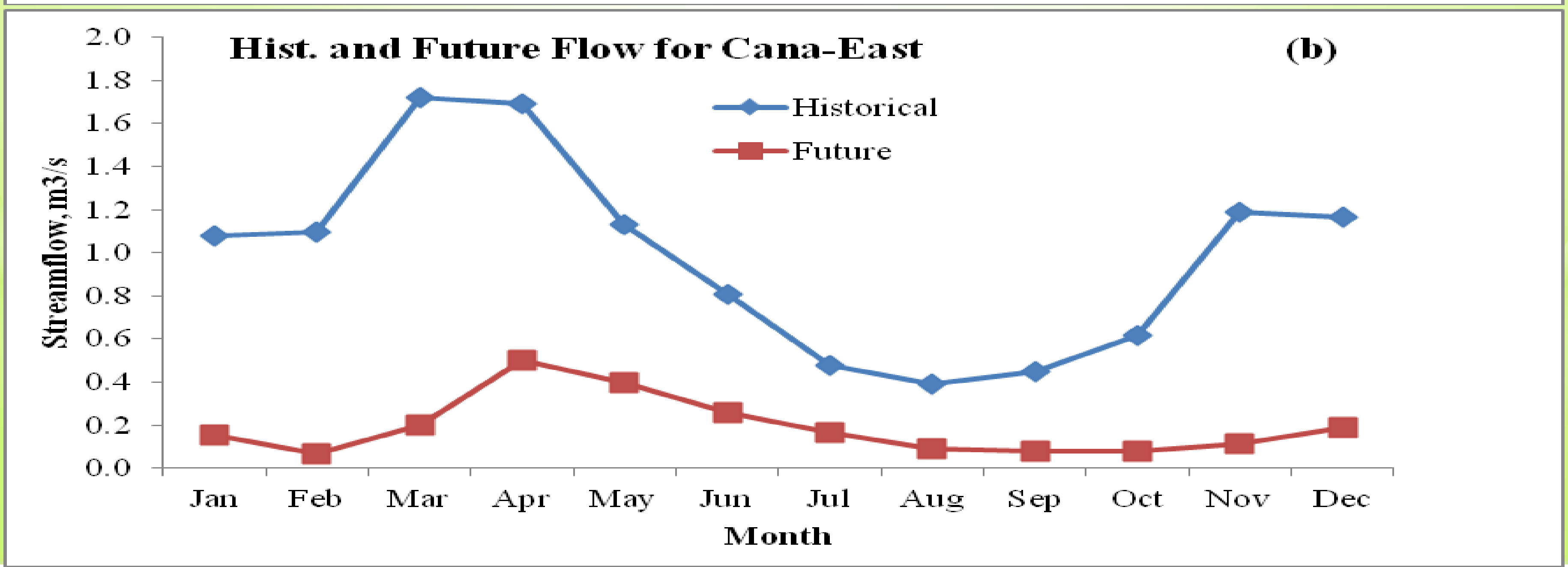


Avg. Mass Balance (1974-2003) Vs. (2015-2044)

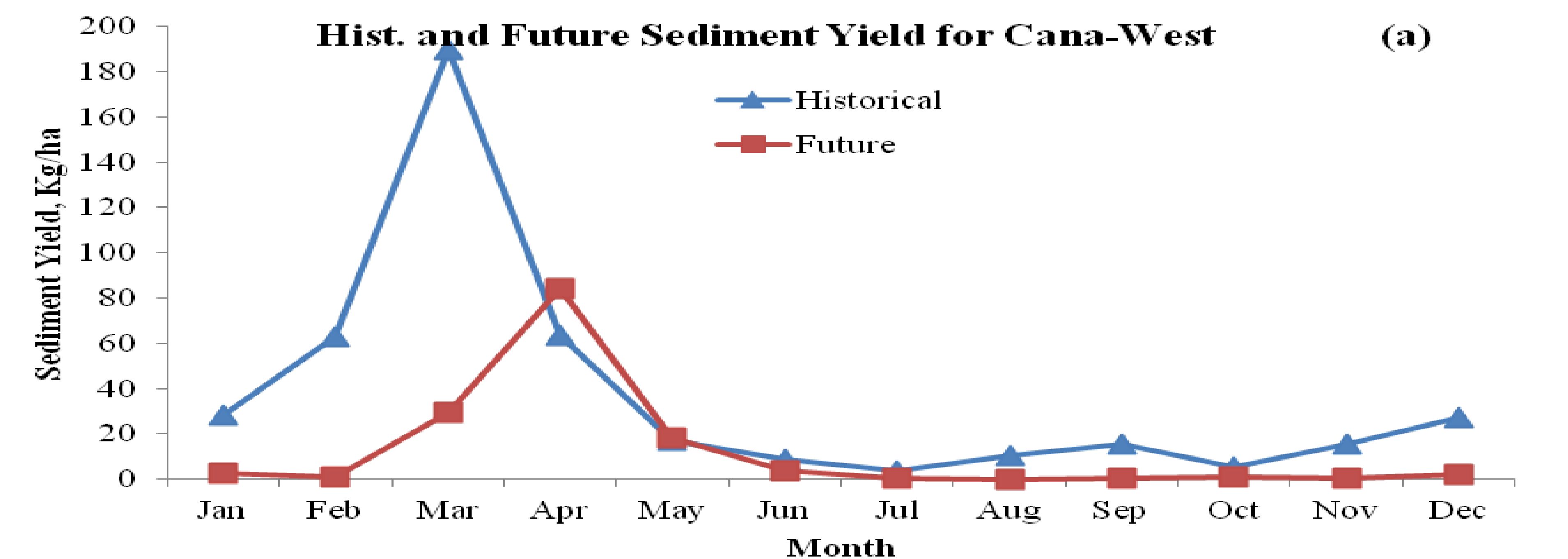
Watershed	Precip (mm)	ET (mm)	SRO (mm)	GW (mm)	SF (mm)
Cana-East (1974-2003)					
Total	938	506	169	200	388
% of Precip		54	18	21	41
Cana-East (2015-2044)					
Total	776	469	70	184	270
% of Precip		60	9	24	35
Cana-West (1974-2003)					
Total	899	481	165	212	392
% of Precip		53	18	24	44
Cana-West (2015-2044)					
Total	744	422	69	212	296
% of Precip		57	10	29	40

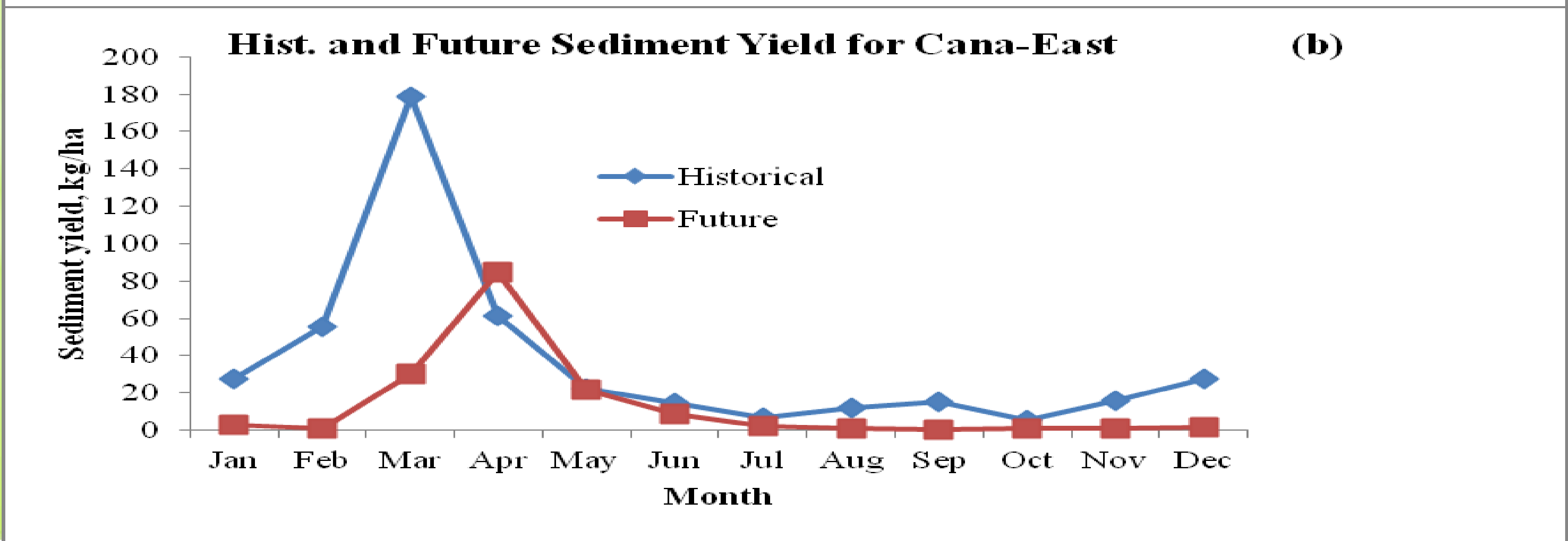
Stream flow Hist = 1974-2003, Future = 2015-2044



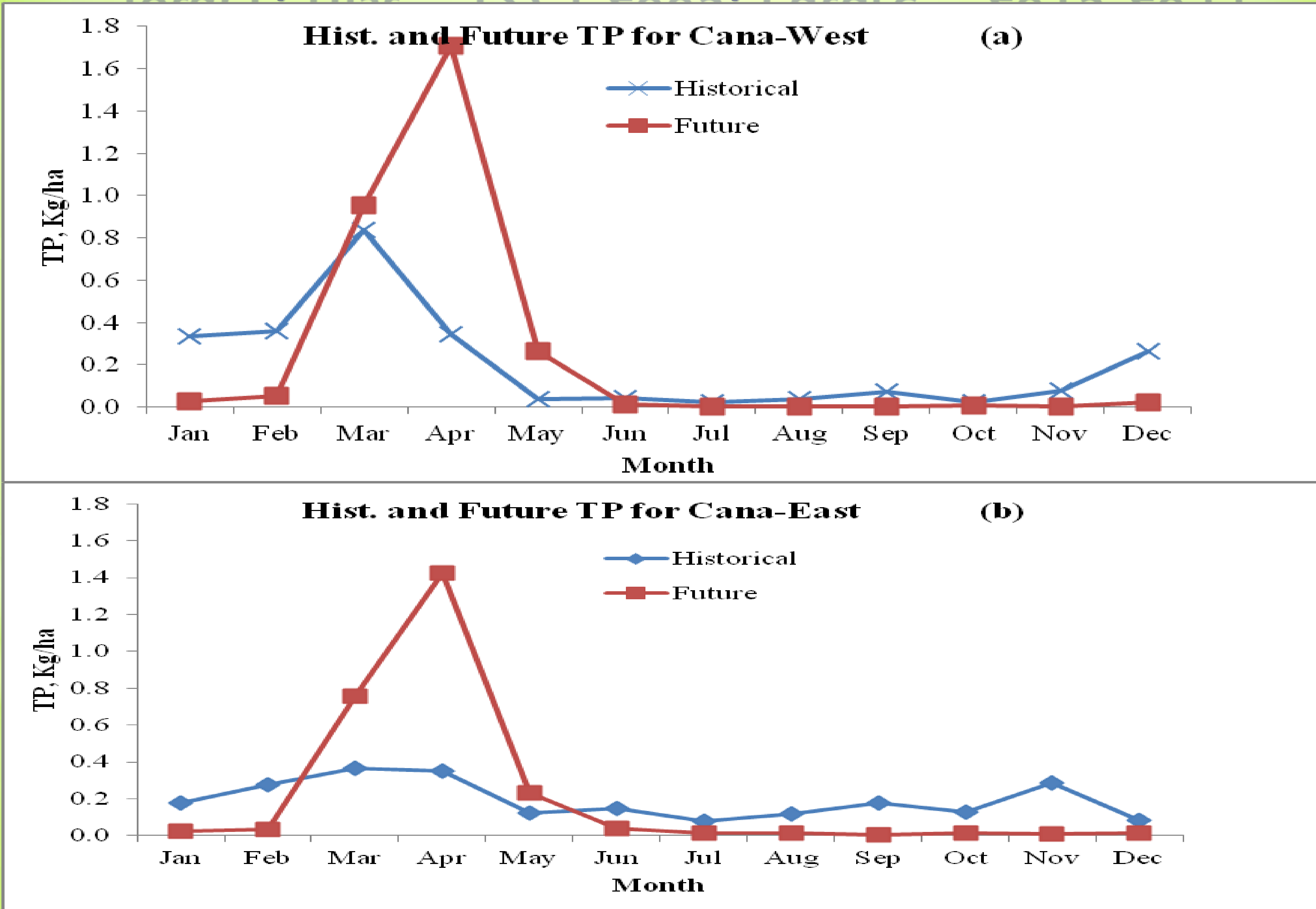


Sediment Yield Hist = 1974-2003, Future = 2015-2044

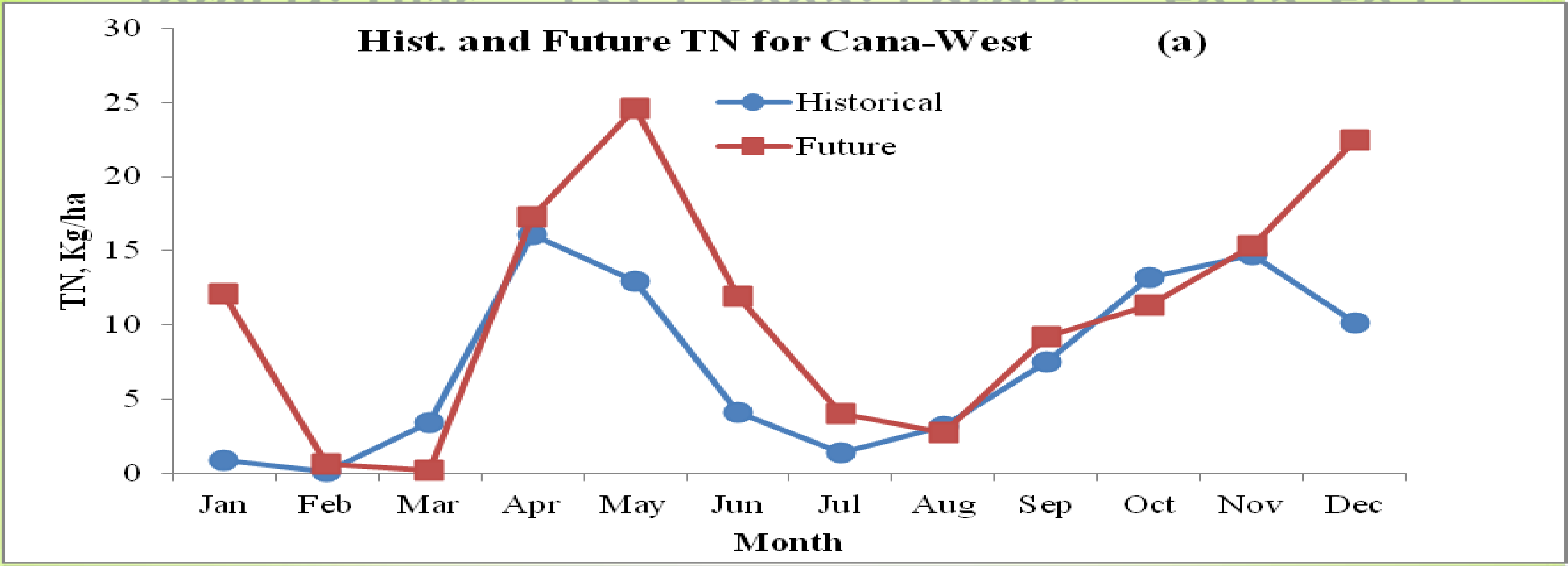


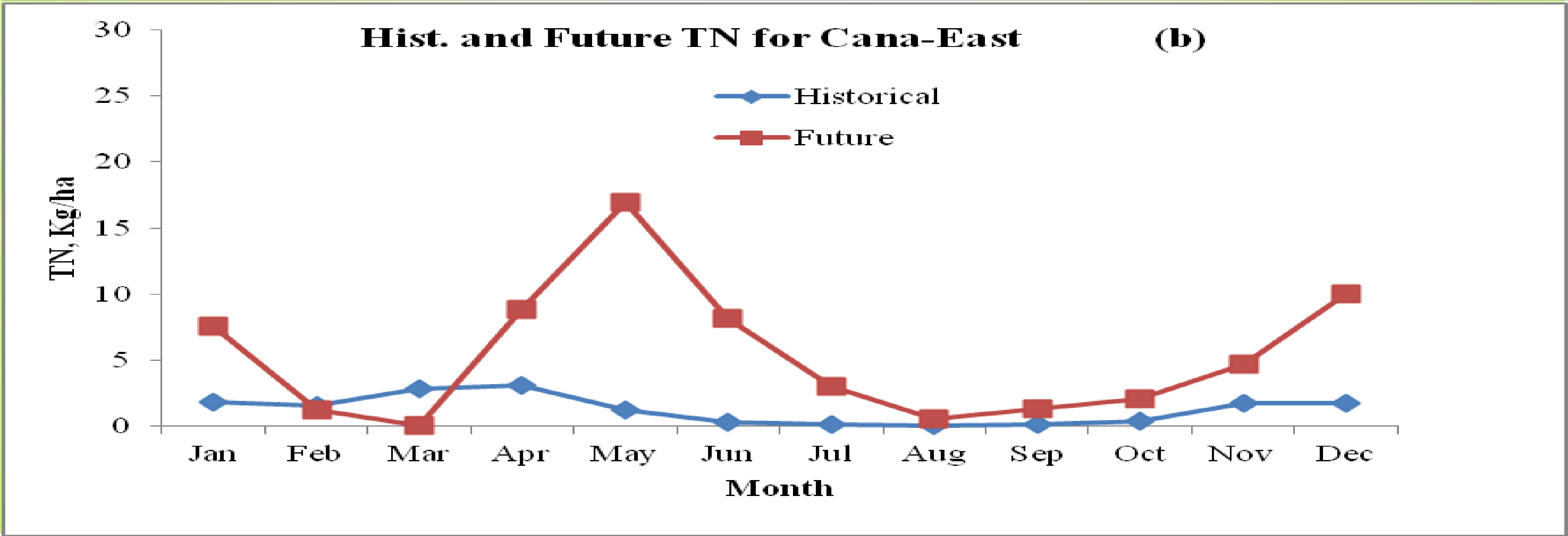


Total P, Hist = 1974-2003, Future = 2015-2044



Total N, Hist = 1974-2003, Future = 2015-2044





Pollutants - Hist = 1974-2003, Future = 2015-2044

Waters-hed	Sediment Yield (kg/ha)		Total P (kg/ha)		Total N (kg/ha)	
	Hist	Future	Hist	Future	Hist	Future
Cana-W	448	143	2.5	3.0	87.7	132.0
Cana-E	444	157	2.3	2.5	15.5	64.6

CONCLUSIONS …

- The calibration results showed a good comparison between the observed and the SWAT simulated daily, monthly, and annual stream flow with the monthly R^2 and Nash-Sutcliffe (NS) values of 0.87 to o.84 for these watersheds.
- The statistical analysis of simulated seasonal and annual stream flow with the observed ones also showed very similar trends for stream flow. The simulated annual stream flow was 6% less than the observed stream flow for calibration period for West Canagagigue; however, model over predicted for East Canagagigue.
- The validation of SWAT model also showed the over prediction of stream flow; however, results were satisfactory to simulate the model for future conditions.

CONCLUSIONS…

- SWAT model simulated flows for Canagagigue Creek very close to the observed flow; however, long-term data for calibration would be needed for the site
- Comparison of simulated sediment yield for East and West Canagagigue watershed was good when compared using the historical observed data.

CONCLUSIONS…

- The annual analysis for historical and future precipitation indicates that future predicted precipitation was -17.27% and -17.24% lower than the historic ones for Cana-East and Cana-West watersheds, respectively.
- SWAT simulation of stream flow and sediment loads suggests that much more ET is expected in future. Therefore, total water yield measured in streams may decrease significantly.
- The simulations indicated that the amount of future stream flow decreased 30% to 24% for the study watersheds when compared with historical ones.

CONCLUSIONS…

- The monthly flow rates in summer for the future were similar to those for historical summer, but the average future flow rates in the fall months were much smaller than the historical ones in the same months.

- Also, the amount of future surface runoff showed a consistent decreasing trend and the amount of future groundwater showed an increasing trend for all the watersheds.

- The monthly averaged sediment loads peaks occur in the same months when the historical peaks occur; however, the peaks for future are more frequent in April. Also, the magnitude of the peaks in future is much less and can be explained by the future lower flow rates.

CONCLUSIONS…

- The annual analysis of the historical and future stream flow and sediment yield indicated that the fluctuations in annual stream flow are much higher for historical period than the annual stream flow for the future period.
- The analysis of the monthly averaged total phosphorus loads for historical and future periods showed the peaks in March and April for historical and future periods, respectively. The amount of phosphorus increased for both the watersheds.
- The comparison of the monthly averaged total nitrogen loads for historical and future periods showed higher loads for future period for April to July and then again for December and January. The trend for TN load was opposite to the sediment yield and phosphorus load for future. The amount of future total nitrogen significantly increased for these watersheds which could be due to the higher amount of future groundwater contribution for these watersheds.

*Comments/Questions ?????