Contrasting Spatial Distribution of the Emission and Export of Diffuse Nutrient at Watershed Level

Wenchao Li, Limei Zhai, Qiuliang Lei, Shen Liu, Wanli Hu, Hongbin Liu*, Tianzhi Ren

Key Laboratory of Nonpoint Pollution Control, Ministry of Agriculture;
Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences

Non-point source (NPS) pollution is regarded as a major concern for water quality deterioration. (Ongley et al., 2010)

Relative to point source pollution, NPS pollution is difficult to measure and regulate because of its dispersed origins and intermittent distribution. (Carpenter et al., 1998;Arabi et al., 2006)

However, many studies have indicated that proportional much of nutrient loss originates from relatively small areas which are called critical source areas (CSAs) or priority management areas (PMAs) (Huang et al., 2015; Pionke et al., 2000; Shang et al., 2012; Sharpley et al., 2011;Chen et al., 2014b; Shen et al., 2015)

Targeting the CSAs for implementing best management practices (BMPs) has been recognized as an effective and efficient way to control NPS pollution. (Chen et al., 2014a; Heathwaite et al., 2005; McDowell and Srinivasan, 2009)

Understanding the spatial characteristics of NPS pollution is the key first step to identify the CSAs

The pollutant flux of a certain geographical unit out of from a watershed depends on not only nutrient emission from the landscape but also the biochemical transformations within the delivery process. (Aguilera et al., 2012; Alexander et al., 2002; Bettez et al., 2015)

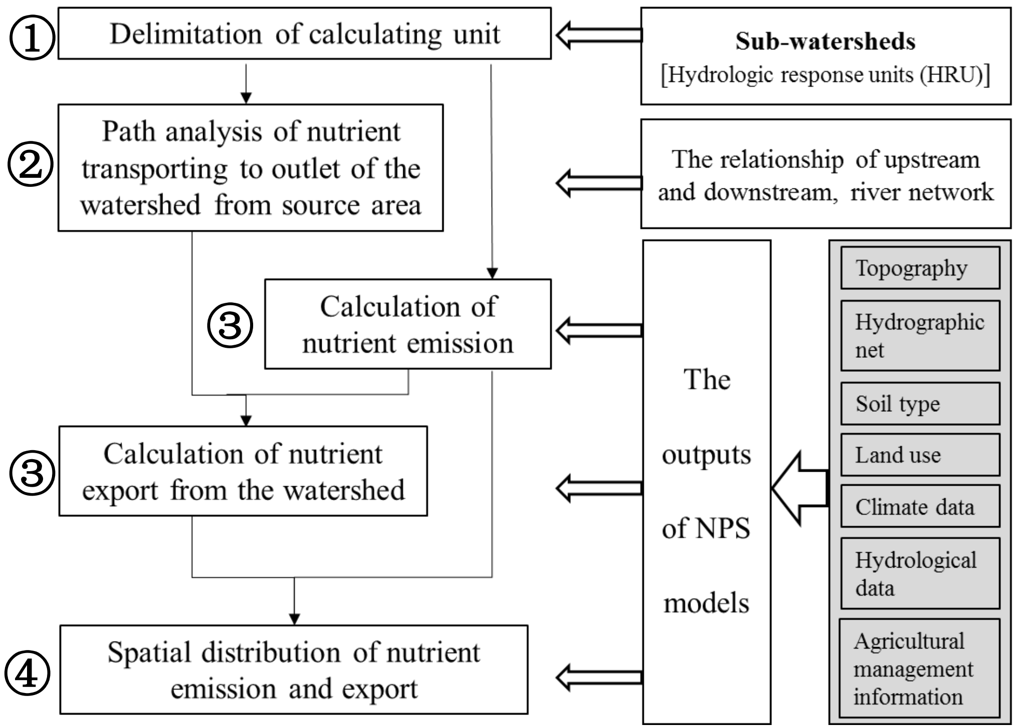
Delivery process may result in the difference between the emission (to water or reach nearby) and export (to receiving water bodies) of diffuse nutrient in spatial distribution. (Shen et al., 2015)

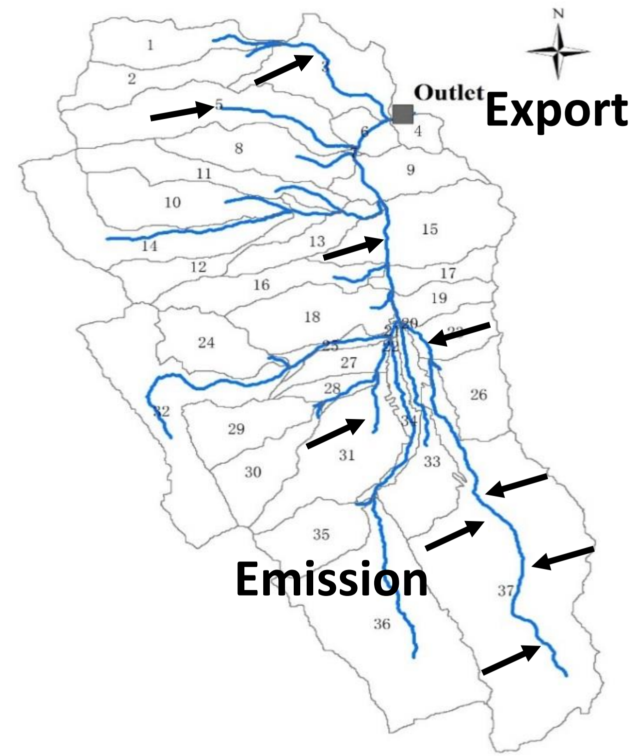
Understanding the spatial characteristics of NPS pollution require evaluating the influence of delivery process.

Objectives to…

- ✓ 1) evaluate the export (to receiving water body) of diffuse nutrient from the watershed;
- ✓ 2) contrastively analyze the spatial features of diffuse nutrient emission(to water or reach nearby) and export;
- ✓ 3) assess the impact of delivery process on the difference between the emission and export of diffuse nutrient in spatial distribution.

Methodology

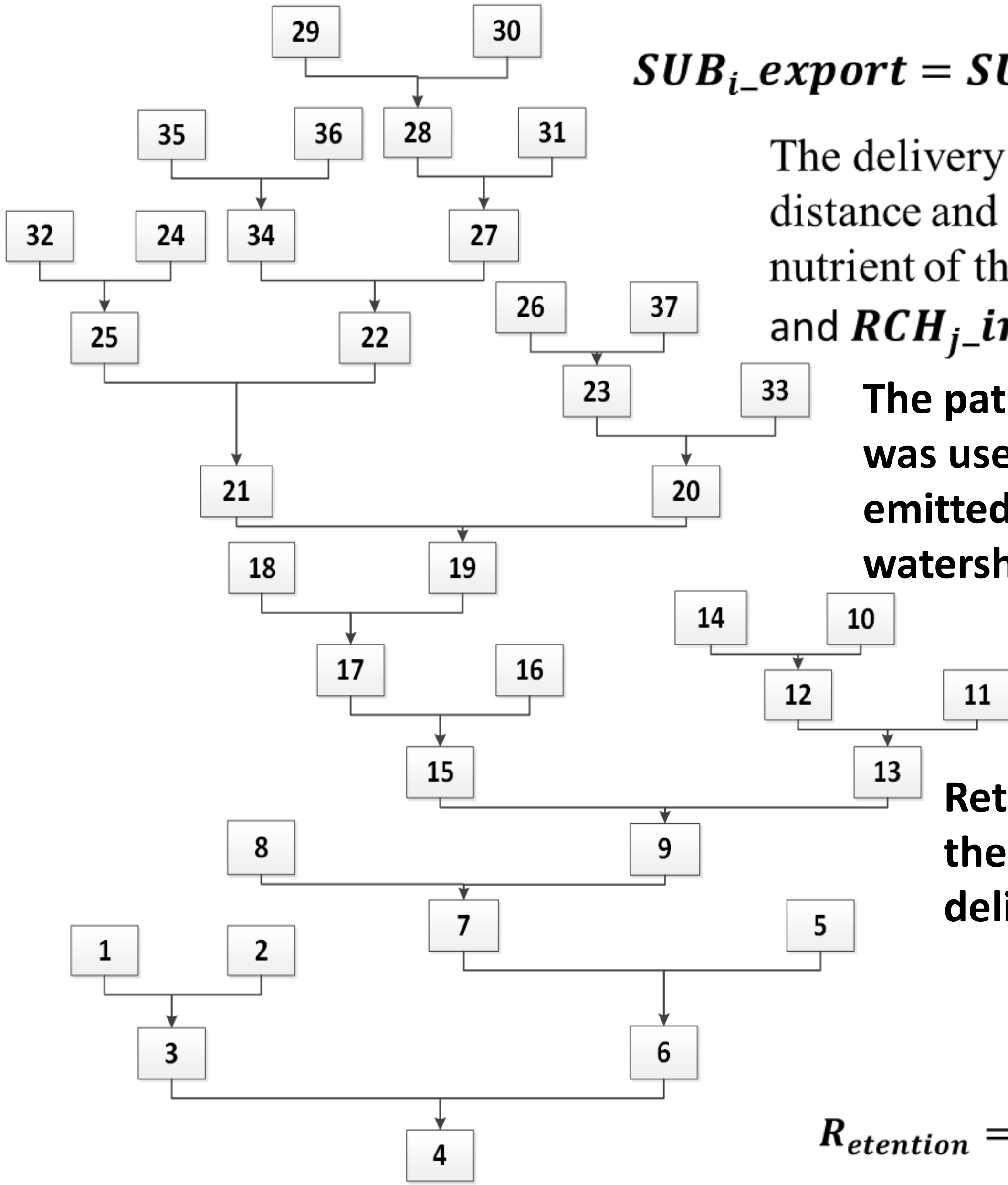




The SUB_emission of nutrient was the nutrient (N and P) that was transported by the runoff and with the sediment into the reach described in the SUB files

$$SUB_{i\_}export = SUB_{i\_}emission * \prod_{j=i}^{n} \frac{RCH_{j\_}out}{RCH_{j\_}in} \qquad (1)$$

The SUB_export was the proportion of subwatershed-emitted nutrient that exported to the outlet of the watershed, which is the result of SUB_emission and the delivery process (Function 1)



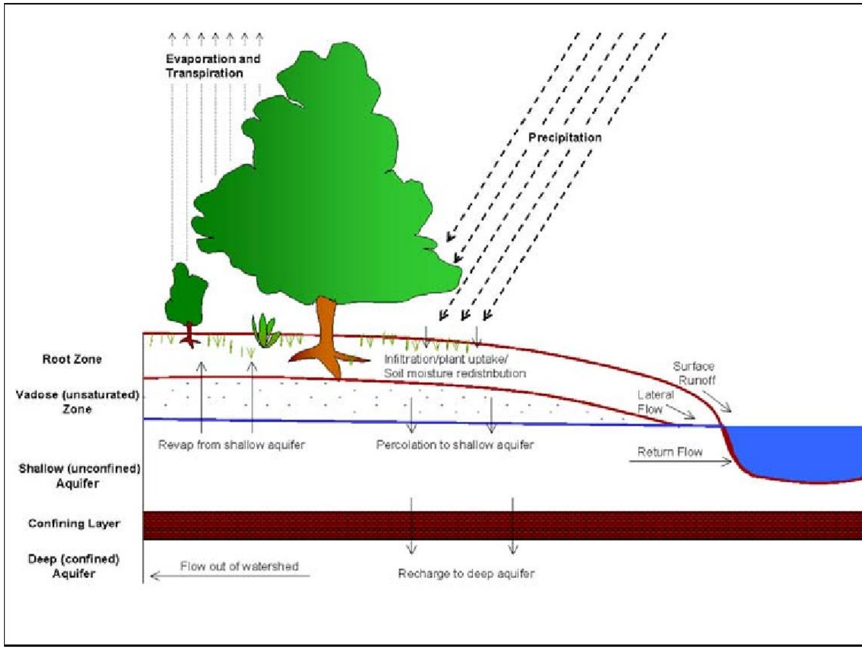
$$SUB_{i}\_export = SUB_{i}\_emission * \prod_{j=i}^{n} \frac{RCH_{j}\_out}{RCH_{j}\_in} \qquad (1)$$

The delivery process was described by the migration distance and the percentage of output to input nutrient of the reach, such as RCH_{j}_out and RCH_{j}_in in the function 1

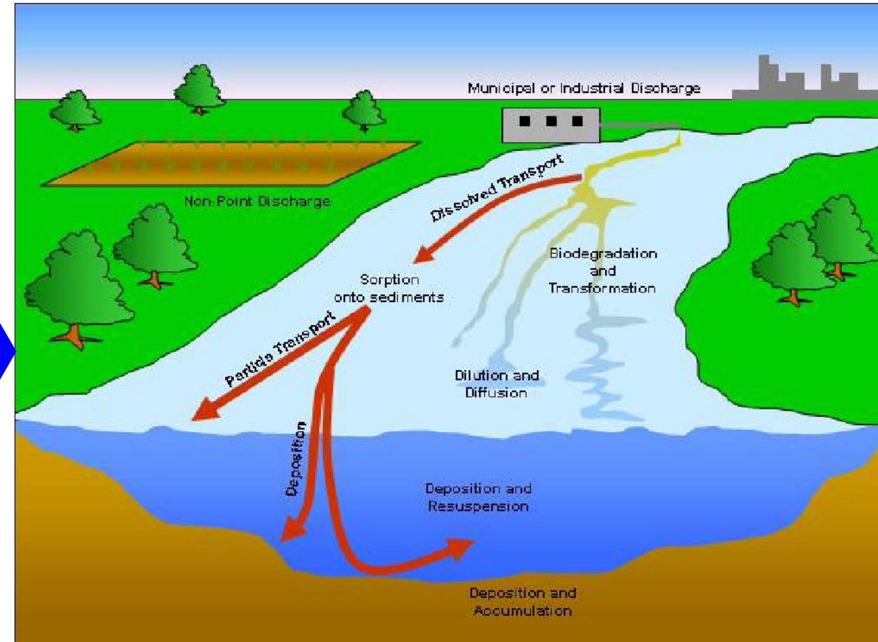
The path relationship of the routing reaches was used to calculate the migration distance of emitted nutrient move to outlet of the watershed from the source sub-watershed

Retention coefficient was used to describe the changes of emitted nutrient within the delivery process (Function 2)

$$R_{etention} = \frac{SUB\_emission - SUB\_export}{SUB\_emission} \qquad (2)$$



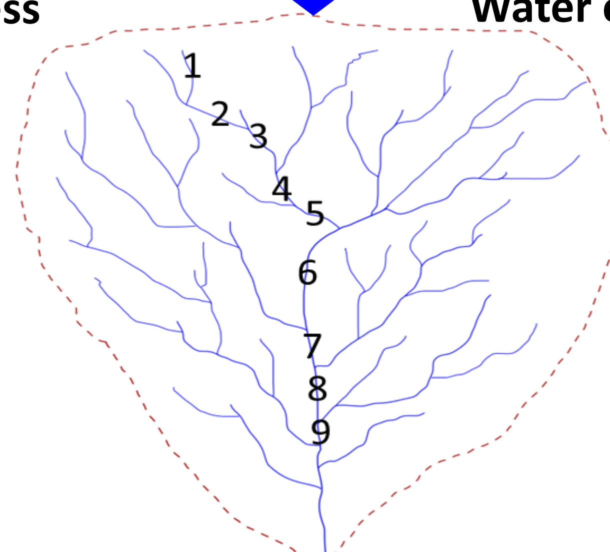
Land phase or process



Water or routing phase or process

The SWAT model is used in this method

Calculation of the emission of nutrient described in the SUB output files



Receiving water body

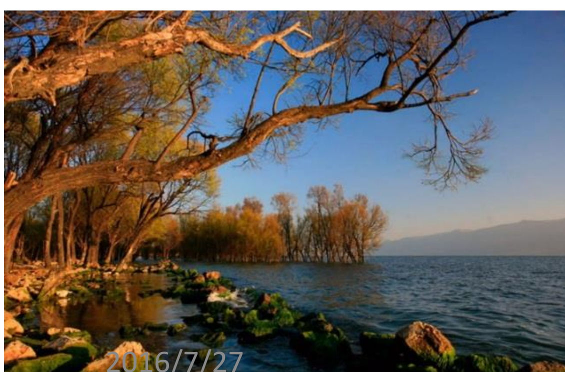
Calculation of the input and output nutrient of the reaches described in the RCH output files

(Arnold et al. 1998)

Research area-

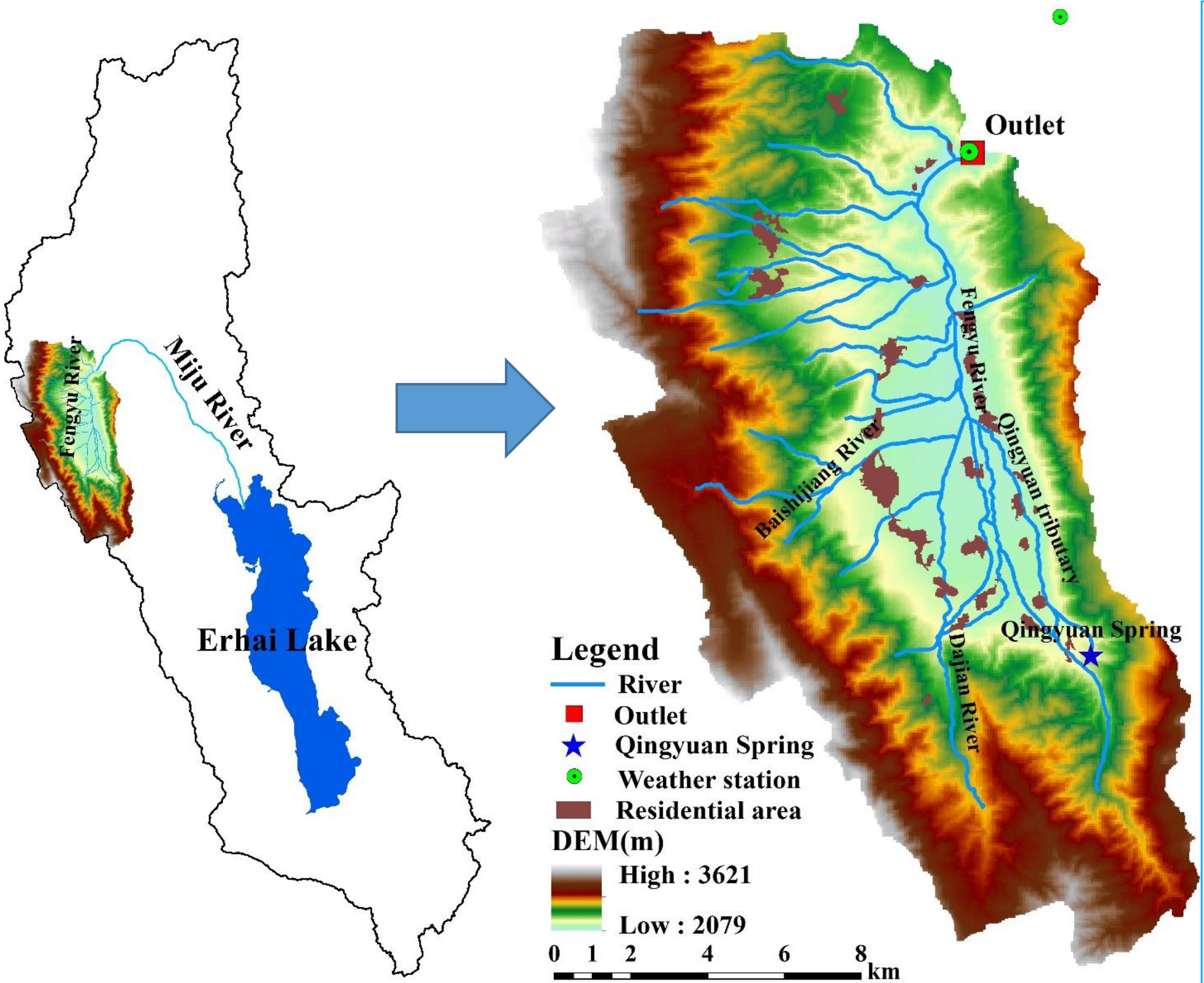
A headwater watershed of Erhai Lake area in Southwestern China

Fengyu River watershed



Agricultural NPS pollution is the major concern of water quality deterioration of Erhai Lake

Research area-Fengyu River watershed



- ✓ **Area:** 218 km^2
- ✓ **Subtropical plateau monsoon climate:**

  Annual mean temperature:

  13.9 ℃

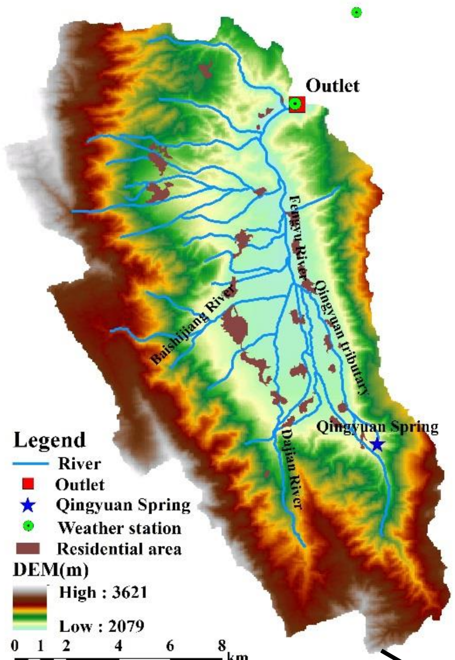
  Rainfall depth:

  740 mm, with more than 85% occurs from May to October
- ✓ **Residential area:** Population: 39,000 people

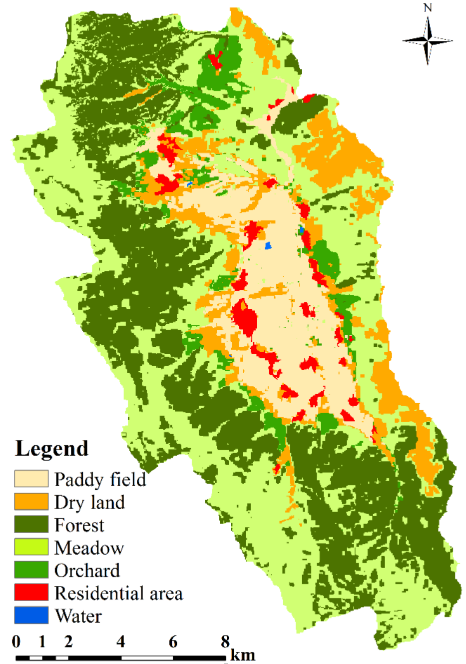
  Cow: 10,000 heads

Databases for SWAT model

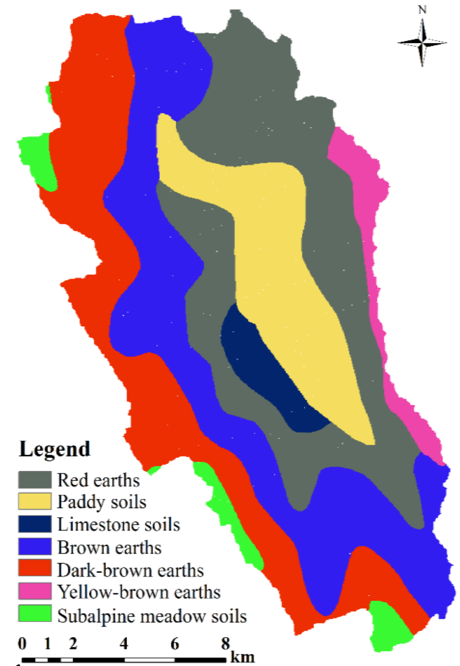
DEM(1:50000)



Land use(1:100000)



Soil(1:500000)



Climate data, soil properties, land cover, etc. → **SWAT** ← Crop planting, fertilizer application, irrigation, tillage, etc.

↓

OUTPUT: discharge, N and P load in HRU and Sub files ← Measured data: stream flow, water quality

Databases -soil and fertilization

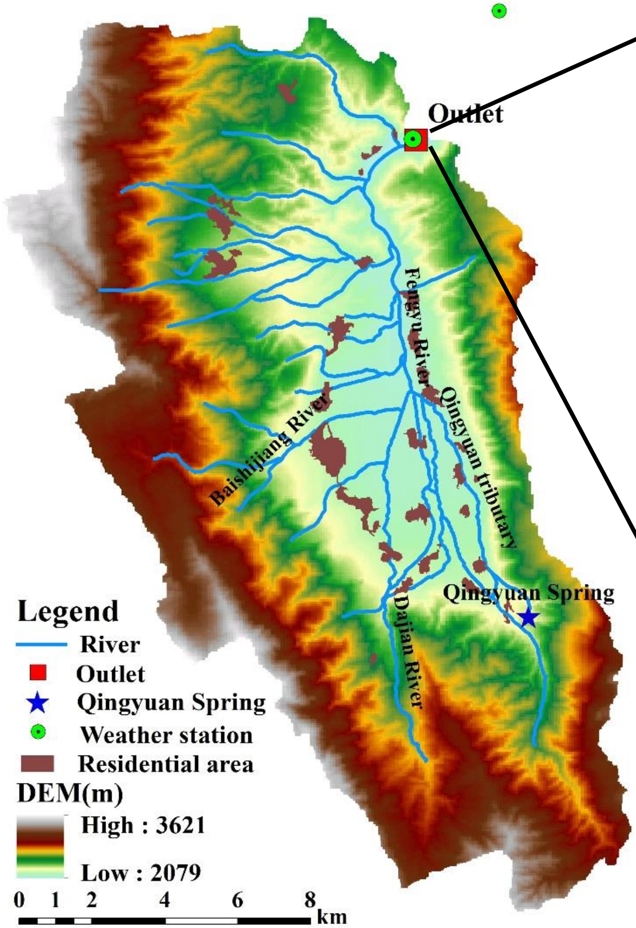
Red earths, brown earths and dark-brown earths are the dominant soils which account for 27.8%, 25.8% and 22.4%.

Soil type	Percentage of area (%)	Bulk density (g/cm^3)	Clay (%)	Silt (%)	Sandy (%)	Organic carbon (%)	TN (g/kg)	TP (g/kg)
Red earths	27.8	1.27	5.3	51	43.7	2.1	1.5	0.7
Paddy soils	14.3	1.40	8.9	60.1	31	1.9	1.7	0.6
Limestone soils	3.0	1.53	6.5	79.6	13.9	1.7	1.6	0.8
Brown earths	25.8	0.88	14	82	4	3.3	2.4	0.9
Dark-brown earths	22.4	0.89	9	75	16	3.5	2.6	1.0
Yellow-brown earths	3.7	1.04	8	63.9	28.1	1.9	1.7	1.1
Subalpine meadow soils	3.1	0.73	8.7	57.4	33.9	9.6	7.3	1.8

Dominant land use includes meadow (35.6%), forest (33.0%), and crop land (29.0%) which is classified into paddy field(12.9%), dry land(11.1%) and orchard(5.0%).
Rice-broad bean/rape in paddy field
Corn-broad bean/rape in dry land
prune tree in orchard

Crop type	**Data of fertilizer application**	**Livestock manure**		**Chemical fertilizer**	
		N(kg hm^{-2} a^{-1})	P(kg hm^{-2} a^{-1})	N(kg hm^{-2} a^{-1})	P(kg hm^{-2} a^{-1})
Paddy rice	May 1	70	30	53.6	28.3
	June 1			57.9	0.0
	July 1			57.9	0.0
	Total	70	30	169.4	28.3
Corn	May 1	81	36	48.4	38.9
	June 1			59.9	9.0
	July 1			59.9	9.0
	Total	81	36	168.2	56.9
Fava bean	October 1	120	55	30.4	47.7
	November 15			27.2	11.3
	January 1			27.2	11.3
	Total	120	55	84.8	70.3
Rape	October 1	131	61	53.0	26.8
	November 15			56.9	12.0
	January 1			56.9	12.0
	Total	131	61	166.5	50.8

Measured data and model setup

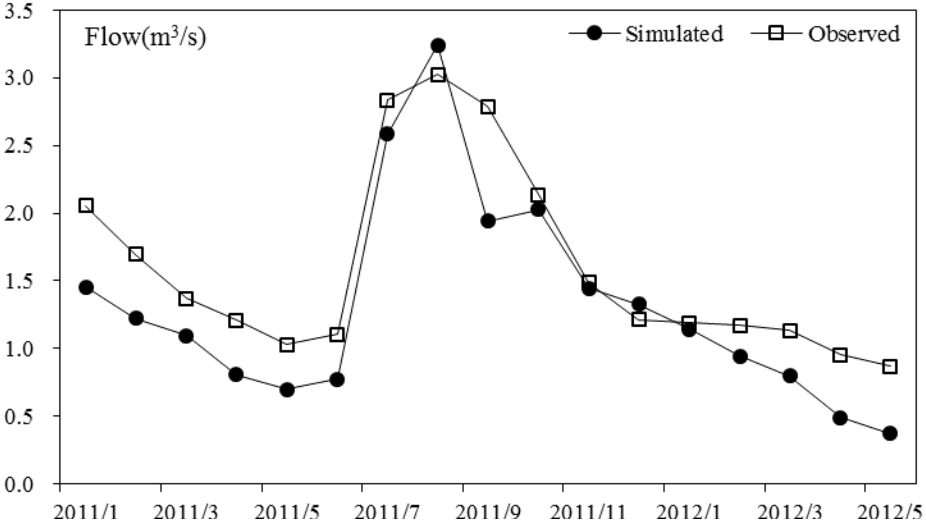


- **Discharge:** 2011-2013, daily
- **Water quality: Oct.** 2010-2013, daily
- **Water quality parameters: TN, TP**

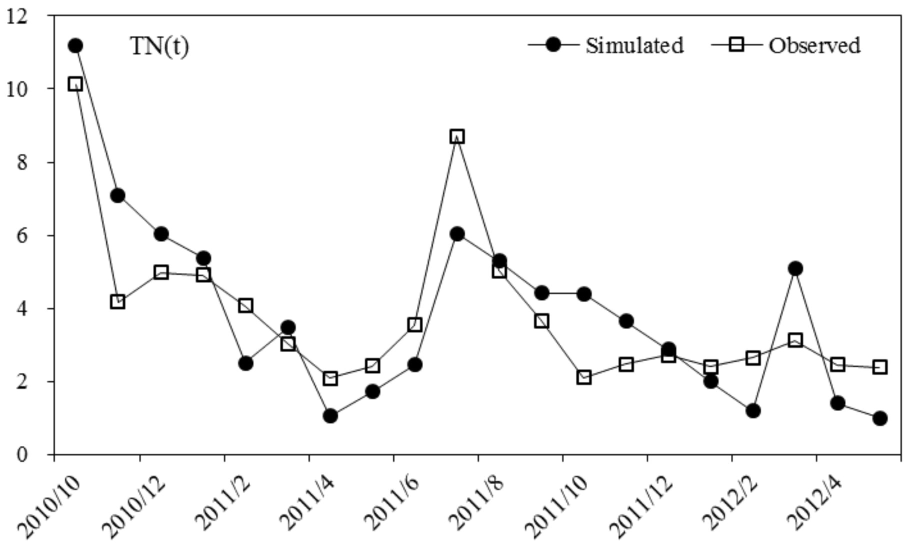
Constituent	Calibration	Validation
Discharge	**Jun. 2012 to Dec. 2013**	**Jan. 2011 to May 2012**
Sediment	**Jun. 2012 to Dec. 2013**	**Jan. 2011 to May 2012**
Nutrients(TN,TP)	**Jun. 2012 to Dec. 2013**	**Oct. 2010 to May 2012**

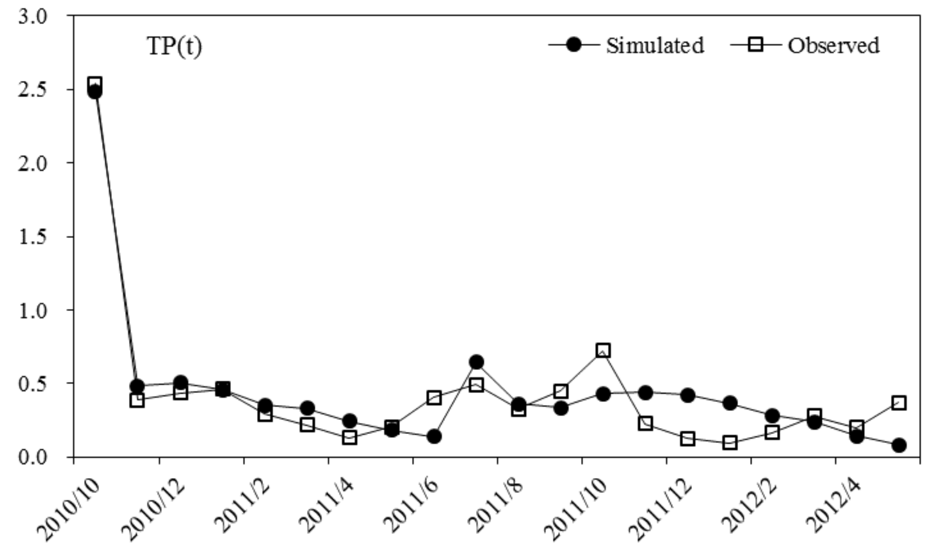
- **SWAT version 2009**
- **37 sub-watersheds**

Stream flow discharge and nutrient load



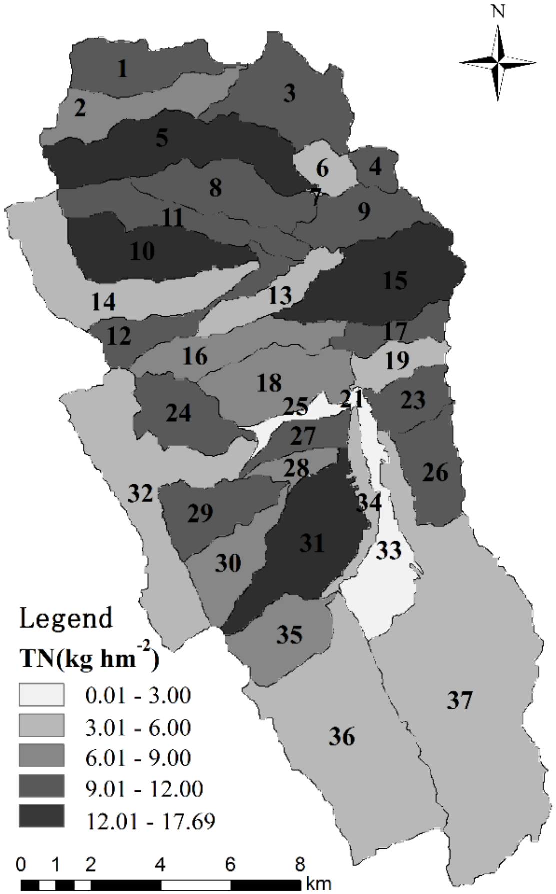
Constituent	r^2	ENS
Discharge	0.88	0.68
TN	0.67	0.54
TP	0.89	0.89

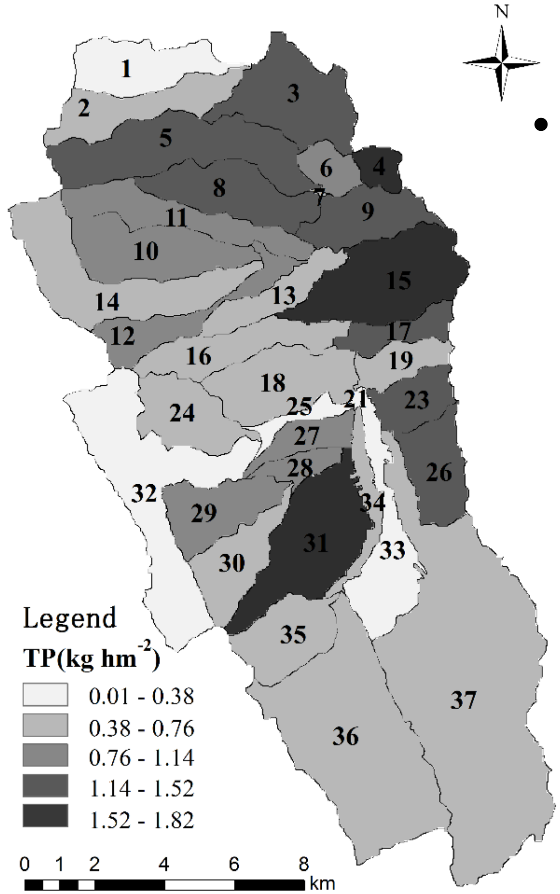




- **The agreement between the simulated and monthly observed data for the TN and TP load was satisfactory**

Spatial distribution of nutrient emission



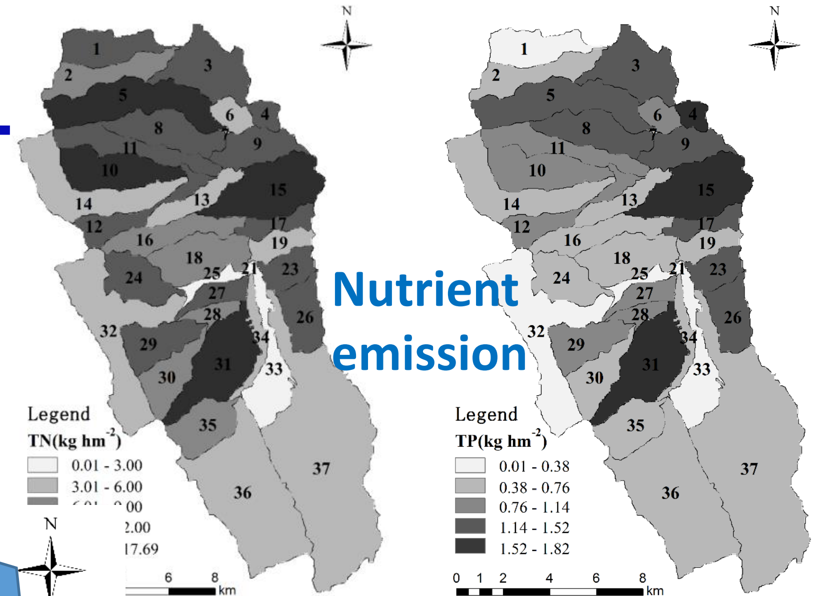


- The emission intensity showed enormous spatial variations that varied from 0.01 to 17.69 kg hm^{-2} for TN , with the TP range from 0.01-1.82 kg hm^{-2}

- Sub-watersheds 5, 10, 15 and 31 emitted higher level of TN
- Sub-watersheds 4, 15 and 31 emitted higher level of TP
- Sub-watersheds 15 and 31 were the hot areas both for TN and TP emission

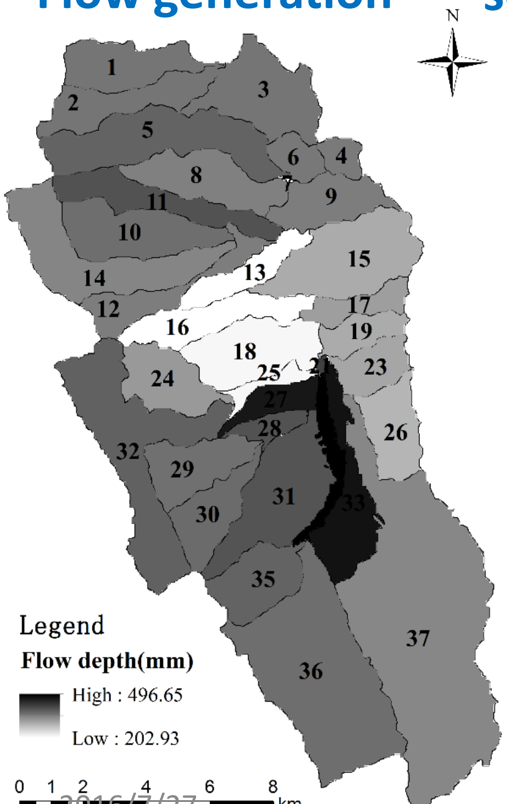
Relationship between nutrient emission and flow and sediment

The sub-watersheds with higher level of TN emission were located in the areas with middle level of flow depth.

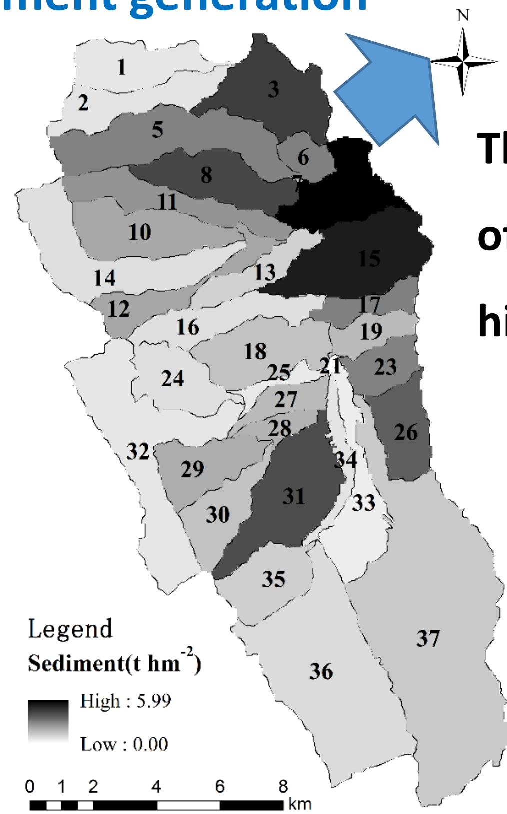


Nutrient emission

Flow generation



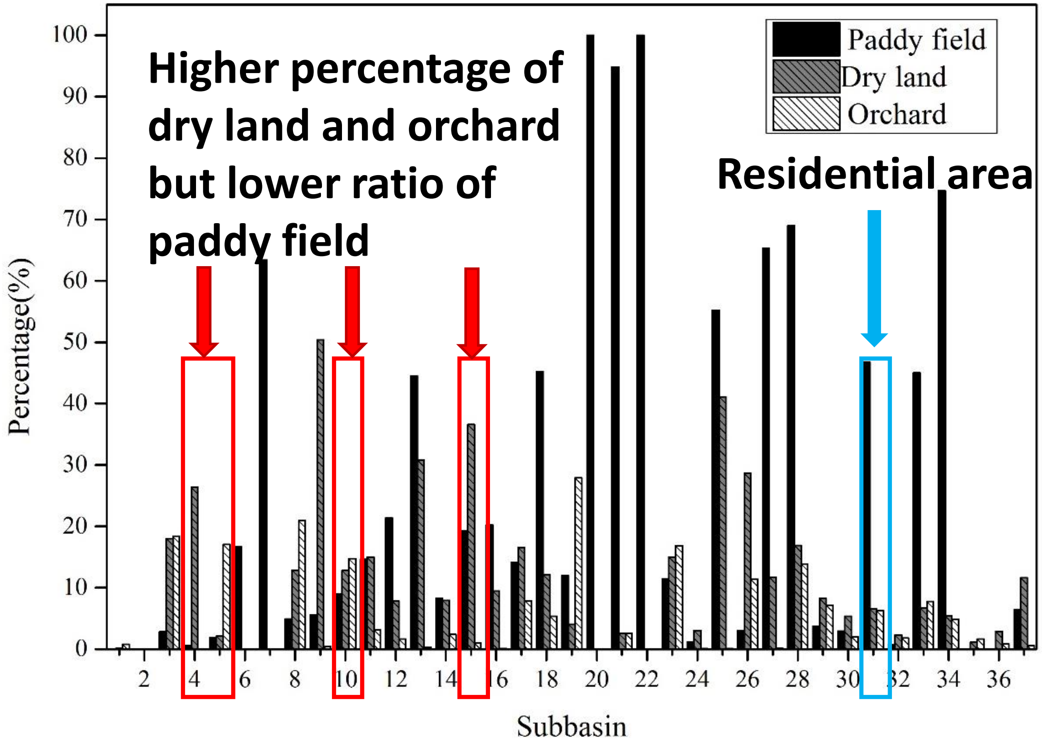
sediment generation

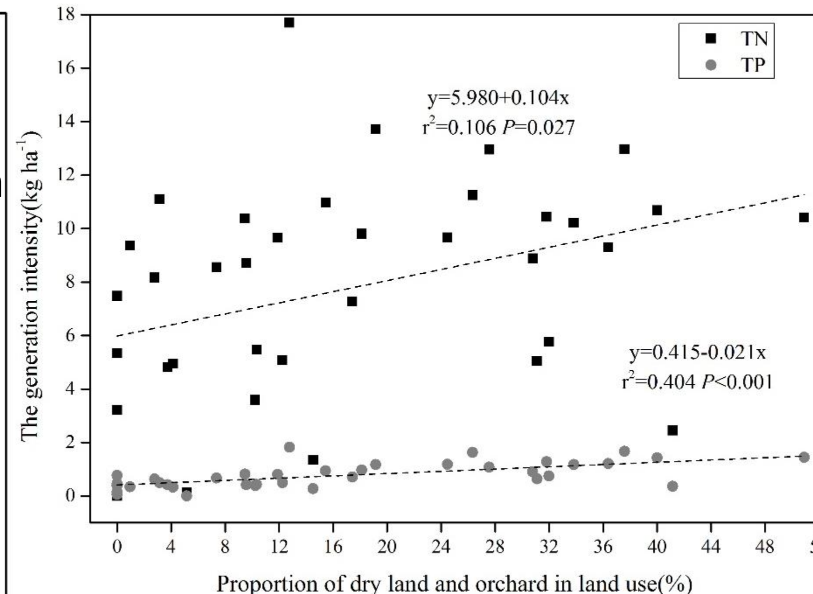


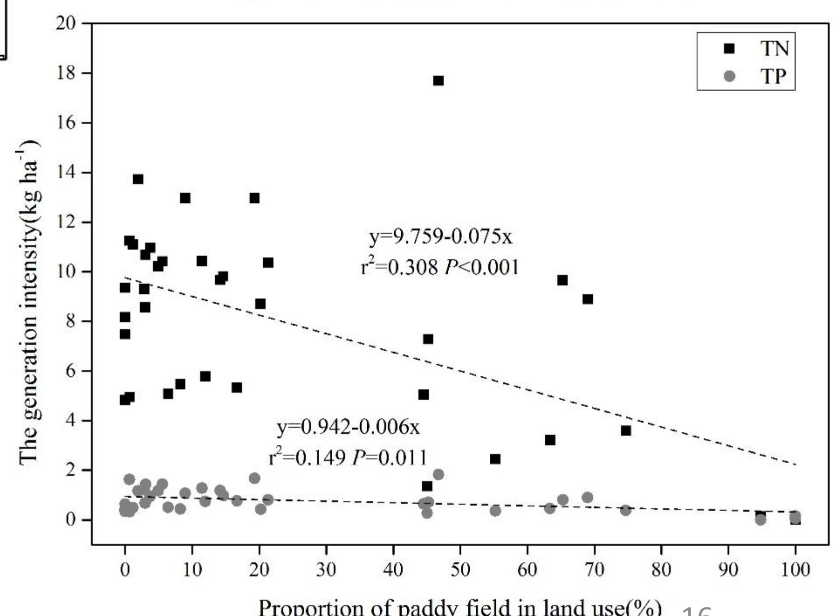
The sub-watersheds with higher level of TP emission distributed in the higher sediment generation areas.

Good hydrological condition and soil erosion is one of important factors affecting nutrient emission, but not the only.

Relationship between nutrient emission and land use



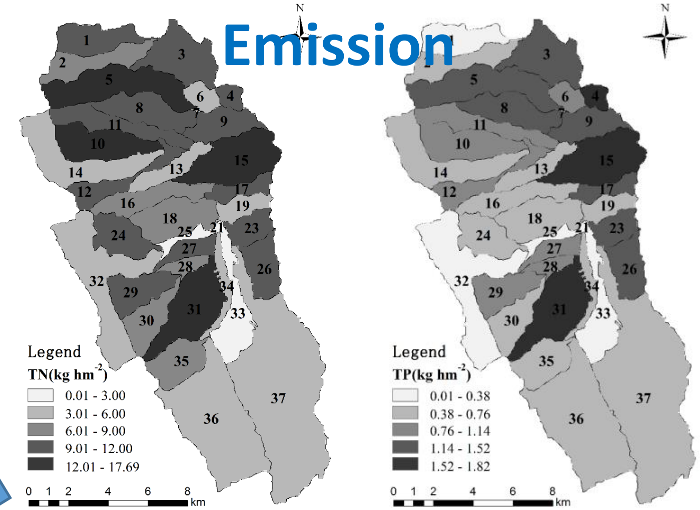


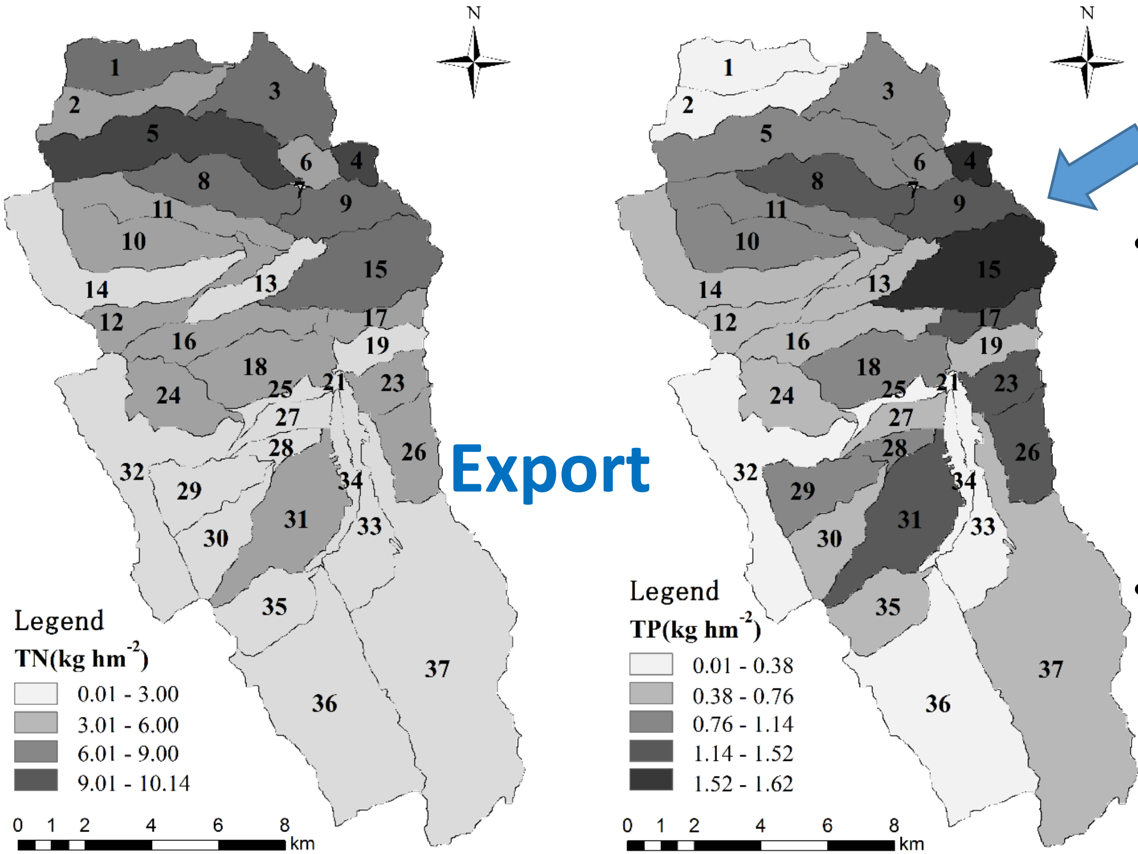


Relatively higher percentage of dry land and orchard but lower ratio of paddy field or the existence of residential area were also the necessary factors that affected the emission of nutrient

Spatial distribution of nutrient export

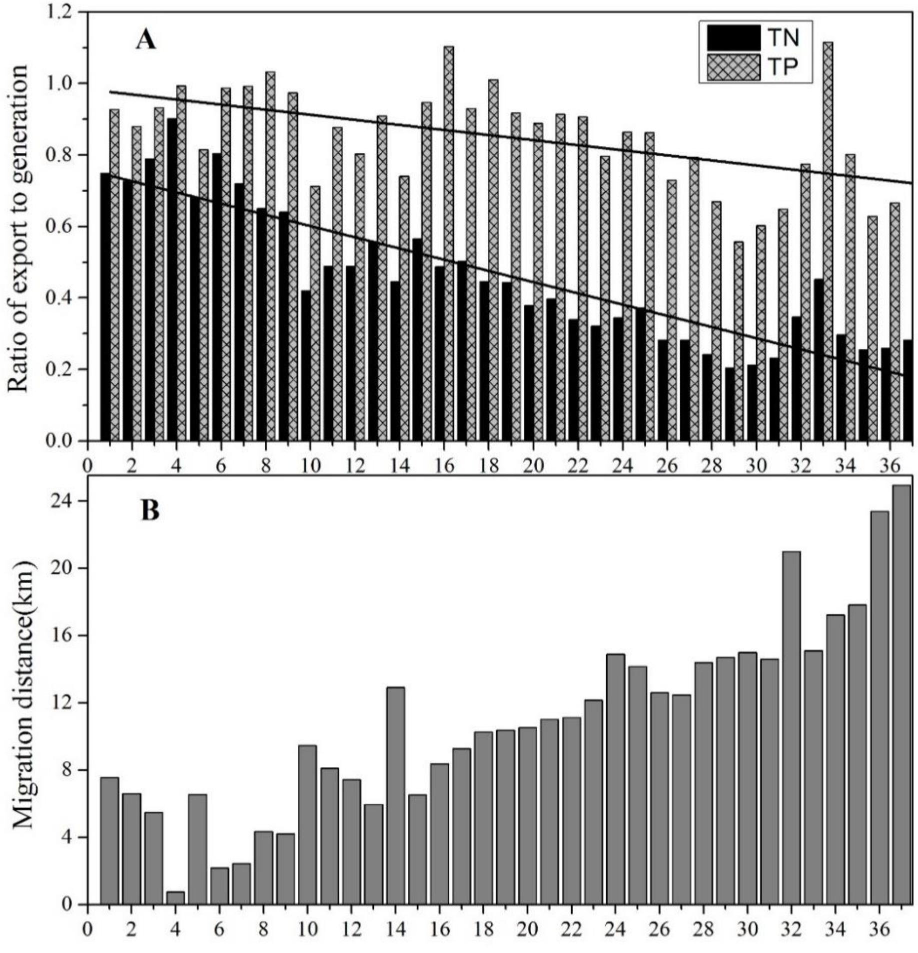
- **Heavily polluted sub-watersheds were located close to the outlet of the watershed;**
- **5.3% of total area contributed 13.8% of TN loads;**
- **5.0% of total area exported 12.5% of TP loads.**

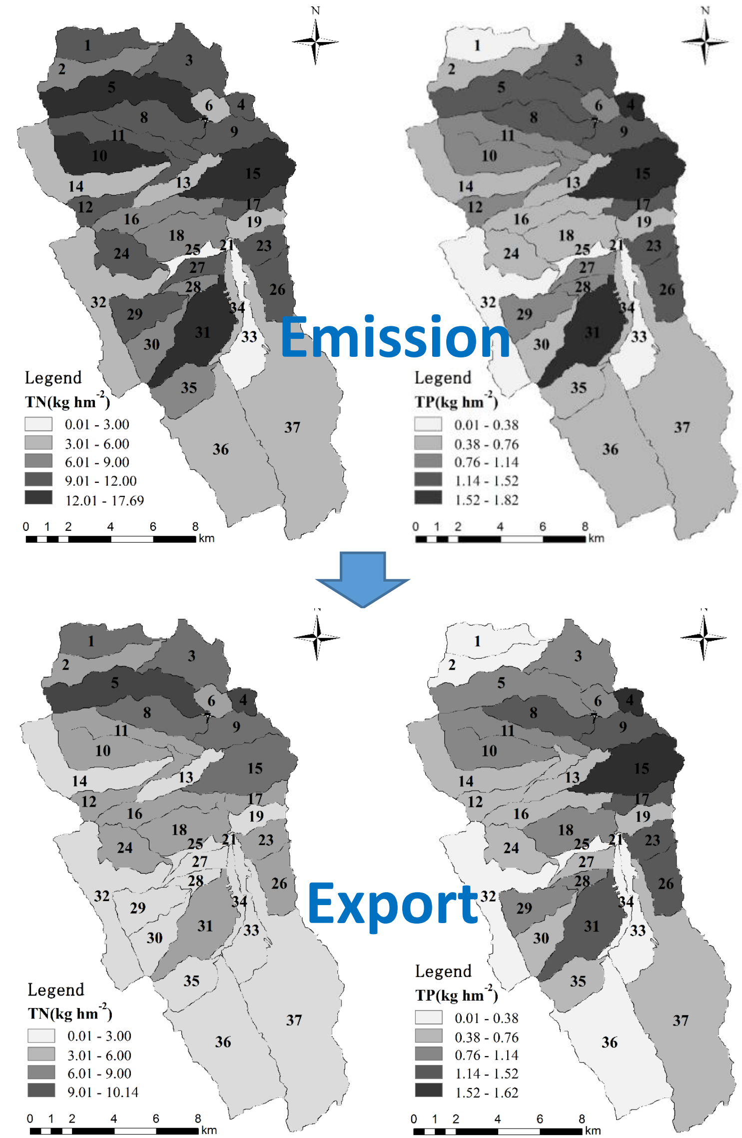




- **Heavily polluted sub-watersheds coincided with the areas with high level of nutrient emission, but distributed area reduced;**
- **The export load in these sub-watersheds were lower than nutrient emission intensity.**

Variation between nutrient emission and export

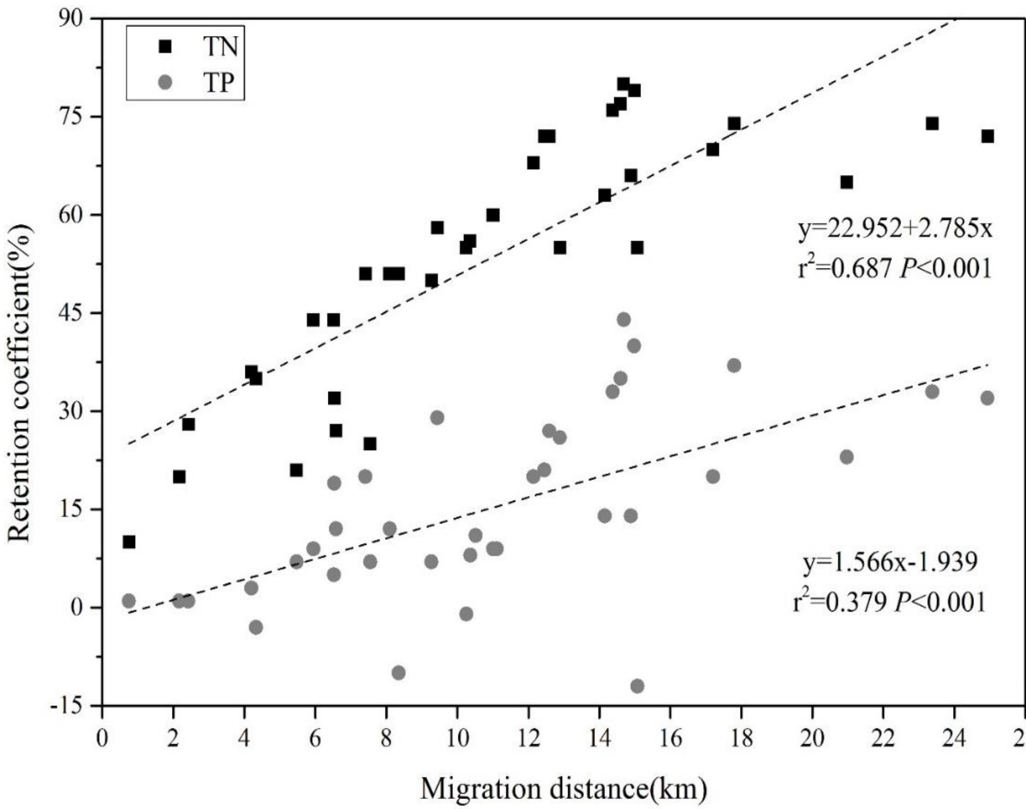


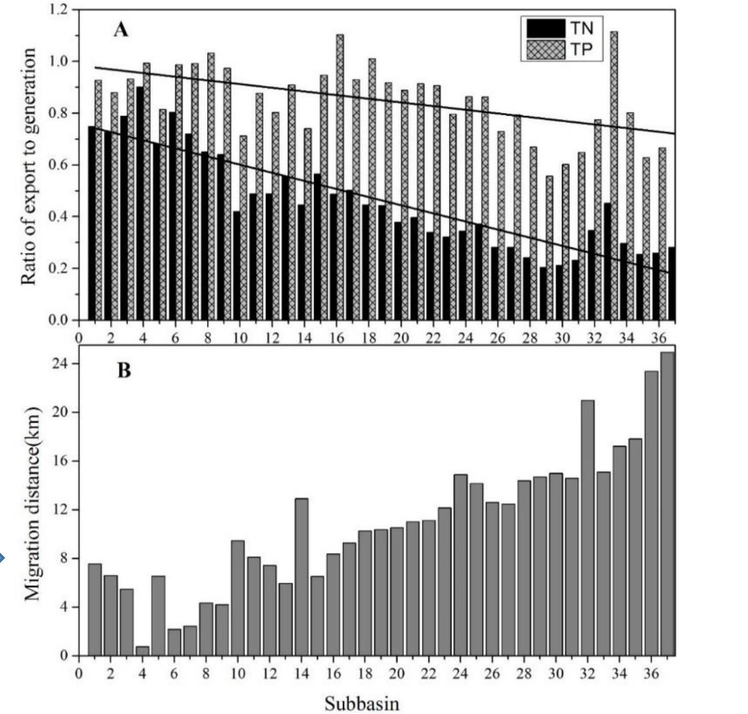


Considerable variation occurred among sub-watersheds in the proportion of diffuse nutrient emission that exported out from watershed but the ratio of export to emission decreased with increasing sub-watershed number generally.

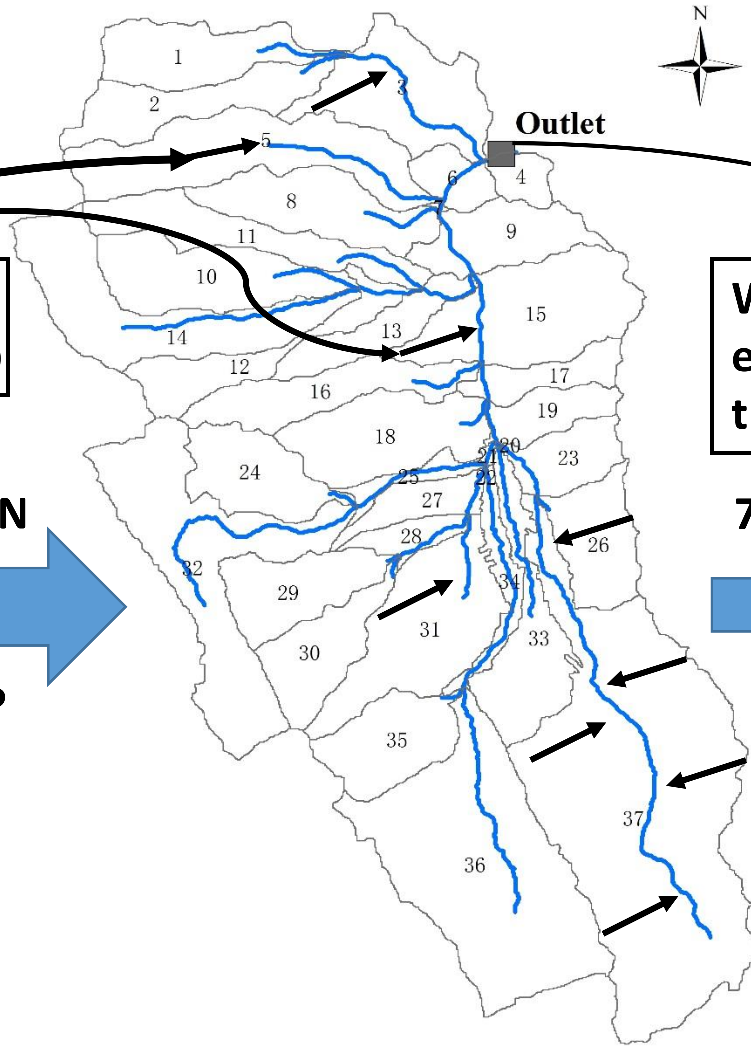
Nutrient retention in delivery process

Retention coefficient was defined as the proportion of the emission of diffuse nutrient that was removed in the transporting process.





- **Retention coefficient was positively related to migration distance because the travel time was calculated from migration distance divided by flow velocity.**



Watershed Nutrient emission (to the reach)

Watershed Nutrient export (at the outlet of the watershed)

179.4 t/a for TN

17.2 t/a for TP

79.4 t/a for TN

13.9 t/a for TP

Multiple-year (2010-2013) mean annual 56% of emitted TN and 19% of TP emission was removed in the delivery process

Conclusion

- **The emission of diffuse nutrient was positively related to the ratio of dry land and orchard but negatively related to the percentage of paddy field.**

- **Spatial distribution of the export of diffuse nutrient was determined by both nutrient emission and the delivery process, which showed significant variations relative to nutrient emission due to the delivery process.**

- **Nutrient retention showed great variations among sub-watersheds because of the different migration distances.**

Agricultural Non-point Source (NPS) Pollution Research Group

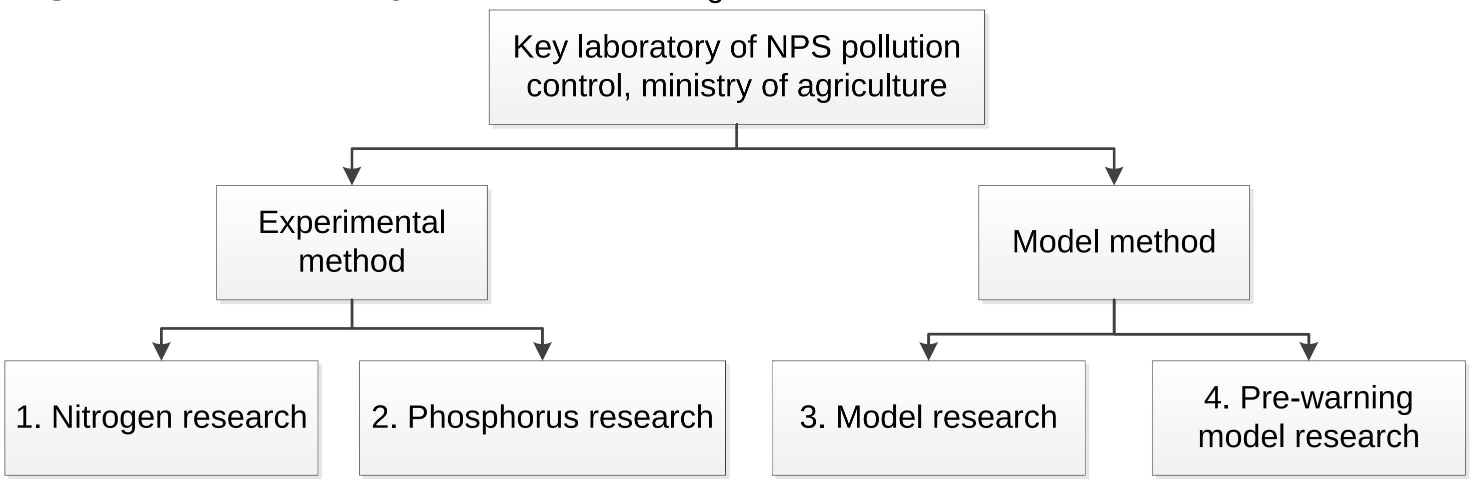
Monitoring the nutrient loss at field/farm and watershed level.

Evaluating the influence of agricultural NPS pollution on the regional water quality.

Hongbin Liu

Optimizing nutrient management strategies at Field/Farm and watershed Scales

Agricultural NPS pollution control and prediction



Hongyuan Wang

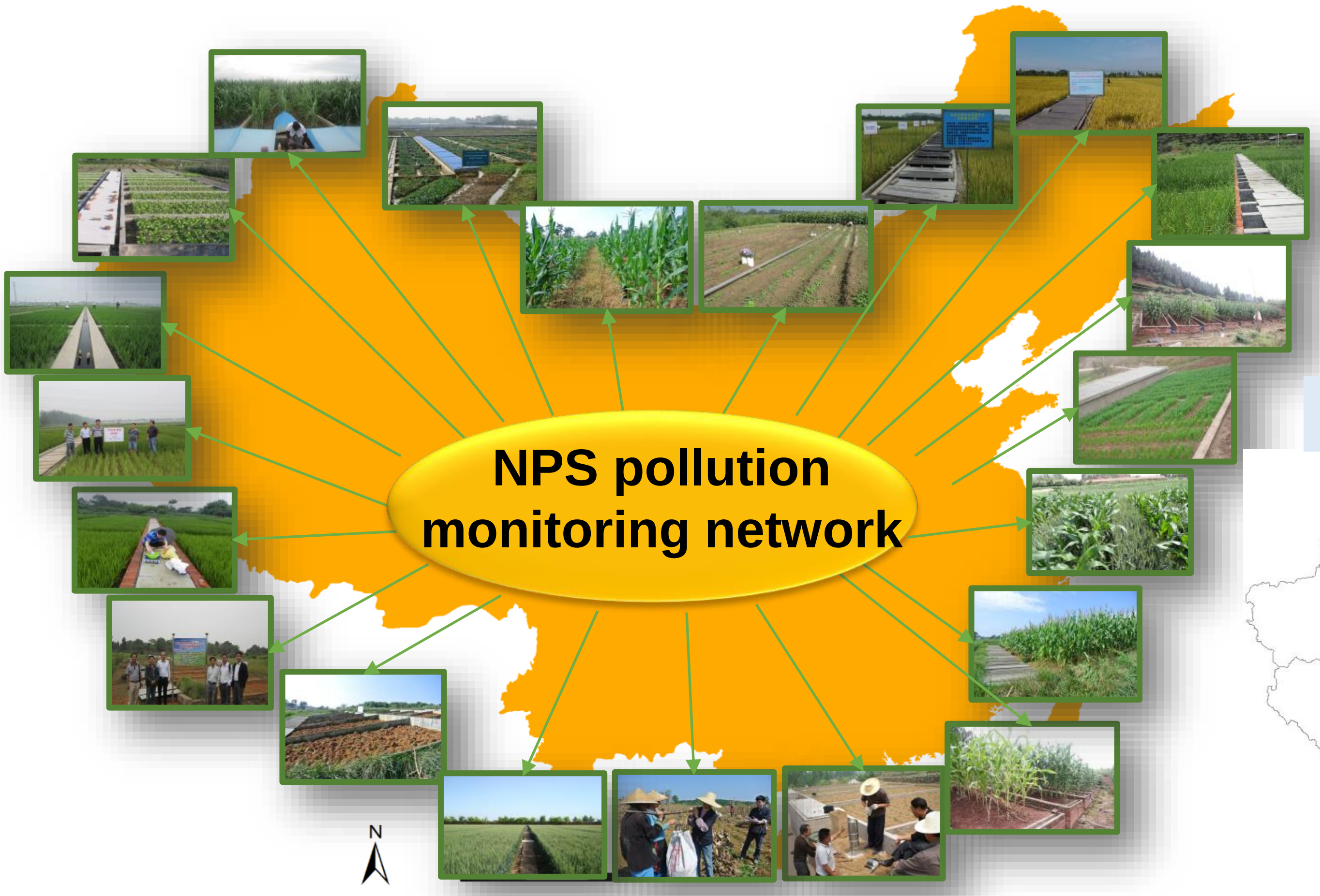
Limei Zhai

Qiuliang Lei

Shen Liu

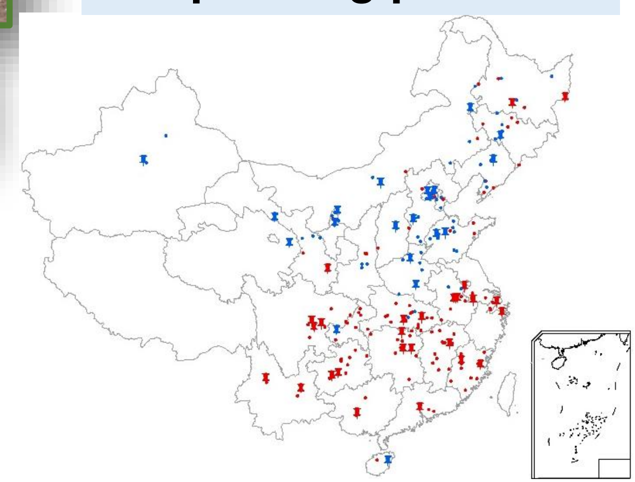
Monitoring Sites at field/farm scale in China

We have established a national wide agricultural NPS pollution monitoring network sine 2007, supported by the Special Fund for Agro-scientific Research in the Public Interest from the Ministry of Agriculture, China (Grant No.: 201303089 and No.: 201003014)



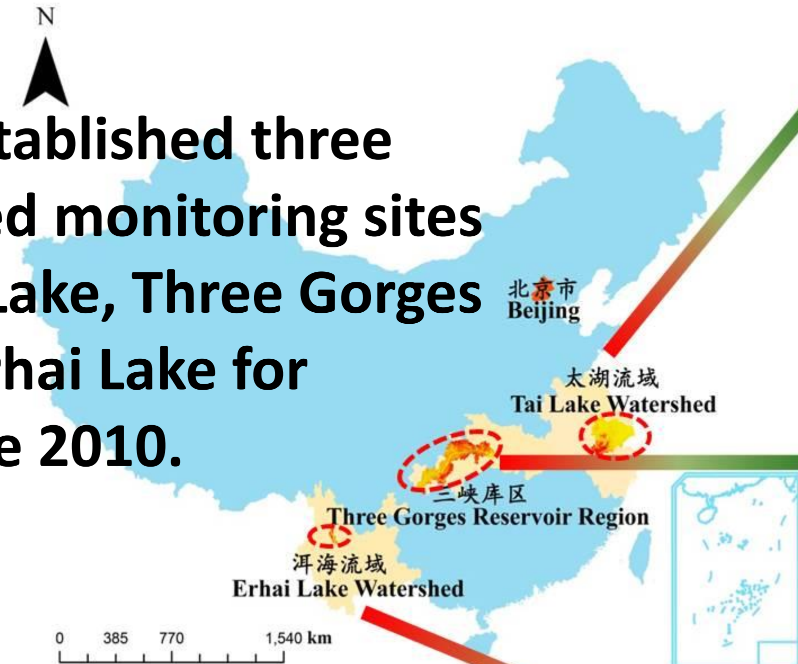
273 monitoring sites for nutrient loss via runoff and leaching

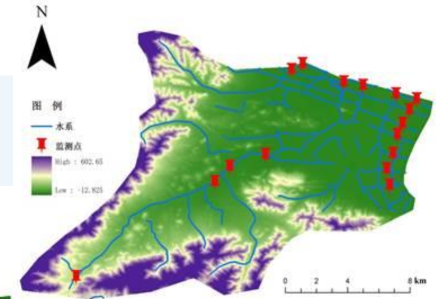
35 planting patterns



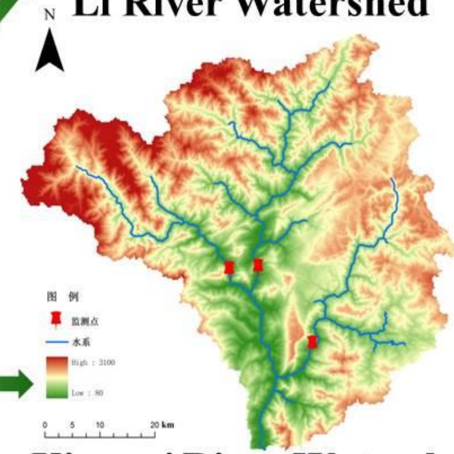
Monitoring Sites at watershed scale

We also have established three typical watershed monitoring sites including Taihu Lake, Three Gorges Reservoir and Erhai Lake for nutrient loss sine 2010.

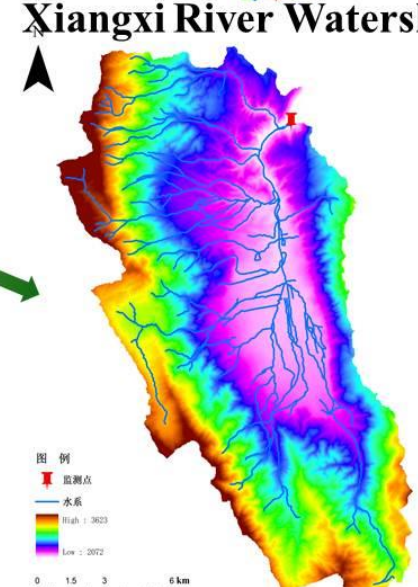




Li River Watershed



Xiangxi River Watershed



Fengyu River Watershed

International cooperation and exchanges-China-UK

Family team

Thanks