UNI KASSEL VERSITÄT

Bauingenieur - und Umweltingenieurwesen

Institut für Geotechnik und Geohydraulik

Evaluating the impacts of climate change on streamflow and water resources management:

Aharchai River, Iran, case study

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Introduction

- The growing population rate and the limitations of available water resources as an undeniable vital factor for human's survival increase the likelihood of water scarcity in future years.

- This situation is exacerbated by the rising trend in climate variability due to global climate change where the available current water resources and bodies will be adversely affected, which may result in some hydro-climatic disasters with severe losses for the vulnerable natural systems and communities.

- Therefore, the first inevitable task to prepare ourselves is to identify the climate variations, followed by a prediction of the future hydro-climatic conditions and so, eventually, to be able to define adaptation plans that can mitigate the mentioned negative impacts on water supply systems.

Literature Review

The impacts of changing climate on available water resources

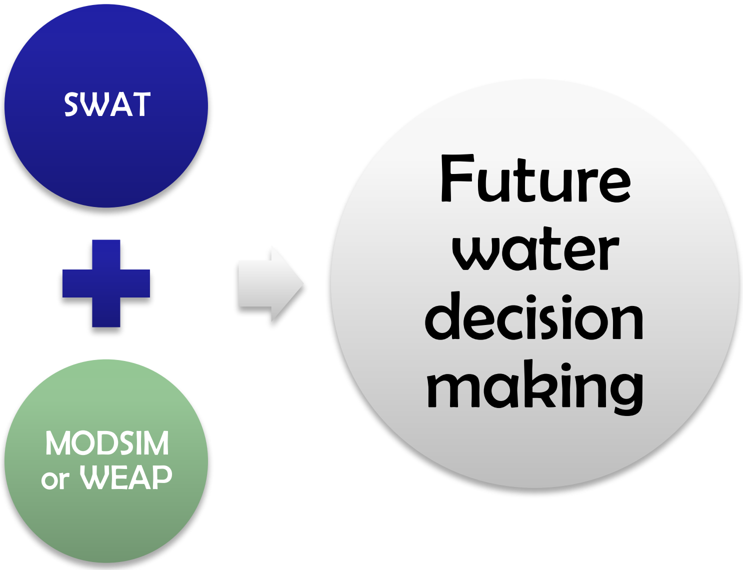
Chien et al. (2013); Koch and Cherie (2013); Jha et al. (2007)

GCM → Downscaling → Climate variables prediction → SWAT hydrologic simulation model → Hydrologic changes prediction

Literature Review

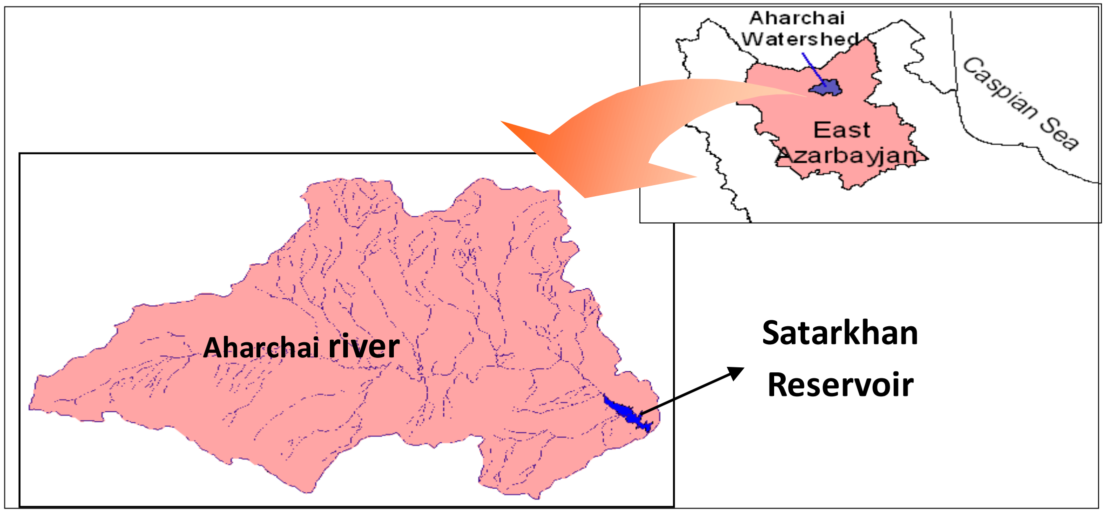
Long-term evaluation of future water use due to climate change impacts

Vaghefi et al. (2012); Tegegne et al. (2013); Ahn et. al (2012); McCartney et al. (2012)



Case Study

Abbaspour et al. (2009) indicated that climate change will affect Iran in future years with more frequent and larger-intensity floods in the wet regions and more prolonged droughts in the dry regions.



Methods

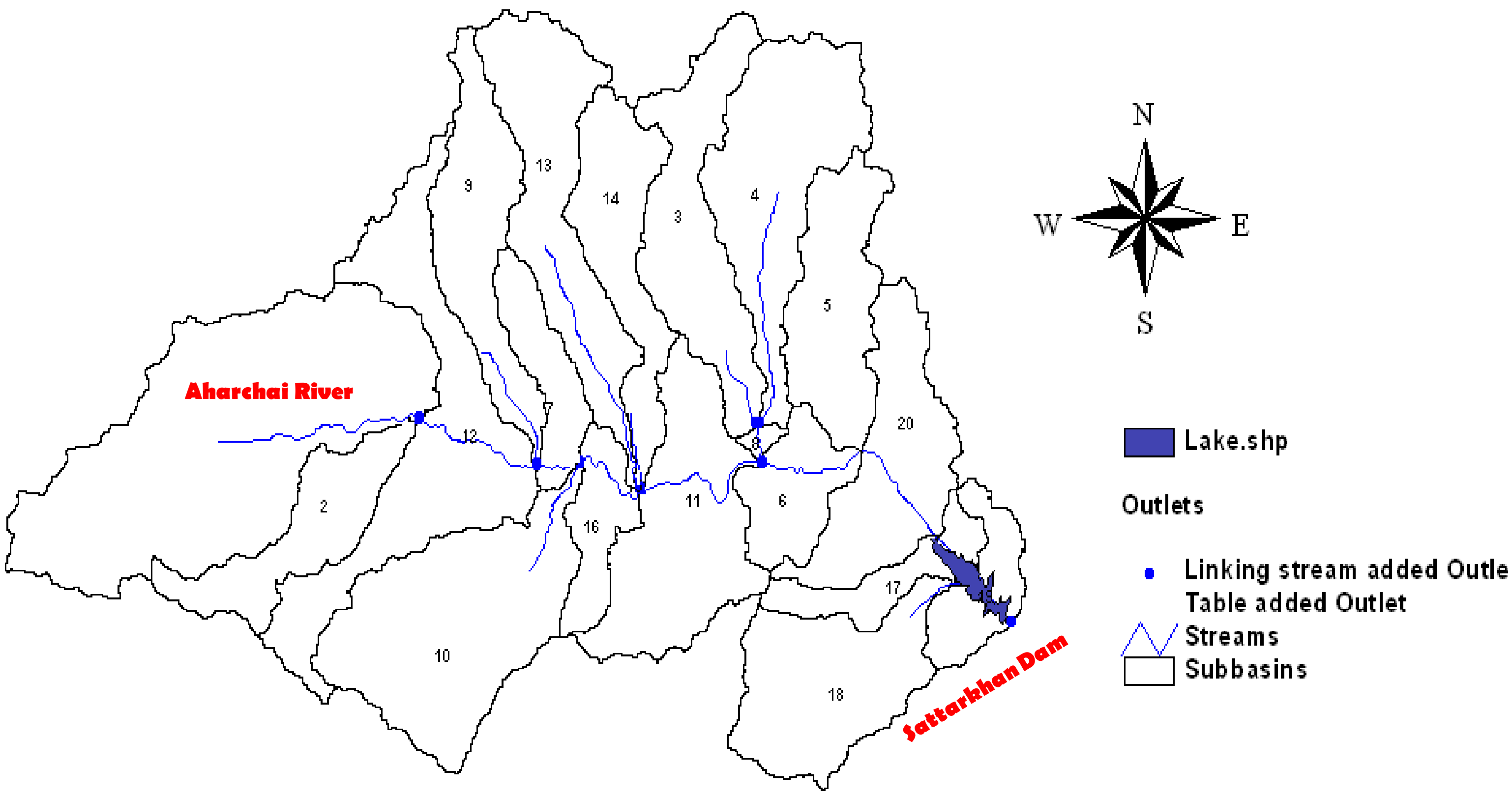
Hydrologic simulation modeling with SWAT

- SWAT integrated hydrologic simulation model is a physically-based, semi-distributed, time continuous rainfall- runoff simulation model that operates on a daily time step.

- This watershed model is used to investigate climate change impacts on hydrologic changes while it includes procedures to describe how changing climate parameters such as CO_2 concentration, precipitation, temperature and humidity affect plant growth, evapotranspiration, snow and runoff generation, among other variables. (Abbaspour et al., 2009)

Methods

Hydrologic simulation modeling with SWAT



Methods

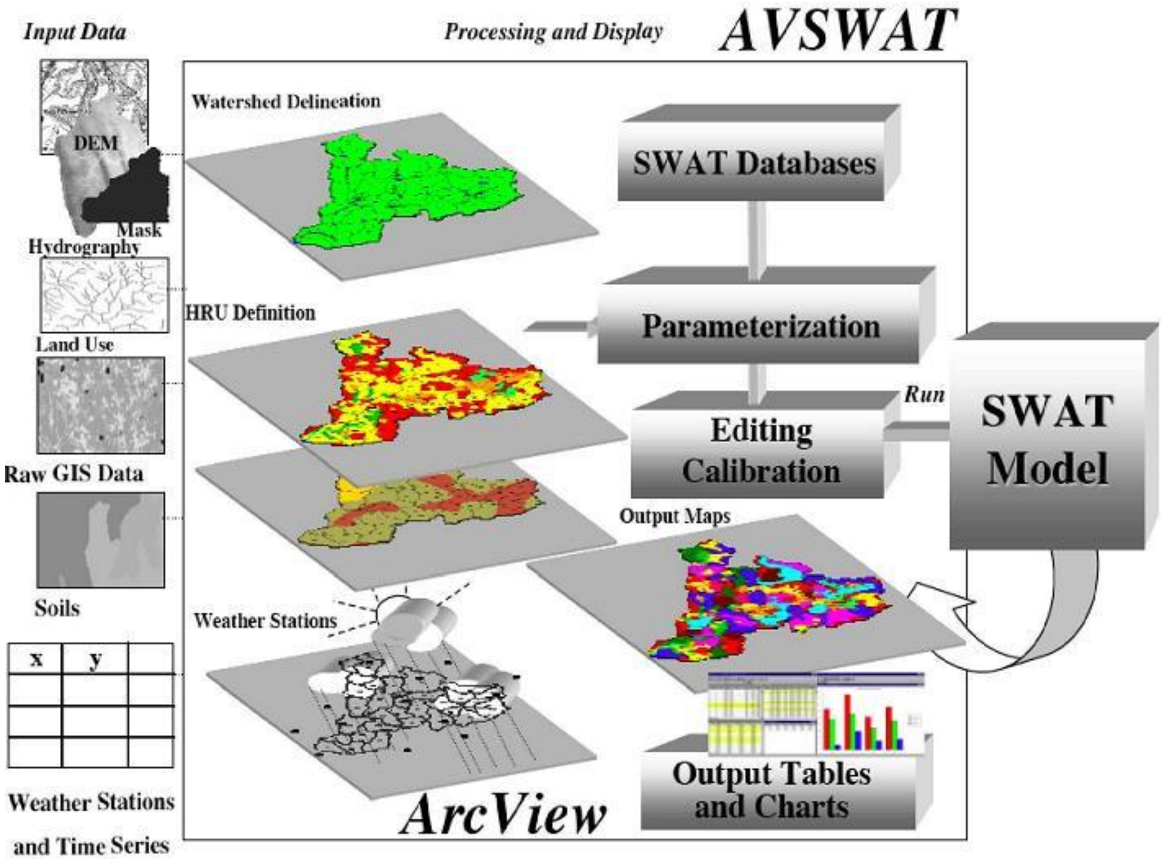
Hydrologic simulation modeling with SWAT

The following data is used in this modeling:

- ✓ Digital elevation model (DEM), produced by the Iranian surveying organization scale: 1:250,000
- ✓ Land use map, produced by Rooyan consulting engineers in 2006 with a scale of 1:180,000
- ✓ Soil map, produced by the Iranian research center of soil and water, scale: 1:250,000
- ✓ Climatic data including daily precipitation and maximum and minimum temperatures for four precipitation (Kasanagh, Khormazard, Pordel and Payam) and one temperature (Ahar) stations in the study area over a variable period of 10-40 years (1965–2005)

Methods

Hydrologic simulation modeling with SWAT



Methods

Statistical downscaling with SDSM

(Statistical DownScaling Model)

- Second Hadley Centre coupled ocean-atmosphere GCM (HadCM3) data in two series scenario A2 and B2 which are available from year 2000 to 2099, is used as the models inputs to determine future weather variables (Massah, 2006).

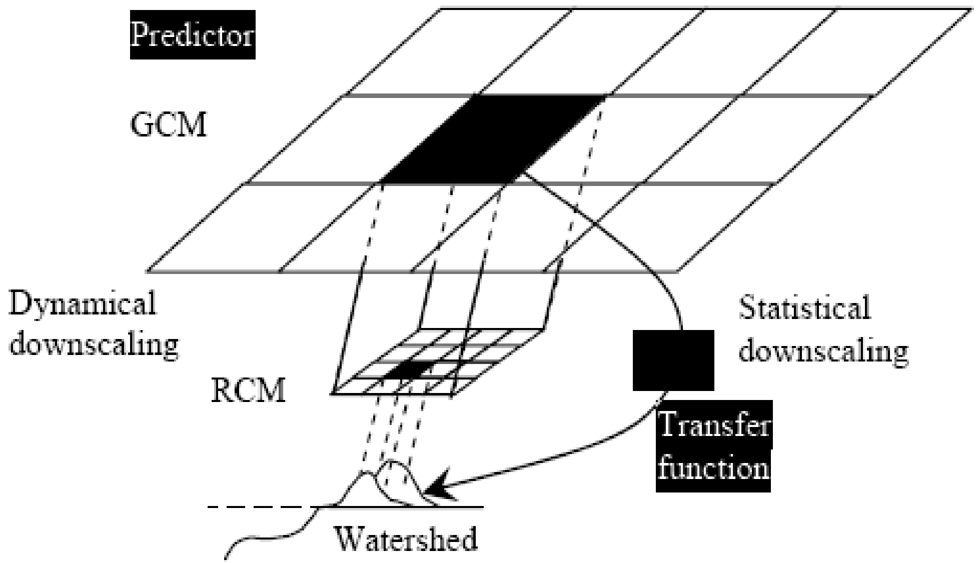
- The minimum and maximum temperature and the precipitation were predicted and then used as input to the hydrologic simulation model.

- The future changing climate is predicted by SDSM model using Kasanagh and Ahar as representative stations for precipitation and temperature changes.

Methodology

Statistical downscaling with SDSM

(Statistical DownScaling Model)



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Methods

Water decision making model MODSIM

The river basin model is represented in MODSIM as a network of links and nodes considering unregulated inflows, reservoir operating targets, consumptive and in-stream flow demands, evaporation and channel losses, reservoir storage rights and exchanges, and stream–aquifer modeling components (Fredericks et al. 1998).

Minimize $\sum_{l \in A} c_i q_i$

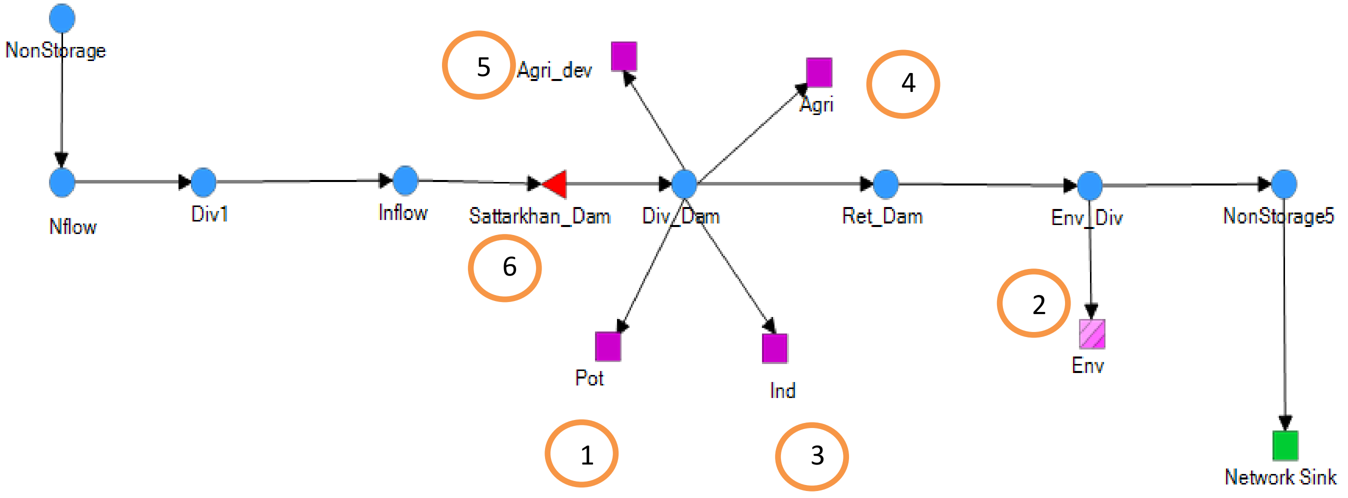
Subject to:

$$\sum_{j \in o_i} q_j - \sum_{k \in l_i} q_k \; (i \in N)$$

$$l_l \leq q_l \leq u_l \;\; (i \in A)$$

Methods

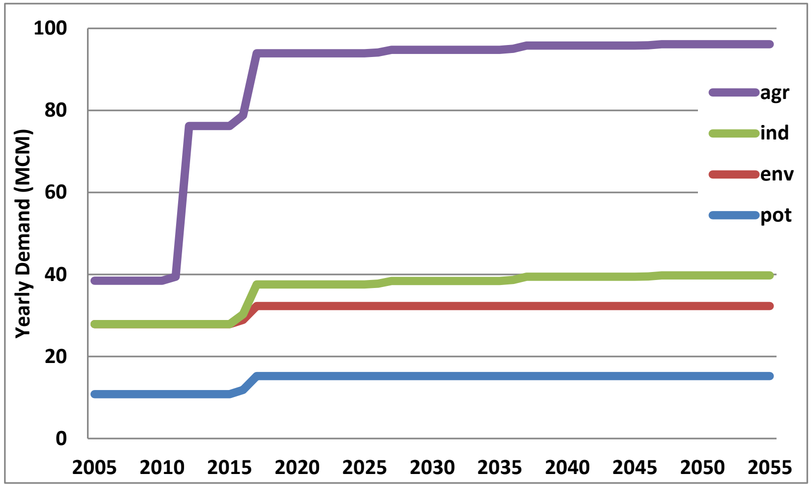
Water decision making model MODSIM



Methods

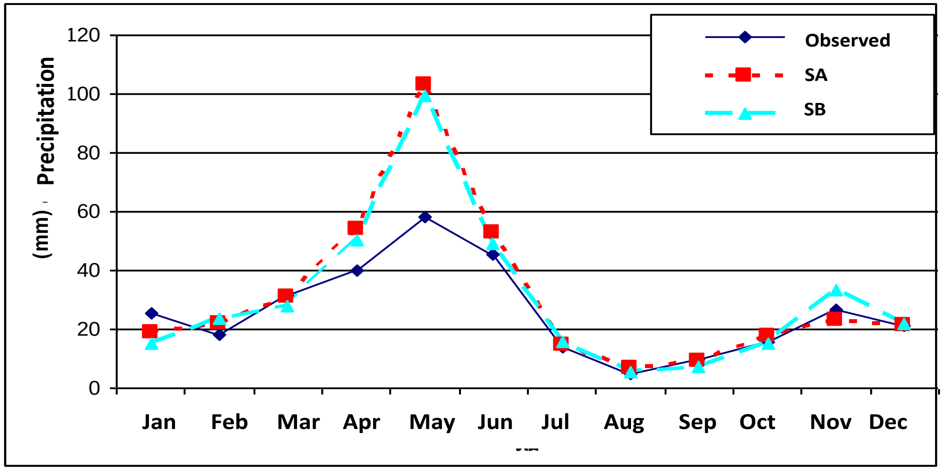
Water decision making model MODSIM

The water uses in order of supplying priority for future conditions:
Potable, Environmental, Industrial and agricultural, agricultural developing water uses and filling of reservoir.



The changes of future demands supplied from Sattarkhan Dam in next 50 years, base year 2005

Results

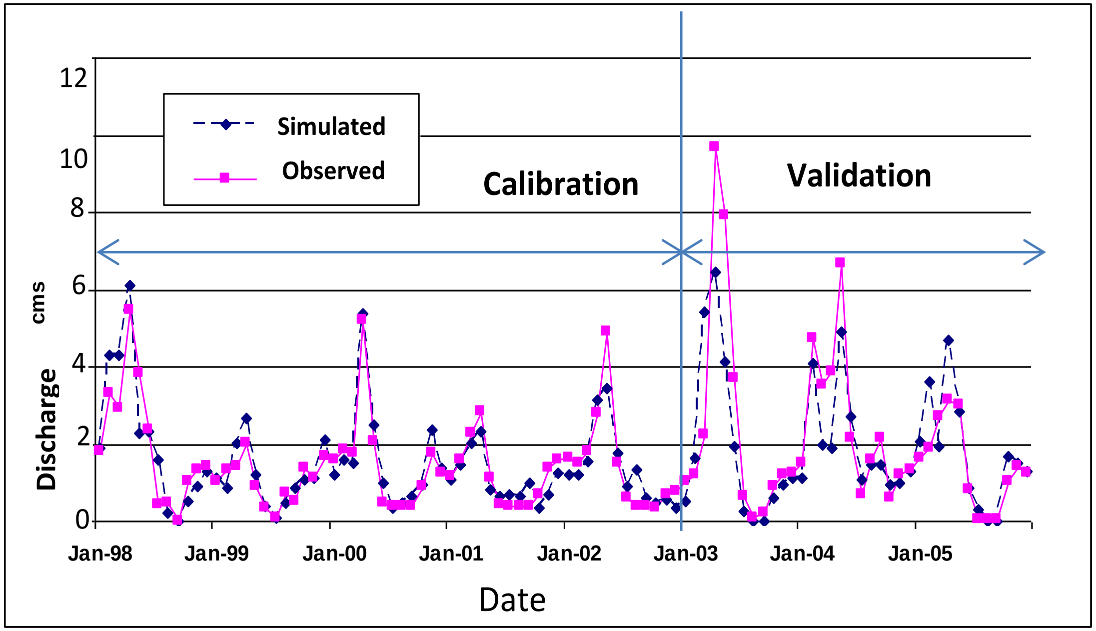


Calibration results for two precipitation scenarios in Kasanagh station

The objective functions values for model calibration and validation using SUFI-2

Objective Function Value	Calibration	Validation
Nash–Sutcliffe coefficient of efficiency (E)	0.7	0.82
Correlation Coefficient (R^2)	0.83	0.72

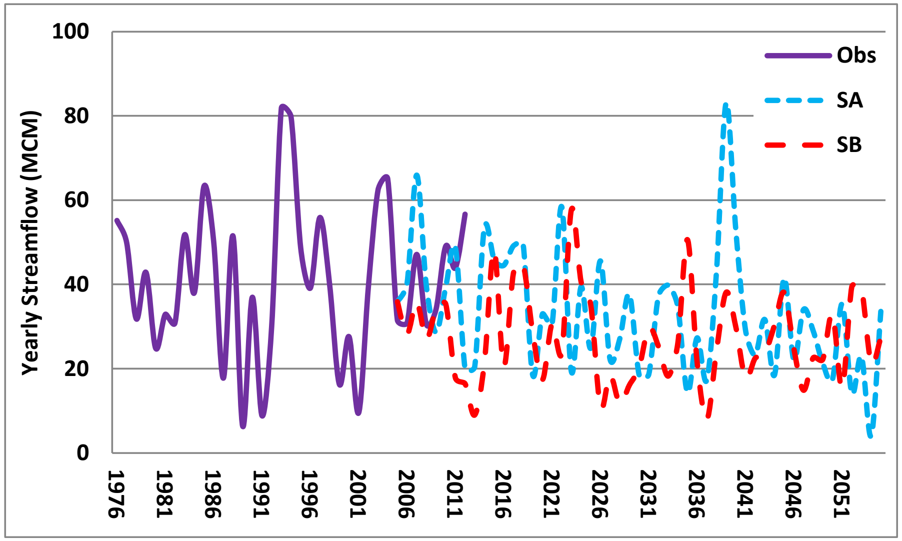
Results



Model calibration and validation results for monthly inflow to the reservoir

SWAT model of Aharchai was calibrated using SUFI-2 model (Abbaspour et. al. 2004) using 1000 run iterations and 27 model parameters such as CN2, USLE_P, SOL_AWC, and PPERCO (Emami , 2009).

Results



The yearly changes of observed and 50 years predicted scenarios for streamflow entering Sattarkhan dam

The reservoir inflow for both SA and SB scenarios are mostly decreased in comparison with the observed inflow

Results

Met demands summarized results for the reservoir inflow prediction and water management scenarios

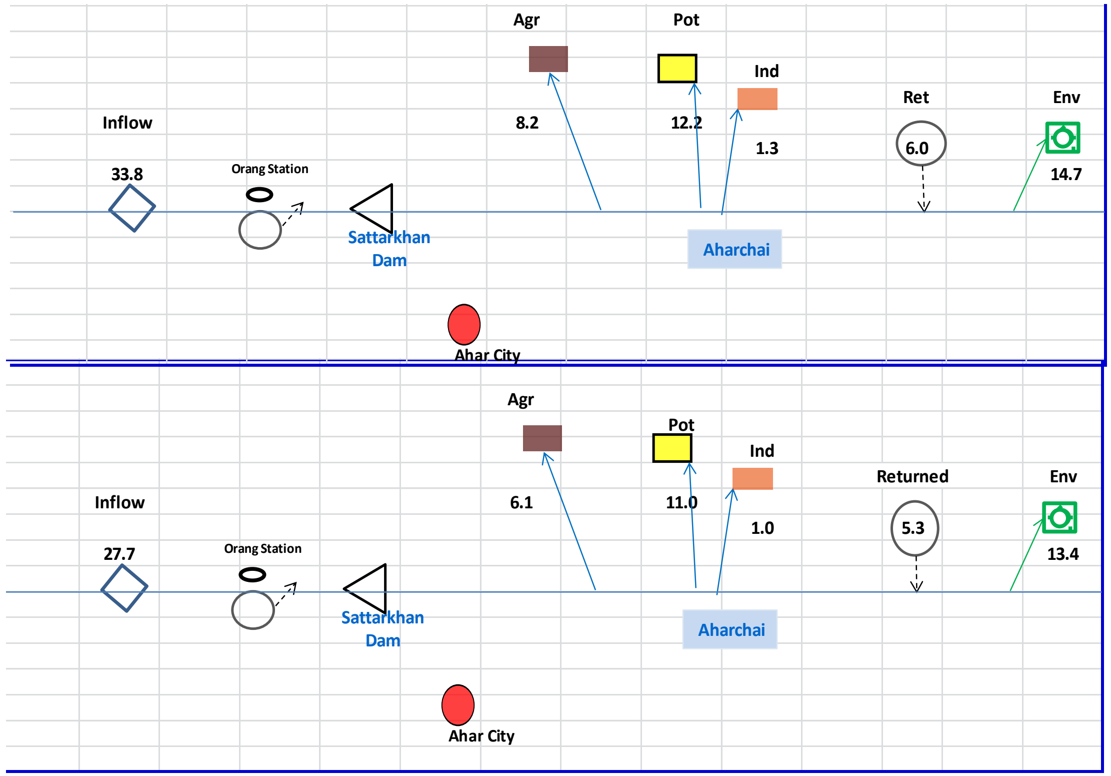
Reservoir Inflow Scenario	Water Management Scenario	Met %	Pot	Env	Ind	Agr
Observed		v	100	100	---	100
		t	100	100	---	100
SA	WM1	v	73	48	65	18
		t	58	42	56	29
	WM2	v	86	63	86	78
		t	91	77	74	76
SB	WM1	v	70	61	45	12
		t	54	38	54	25
	WM2	v	78	78	48	58
		t	69	63	62	59

Water management scenarios

WM1 complete development of future water demands

WM2 sustainable water management scenario

Results



Schematic of water allocation model based on inflow predictions scenarios SA (a) and SB (b) based on WM2

Conclusion

- The efficiency of the calibrated model with SUFI-2 method for streamflow was tested by Nash- Sutcliff coefficient which varies between 0.75 to 0.66 for calibration and 0.58 to 0.49 for validation.

- The reservoir inflow are mostly decreased for both SA and SB scenarios in comparison with the observed inflow. However, the fluctuation trend are the same.

- Comparison of the simulated water uses with the observed model shows a considerable decrease in met demands and more deficits for every demand type especially drinking and environmental demands.

Conclusion

- Regarding to the results of WM2 as recommended scenario, the agricultural water use should be remain to the current allocated water use (10.6 MCM/ year) and the industrial demands is limited to 175 m3/ hr.

- While the irrigation efficiency can be increased from 45% to 55% the agricultural demand will decrease 20% and this amount can be allocated to the developing agricultural areas. In addition, some deficit irrigation practices or rising efficiency such as using pressurized irrigation can be implemented in order to accomplish a limited agricultural development.

- For the industrial water use especially Soongoon Complex water use, recycling water and water transfer projects can be mentioned as some alternatives.

Conclusion

❖ In order to adapt future climate change, the agricultural and industrial water use cannot increase and they should focus on enhancing the efficiency of water uses.

❖ It can be recommended adding or coupling a water decision making module to SWAT as a watershed management model, can enhance its capabilities for integrated watershed management based on sustainable management principles.

THANK YOU FOR YOUR ATTENTION!