Modelling of the Hydrology, Soil Erosion and Sediment transport processes in the Lake Tana Catchments of Blue Nile River Basin, Ethiopia

Combining Field Data, Mathematical Models and Geographic Information Systems (GIS)

CALIBRATION and Validation of SWAT2005/ArcSWAT in Anjeni Gauged Watershed, Northern Highlands of Ethiopia

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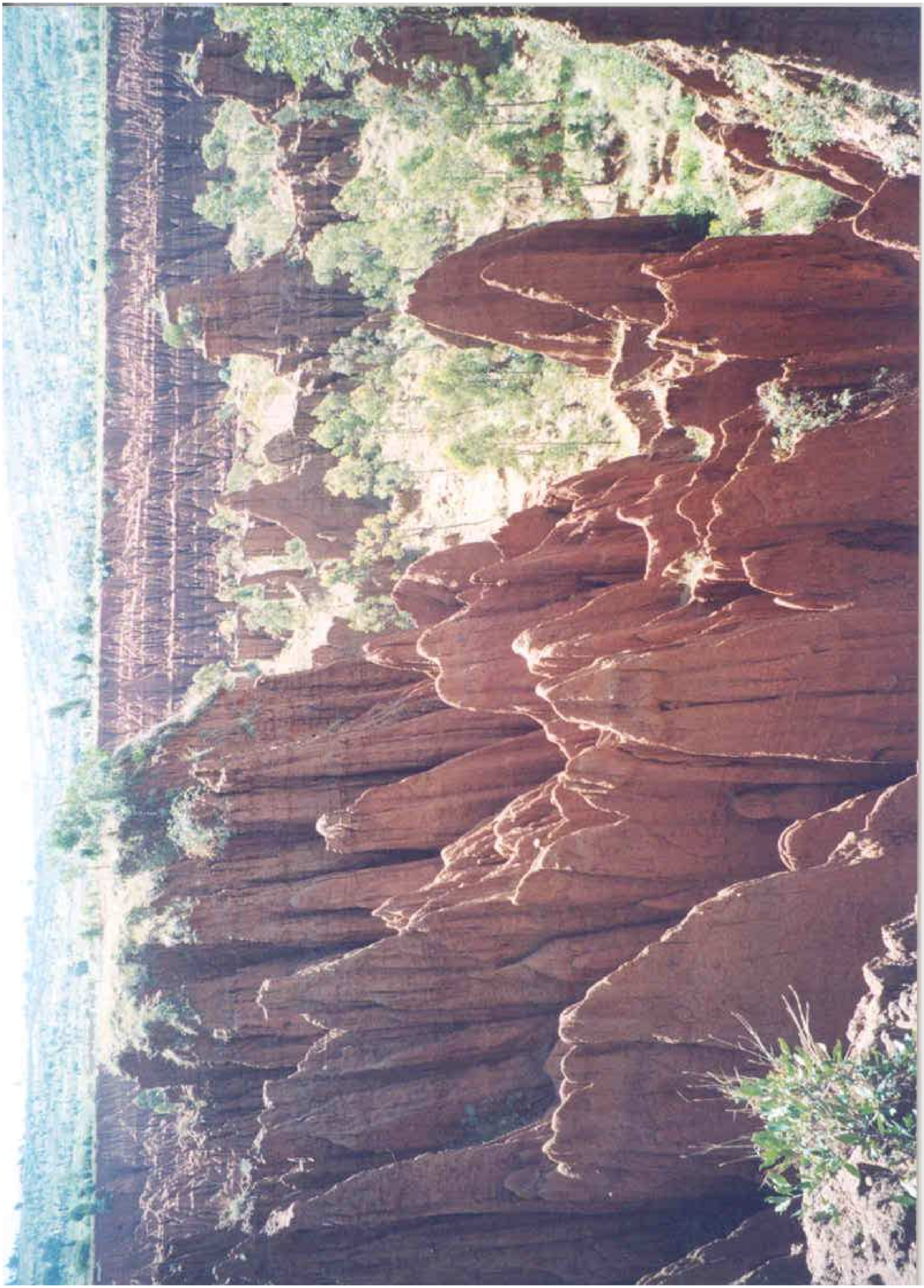
Outline

- Background (Project Summery)
- General objective
- Specific objective/immediate activity
- Description of the study area
- Modelling tools and methods
- Results and conclusion

Background

- Soil erosion & Land degradation are major problems on the Ethiopian highlands.
- Eroded sediments carry nutrients, herbicides, and pesticides
  - degrade the quality of streams, rivers and lakes.
- The soil depth is less than 35 cm in 34% of the land.
- Ethiopia loses an est. 1.3 billion metric tons of fertile soil every year.



Background Cont.

- The poor land use practices and management system has played significant role.

- Effective measures are not taken sufficently to combat the soil erosion and sedimentation problems
  - due to lack of relevant decision-making tools.

- Adequate research is lacking for understanding the process and effects of soil erosion and sedimentation

- It is important to model the physical processes in the Lake Tana watershed in particular and the Blue Nile River Basin in general

General Objectives of the study

1. Evaluate the performance and applicability of the watershed model in predicting the hydrology, soil erosion and sediment transport

2. Modelling of the hydrology and soil erosion yield from the catchments and sediment transport into the lake

3. Water quality Modelling

4. Working towards the identification of best land and water management practices

➢Specific Objective of the study

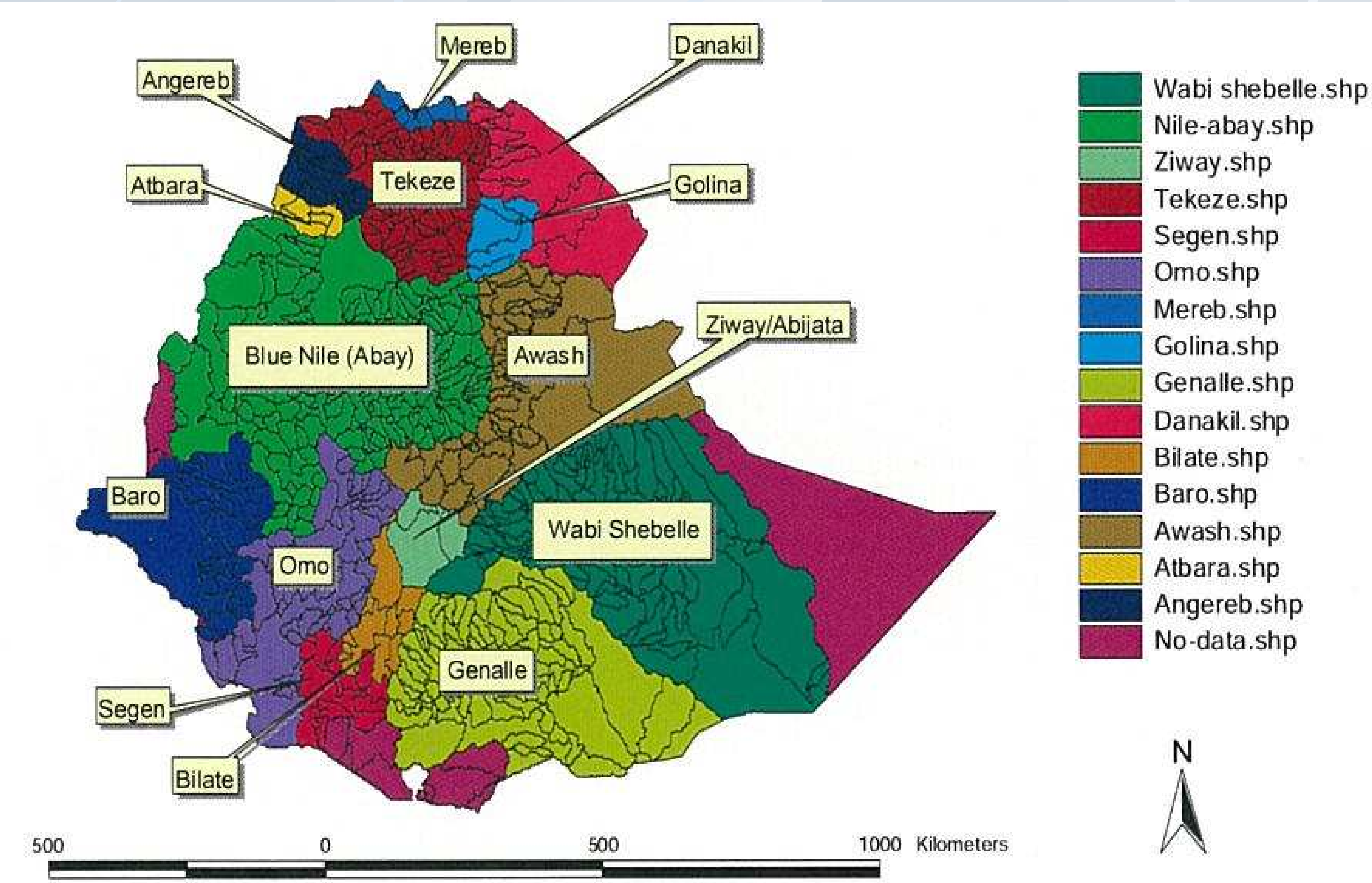
1. Calibration and validation of the SWAT2005 (ArcSWAT)
    1. Flow
    2. Sediment
    3. Nutrient

2. Modelling of the hydrology, soil Erosion, sediment and pollutant transport in Lake Tana basin

Description of the study area

- Ethiopia is known for its extensive water resources potential.
- The source of the Nile river and many trans-boundary rivers such as Baro-Akobo, Wabi Shebele, Tekeze.
- The total annual runoff is estimated at 110 Billion m3

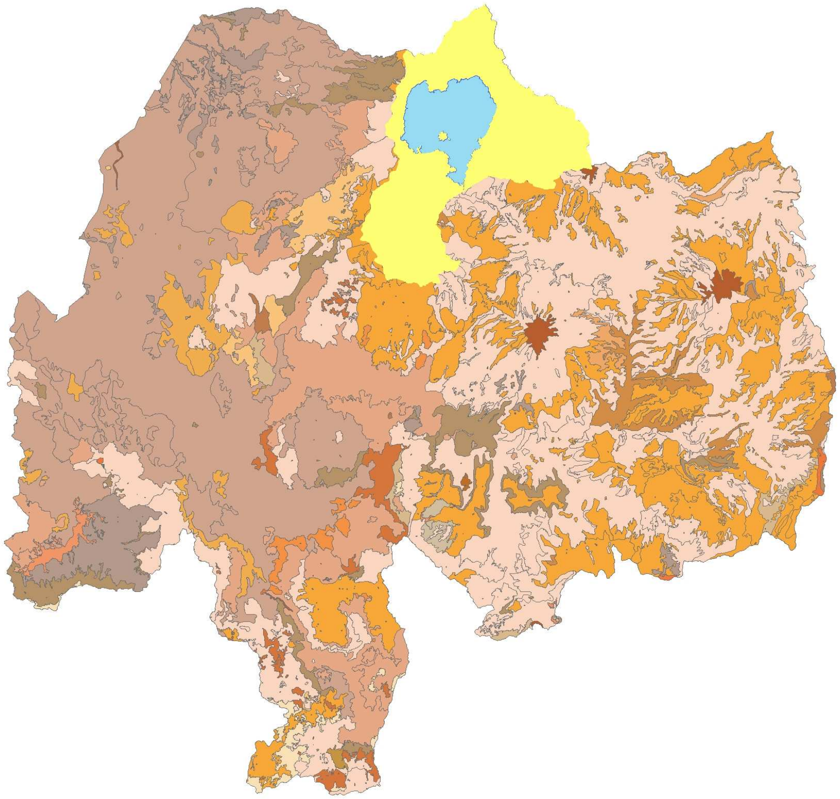
Ethiopian Major River Basins



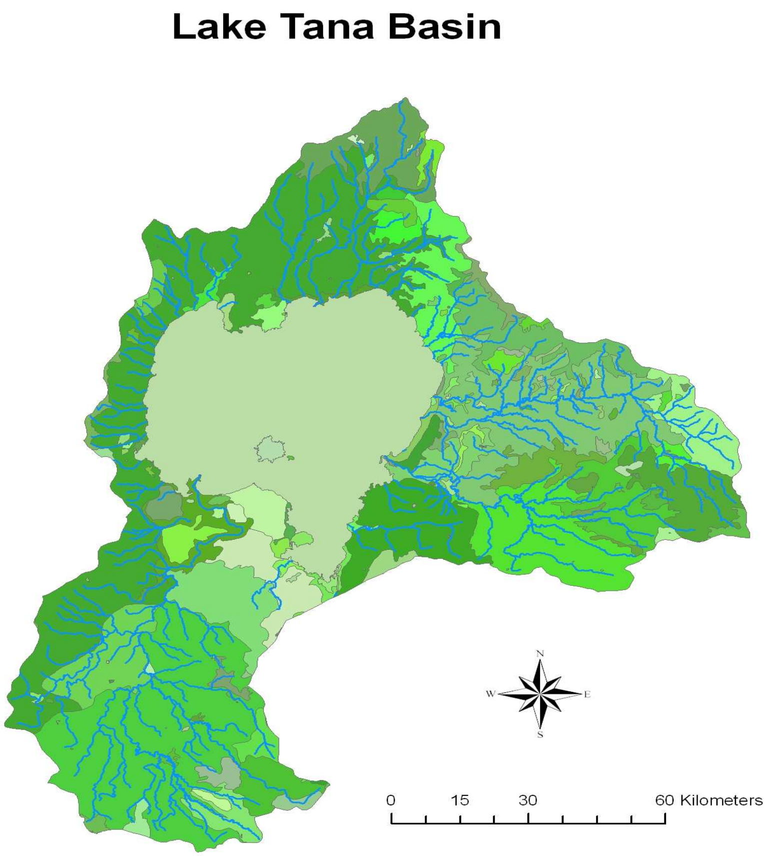
Blue Nile River Basin

- Blue Nile River has an average annual run off of about 52 B m^3.

- This basin contributes an average of 62% to Nile river.



Lake Tana Basin



- Lake Tana is the source of the Blue Nile
- The lake covers 3000 - 3630 km^2 area
- Elevation of 1800 m and with a maximum depth of 15m.
- Rainfall averages 1315 mm/year
- Four perennial rivers and numerous seasonal streams feed the lake.

Anjeni Gauged Watershed

- Its altitude ranges from 2407 - 2507 m asl.

- Hydrological catchment area is 113.4 ha.

- Mean annual rainfall and temperature are 1690 mm and 16 °C.

Modelling tools and methods

- SWAT2005
- ArcGIS/ArcSWAT
- The hydrologic simulation is based on the water balance equation

$$SW_t = SW_0 + \sum_{i=1}^{t} \left(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw} \right)$$

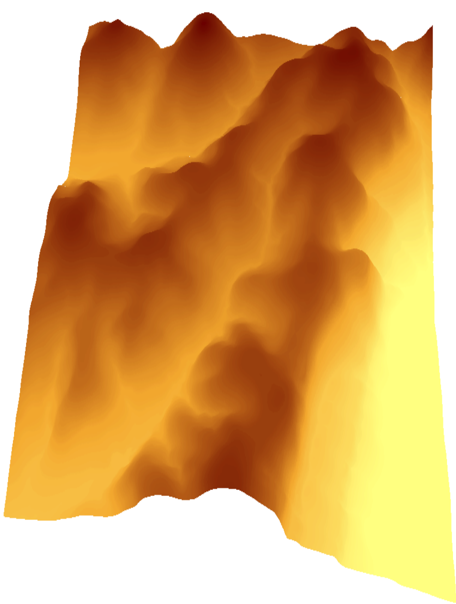
- Runoff is predicted separately for each HRU using SCS curve method
- Potential evapotranspiration was estimated using the Penman Monteith equation.

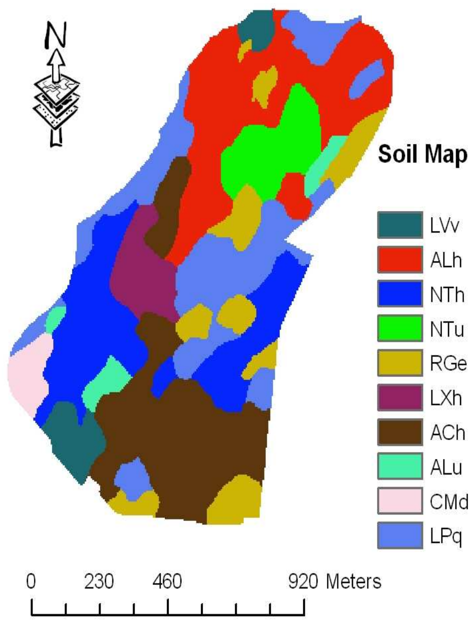
Modelling tools and methods Contd.

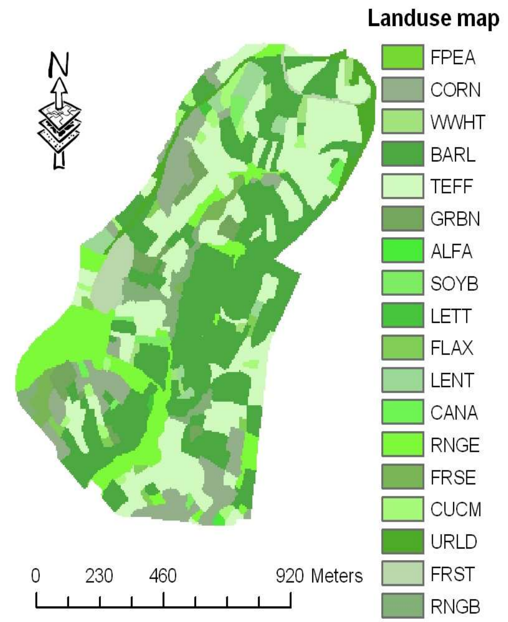
- Calibration Method
  - Parasol
- Variation Method
  - Multiply by value (%)
- Objective function
  - Sum of the Squared of the Residuals (SSQ)
- Average and threshold Criteria
  - Average

Model Input

- GIS input files used for the SWAT model include
  - the digital elevation model (DEM),
  - land cover, and
  - soil layers.







Model Input Contd.

- **Soil physical properties**
- **Metrological Data**
  - **10 years precipitation, air temperature, solar radiation, wind speed and relative humidity.**
  - **10 years River Discharge**
- **Land Management**

Results and Discussion

Sensitivity analysis

- Twenty six hydrological parameters were tested for sensitivity analysis for the simulation of the stream flow.
- Eighteen parameters were found to be sensitive.
- Eight parameters had shown no effect on the monthly stream flow simulations
- The most eight sensitive ones were considered for calibration processes

Sensitive parameters considered for calibration processes

Parameter	Description	Rank
Cn2	Initial SCS CN II value	1
Alpha_Bf	Base flow alpha factor [days]	2
Gw_Delay	Groundwater delay [days]	3
Sol_Awc	Available water capacity [mm WATER/mm soil]	4
Ch_K2	Channel effective hydraulic conductivity [mm/hr]	5
Esco	Soil evaporation compensation factor	6
Gw_Revap	Groundwater "revap" coefficient	7
Sol_Z	Soil depth [mm]	8

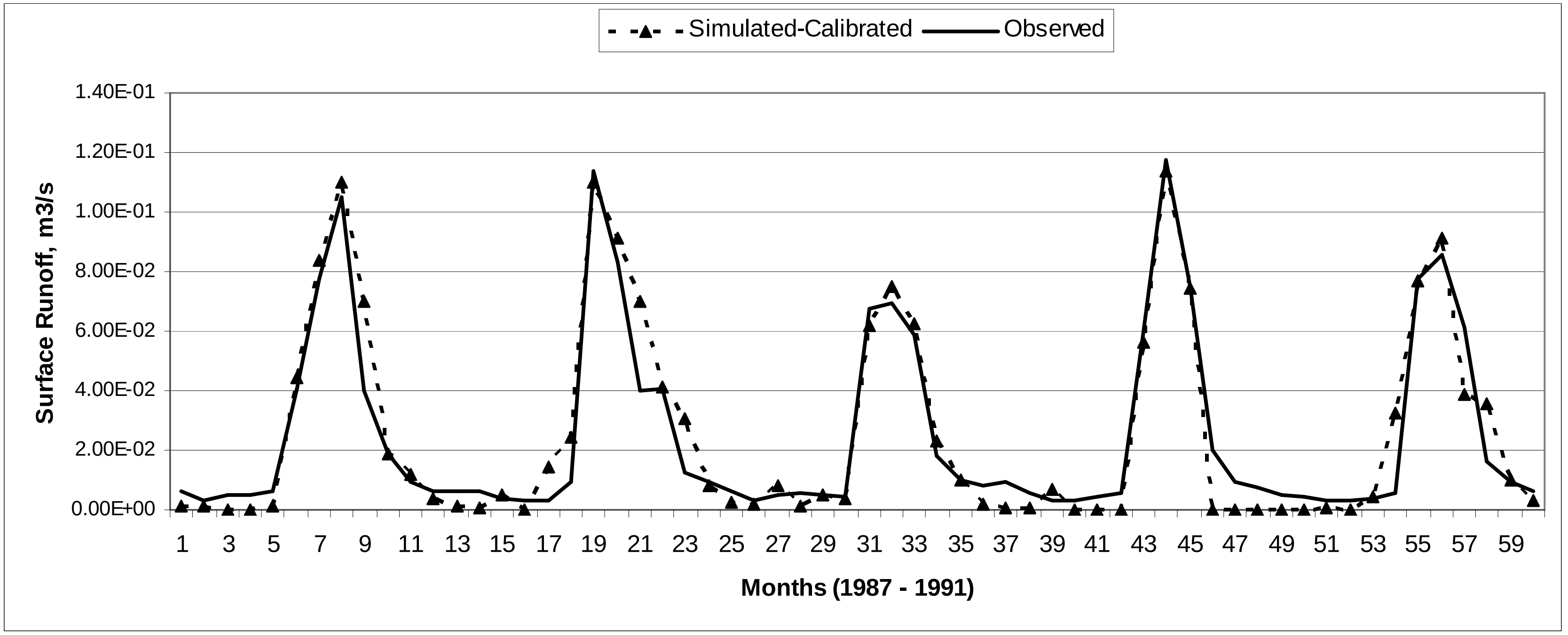
Parameters shown no effect on the monthly stream flow simulations

Parameter	Description	Rank
Revapmin	Threshold water depth in the shallow aquifer for "revap" [mm]	27
Gwqmn	Threshold water depth in the shallow aquifer for flow [mm]	27
Smfmx	Melt factor for snow on June 21 [mm H_2O/ºC-day]	27
Smfmn	Melt factor for snow on December 21 [mm H_2O/ºC-day]	27
Sftmp	Snowfall temperature [ºC]	27
Smtmp	Snow melt base temperature [ºC]	27
Timp	Snow pack temperature lag factor	27
Tlaps	Temperature lapse rate [°C/km]	27

Model Calibration

- Manual and automatic calibration method
- Seven years, Jan 1984-Dec 1991, hydrometric flow data were utilized
- A good agreement between observed and simulated flows at Anjeni station.
- The coefficient of determinations (R2), 0.92 and the Nash-Suttcliffe simulation efficiency (NS), 0.91

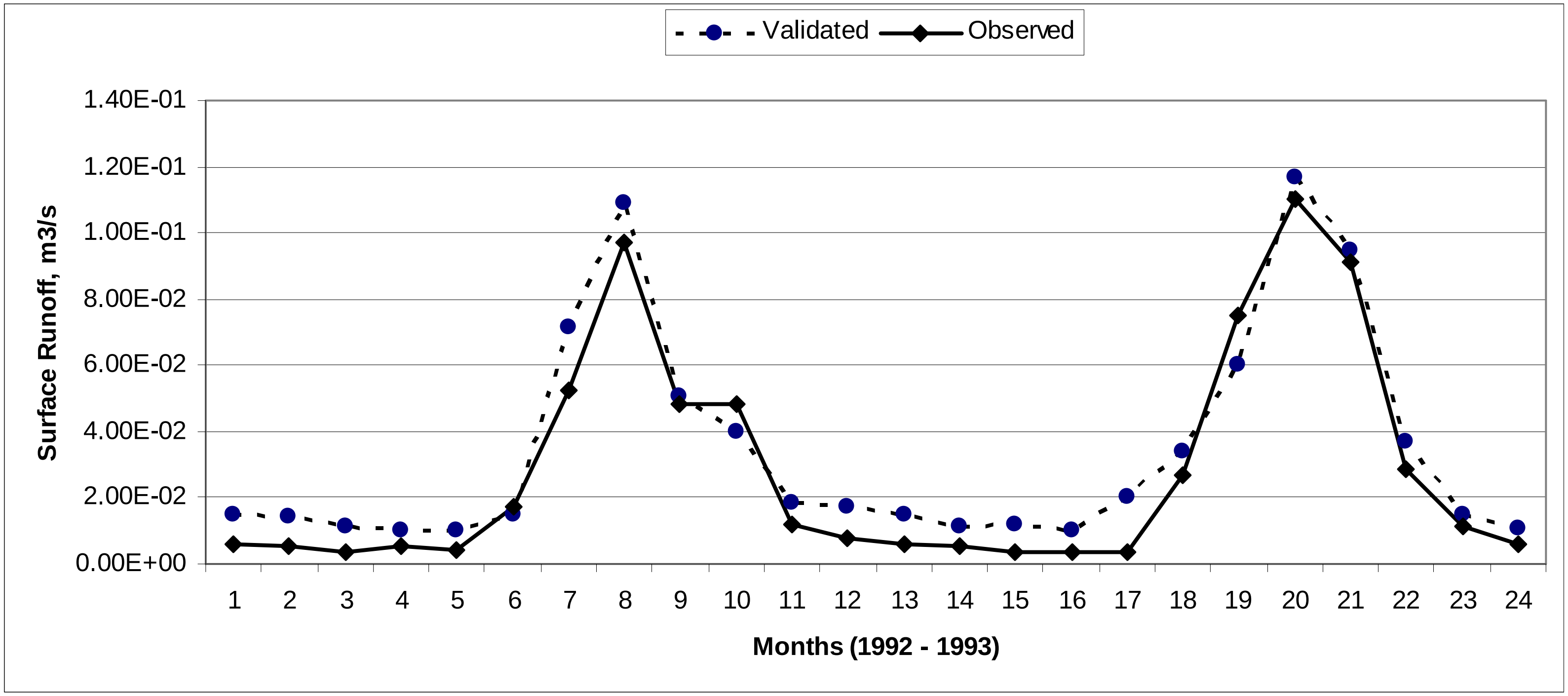
Comparison between observed monthly flow and Simulation using calibrated parameters for the calibration period (1987 – 1991)



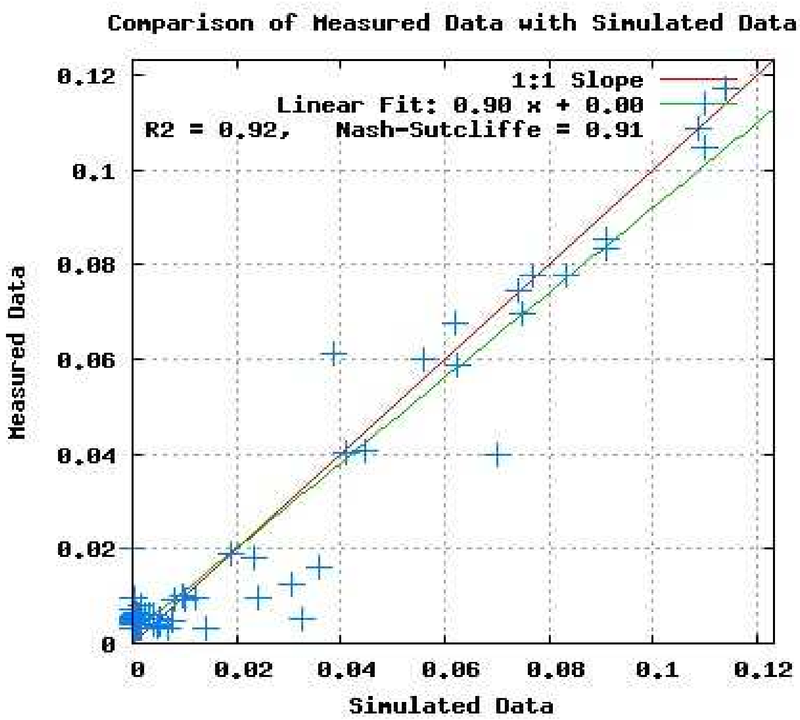
Model Validation

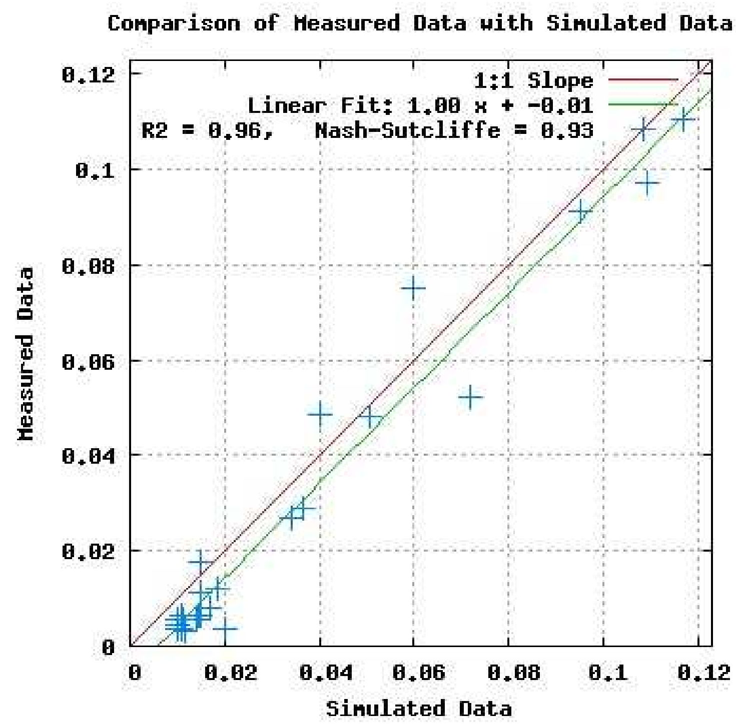
- Model validation involved re-running the model using input data independent of data used in calibration.
- Two years observed flow data from 01 January 1992 to 31 December 1993
- The validation process resulted in R2 =0.96 NS = 0.93

Comparison between observed monthly flow and Simulation result



Scatter plot of monthly simulated versus observed flow





Conclusion

- The model was successfully evaluated through sensitivity analysis, model calibration, and model validation.
- Curve number, Base flow alpha factor, and groundwater delay time are the most sensitive parameters in Anjeni watershed.
- The calibration and validation study has shown that the SWAT model can produce reliable estimates of monthly runoff.

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Thank you!