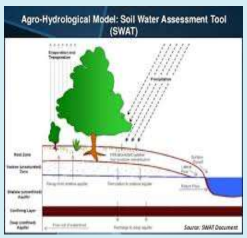
2018 International SWAT Conference, 10-12 Jan, 2018



Climate Change Sensitivity Assessment using SWAT for a Highly Agricultural Watershed, Shell Creek, Nebraska, USA

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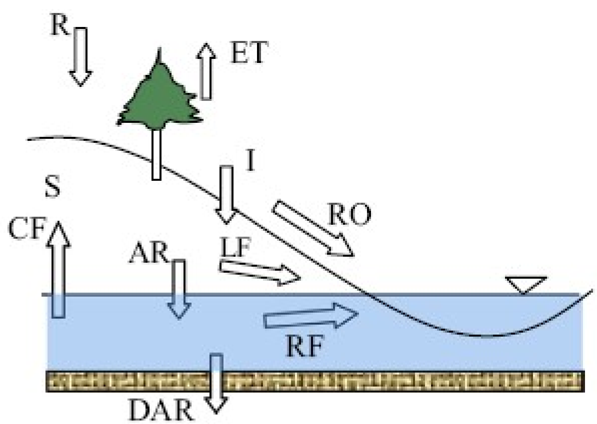
Outline of the Presentation

- Introduction
- Methodology
- Study Area Description
- Results and Discussion
- Conclusion
- References

Introduction

- Water resources around the globe come under increasing pressure due to climate change causing emerging trends in world food demand.
- Current scenario in all over the world are shift in the rainfall pattern, scarcity of water, climate change, vulnerability of available resources etc.
- Hydrological models are important tools for planning sustainable use of water resources to meet various demands.



R=rainfall,
ET=evapotranspiration,
I=infiltration,
RO=runoff,
RF=return flow,
LF=Lateral flow
CF=capillary flow,
AR=aquifer recharge,
DAR=deep aquifer recharge
S=Soil moisture

Hydrological Modelling

- Delineation of watershed
- Obtaining hydro-meteorological variables and geographic data
- Selection of modeling approach
- Calibration and Validation
- Use of the model for assessment/prediction/design

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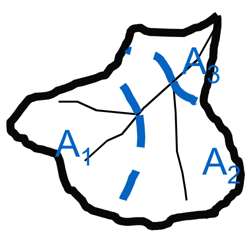
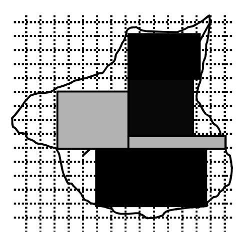
Hydrological Modelling (Contd.)

- Spatio-temporal scale of interest
- Hydrologic quantity of interest
- Availability of hydro-meteorological data of watershed
- Computational accuracy and requirement

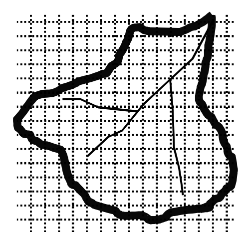
Lumped



Semi-Distributed



Fully-Distributed



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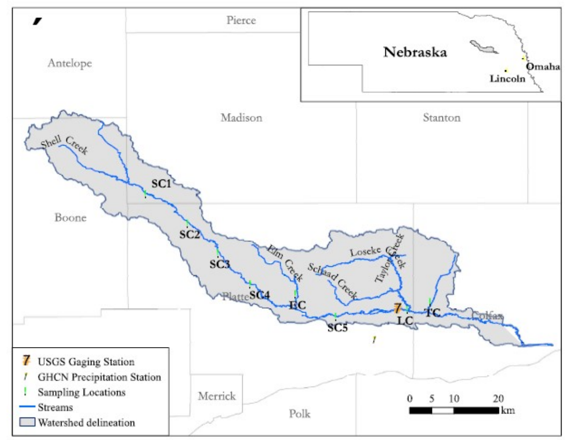
Soil Water Assessment Tool

- Rainfall is the main driver for the hydrological processes of ecosystem of a catchment.
- Basin yield is basic variable defining the agricultural water availability
- Accurate simulation of basin yield is vital for the management and adaptation

- SWAT is a widely used semi distributed hydrological model for estimating surface flow at catchment level and basin yield

- SWAT is able to simulate the hydrology and agricultural water availability
- Widely used to predict the impact of land use and management on water, sediment, and agricultural chemical yields in ungauged watersheds.

Case Study: Shell Creek River Basin, Nebraska, USA



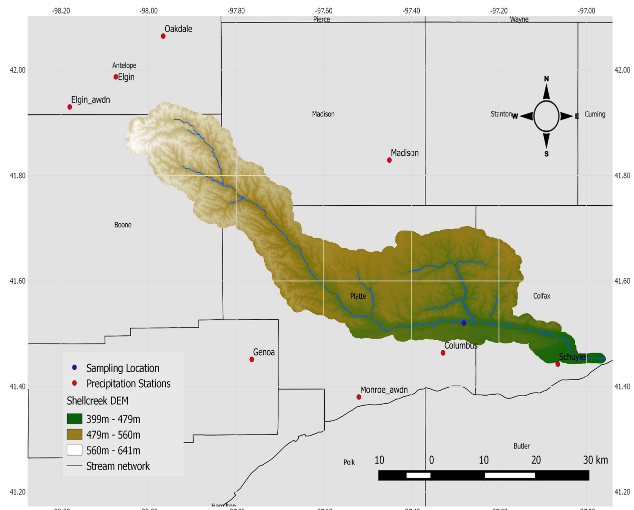
- Located within Boone, Madison, Platte and Colfax counties of Nebraska
- Watershed area as 1200 km^2 in east-central Nebraska.

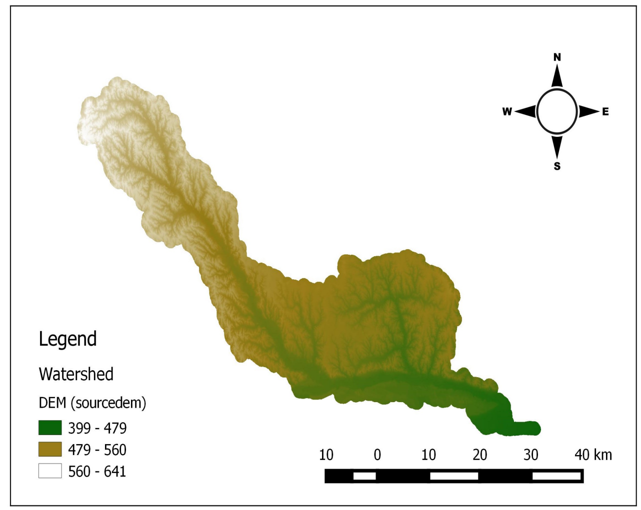
•The towns of Schuyler, Platte Center, Lindsay and Newman Gove comes under the Shell Creek watershed

- City of Columbus is towards South of the basin.

•Three major tributaries: Elm Creek, Loseke Creek and Taylor Creek.

Case Study: Digital Elevation Map (DEM)





Resolution: 30 m

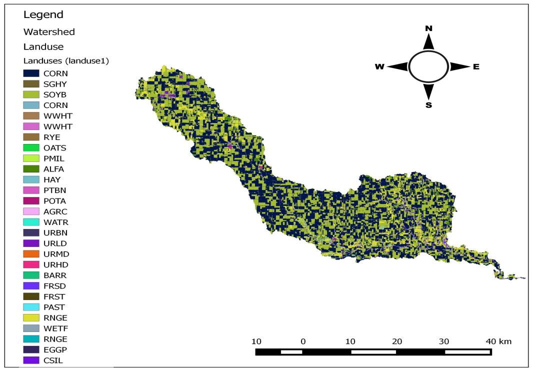
Minimum: 399 m

Maximum: 641 m

Source: United States Geological Survey (USGS) National Elevation Dataset

Land Classification

- Corn is the most important crop, with much of it going to feed cattle and hogs. Other leading crops are soybeans, wheat, hay, and other crops raised it include beans, sugar beets and potatoes etc.
- The Shell Creek watershed consists of 370,500 acres (1,499 km^2), Native rangeland (73%), Forest (24%), Irrigated cropland, pasture and hayland (3%).
- There are over 10,500 acres (42 km^2) of irrigated lands in the Shell Creek watershed; the greater part (92%) of which is in the lower portion-downstream from the town of shell.

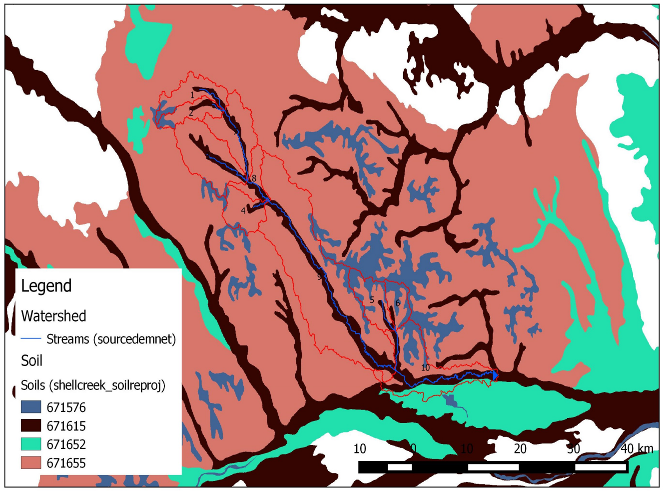


Station location data

Station name	Latitude	Longitude	Elevation
Columbus	41.4638	-97.3277	442
Elgin	41.9872	-98.0747	589.8
Genoa	41.4513	-97.7644	484.6
Madison	41.8291	-97.45	481.6
Oakdale	42.0644	-97.9666	533.1
Schuyler	41.4424	-97.0655	411.5
Elgin_awdn*	41.93	-98.18	619
Monroe_awdn*	41.38	-97.52	472

*These are the station locations for temperature and precipitation. Solar Radiation, Relative humidity and Wind speed data is obtained for the highlighted stations
Source: HadGEM2-ES

Soil Classification

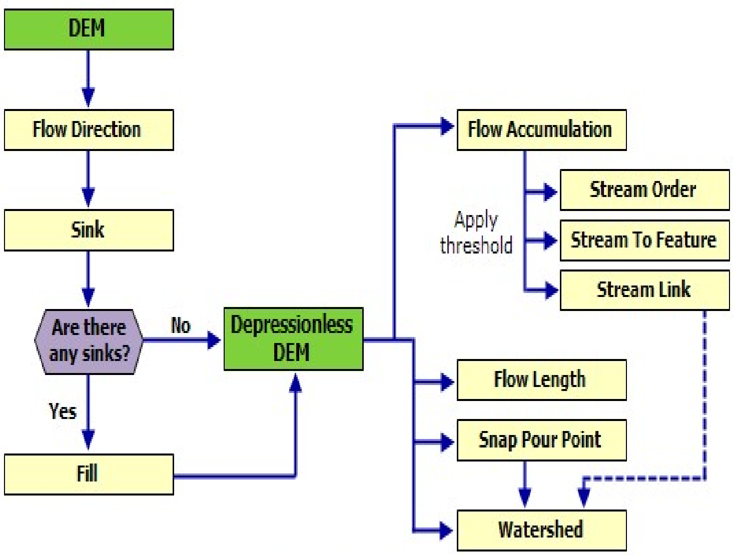


ID Name	Soil Texture
671576	Silty Clay Loam
671615	Silt Loam Stratified Silt Loam (SIL-SR_SIL)
671652	Loam
671655	Silty Clay

Methodology

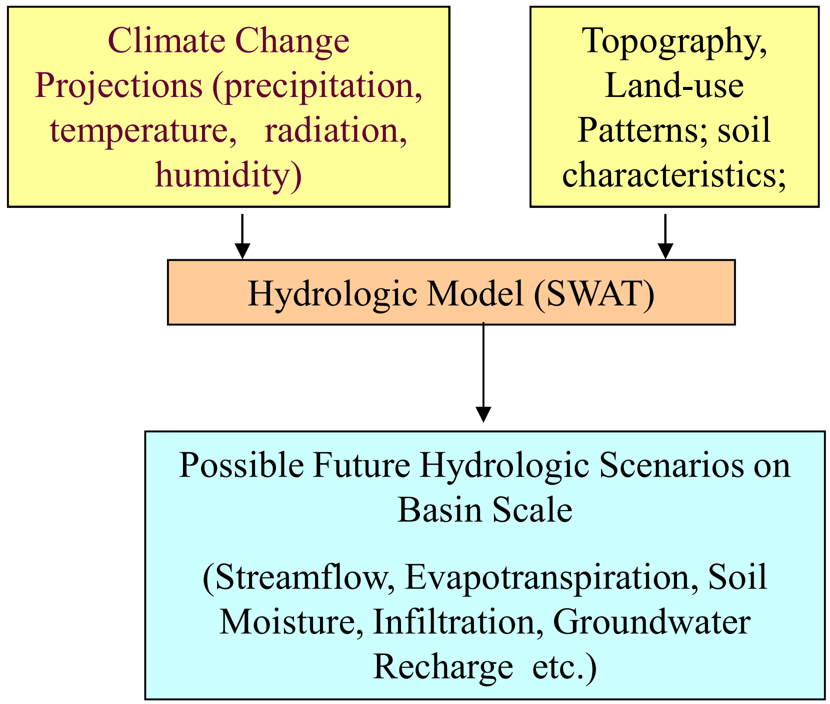
There are three steps in setting up the model and

1. Watershed delineation
2. HRU(Hydrologic Response Units) Creation
3. Run SWAT by building input tables into the database
4. Calibration of a Model by using SWAT-CUP



Hydrological modeling flowchart

Projecting Climate Change Impacts on Hydrology



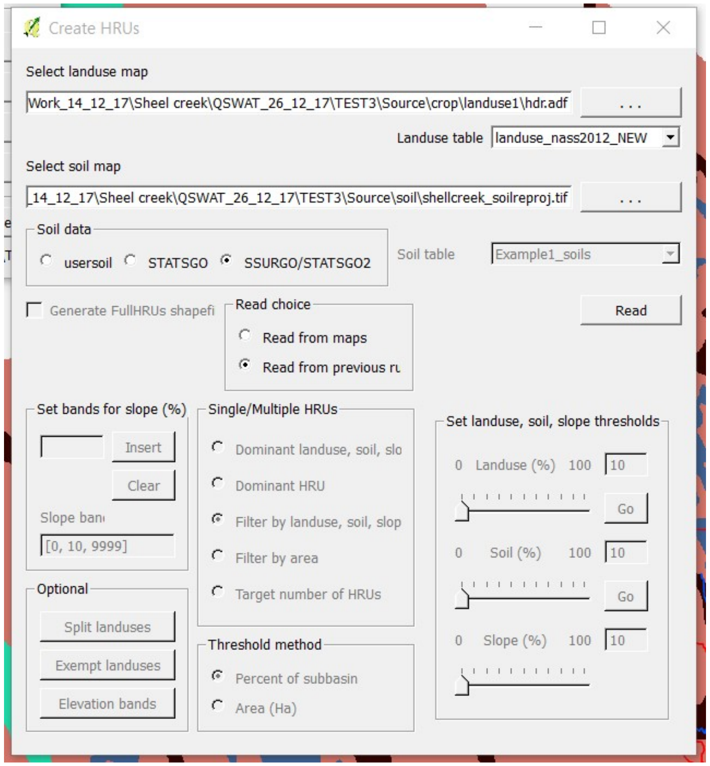
Watershed delineation

- Create stream network using the DEM(Digital Elevation Map).
- A sub basin is an area draining into a stream reach. Identify the outlet for sub basins which are very close to the discharge stations for which we have the observed data for comparison.
- Create watersheds or sub basins.
- Merge the smaller sub basins to avoid these during analysis.

HRU(Hydrologic response units) Creation

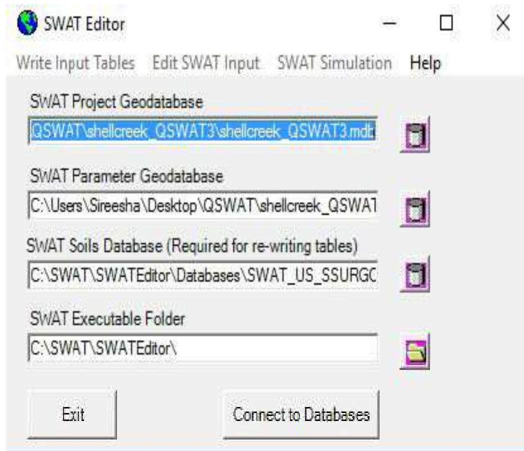
- HRUs are Hydrological Response Units which are individual units having unique characteristics such as land use type and soil type i.e all the points in this unit exhibit a similar categorization.

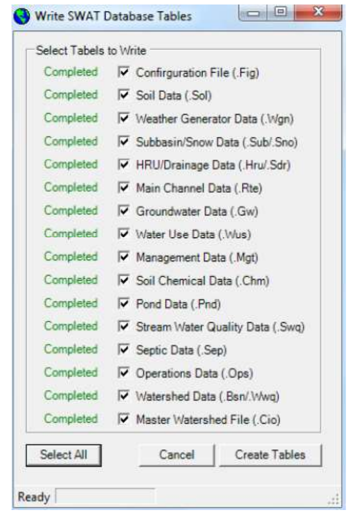
- Using the land use, soil and slope categorization, we filter the data.

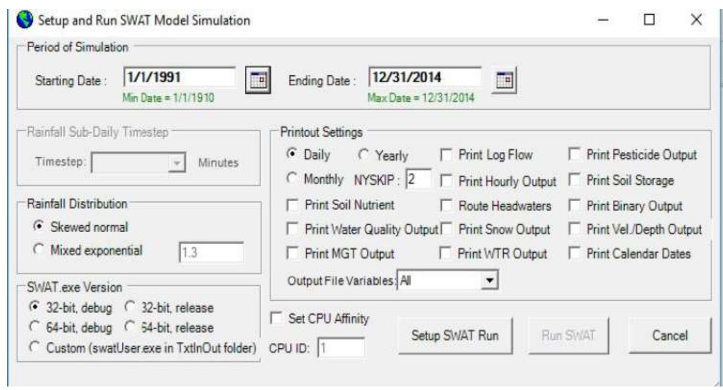


Run SWAT by Building Input Tables into the database

- Input tables are weather stations and SWAT database tables.
- After that go to the setup and run SWAT model window.
- Set the period of simulation, daily or monthly, number of years skip etc.,
- Then Finally setup and run SWAT Model, read the required output and save Simulation.







Calibration of QSWAT using SWATCUP

- SWAT-CUP provides a decision-making framework that incorporates a semi-automated approach (SUFI2) using both manual and automated calibration incorporating sensitivity and uncertainty analysis.

- In SWAT-CUP, all SWAT parameters can be included in the calibration process with standard default values as provided in the literature.

- The model is considered and setup for the manual calibration because it forces to better understand the model.

- The weakness in a comprehensive watershed model is the high number of parameters, which complicates model parameterization and calibration.

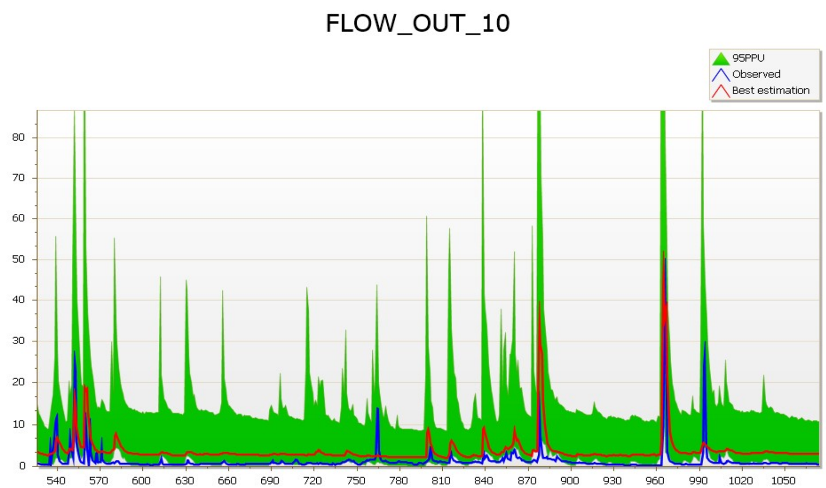
Results and Discussion

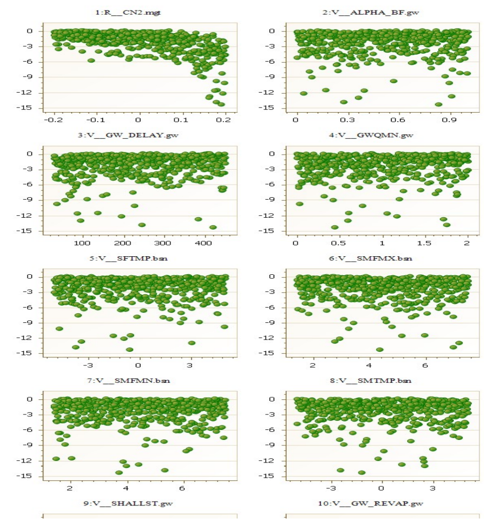
- Calibration has performed in SWAT-CUP by choosing standard values from the literature and model is run for 500 simulations.
- The model is set for the Nash-Sutcliff objective function.
- Based on the p values after the iteration rank is assigned in a ascending order.

Iteration	No_Simulation	Parameter Name	File Ext.	Method	Min	Max	R^2	N-S
Ite_1	500	CN2	.mgt	Relative	-0.2	0.2	0.37	0.23
		ALPHA_BF	.gw	Replace	0	1		
		GW_DELAY	.gw	Replace	30	450		
		GWQMN	.gw	Replace	0	2		
		SFTMP	.bsn	Replace	-5	5		
		SMFMX	.bsn	Replace	1.4	7.5		
		SMFMN	.bsn	Replace	1.4	7.5		
		SMTMP	.bsn	Replace	-5	5		
		SHALLST	.gw	Replace	0	5		
		GW_REVAP	.gw	Replace	0.02	0.2		
		REVAPMN	.gw	Replace	0	100		
		RCHRG_DP	.gw	Replace	0	1		
		ESCO	.bsn	Replace	0.01	1		
		EPCO	.bsn	Replace	0.01	1		
		SLSUBBSN	.hru	Relative	-1	1		
		HEAT_UNITS	.mgt	Relative	-1	1		
		OV_N	.hru	Relative	-1	1		
		SOL_K	.sol	Relative	-1	1		
		SOL_AWC	.sol	Relative	-1	1		
		SOL_BD	.sol	Relative	-1	1		
		SURLAG	.bsn	Replace	0.001	20		
		CH_K2	.rte	Relative	0	150		
		CH_N2	.rte	Replace	0.01	0.15		

Parameter Name	t-Stat	P-Value	Rank
9:V__SHALLST.gw	0.65	0.518	15
8:V__SMTMP.bsn	0.12	0.905	23
7:V__SMFMN.bsn	-0.70	0.486	13
6:V__SMFMX.bsn	-1.17	0.242	8
5:V__SFTMP.bsn	0.21	0.833	22
4:V__GWQMN.gw	-0.52	0.605	17
3:V__GW_DELAY.gw	2.57	0.010	5
23:V__CH_N2.rte	14.02	0.000	2
22:R__CH_K2.rte	0.15	0.881	21
21:V__SURLAG.bsn	-0.89	0.373	10
20:R__SOL_BD(..).sol	0.87	0.387	11
2:V__ALPHA_BF.gw	0.68	0.494	14
19:R__SOL_AWC(..).sol	13.71	0.000	3
18:R__SOL_K(..).sol	-0.64	0.524	16
17:R__OV_N.hru	1.75	0.081	7
16:R__HEAT_UNITS{..}.	1.99	0.048	6
15:R__SLSUBBSN.hru	4.71	0.000	4
14:V__EPCO.bsn	0.32	0.747	20
13:V__ESCO.bsn	-0.32	0.745	19
12:V__RCHRG_DP.gw	0.77	0.441	12
11:V__REVAPMN.gw	-0.42	0.676	18
10:V__GW_REVAP.gw	1.00	0.316	9
1:R__CN2.mgt	-21.47	0.000	1

Sensitivity of the parameters to the objective function





Goal_type= Nash_Sutcliff   No_sims= 500   Best_sim_no= 11   Best_goal = 2.323040e-001

Variable   p-factor r-factor R2   NS   bR2   MSE   SSQR   PBIAS KGE RSR MNS VOL_FR --- Mean_sim(Mean_obs)
StdDev_sim(StdDev_obs)
FLOW_OUT_10   0.68   2.62   0.37 0.23 0.1741 2.6e+001 1.1e+001 -120.7-0.29 0.88 -0.67 0.45   3.67(1.66)
4.42(5.81)

Sensitivity Analysis (contd..)

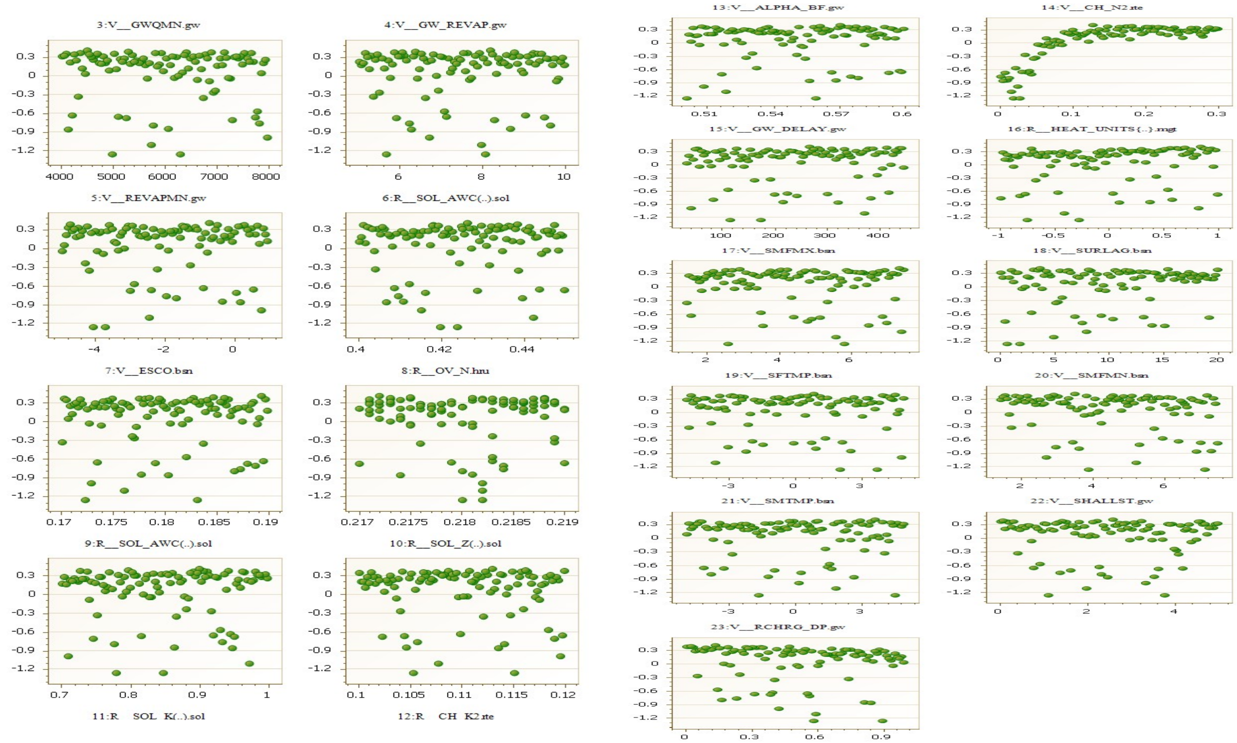
In the second iteration the simulation is set for 100 runs with modified ranges and tested for improvement over objective function (Nash-Sutcliff).

Iteration	Simulation	Parameter Name	File Ext.	Method	Min	Max	R^2	N-S
2	100	SLSUBBSN	.hru	Relative	0.036	0.039	0.43	0.41
		CN2	.mgt	Relative	-0.0024	-0.0025		
		GWQMN	.gw	Replace	4000	8000		
		GW_REVAP	.gw	Replace	5	10		
		REVAPMN	.gw	Replace	-5	1		
		SOL_AWC	.sol	Relative	0.4	0.45		
		ESCO	.bsn	Replace	0.17	0.19		
		OV_N	.hru	Relative	0.217	0.219		
		SOL_AWC	.sol	Relative	0.7	1		
		SOL_Z	.sol	Relative	0.1	0.12		
		SOL_K	.sol	Relative	0.075	0.08		
		CH_K2	.rte	Relative	-28	-30		
		ALPHA_BF	.gw	Replace	0.5	0.6		
		CH_N2	.rte	Replace	0	0.3		
		GW_DELAY	.gw	Replace	30	450		
		HEAT_UNITS	.mgt	Relative	-1	1		
		SMFMX	.bsn	Replace	1.4	7.5		
		SURLAG	.bsn	Replace	0.001	20		
		SFTMP	.bsn	Replace	-5	5		
		SMFMN	.bsn	Replace	1.4	7.5		
		SMTMP	.bsn	Replace	-5	5		
		SHALLST	.gw	Replace	0	5		
		RCHRG_DP	.gw	Replace	0	1		

Parameter Name	t-Stat	P-Value	Rank
12:R__CH_K2.rte	-0.03	0.98	23
15:V__GW_DELAY.gw	-0.07	0.95	22
13:V__ALPHA_BF.gw	-0.10	0.92	21
4:V__GW_REVAP.gw	0.16	0.87	20
2:R__CN2.mgt	0.24	0.81	19
6:R__SOL_AWC(..).sol	0.25	0.80	18
10:R__SOL_Z(..).sol	-0.29	0.77	17
7:V__ESCO.bsn	0.31	0.76	16
21:V__SMTMP.bsn	-0.33	0.74	15
18:V__SURLAG.bsn	0.39	0.70	14
23:V__RCHRG_DP.gw	-0.41	0.68	13
1:R__SLSUBBSN.hru	-0.44	0.66	12
5:V__REVAPMN.gw	0.46	0.65	11
8:R__OV_N.hru	-0.52	0.60	10
19:V__SFTMP.bsn	-0.53	0.60	9
22:V__SHALLST.gw	-0.60	0.55	8
16:R__HEAT_UNITS{..}.mgt	1.07	0.29	7
3:V__GWQMN.gw	1.18	0.24	6
9:R__SOL_AWC(..).sol	1.30	0.20	5
17:V__SMFMX.bsn	-1.60	0.11	4
11:R__SOL_K(..).sol	-1.70	0.09	3
20:V__SMFMN.bsn	-1.95	0.05	2
14:V__CH_N2.rte	9.59	0.00	1

Sensitivity Analysis (contd..)

- By comparing with the previous iteration it is observed that the performance value has been increased to 0.41. In this case of dotty plots the points are scattered and haphazard so sensitivity is low.



Future Projections of Discharge

- The annual discharges from 1993 to 2014 period at USGS gauging station averages 1.662 ± 3.05 m^3/s.
- The Future annual discharges from 2015 to 2020 at USGS gauging station averages 3.426 ± 4.201 m^3/s.
- SWAT model with manual calibration has been performed using SWAT-CUP calibrated sensitive parameter values for future flow prediction.

Year	Annual flow (m^3/s)
1993	3.905
1994	1.836
1995	1.76
1996	1.758
1997	1.269
1998	1.936
1999	2.56
2000	1.114
2001	1.415
2002	0.662
2003	0.909
2004	1.817
2005	0.803
2006	0.522
2007	2.285
2008	3.374
2009	1.284
2010	3.07
2011	1.694
2012	0.859
2013	0.839
2014	0.897

Year	Annual Flow (m^3/s)
2015	4.201
2016	8.356
2017	3.366
2018	1.294
2019	0.669
2020	2.673

GCM: Met Office Hadley Centre , UK . HadGEM2-ES For RCP 4.5

Conclusions

- The QSWAT interface of SWAT model is successfully used for exploring hydrological characteristics of Shell Creek basin.
- The automatic watershed delineation at HRU level clearly shows the basic features like land use, soil and slope have an effect on the hydrology of the catchment.
- SWAT-CUP advance calibration and uncertainty analysis tool is used for automatic calibration of stream flow measurement on daily basis for the period from 1993 to 2007 using the SUFI-2 procedure and the remaining period from 2018-2014 considered for validation.
- The sensitivity analysis adopted for calibration shows variations between parameter values which had been initialized for model calibration on daily basis.

Conclusions (contd..)

- After considering all the uncertainties like inconsistency in the observed flow data and with only one outlet available, the SWAT model is a good result for daily simulated flow.
- The developed SWAT model is calibrated and the results obtained is of NSE 0.43 during calibration. In the case of validation, the results obtained is 0.44.
- The calibrated and validated model is used with HadGEM2-ES For Research Concentration Pathways (RCP) 4.5 for the prediction of future hydrologic scenarios.
- The increase in annual discharges from 2015 to 2020 at USGS gauging station averages around 3.426 ± 4.201 m^3/s.

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Thank you