Using SWAT model to assess different land use scenarios impact on streamflow in Fuhe basin, China

TAO Can[1], CHEN Xiaoling[1,2], LU Jianzhong[1],
SAUVAGE Sabine[3,4], SANCHEZ PEREZ José-Miguel[3,4]

[1]State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing, Wuhan University, Wuhan 430079, China
[2]Key Laboratory of Poyang Lake Wetland and Watershed Research, Ministry of Education, Jiangxi Normal University, Nanchang 310022,China
[3]University of Toulouse; INPT, UPS; Laboratoire Ecologie Fonctionnelle et Environnement (EcoLab), Avenue de l'Agrobiopole, 31326 Castanet Tolosan Cedex, France
[4]CNRS, EcoLab, 31326 Castanet Tolosan Cedex, France

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Outline

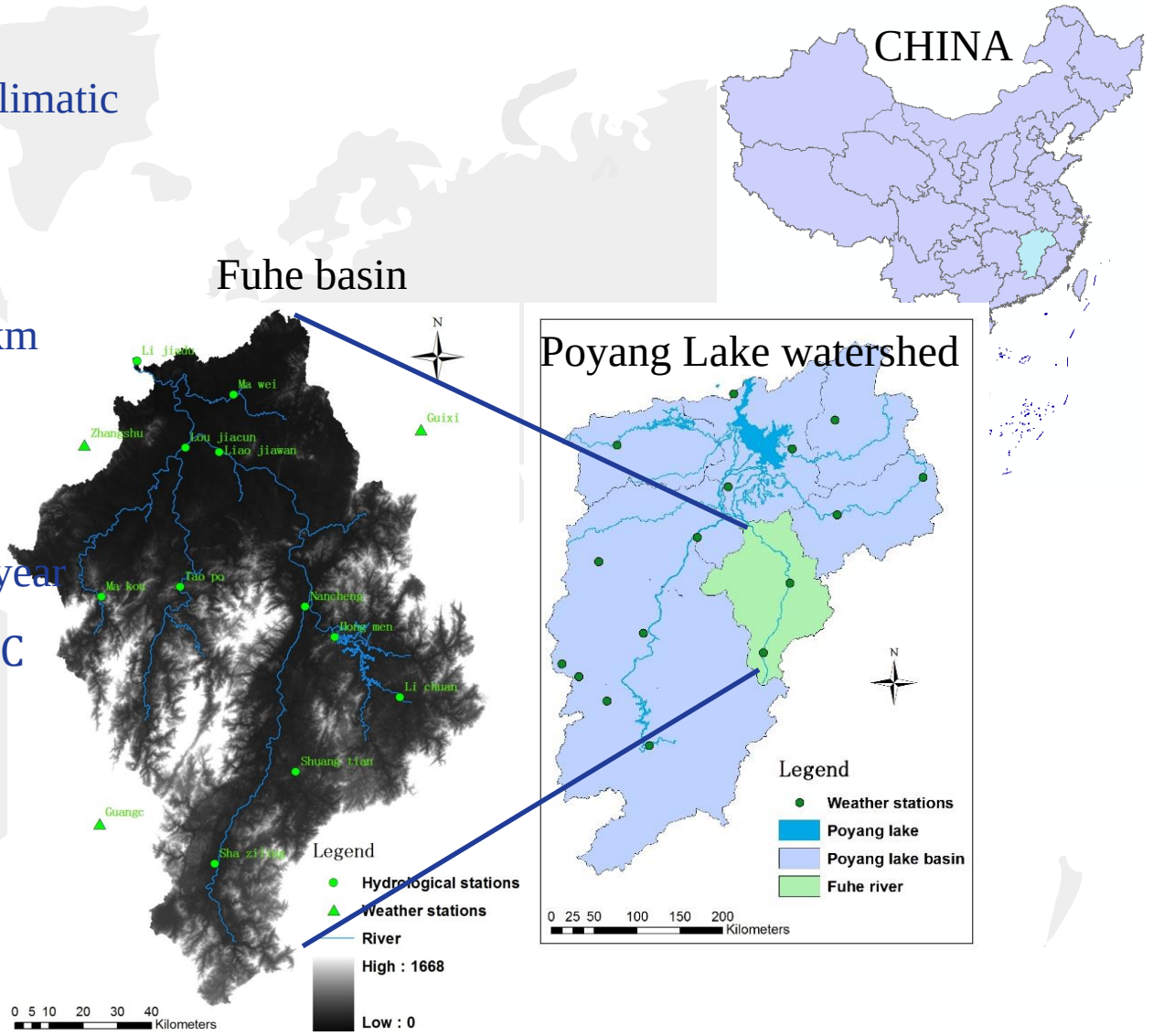
- Background
- Study area and data
- Methodology
- Results analysis and discussion
- Conclusion

Background

- The Poyang Lake is the biggest fresh water lake in China. The Fuhe river is the second largest river flowing into the Poyang Lake. It is essential to assess the water flow in the basin, which can offer scientific supports to manage and utilize water resource reasonably.
- According previous research, vegetation coverage is the key factor affecting soil erosion and surface runoff in the mountainous region, and runoff is very sensitive to land use change.
- In recent years, there are many studies on how the different LUCCs (especially forest) impact runoff. However, because of different research scales, different climatic and hydrologic conditions in different basins, there are different results. there have not been a certain consequence yet.
- In order to assess the impact of different land use on river flow, the SWAT model for the Fuhe basin is established to model the water flow variation under different land use scenarios.

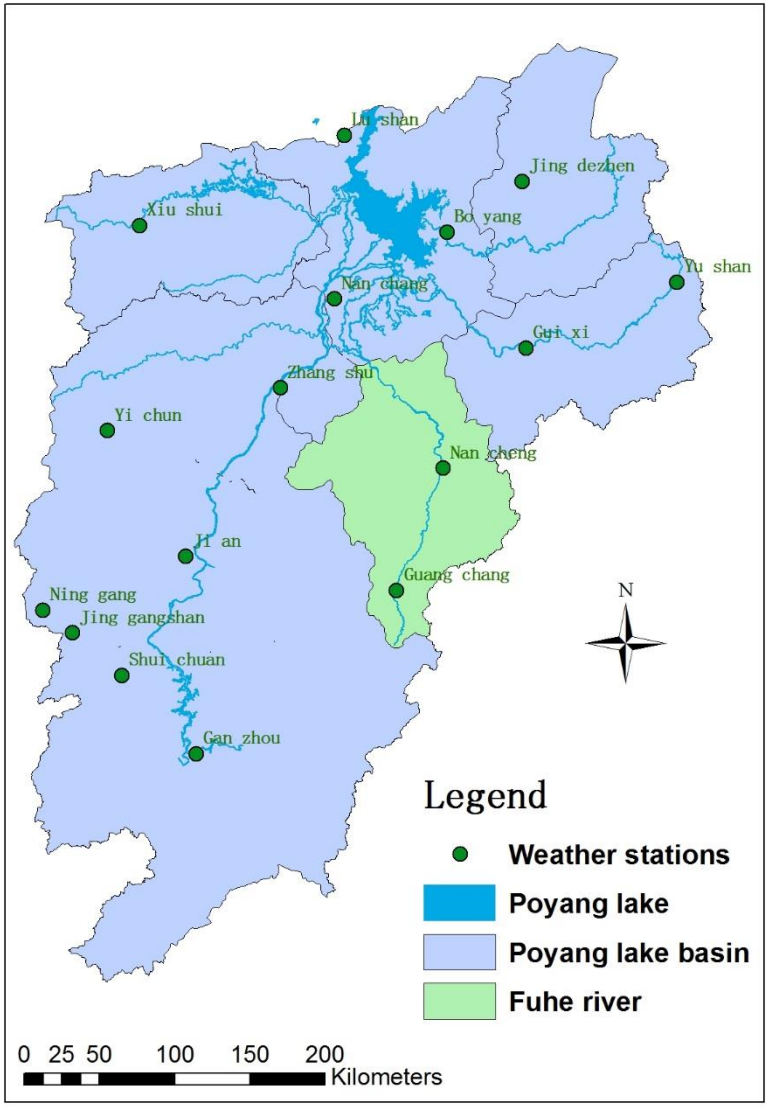
Study area and data

- Subtropics humid monsoon climatic region
- Area: 14,778 km^2
- Length of main stream: 348 km
- Runoff: 126×10^8 m^3/year
- Rainy days: 170/year
- Precipitation:1500-2000mm/year
- Mean temperature:16.9-18.2℃
- Mean humidity: 80%.



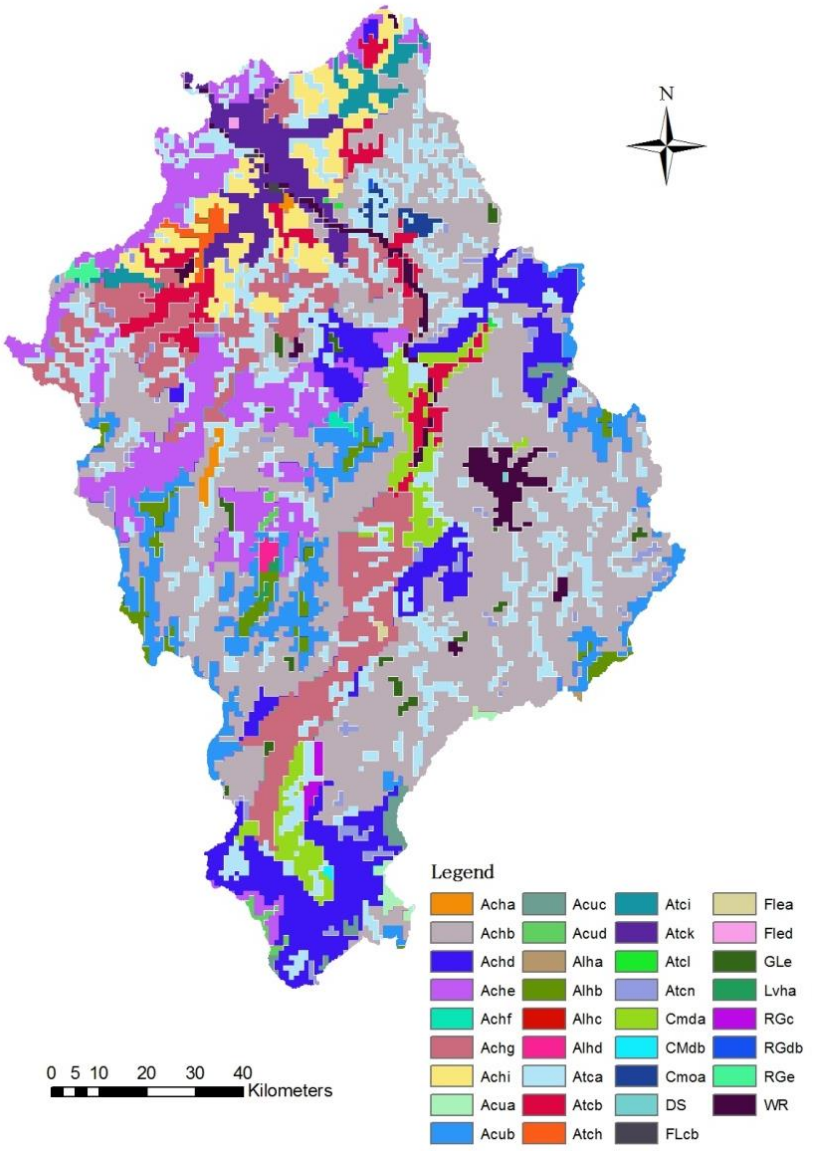
Study area and data

- Weather generator database
  - 50 years daily data
- Mean monthly climatic data were used to create the weather generator database for the whole Poyang Lake.
- 3 weather stations close to the basin: Zhangshu, Guixi and Guangchang.



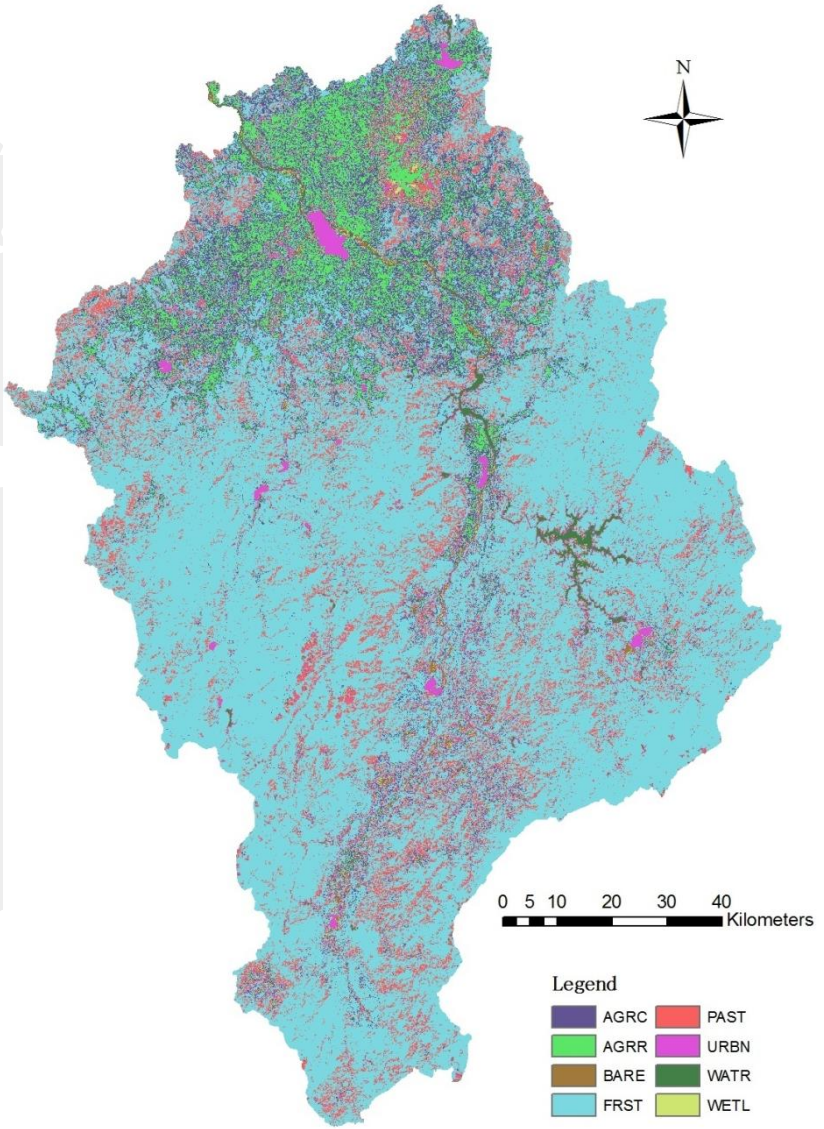
Study area and data

- The main soil type in Fuhe river basin is red soils, amounting to 65.9% of the whole basin, They are defined as mineral soils which contain no calcareous material anywhere within the soil, have less than 35% base saturation throughout the soil.
- Soil map was generated by Harmonized World Soil Database (HWSD)
- The SPAW software, developed by U.S. Department of Agriculture, was used to calculate the SOL_AWC and SOL_K for each soil type.



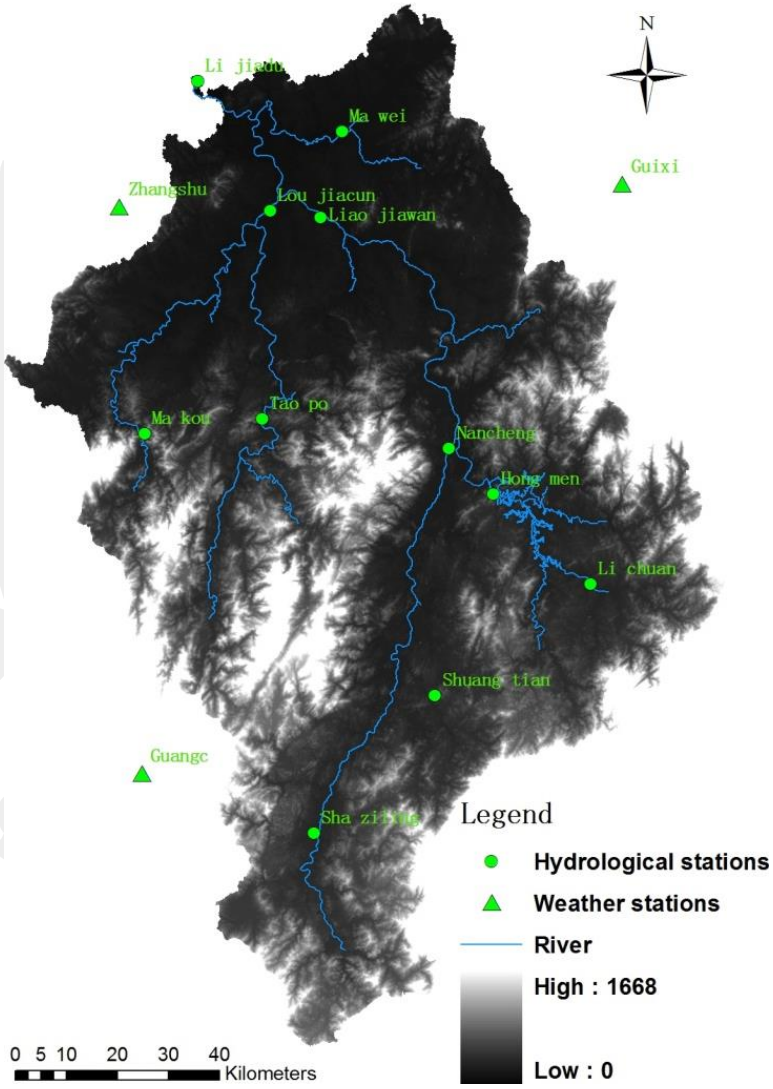
Study area and data

- The land use map was generated by TM/ETM+ (30m resolution) remote sensing images (November, 2000).
- Land uses classifications
  - Land-close-grown
  - Agricultural land
  - Forest
  - Pasture
  - Residential
  - Water
  - Wetland
  - bare land
- Forest is the main land use type, account for 60% of the whole areas, and agricultural land is the second, which are over 15 %.



Study area and data

- The DEM (30m resolution) was generated from ASTER GDEM for the Fuhe river basin.
- Monthly water discharge data from 2001-2007 were used for calibration and validation.
- Hydrologic data from 8 gauge stations within the basin: Shaziling, Shuangtian, Taopi, Makou, Liaojiawan, Loujiacun, Maxu, Lijiadu.



Methodology

Water Balance Equation

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

Where

SW_t is the final soil water content(mm H_2O),

SW_0 is the initial soil water content on day i(mm H_2O),

t is the time(days),

R_{day} is the amount of precipitation on day i(mm H_2O),

Q_{surf} is the amount of surface runoff on day i(mmH_2O),

E_a is the amount of evapo transpiration on day i(mm H_2O),

W_{seep} is the amount of water entering the vadose zone from the soil profile on day i(mm H_2O),

and Q_{gw} is the amount of return flow on day i(mm H_2O).

Methodology

Model Performance Equation

- The Nash-Sutcliffe Efficiency:

$$E_{ns} = 1 - \frac{\sum_{i=1}^{n}(Q_{obs,i} - Q_{\sin,i})^2}{\sum_{i=1}^{n}(Q_{obs,i} - \overline{Q}_{obs})^2}$$

- The Coefficient Of Determination:

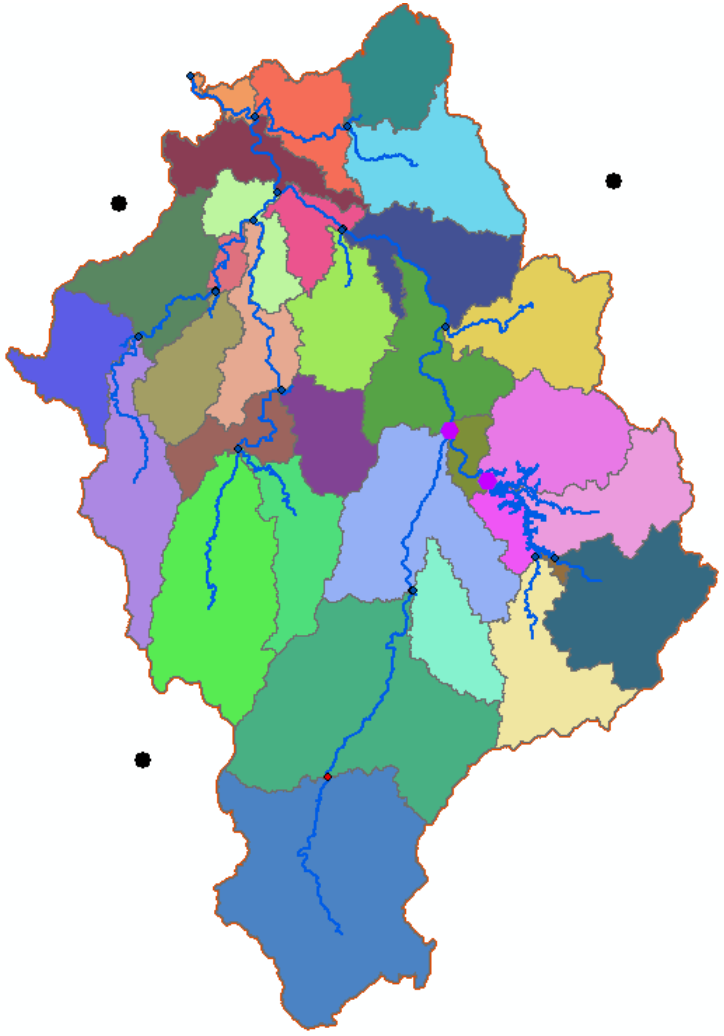
$$R^2 = \left[\frac{\sum_{i=1}^{n}(Q_{obs,i} - \overline{Q}_{obs})(Q_{\sin,i} - \overline{Q}_{\sin})}{\sqrt{\sum_{i=1}^{n}(Q_{obs,i} - \overline{Q}_{obs})^2}\sqrt{\sum_{i=1}^{n}(Q_{sim,i} - \overline{Q}_{sim})^2}} \right]^2$$

- The Relative Error Index:

$$R_e = \frac{|Q_{sim} - Q_{obs}|}{Q_{obs}} \times 100\%$$

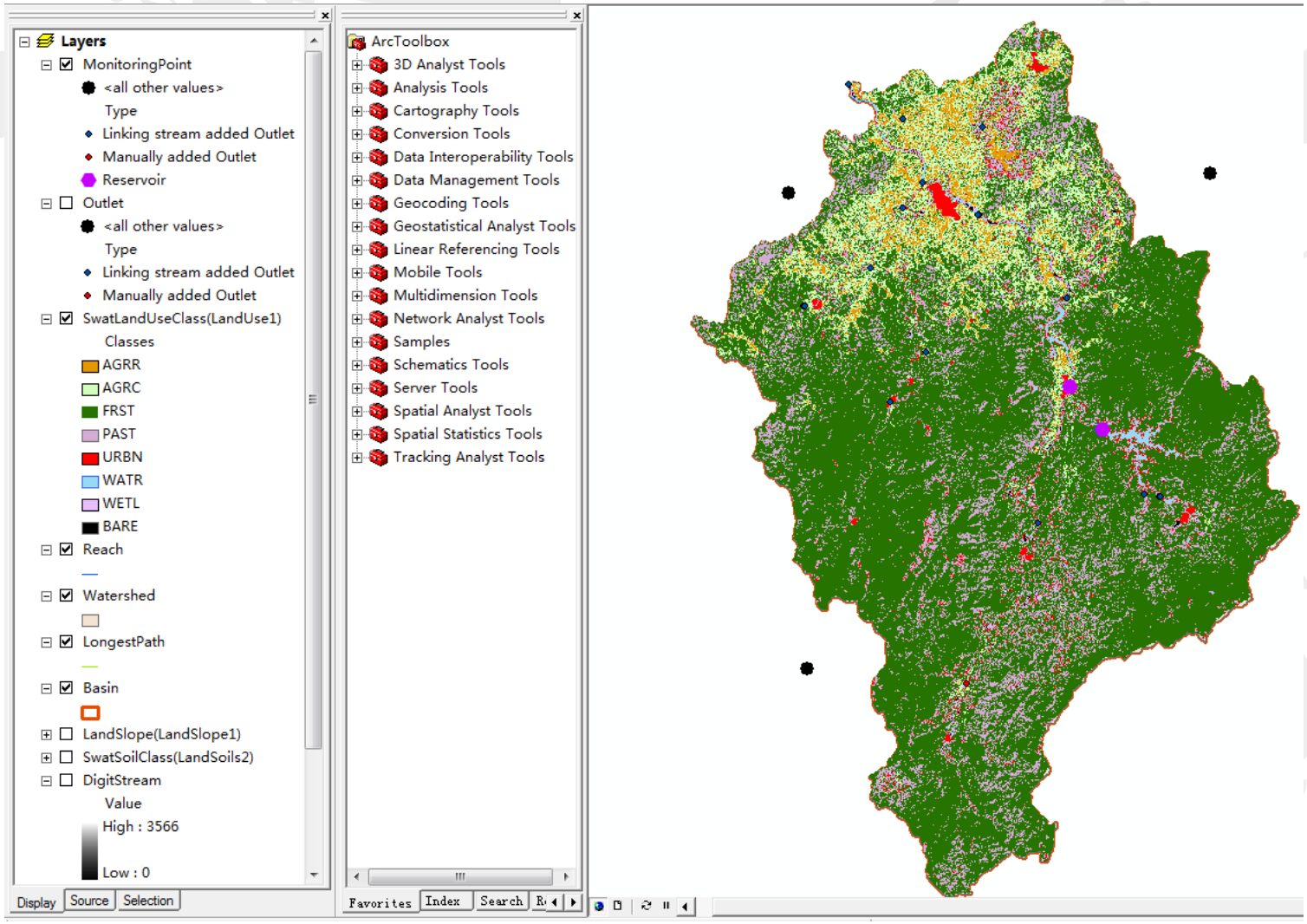
Methodology

- The basin and subbasin boundaries, as well as stream networks needed by SWAT were delineated using the ArcHydro Tools software with ArcGIS interface based on DEM data.
- The basin was divided into 32 subbasins. The overlay of soil, land use maps and slope resulted in 329 HRUs, representing homogeneous land use and soil. Meteorological data were introduced into the model, and databases of soil and land use properties were edited and made available in this study area.



Methodology

Input data into the model



Methodology

Sensitivity Analysis and Parameters Calibration results

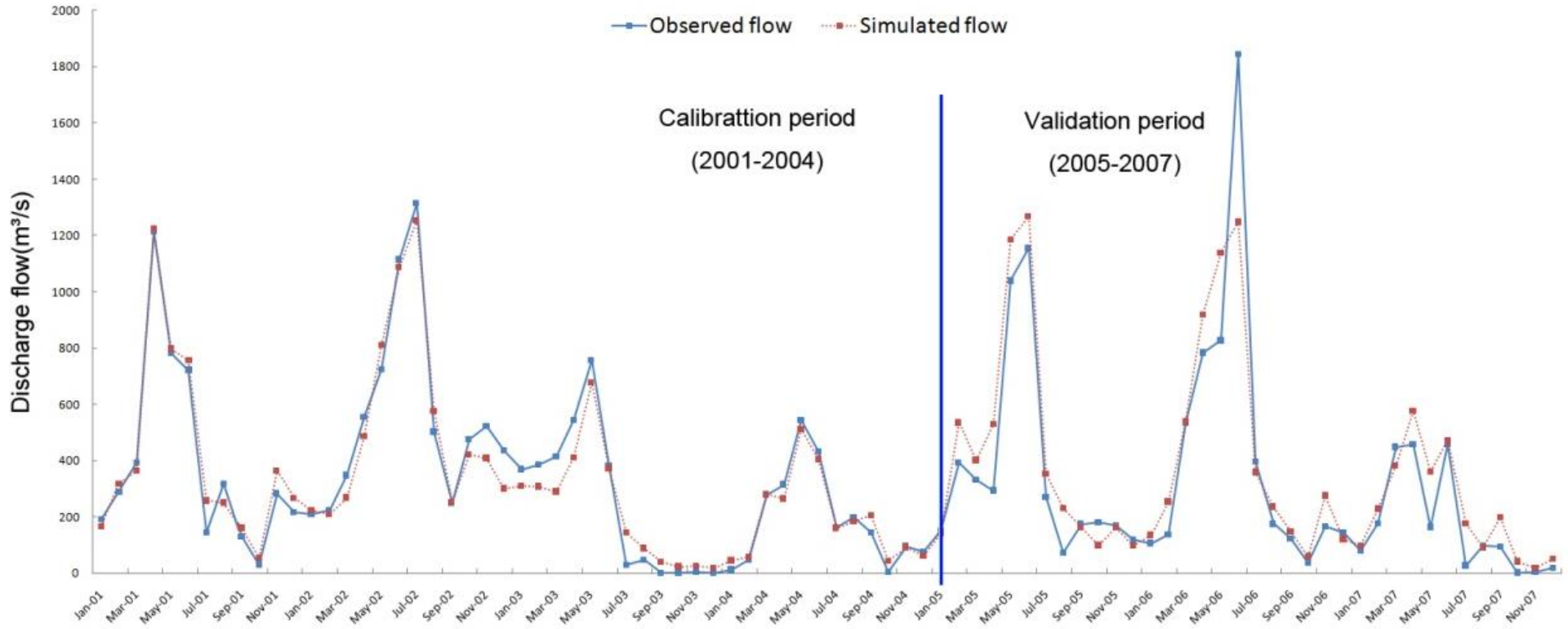
- Streamflow and historical meteorological data for the period 2001-2004 were used for sensitivity analysis.

Parameters(Definition)	Rank	Calibrated value
Cn2（Initial SCS runoff curve number for moisture condition II）	1	80(Agricultural Land)
		65(Residential)
		70(forest)
		70(pasture)
		65(bare)
Esco（Soil evaporation compensation factor）	2	0.89
Gwqmn（Threshold depth of water for return flow）	3	0.36
Sol_Awc（Available water capacity of the soil layer）	4	Multiply by 1.3 on original values
Alpha_Bf（Baseflow alpha factor）	5	0.86
Ch_K2（Effective hydraulic conductivity in main channel alluvium）	6	107.9

Methodology

The Calibration and Validation Results of SWAT

- We calibrate the SWAT model for the basin by 2001 to 2004 observed data and then validate the model by 2005 to 2007 observed data.
- The graph shows that the observed data and simulated data are approximately fitting.



Methodology

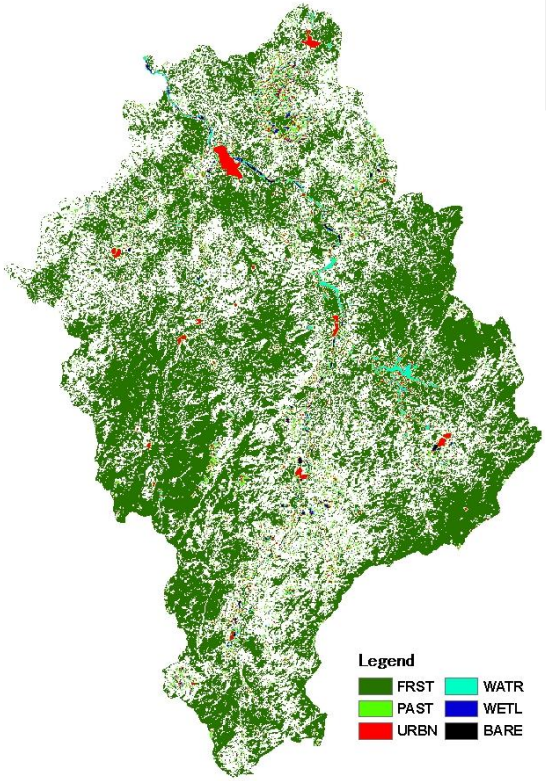
- **The Calibration and Validation Results of SWAT**
  - These evaluation parameters indicate that this result can be used to analyze the relationship between LUCC and runoff.

The difference between observed mean monthly flow value and the simulated value

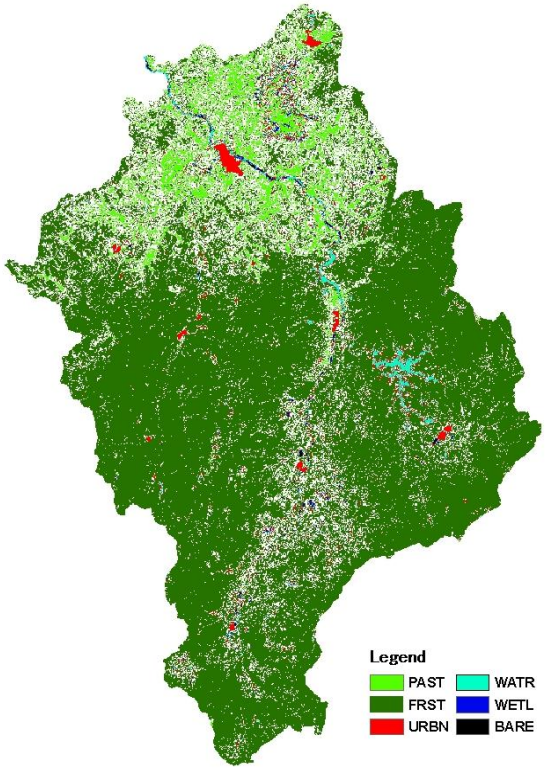
	R_e(%)	R^2	E_{ns}
Calibration period(2001-2004)	2.4	0.96	0.96
Validation period(2005-2007)	13.7	0.82	0.86

Methodology

- Four different scenarios



Scenario1: agricultural land->forest

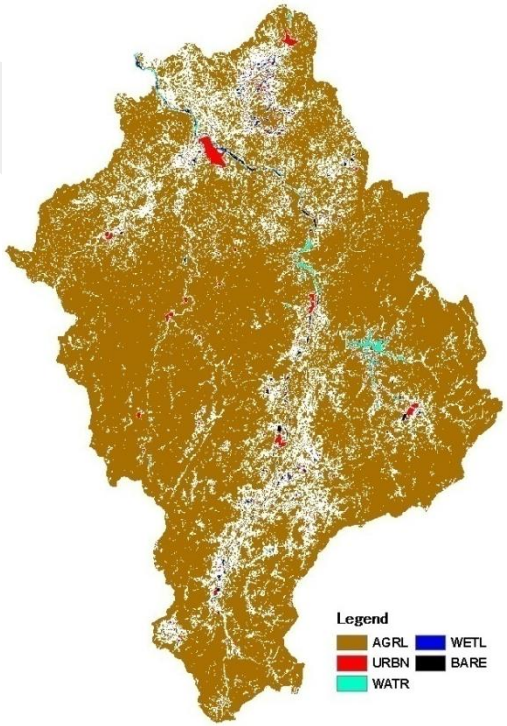


Scenario2: agricultural land->pasture

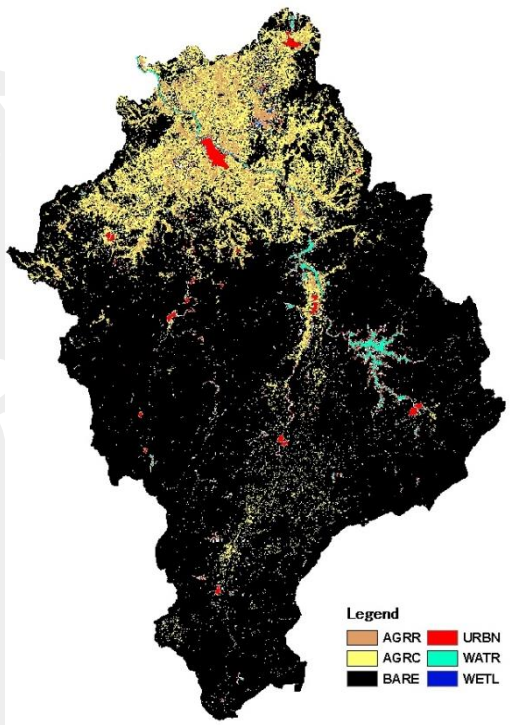
In these two scenarios, we transform the same area of agricultural land to vegetation-covered area to discuss the capacity of conserving water for forest and pasture.

Methodology

- Four different scenarios



Scenario3: vegetation-> agricultural land



Scenario4: vegetation-> bare land

In these two scenarios, we transform the same area of vegetation-covered area to non-vegetation-covered area to discuss the soil erosion vulnerability of agricultural land and bare land

Methodology

- Four different scenarios

Land use	Original scenario0		Scenario 1 AGR-FRST		Scenario 2 AGR-PAST		Scenario 3 VEG-AGR		Scenario 4 VEG-BARE	
	Area /km²	%	Area /km²	%	Area /km²	%	Area /km²	%	Area /km²	%
AGRR	2231	15.1	0	0	0	0	13780	93.3	2231	15.1
AGRC	1246	8.4	0	0	0	0			1246	8.4
FRST	8960	60.6	12439	84.2	8960	60.6	0	0	0	0
PAST	1342	9.1	1342	9.1	4821	32.6	0	0	0	0
URBN	516	3.5	516	3.5	516	3.5	516	3.5	516	3.5
WATR	171	1.2	171	1.2	171	1.2	171	1.2	171	1.2
WETL	37	0.3	37	0.3	37	0.3	37	0.3	37	0.3
BARE	272	1.8	272	1.8	272	1.8	272	1.8	10575	71.6

Results analysis and discussion

Year	Original scenario0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
2001	414.8	331.6	360.6	419.7	440.5
2002	524.8	452.2	475.8	536.2	551.2
2003	304.9	259.2	276.8	305.2	320.4
2004	192.6	130.8	153.7	192.2	203.4
2005	430.1	372.1	389.1	437.9	458.0
2006	452.3	393.0	418.8	457.2	469.4
2007	224.0	180.9	200.9	218.9	237.6
Annual streamflow	352.0	302.8	325.1	366.7	382.9

- rank of the streamflow: Scenario4> Scenario3>reference or scenario0> Scenario2> Scenario1.
- annual streamflow decreases along with the areal decreasing of pasture land and forest land, and increase along with increasing of agricultural land and bare land.
- In Scenario1 and Scenario2, when same area of agricultural land change to same area of forest and pasture, forest show better capacity to conserve water than pasture land.
- In Scenario3 and Scenario4, when same area of land cover change to same area of agricultural land and bare land, streamflow increases more in scenario4, which means the soil erosion is more serious with more area of bare land than agricultural land.

Results analysis and discussion

- In the study of Weber et al.(2001), it concluded that agricultural land lead to an increase in surface runoff during those months when the soil is uncovered by plants and surface sealing as an initial step of interrill erosion takes place. In the same way, Pastures on steep hills are also easily damaged by trampling, and therefore, particularly susceptible to erosion. On the other hand, forest covers the soil throughout the year with litter, and a high percentage of rainfall is conversed by canopy storage. Even during the dry period, in autumn, the extended root system of the trees is still capable of water uptake from lower soil zones, and evapotranspiration still proceeds at higher rates than in field crops. So more agricultural land and more pasture land lead to more runoff, but river flow and surface runoff can decrease with the increase of forest area.

Conclusion

- Scenario simulation results showed conclusions
  - Water discharge dropped under increasing forest land and grassland areas and decreasing agricultural land and urban areas in the Fuhe basin.
  - Forest land have better capacity to conserve the water than pasture land in the Fuhe basin.
  - Agricultural land are better than bare land to prevent the soil erosion which results the runoff increase in the Fuhe basin.
- SWAT model has a good ability to simulate hydrology process at the monthly step in the south of China watershed. After calibration, its simulated water discharge values can well fit the observed values, furthermore, we can predict the future water discharge in this watershed credibly.
- Sediment fluxes will be studied with this model in the Poyang Lake in our future research.

Thank you !

Email: lujzhong@whu.edu.cn