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Landscape pattern effects on surface runoff: Assessment using a hydrologic model in the Fuhe River Basin of Poyang Lake Watershed

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Outline

1. Introduction
2. Study area and data
3. Method
4. Results and discussion
5. Conclusion

Introduction

- With the development of social economics recently, human activities intensively change the landscape, which significantly impacts the water cycle in the watershed.

- It will lead to water problems such as water pollution, water redundancy and shortage.

Introduction

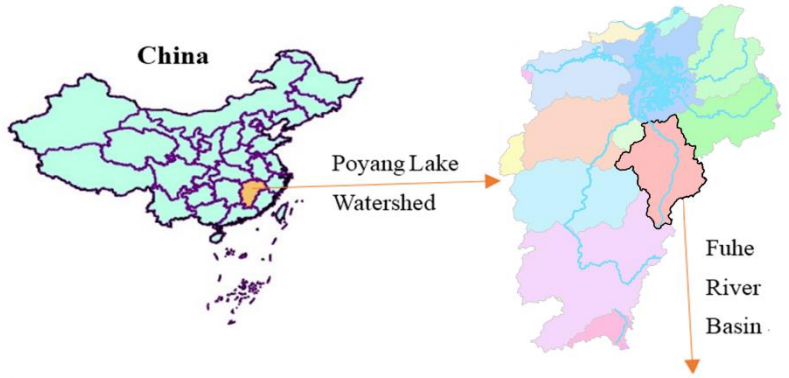
❖ **Impact assessment of landscape change on surface runoff in watershed will provide**

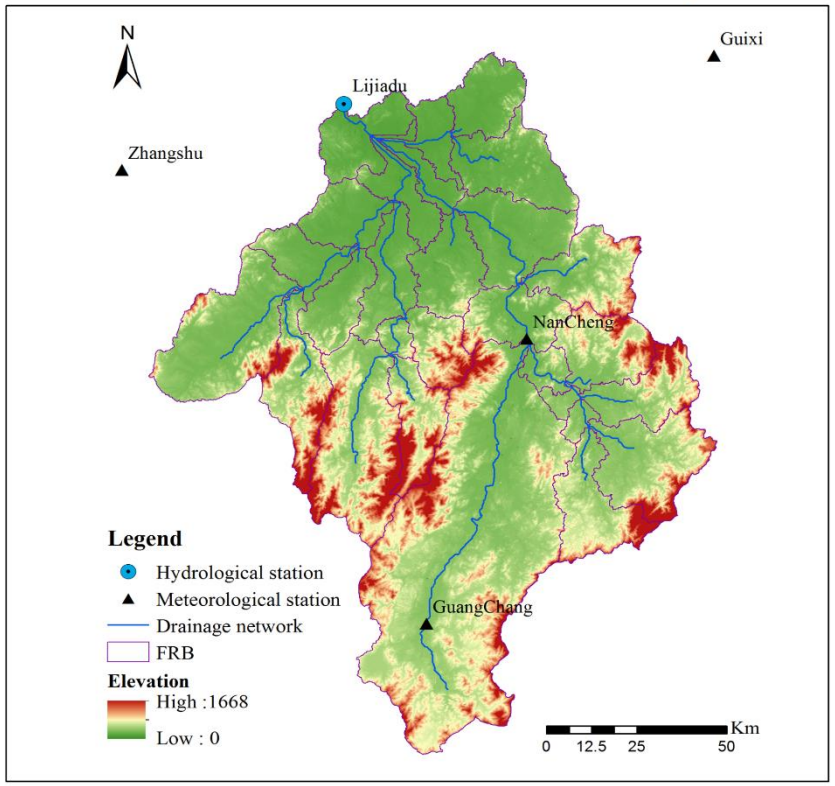
- Knowledge for water resources management
- Information of Best Management Practices for land development
- Regulation of water cycle under regional landscape changes
- River discharge for drought and flood prediction

Study area and data

❖ Fuhe River basin (FRB) in Poyang Lake watershed

- Poyang Lake is the large freshwater lake in China.
- Fuhe River is one of the five major tributaries of Poyang Lake, and its drainage area is the second largest basin in Poyang lake watershed with area 16493 km^2
- There are four ground-based meteorological stations named Guangchang, Nancheng, Zhangshu, and Guixi within and around the basin.
- The Lijiadu hydrological station measures discharge of the basin.

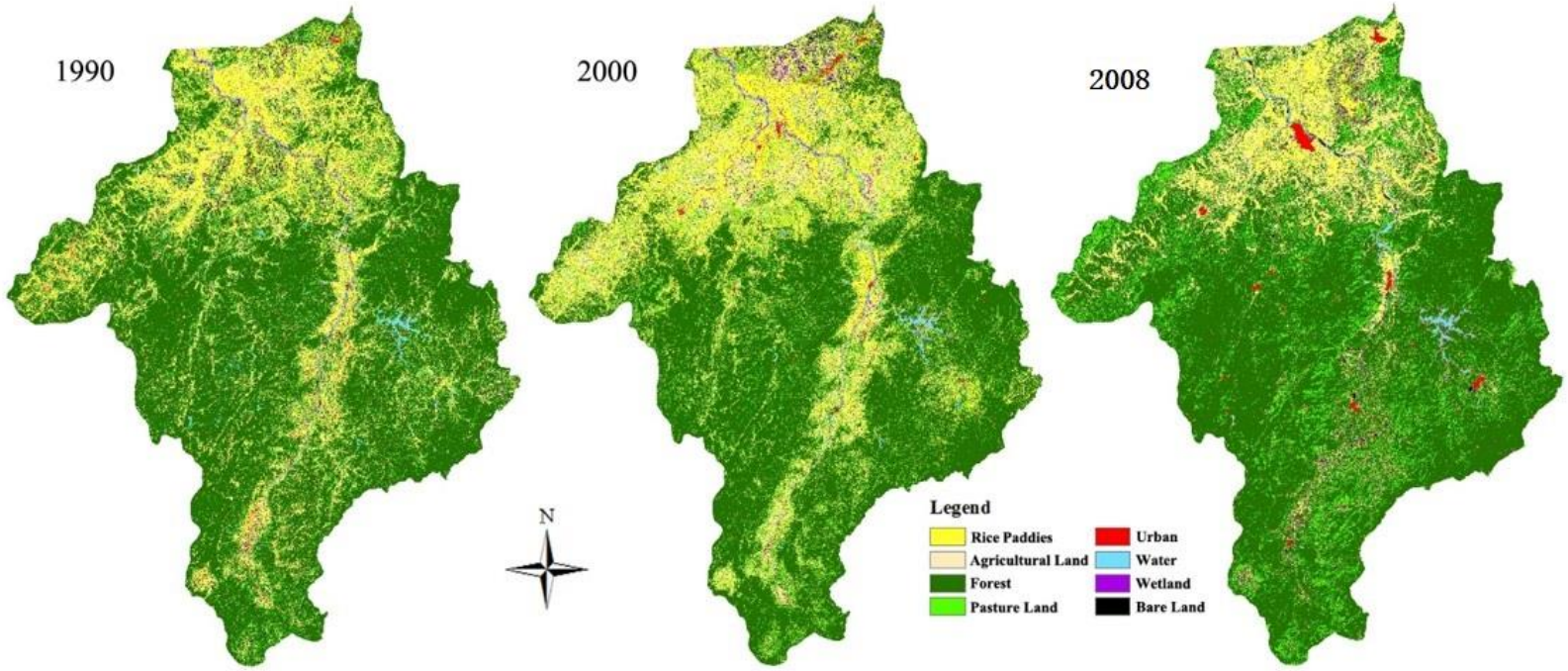




Study area and data

❖ Data processing

- Land use and cover change
  - Supervised classification method is applied to the satellite images, including Landsat TM images in 1990, Landsat ETM+ images in 2000, and HJ-1A/B CCD images in 2008.
  - Land use cover was divided into 8 classes, including Rice paddies, Agricultural land, Forest, Grassland, Urban, Water, Wetland and Bare land.

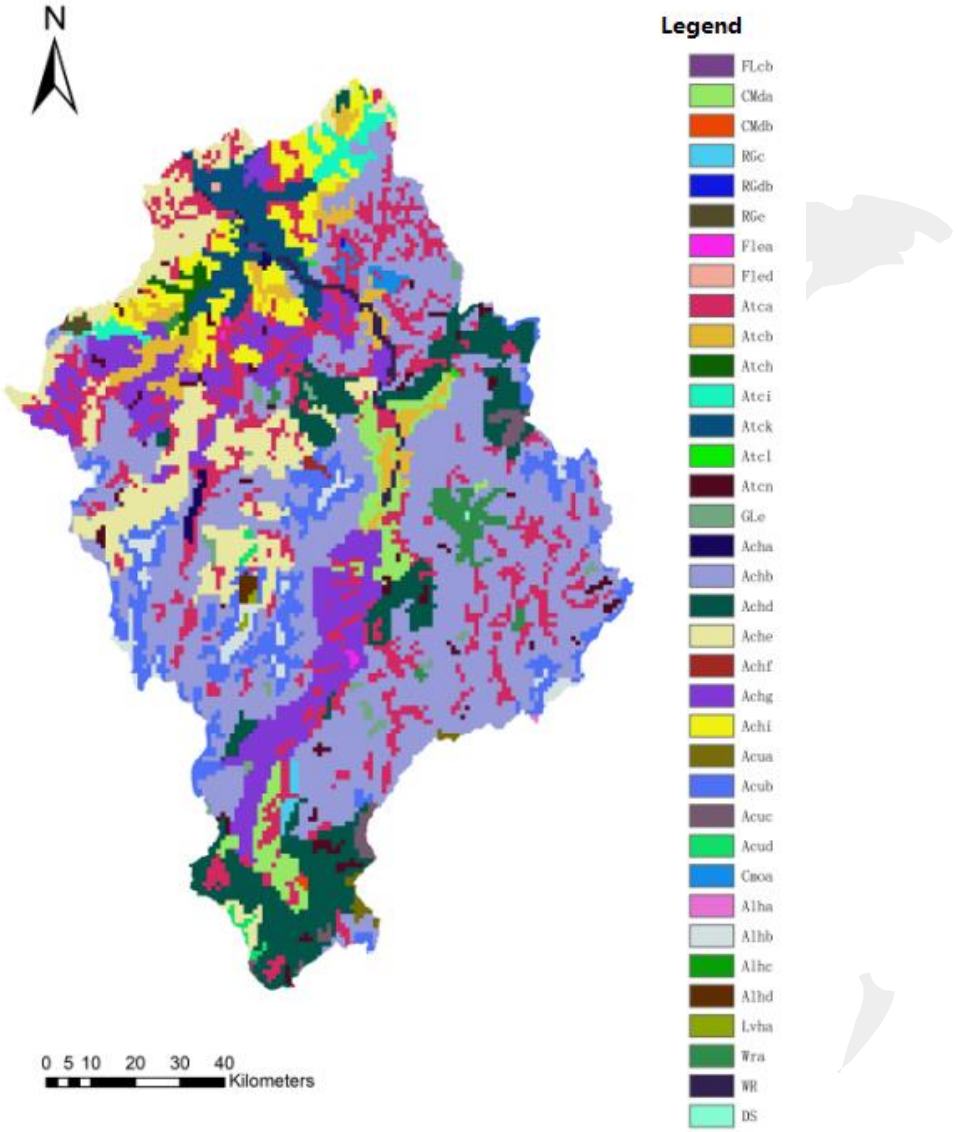


Study area and data

❖ Data preparation

- DEM
  - ASTER GDEM
  - 30m ground resolution

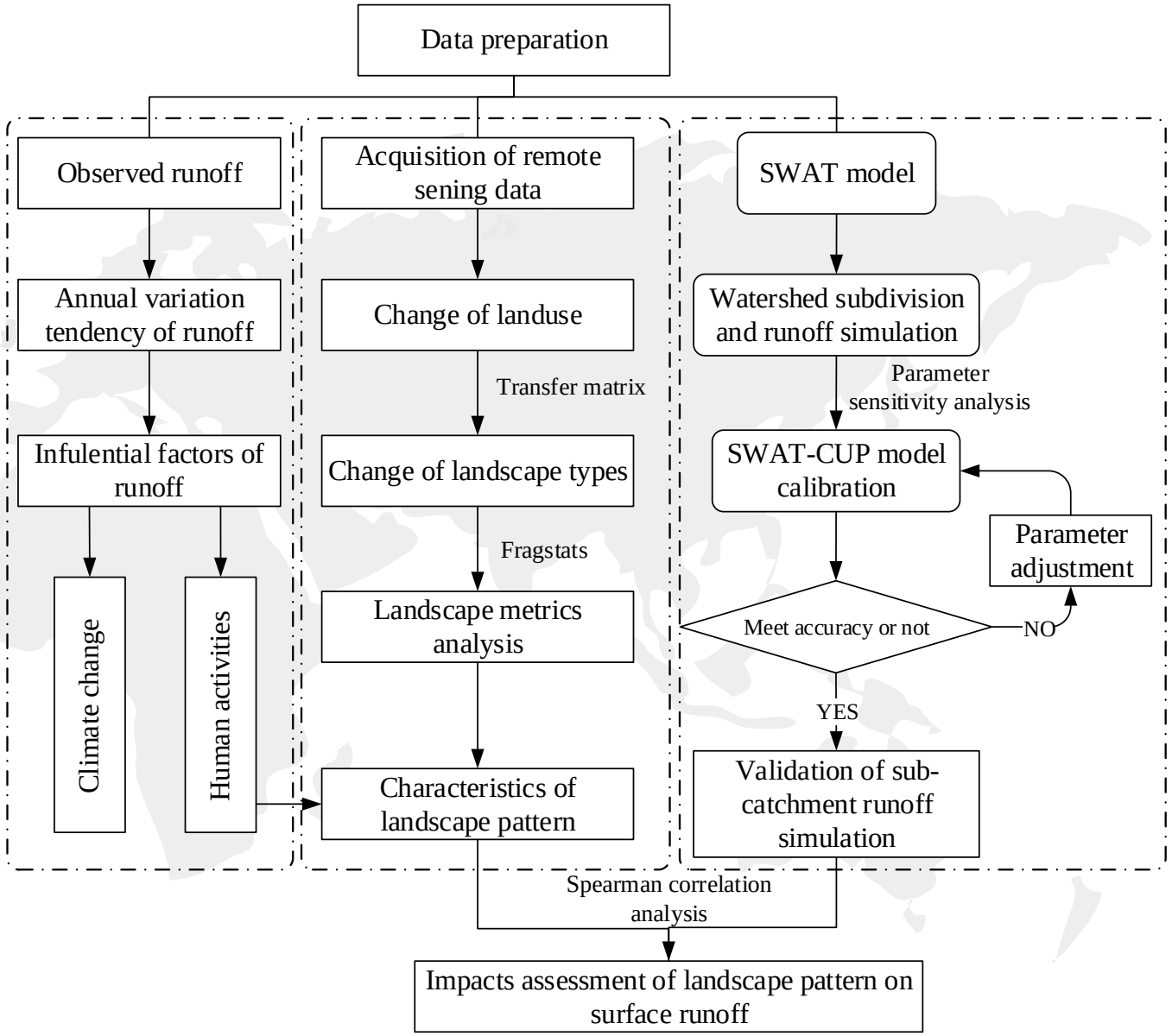
- Soil map
  - Soil type map and soil physical property database. The soil type map was from the 1:1 000 000 Harmonized World Soil Database (HWSD)



Method

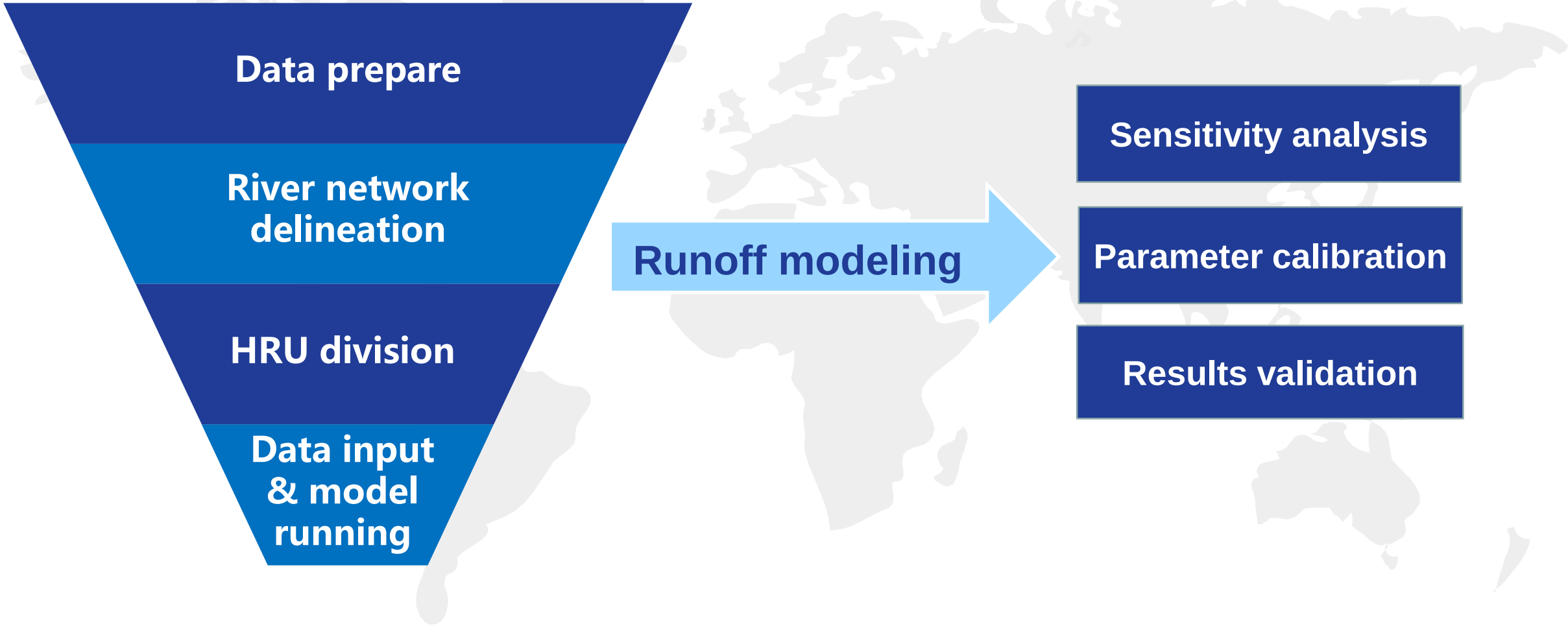
❖ Flowchart

- Runoff characteristics analysis in the basin
- Analysis of landscape pattern changes
- Watershed runoff modeling
- Impacts assessment of landscape change on surface runoff



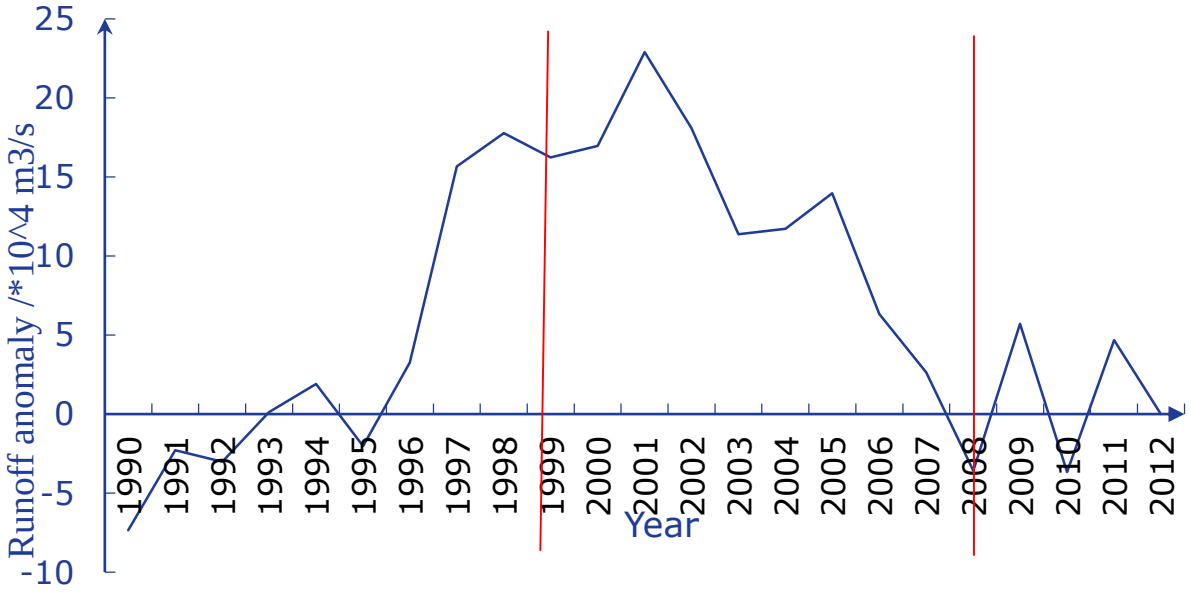
Method

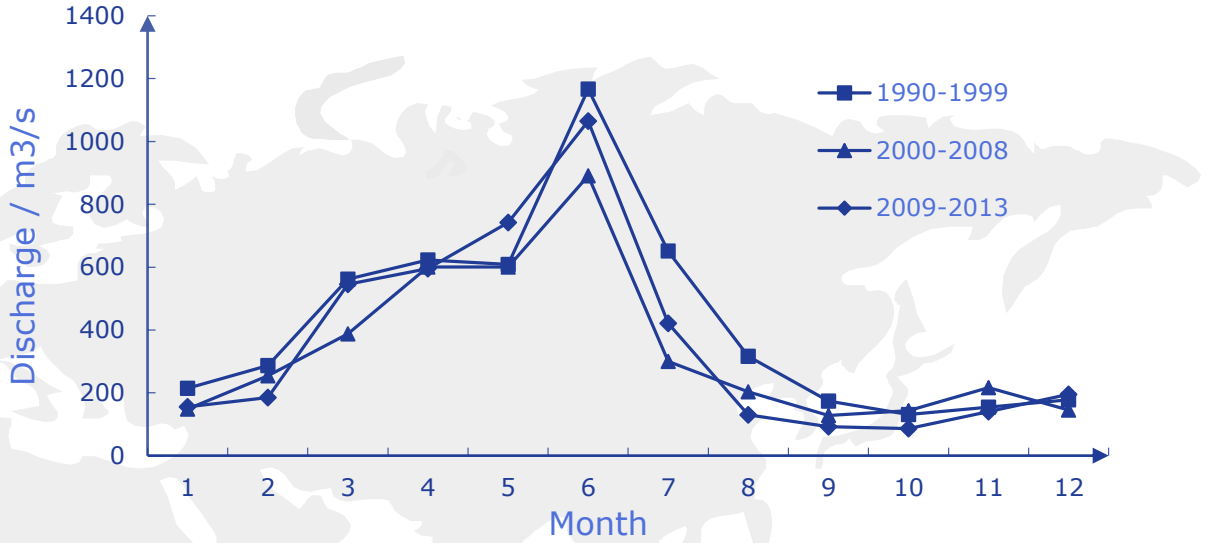
❖ SWAT model setup in FRB



Results and discussion

❖ Runoff variations in FRB



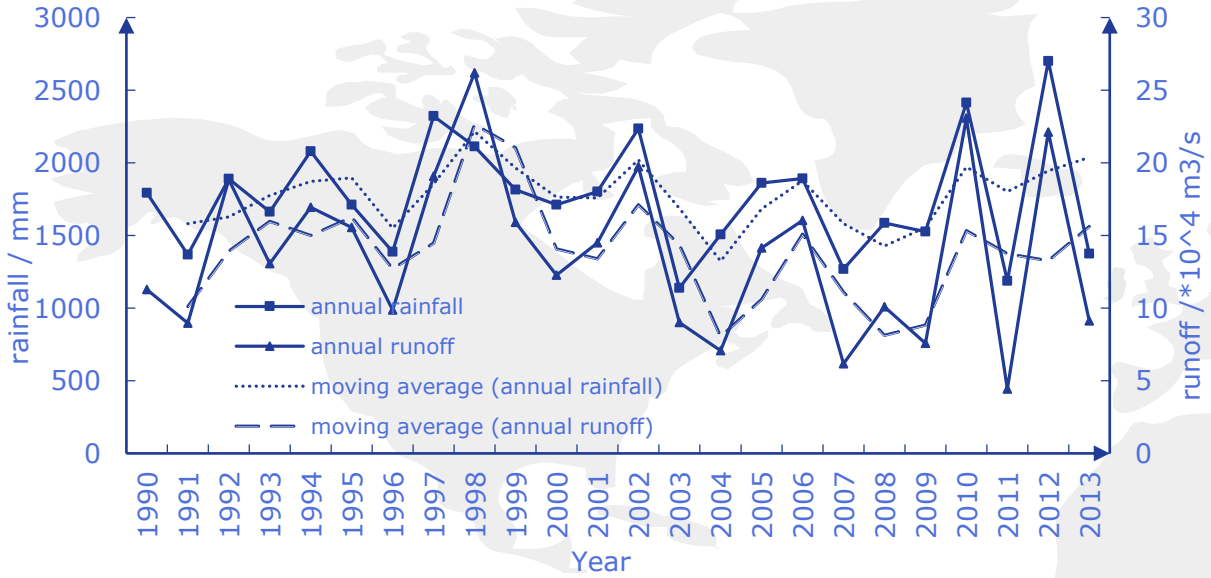


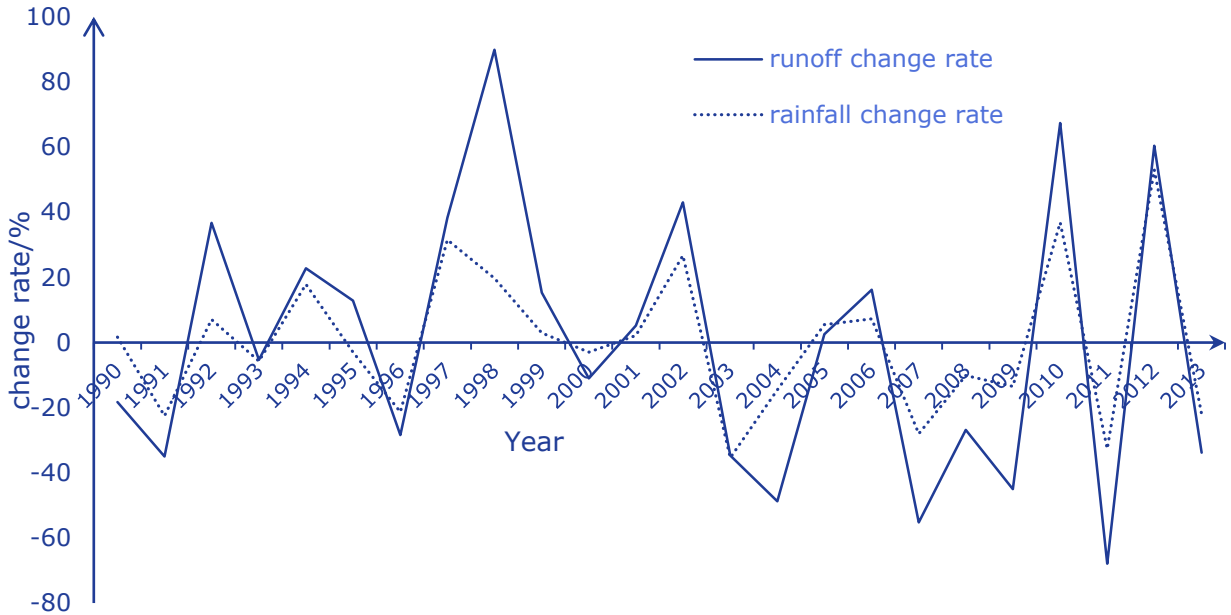
- Runoff variations during three periods
  - Increasing during 1990–1999
  - Decreasing during 2000–2008
  - Fluctuation during 2009–2013

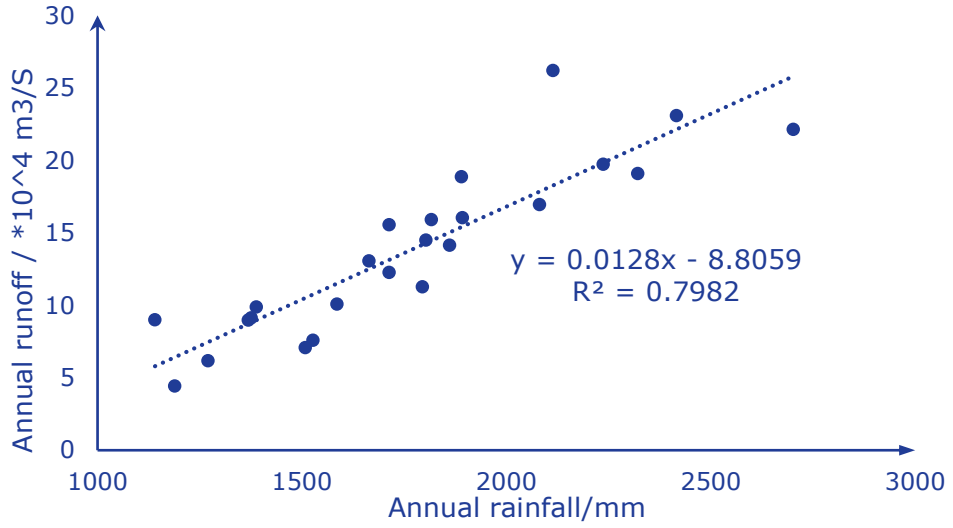
- During three periods, monthly average maximum discharge increases then decrease, and minimum discharge continuous declined.

Results and discussion

❖ Runoff variations in FRB



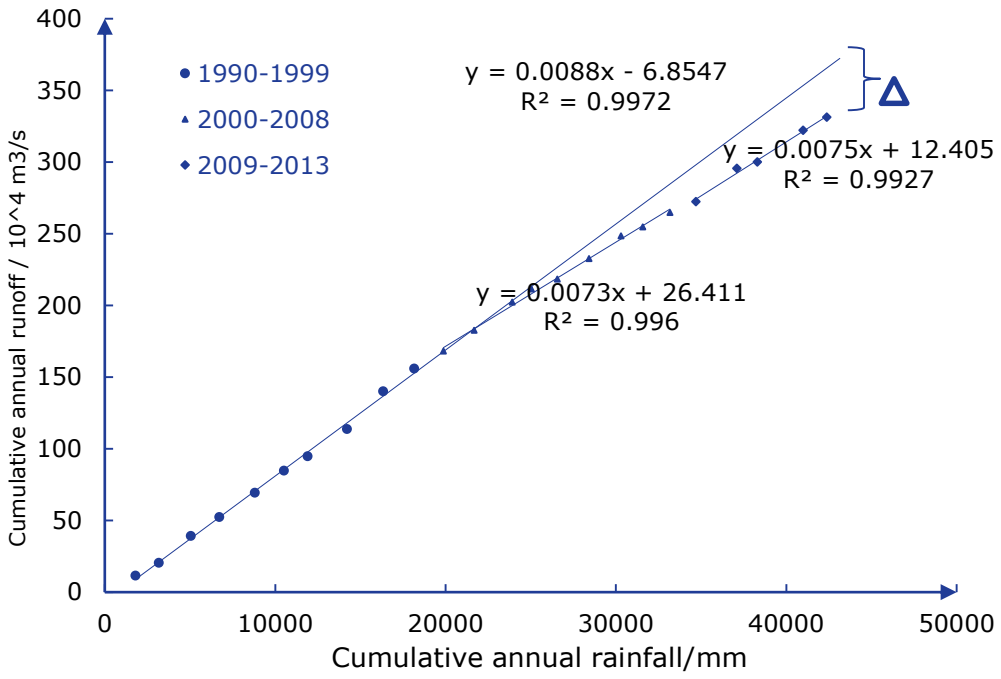




- The moving average of rainfall and runoff fluctuates in the same trend and in the same direction, and R^2 of both reaches 0.798, indicating that precipitation can significantly affect runoff.
- The change rate curve shows that the variation range of runoff is much stronger than that of rainfall. Precipitation is one of the influential factors of runoff, and other factors such as human activities also have great influence.

Results and discussion

❖ Runoff variations in FRB

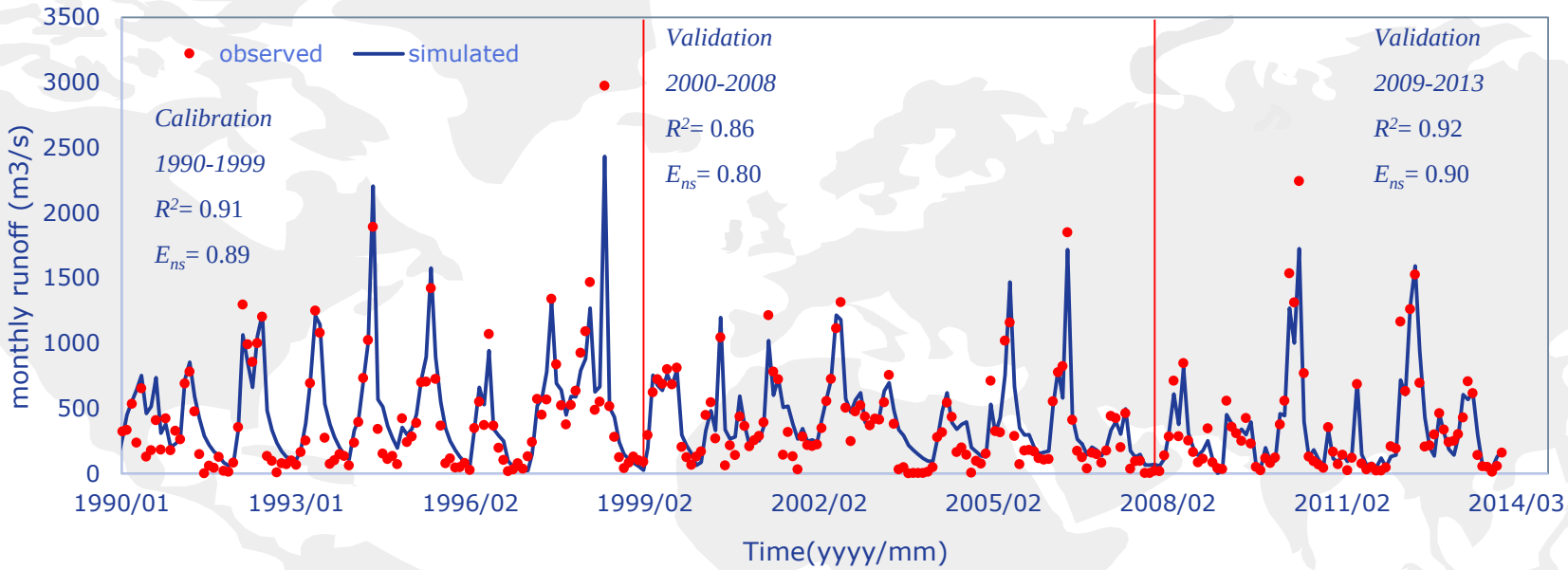


- Runoff is mainly affected by climate change and human activities. By using the mathematical relationship of three periods derived from Double Cumulative Curve Method, the contributions of climate and human activities to surface runoff was calculated in FRB from 1990 to 2013.

Period	Annual rainfall (mm)	Runoff（m^3/s）		Climate Change			Human activities	
		Observed annual mean runoff	Calculated annual mean runoff	Total changes	Impacted amount (m^3/s)	Contribution rate(%)	Impacted amount (m^3/s)	Contribution rate (%)
1990-1999	1814.90	15.57	–	–	–	–	–	–
2000-2008	1667.75	12.11	14.36	-2.24	-1.16	**33.39%**	-2.30	**66.61%**
2009-2013	1741.33	13.27	16.21	-2.94	0.63	**-21.54%**	-2.94	**127.46%**

Results and discussion

❖ Runoff results simulated by SWAT model



- The simulated and observed runoff fitted well, and the R^2 and E_{ns} of the three periods were 0.91, 0.86, 0.92 and 0.89, 0.80 and 0.90, respectively.
- The built SWAT Model is able to generate accurate result of hydrology prediction in FRB.

Results and discussion

❖ Landscape pattern changes in FRB

Year	Area and rate	Rice paddy	Agricultural land	Forest	Grassland	Water	Wetland	Urban	Bare land
1990	Area/km^2	2877.68	1685.42	8206.12	1360.37	202.75	20.68	211.20	172.97
	Percentage/%	19.53	11.44	55.68	9.23	1.38	0.14	1.43	1.17
2000	Area/km^2	2166.51	1607.66	8467.46	1574.34	295.24	33.64	362.29	353.36
	Percentage/%	14.58	10.82	56.98	10.59	1.99	0.23	2.44	2.38
2009	Area/km^2	2249.28	1251.28	8907.58	1341.20	172.16	37.04	518.09	272.27
	Percentage/%	15.25	8.48	60.39	9.09	1.17	0.25	3.51	1.85
1990–2000	Change rate %	**-24.71**	**-4.61**	**3.18**	15.73	45.62	**62.67**	**71.54**	104.29
2000–2008	Change rate /%	**3.82**	**-22.17**	**5.20**	-14.81	-41.69	**10.11**	**43.00**	-22.95

- From 1990 to 2008, the area of rice paddy and bare land decreased significantly, while the area of forest, wetland and urban area increased.

Results and discussion

❖ Landscape pattern changes in FRB

		2008							
		Rice paddy	Agricultural land	Forest	Grassland	Water	Wetland	Urban	Bare land
1990	Rice paddy	1023.02	406.87	944.95	232.79	17.65	4.85	172.42	74.84
		35.55%	14.14%	32.84%	8.09%	0.61%	0.17%	5.99%	2.60%
	Agricultural land	551.33	245.12	531.67	167.32	13.36	7.13	101.39	67.93
		32.72%	14.55%	31.55%	9.93%	0.79%	0.42%	6.02%	4.03%
	Forest	237.82	382.42	6620.51	756.94	16.31	12.21	118.10	59.43
		2.90%	4.66%	80.68%	9.22%	0.20%	0.15%	1.44%	0.72%
	Grassland	237.18	171.78	677.17	167.07	6.89	3.49	61.86	34.76
		17.44%	12.63%	49.78%	12.28%	0.51%	0.26%	4.55%	2.56%
	Water	31.57	7.19	32.60	2.77	96.05	5.01	16.96	10.59
		15.57%	3.55%	16.08%	1.37%	47.37%	2.47%	8.36%	5.22%
	Wetland	10.13	2.25	1.57	0.21	2.41	0.20	3.28	0.63
		48.99%	10.86%	7.60%	1.03%	11.64%	0.98%	15.85%	3.05%
	Urban	83.18	15.85	54.01	5.22	13.58	2.28	28.53	8.54
		39.39%	7.50%	25.57%	2.47%	6.43%	1.08%	13.51%	4.05%
	Bare land	73.15	18.79	35.14	7.62	5.76	1.83	15.28	15.32
		42.31%	10.87%	20.32%	4.41%	3.33%	1.06%	8.84%	8.86%

Landscape types transfer matrix in 1990-2009

- From 1990 to 2008, a large number of rice paddy, bare land, grassland and water area were transferred to forest and urban area, and some bare land and wetland were transferred to rice paddy.

Results and discussion

❖ Landscape pattern changes in FRB

Landscape indices change of FRB from 1990 to 2008

Year	NP	PD (n/100ha)	MPS (ha)	FRAC_AM	CONTAG(%)	SHDI	SHEI
1990	1047249	71.0612	1.4072	1.3591	51.5206	1.2942	0.589
2000	1499697	100.9184	0.9909	1.335	45.4509	1.3507	0.6496
2008	729528	49.4632	2.0217	1.3652	51.7707	1.277	0.6141

Landscape fragmentation reduced greatly

Patch shapes became complex

Patch connectivity was weak first and then strong

Patch heterogeneity and equilibrium were enhanced

NP (Number of Patches), PD (Patch Density), MPS (Mean Patch Size), FRAC_AM (Fractal dimension of Area Weighted), CONTAG (contagion index), SHDI (Shannon's Diversity Index), SHEI (Shannon's Equilibrium Index)

Results and discussion

❖ Landscape pattern changes in FRB

▪ Landscape fragmentation

- Rice paddy and grassland were the most fragmented landscapes, of which NP and PD values first increased then decreased, and fragmentation degree first increased then decreased, showing an overall weakening trend.

▪ Landscape dominance

- Forest was the dominant landscape in this area, and the degree of dominance increased year by year (PLAND: Percentage of Landscape)

▪ Landscape shape

- The Patch Complexity of urban area increased year by year

▪ Landscape IJI

- The IJI (Interspersion Juxtaposition Index) of urban area is higher than that of other landscape types, indicating that these two types are adjacent to other types, which denotes that human activities have an important impact on the distribution of landscape types.

Landscape indices change of FRB from 1990 to 2008 on landscape type

Year	Landscape	NP	PD (n/100ha)	PLAND (%)	FRAC_AM	IJI (%)
1990	Rice paddy	**300905**	**20.4179**	19.5265	1.3079	58.4875
	Bare land	192943	13.0922	11.4364	1.2564	65.8581
	Forest	116245	7.8878	**55.6827**	1.4477	53.6905
	Grassland	**327128**	**22.1973**	9.2308	1.1434	60.7551
	Water	10330	0.7009	1.3758	1.2635	76.2894
	Wetland	1497	0.1016	0.1403	1.1421	71.3018
	Urban	51998	3.5283	1.4331	**1.1332**	**84.5781**
	Unused land	46146	3.1312	1.1737	1.119	61.3609
2000	Rice paddy	**308133**	**20.735**	10.8183	1.1716	72.8939
	Bare land	175026	11.7779	2.4379	1.0784	90.5337
	Forest	88211	5.9359	**56.9796**	1.4356	74.4457
	Grassland	**451998**	**30.4161**	10.5941	1.1309	75.2194
	Water	3521	0.2369	0.2264	1.1286	65.5796
	Wetland	236553	15.9182	14.579	1.318	67.1805
	Urban	51326	3.4539	1.9867	**1.2084**	**79.3588**
	Unused land	184929	12.4443	2.3779	1.0714	79.4109
2008	Rice paddy	**137983**	**9.3555**	3.5127	1.1106	77.7012
	Bare land	79153	5.3667	15.2505	1.3781	78.2479
	Forest	62172	4.2154	**60.3949**	1.4447	66.2811
	Grassland	**189876**	**12.8739**	8.4839	1.1667	70.8871
	Water	7448	0.505	0.2512	1.1123	58.5912
	Wetland	204014	13.8325	9.0935	1.1646	53.7039
	Urban	6014	0.4078	1.1673	**1.2598**	**67.5951**
	Unused land	42868	2.9065	1.8461	1.1432	78.1797

Results and discussion

❖ Impacts of landscape change on surface runoff

- The SWAT model was used to simulate the surface runoff of 31 sub-basins, and Spearman Correlation Analysis was used to calculate the correlation between the average annual runoff and landscape indices of 31 sub-basins.

Correlation between landscape indices and annual average runoff in sub-basins

Landscape Indices	1990–2000	2000–2008	2008–2013
NP	-0.006	0.068	-0.132
PD	0.323	0.467**	0.225
MPS	-0.323	-0.467**	-0.225
FRAC_AM	-0.448*	-0.448*	-0.507**
CONTAG	-0.328	-0.434*	-0.331
SHDI	0.398*	0.428*	0.335
SHEI	0.366*	0.428*	0.348

**The correlation is significant when the confidence(two-sided) is 0.01.
*The correlation is significant when the confidence(two-sided) is 0.05.

Results and discussion

❖ Impacts of landscape change on surface runoff

Correlation between landscape indices and annual average runoff in different landscape types

Landscape types	Landscape indices	1990–2000	2000–2008	2008–2013
Agricultural land	PLAND	0.42*	0.527**	0.287
	NP	0.028	0.137	-0.142
	PD	0.442*	0.517**	0.238
	FRAC_AM	0.286	0.145	0.213
	IJI	0.465**	-0.134	-0.231
Rice paddy	PLAND	0.553**	0.522**	0.438*
	NP	-0.257	-0.191	-0.055
	PD	-0.066	-0.01	0.255
	FRAC_AM	0.263	0.368*	0.277
	IJI	0.527**	-0.16	0.042
Forest	PLAND	-0.535**	-0.516**	-0.516**
	NP	0.086	0.152	0.019
	PD	0.246	0.437*	0.296
	FRAC_AM	-0.438*	-0.435*	-0.485**
	IJI	0.41	0.205	0.118
Grassland	PLAND	0.034	0.154	-0.292
	NP	-0.102	-0.029	-0.304
	PD	0.275	0.379*	-0.311
	FRAC_AM	-0.222	-0.254	-0.04
	IJI	0.418*	0.458**	-0.424*
Water	PLAND	0.62**	0.497**	0.417*
	NP	0.308	-0.174	-0.001
	PD	0.545**	0.091	0.295
	FRAC_AM	0.518**	0.598**	0.394*
	IJI	0.397*	0.368*	0.5**
Wetland	PLAND	-0.4	0.632**	0.285
	NP	-0.3	0.243	0.181
	PD	-0.1	0.379*	0.253
	FRAC_AM	-0.7	0.497**	0.442*
	IJI	-0.6	-0.26	0.459*
Urban	PLAND	0.469**	0.508**	0.594**
	NP	0.245	0.158	0.014
	PD	0.538**	0.597**	0.543**
	FRAC_AM	0.215	0.447*	0.586**
	IJI	0.096	0.437*	-0.173
Bare land	PLAND	0.535**	0.252	0.179
	NP	0.308	-0.004	-0.036
	PD	0.478**	0.279	0.187
	FRAC_AM	0.554**	0.137	0.079
	IJI	0.305	0.229	-0.031

**The correlation is significant when the confidence(two-sided) is 0.01.
*The correlation is significant when the confidence(two-sided) is 0.05.

Conclusion

- The runoff of FRB showed a downward trend from 1990 to 2013.
- On landscape level from 1990 to 2013, NP and PD decreased while MPS and FRAC_AM increased, as well as SHDI and SHEI increased slightly. The PD, SHDI and SHEI showed a significant positive correlation with surface runoff, while MPS and FRAC_AM showed a remarkable negative correlation with surface runoff. The degree of landscape fragmentation decreased, while the shape of patches in the basin became more and more complex, with the uneven distribution of patches was enhanced, which increased the land surface interception and reduces the runoff yield.
- On landscape types level, NP and PD of rice paddy and grassland decreased, while the PLAND of forest increased continuously, and the FRAC_AM and IJI of urban area increased. The PLAND of bare land, rice paddy, water and urban area is significantly positively correlated with runoff, while the PLAND and FRAC_AM of forest shows a remarkable negative correlation with runoff. The complexity of patch shape in forest enhances the interception of rainfall and transpiration of plants, which reducing the runoff.

Thank you for your attention!