Institute of Agricultural Resources and Regional Planning
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# The Integration of Export Coefficient Method and SWAT Model for Identifying the Contribution of Different Agricultural Sources for Non-point Pollution in the Three Gorges Reservoir Area

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*Carbon and nitrogen cycling and non-point source pollution innovation team*

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# Introduction

**With the increasing pollution control at point sources, attention has gradually shifted to non-point pollution sources such as agricultural pollution.**

| Country | Areas | Agricultural non-point pollution（%） | | Data sources |
|---|---|---|---|---|
| | | Nitrogen | Phosphorus | |
| Denmark | 270 rivers | 94 | 52 | Kronwang et al., 1996 |
| America | Water environment | 87 | 58 | Green et al., 2015 |
| Britain | | 60 | | Wooda et al., 2005 |
| Netherlands | river Po | 63 | 57 | Marcel et al., 2001 |
| Germany | Surface water | 60 | | Kersebaum et al., 2004 |
| China | | 57.2 | 67.3 | Bulletin of the national pollution source census， 2010 |



**In China, agricultural pollution has been the dominant pathway for the accelerated eutrophication of surface water in many important lake basins.**

*(Quansheng et al., 1997; Zhang and Wang, 2002; Wang et al., 2006)*

The Three Gorges Reservoir region of the Yangtze River of China, known as the largest hydropower project in the word, covers an area of 59900 km$^2$ and a population of 16 million.

It is important for agricultural and other economic activities such as water supply, fishing and livestock production. Non-point source pollution tends to dominate pollutant accumulation in Three Gorges Reservoir Area agricultural watershed.

*(Wang et al., 2006; Liang et al., 2007; Liu et al., 2009)*

# Breakthrough point:

**Separating agricultural non-point source from non-point source pollution has a large significance for identifying the contribution of agricultural sources for non-point pollution in the Three Gorges Reservoir Area.**

# Methods of estimating the pollutant output

**Export Coefficient Method**

**Model Simulation Method**

**Actual Monitoring Method**

**Simple and practical, but ignoring the pollutant migration process fro pollutant generation t watershed outlet**

*(Matias and Johnes, 20 Shenet al., 2011)*

**Has been successfully used to simulate the export of non-point pollutant at the basin scale and ha comprehensive consideration of tl pollutant migration process finall releasing into reservoir area.**

*(2013.Zabaleta et al., 2014；Gabrieet al., 20*

**The result is high reliability, but the cost is high and the operation period is long.**

*(Zhu et al., 2012；Chiwa et al., 2015)*

# Aim of this study:

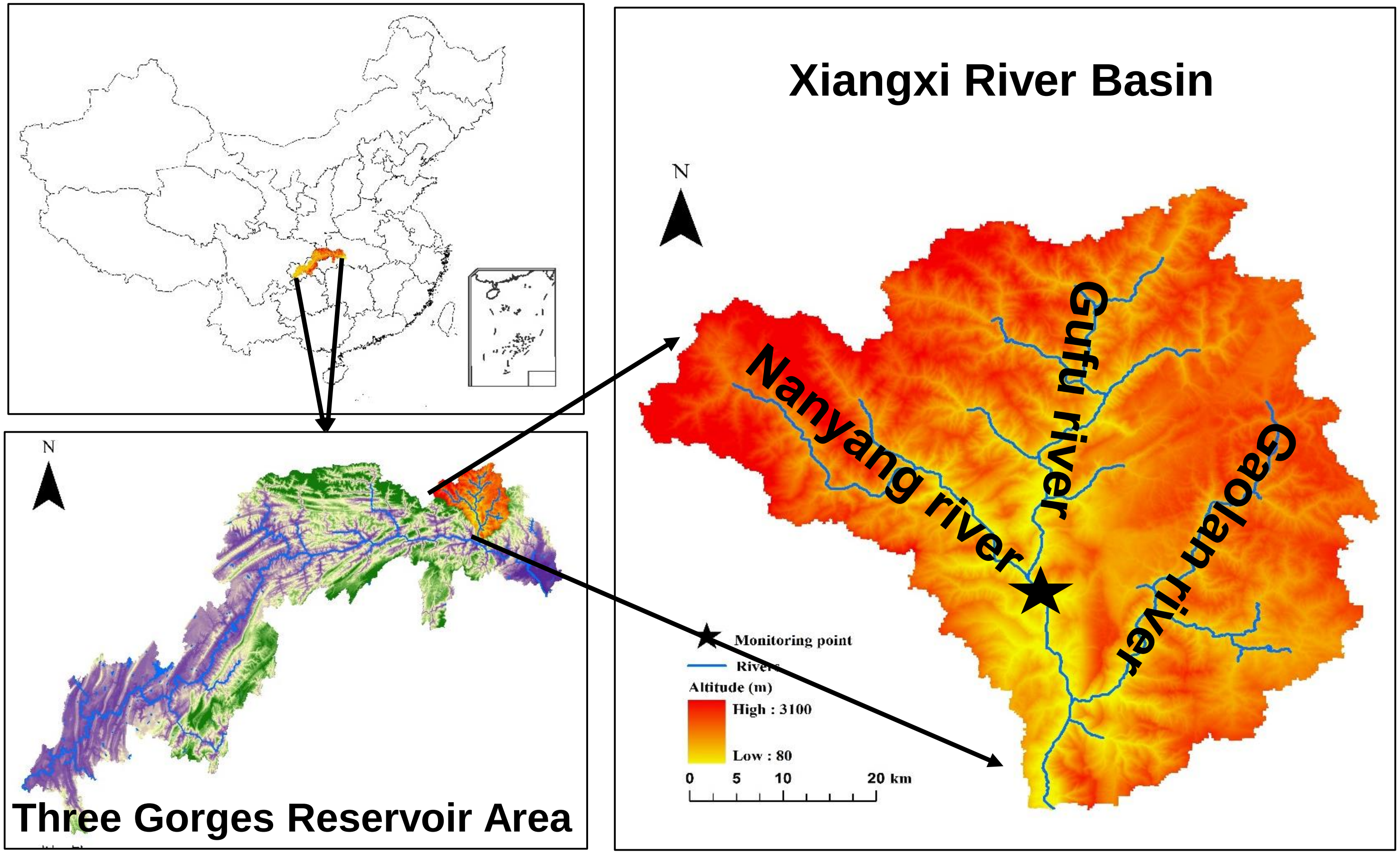
**Method: Integrating the export coefficient method and SWAT model**

**Process: Calculating different agricultural source pollutant generation amounts and the contribution coefficients finally flow into the outlet of watershed**

**Aims: identify the contribution of different agricultural sources for non-point pollution in the Three Gorges Reservoir Area**

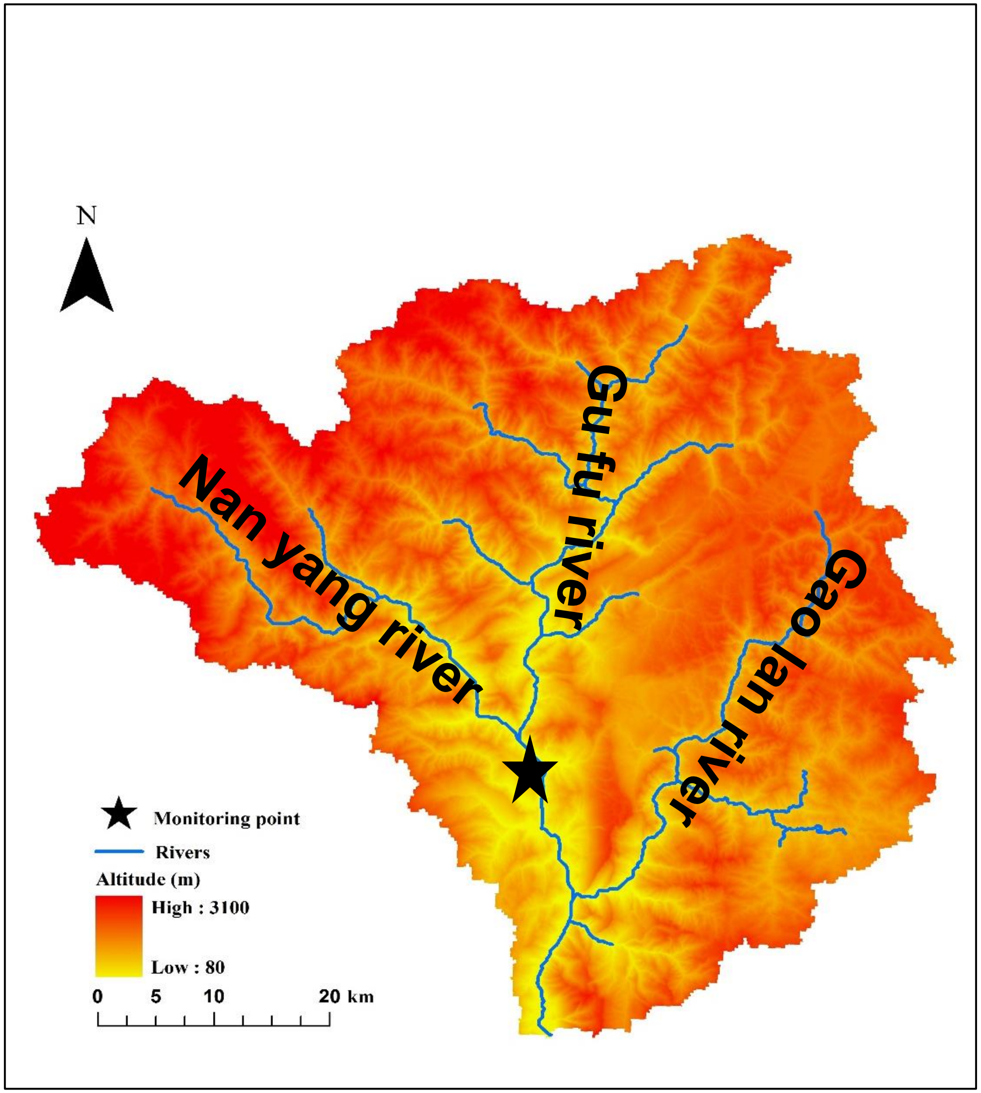
# Materials and methods

## Study area:




**The Xiangxi River basin is located in the downstream area of the Three Gorges Reservoir Region and is the first tributary in the upper reaches of the Three Gorges Dam.**

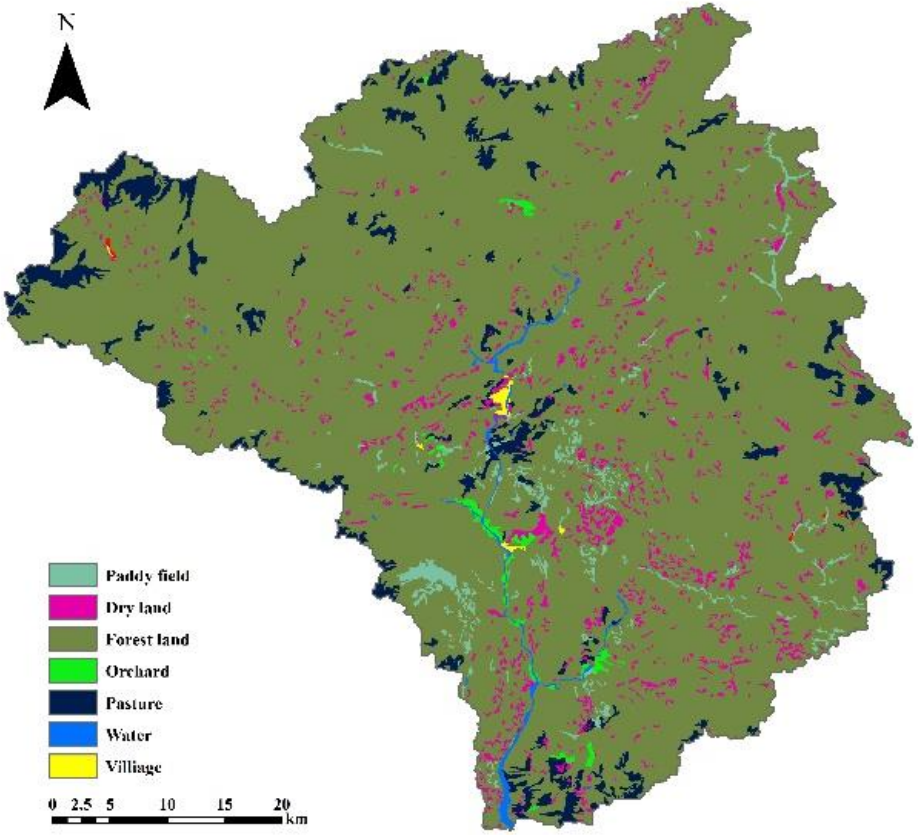
# Study area:

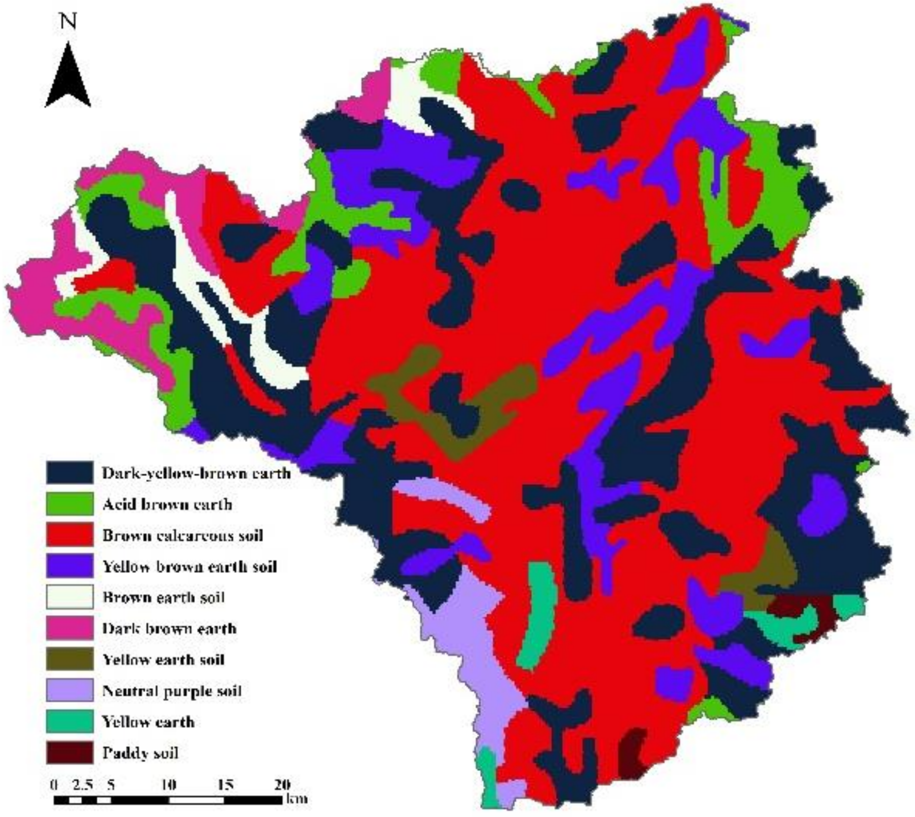



- **Catchment area**: **3150 m$^2$**
- **Location**: **hilly region in South China**
- **Climate**: **subtropical monsoon and humid**
- **Precipitation**: **800-1400 mm**
- **Annual mean T**: **15.3 $^oC$**
- **Tributaries**: **Gu fu river, Nan yang river and Gao lan river**
- **Monitoring point**: **the outlets of Gu fu river and Nan yang river named “Xingshan station”**

## Study area:

**Land use**: forest land(88.1%), pasture(5.21%), paddy field (1.74%), dry land (3.81%) and others (1.14%)
**Soil type**: brown calcareous earth (42.5%), dark yellow brown earth (26%) and others (30.5%)

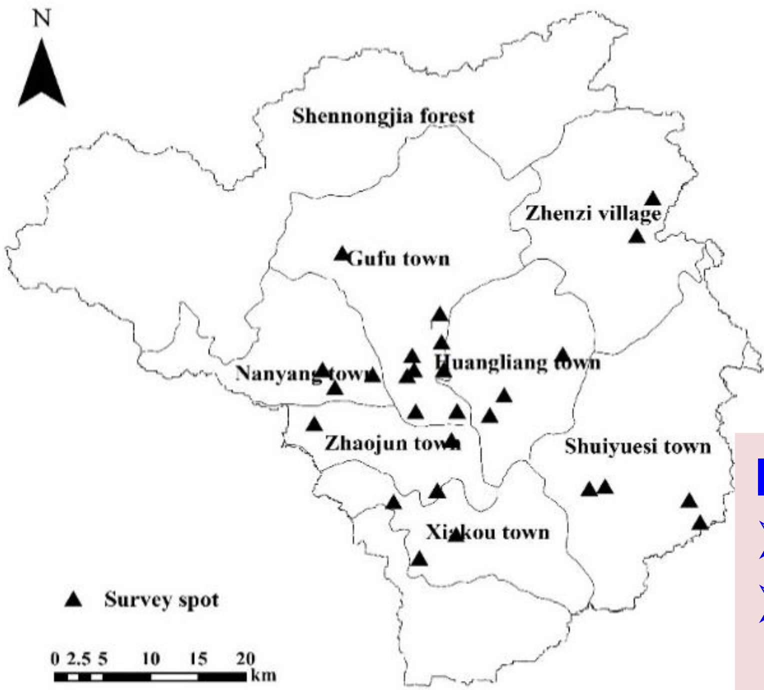



**Land use map and soil type map of the Xiangxi river basin.**

# Acquisition of basic data for pollution export coefficient method:

**The general situation of agricultural pollution sources in terms of the types and scales of agricultural activities including cropland farming, livestock breeding and rural living were counted based on the rural survey and selecting the Agricultural Economic Statistics Yearbook of 2013.**




**Distribution of survey spots**


**Including:**

- **11 towns**
- **27 administrative villages**
- **Over 500 households**

# Quantifying the pollutant loads from different agricultural sources:

**The main agricultural activities in the watershed**

| Crop | | Base fertilizer | Tillage | Irrigation | Planting | Topdressing1 | Topdressing2 | Harvest |
|---|---|---|---|---|---|---|---|---|
| Maize | | 8 May | 8 May | - | 8 May | 15 June | 2 July | 28 September |
| | | 375kg $ha^{-1}$ | - | - | - | 150 kg $ha^{-1}$ | 225 kg $ha^{-1}$ | - |
| Oil seed | | 2 October | 2 October | - | 2 October | 5 December | - | 1 May |
| | | 225 kg $ha^{-1}$ | | - | - | 150 kg $ha^{-1}$ | - | - |
| Rice | | 4 May | 4 May | 3 May | 5 May | 25 May | - | 27 September |
| | | 450 kg $ha^{-1}$ | - | | - | 300 kg $ha^{-1}$ | - | - |
| Orange | | - | - | - | - | 25 February | 2 July | - |
| | | - | - | - | - | 1500 kg $ha^{-1}$ | 2250 kg $ha^{-1}$ | - |

**Pollution export coefficients adopted in this study** 《The First National Pollution Source Census》

| Cropland farming source | | | | | Livestock breeding source | | | Rural living source | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Planting type | Fertilizer loss (%) | | Base loss (kg $hm^{-2}$) | | Type | Pollution export coefficient (kg $head^{-1}$/$feather^{-1}$ $a^{-1}$) | | Source | Pollution export coefficient (g $people^{-1}$ $d^{-1}$) | |
| | TN | TP | TN | TP | | TN | TP | | TN | TP |
| Paddy field | 1.21 | 1.11 | 13.3 | 0.48 | Sow | 13.2 | 2.01 | Sewage | 0.17 | 0.02 |
| Dry land | 0.48 | 0.3 | 2.84 | 0.35 | Swine | 2.25 | 0.044 | | | |
| | | | | | Cow | 14.9 | 0.73 | Rubbish | 0.45 | 0.09 |
| Garden plot | 0.4 | 0.29 | 6.59 | 0.78 | Chicken | 0.003 | 0.002 | | | |

## Calculating formula:

**Cropland farming source**:

$$L_i = \sum_{j}^{n} E_{ij}(S_{ij}P_{ij}) + \sum_{j}^{n} Q_{ij}S_{ij}$$

**$L_i$ represents the TN or TP load in *i* sub basin ; $E_{ij}$ is the loss coefficient of *j* planting type ; $S_{ij}$ is the area of *j* planting type ; $P_{ij}$ is the fertilizer application amount in unit area ; $Q_{ij}$ is the base loss amount.**

**Livestock breeding source**:

$$F_i = \sum_{i=1}^{n} f_0 A_i$$

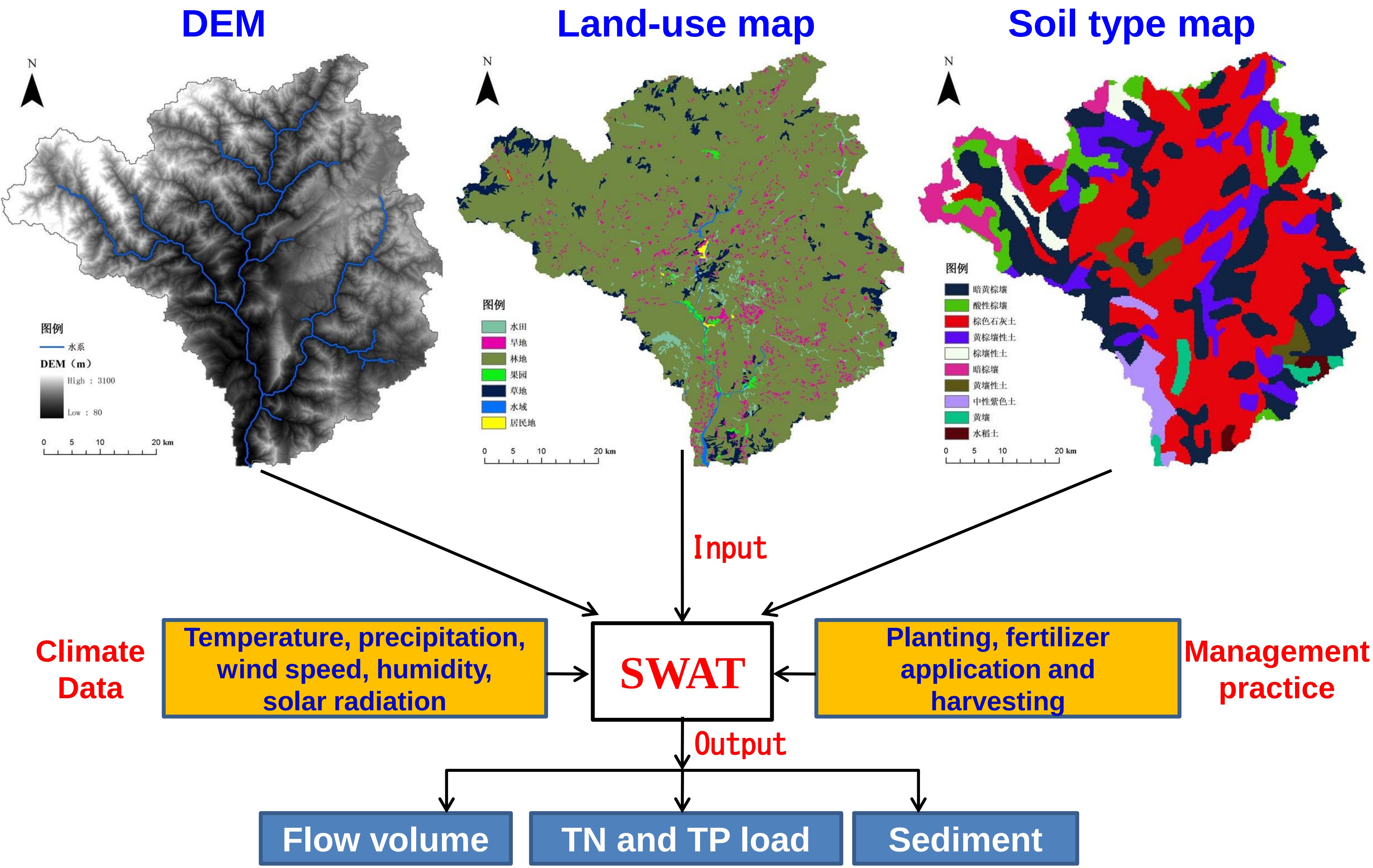
**$F_i$ represents the output load of livestock breeding in *i* sub basin ; $f_0$ is the pollution export coefficient ; $A_i$ is the amount of animals.**

**Rural living source**:

$$P_i = (f_a Q_i + f_b Q_i) \times 365 \times 10^{-6}$$

**$P_i$ represents the output load of rural living source ; $Q_i$ is the population amounts of i sub basin. $f_a$、$f_b$ are the pollution export coefficient of swage and rubbish, respectively.**

# Setting-up the SWAT model:



# Setting-up the SWAT model:

**The basic data required for SWAT model inputs are topography, soil, land-use, climatic and cropland management. The sources and descriptions of the adopted data are summarized in Table 1**

| Data type | Data sources | Data description |
|---|---|---|
| DEM | National Map Seamless Data Distribution System | A grid size of 25m × 25m |
| Soil type map | Institute of Soil Science, China Academy of Sciences | Soil physical and chemistry properties; Scale of soil map (1:1,000,000) |
| Land-use map | Institute of Geographic Sciences and Natural Resources Research, China Academy of Sciences | Land-use classifications (1:100,000) |
| Climate data | Yichang Meteorological Station, China Meteorological Administration | Temperature, precipitation, wind speed, humidity, solar radiation |
| Management practice | The First National Pollution Source Census, China | Planting, fertilizer application and harvesting |

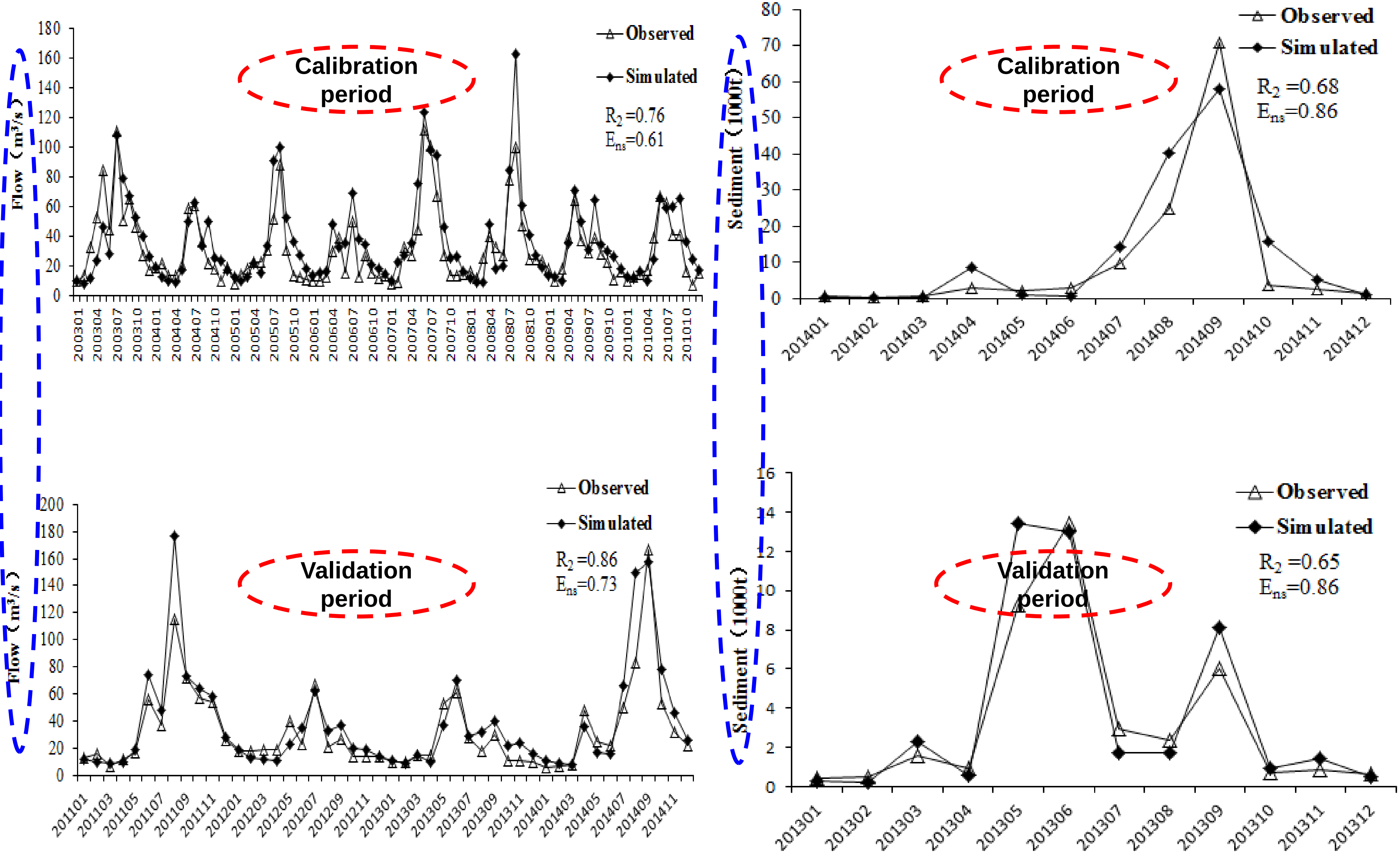
## Calibration and model validation:

**The calibration and validation in this study were performed at the outlets of the Gufu river and the Nanyang river, which is named as the Xingshan Hydrologic Station.**

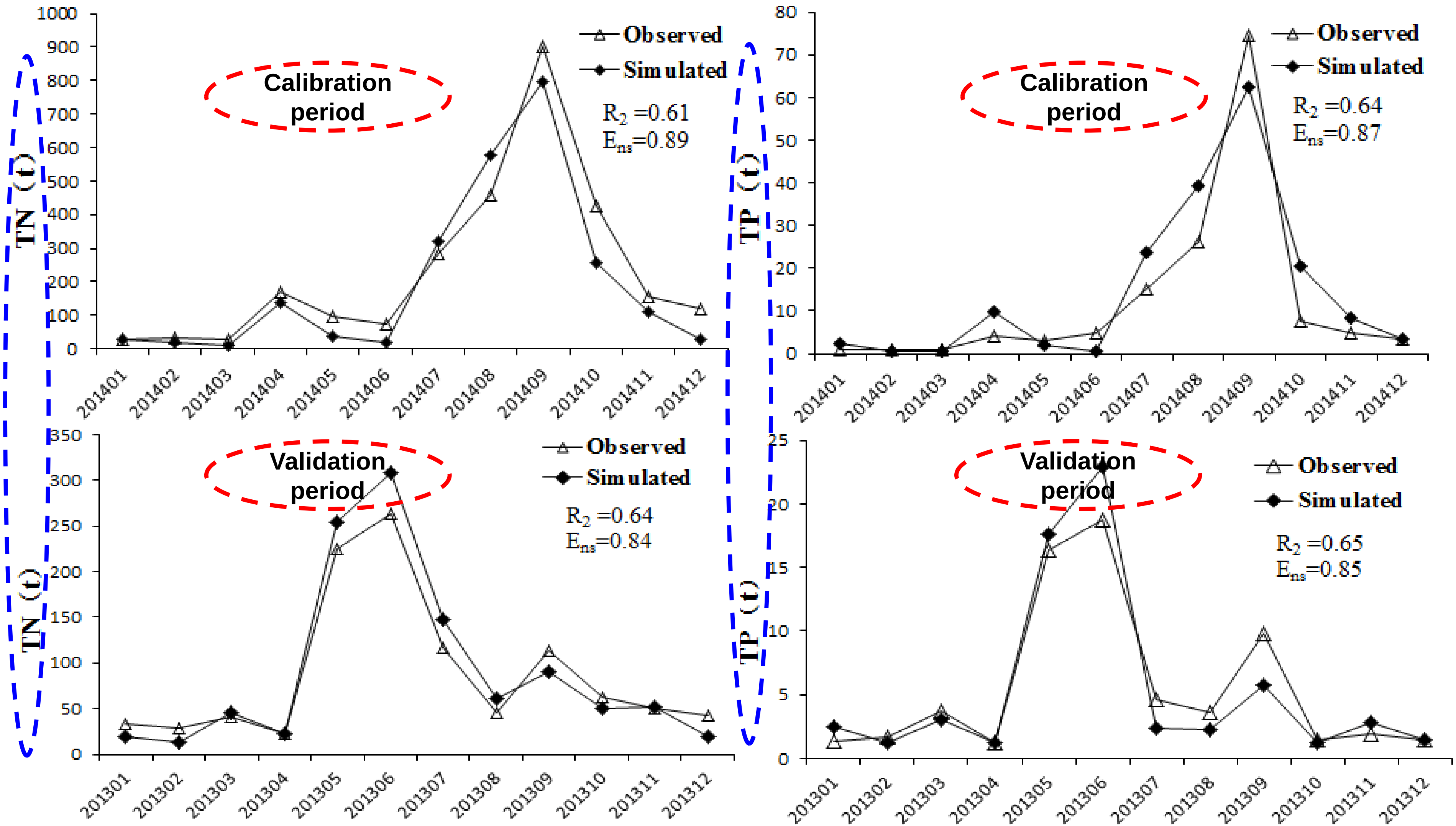
| Object | Time scale | Calibration period | Validation period |
|---|---|---|---|
| Flow volume | Month | 2003.1-2010.12 | 2011.1-2014.12 |
| Sediment | Month | 2014.1-2014.12 | 2013.1-2013.12 |
| TN and TP load | Month | 2014.1-2014.12 | 2013.1-2013.12 |

**The efficiencies of the calibration and validation were evaluated by the coefficient of determination ($r^2$) and the Nash–Sutcliffe Efficiency (Ens; Nash and Sutcliffe, 1970). If the monthly Ens > 0.5 and the monthly $r^2$ > 0.6, the model performance was considered to be acceptable (Santhi et al., 2001).**

# Calibration and model validation:



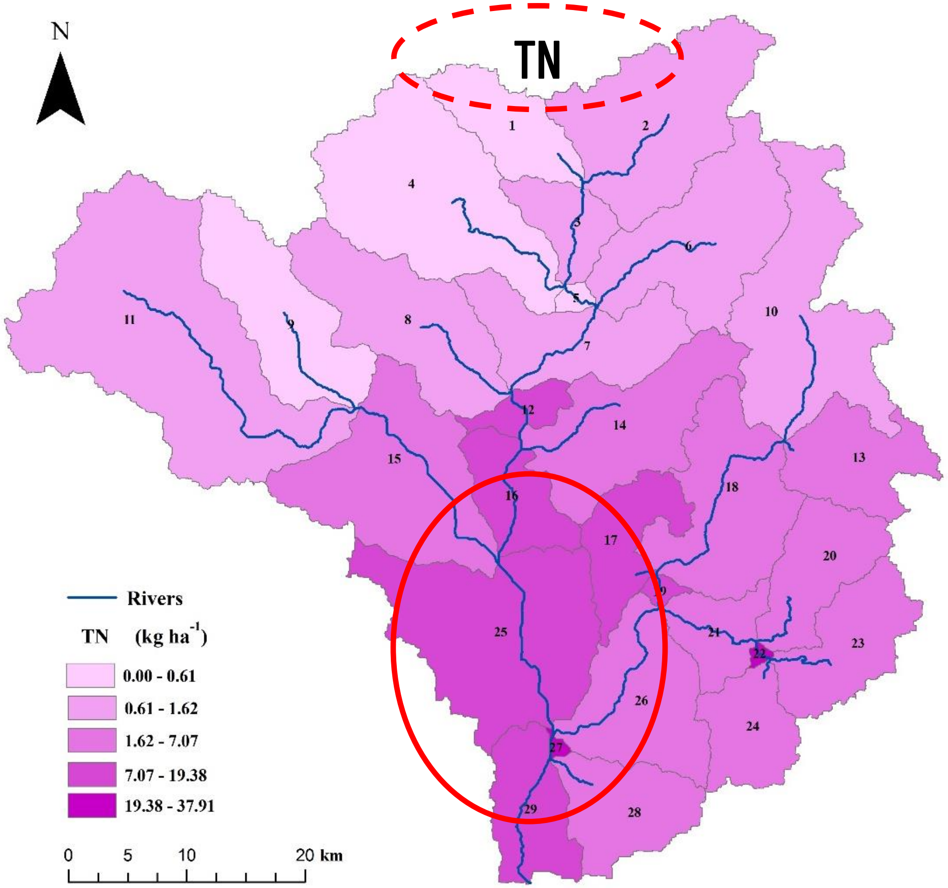
# Calibration and model validation:

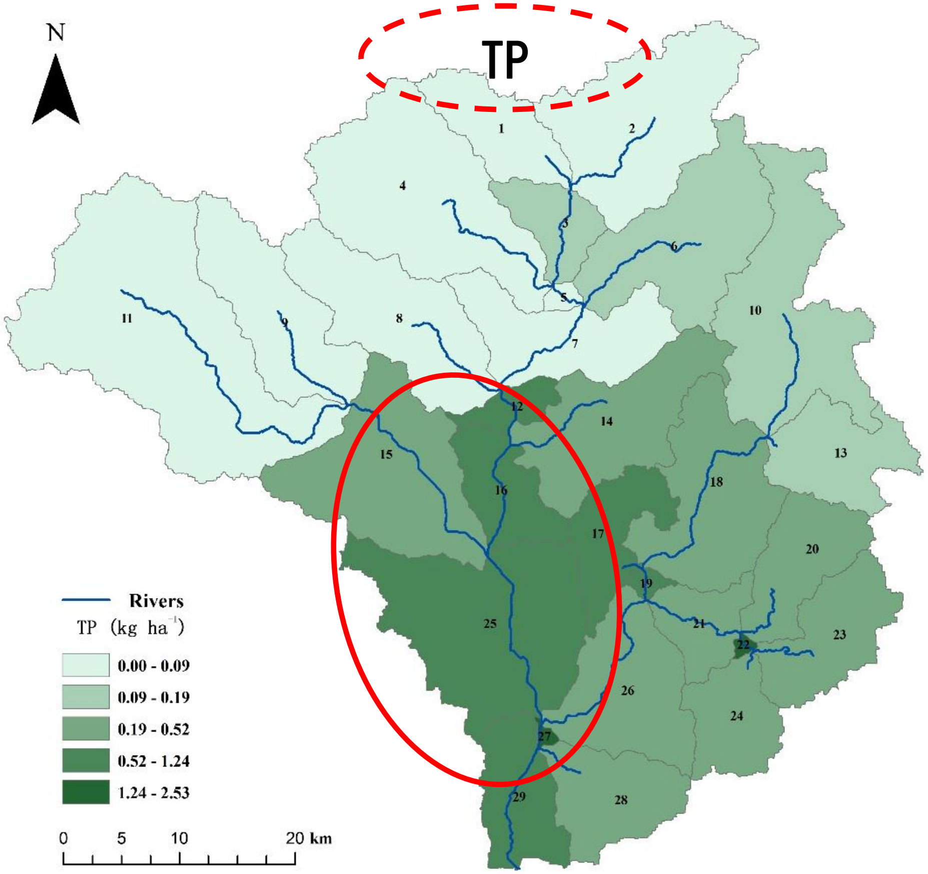



**During the calibration and validation period, the values of $r^2$ and Ens for the flow volume, sediment, TN and TP simulations all reached 0.6 and 0.5. SWAT model has a good adaptability in Xiangxi River basin.**

# Results

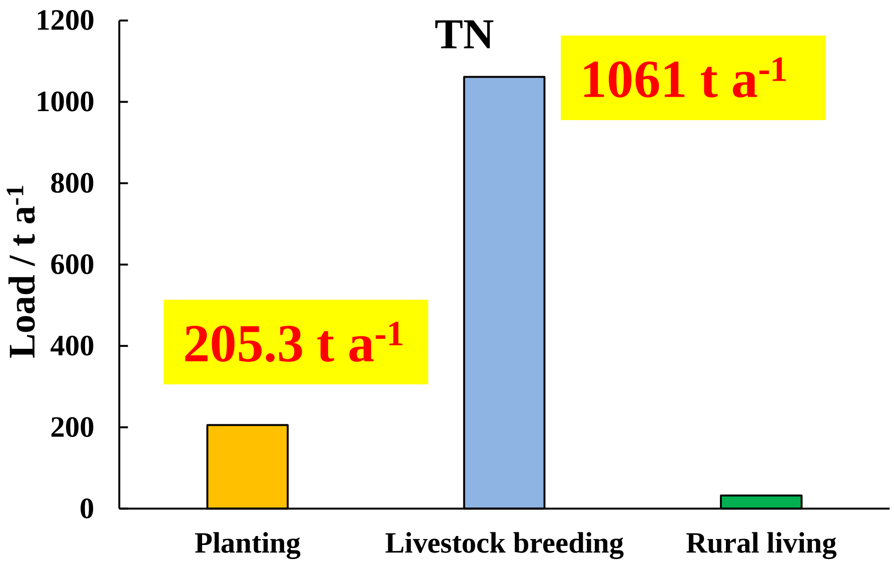
## Generation intensity of TN and TP:

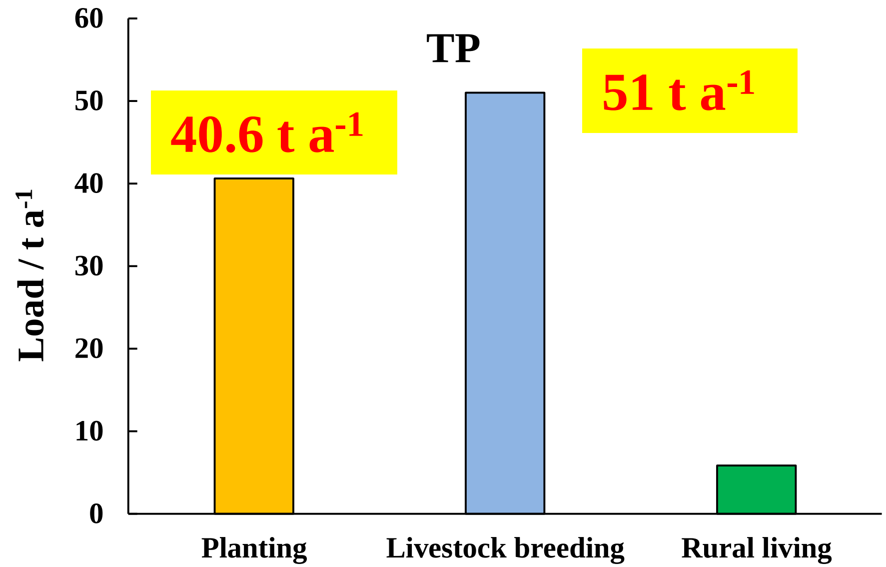


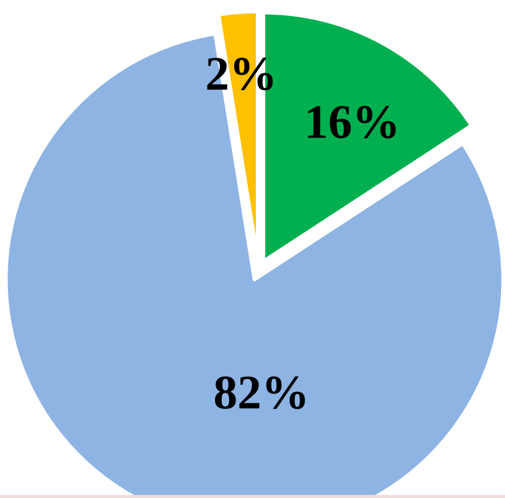



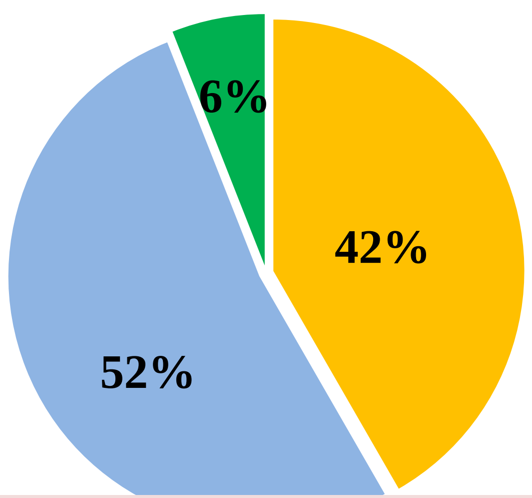

**The middle and downstream coastal area of Xiangxi River Basin is the critical source area for agricultural non-point source pollution generation.**

# Generation loads of TN and TP:



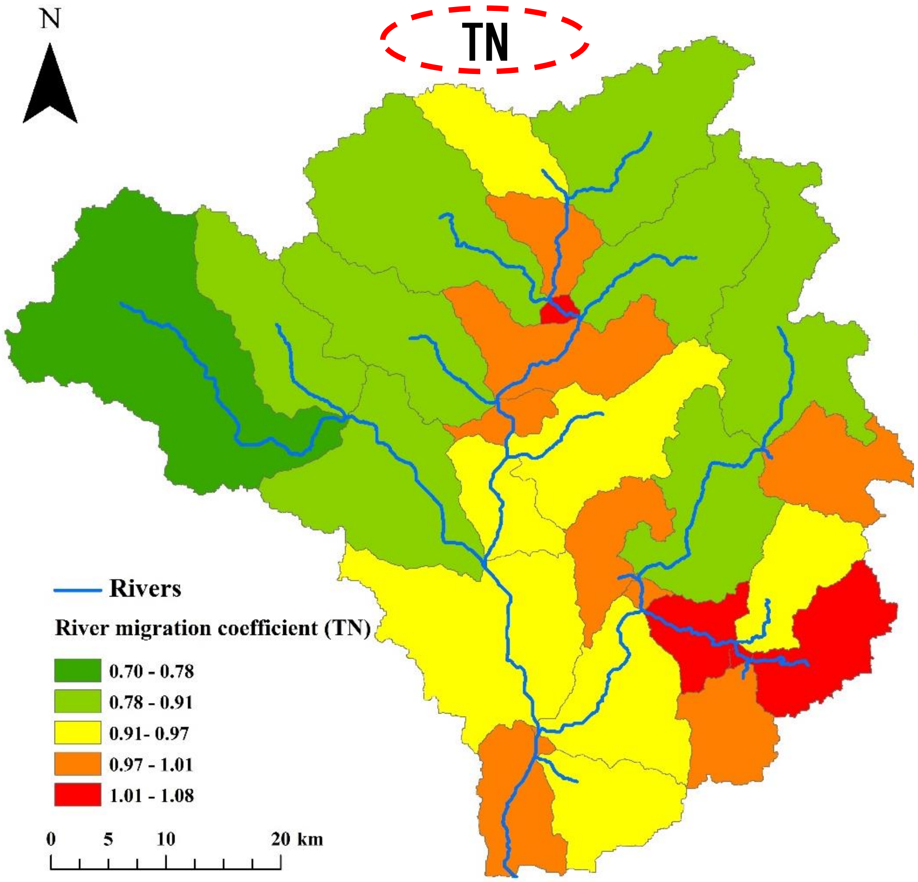



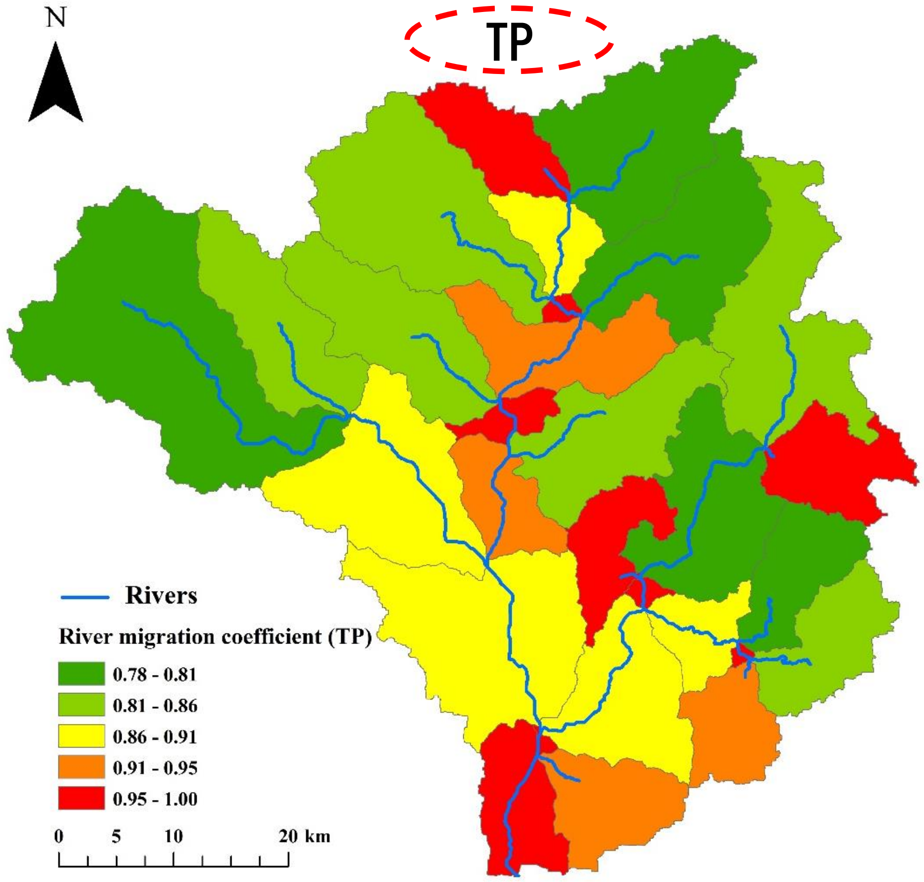




- **Livestock breeding source is the main source of TN load generation.**
- **The generation load of TP is mainly coming from livestock breeding source and planting source.**

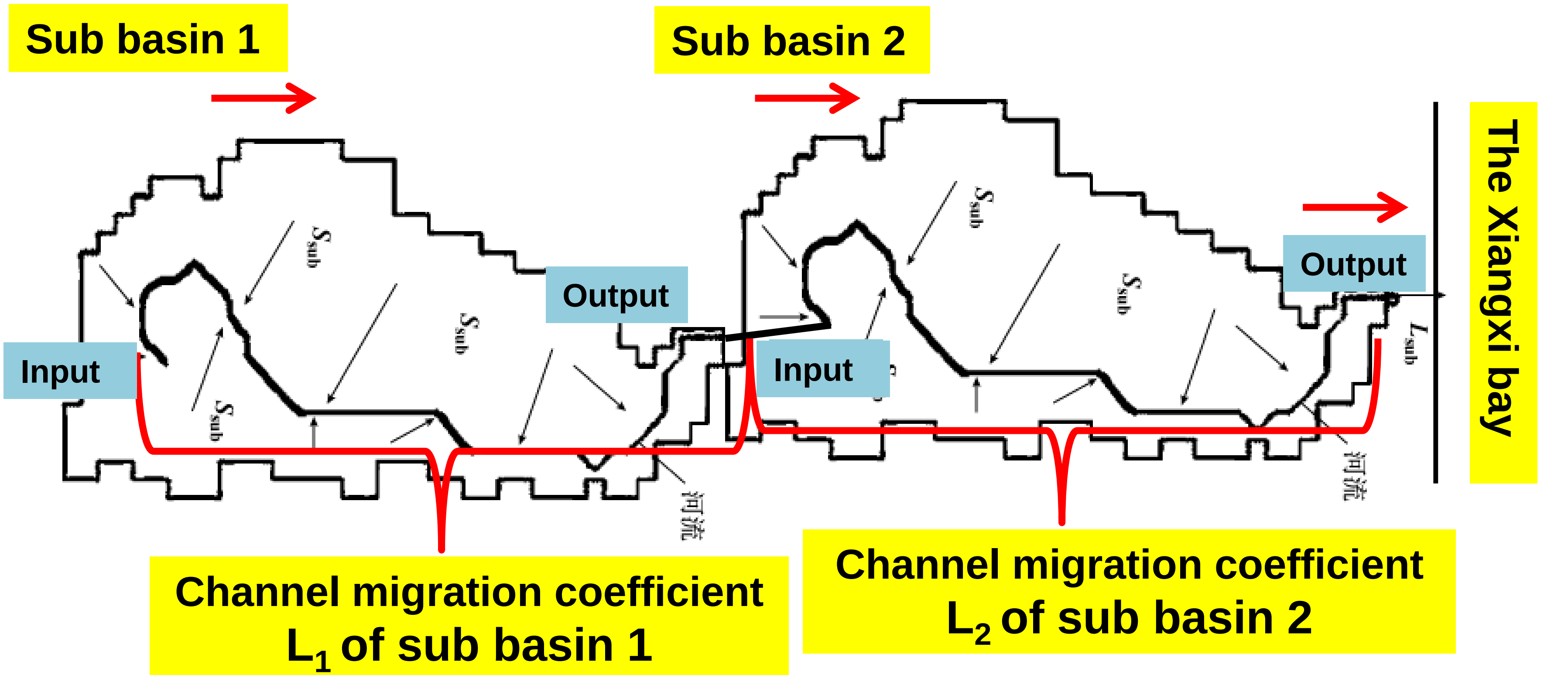
# Channel migration coefficient:




- **The channel migration coefficients of TN varied from 0.78-1.04, and TP varied from 0.78-1.00.**
- **The highest value of TN migration coefficient appeared in 21 and 23 sub basins that over 1, indicating that TN load increased during the migration process in these areas instead of cutting down.**
- **However, TP load reduced during the migration process in all sub basins.**

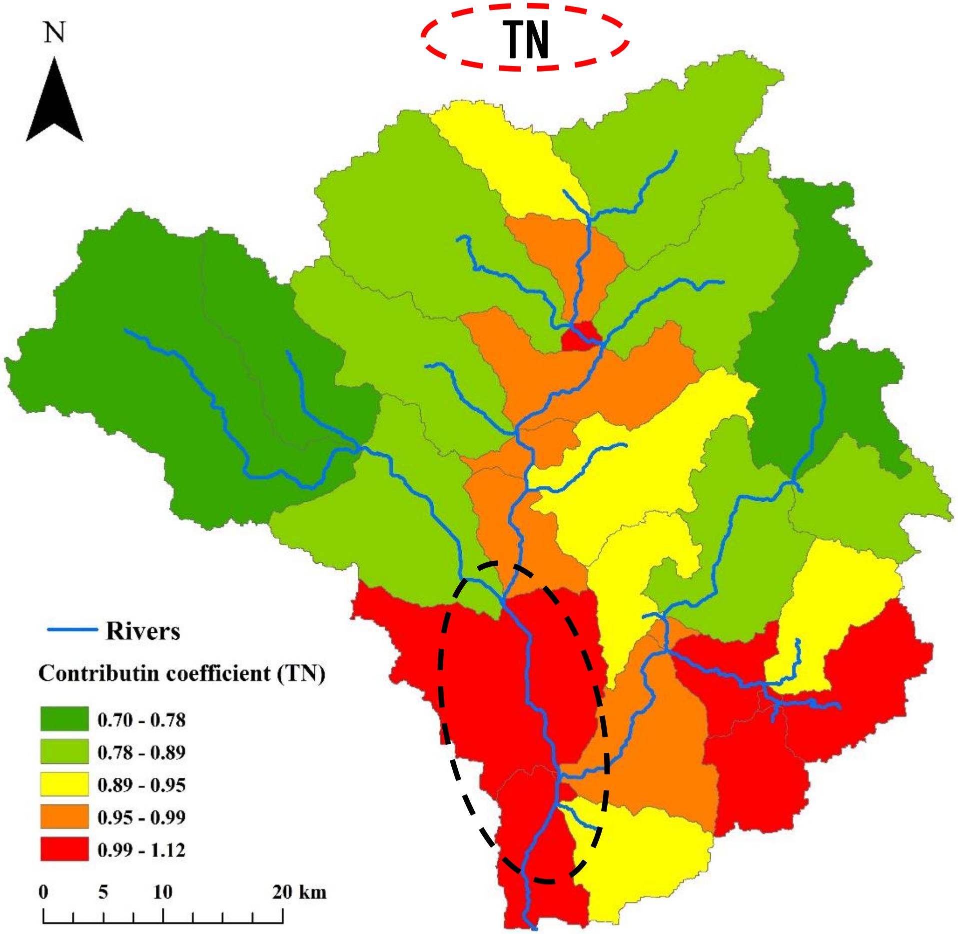
# Calculation of TN and TP pollution contribution coefficients:

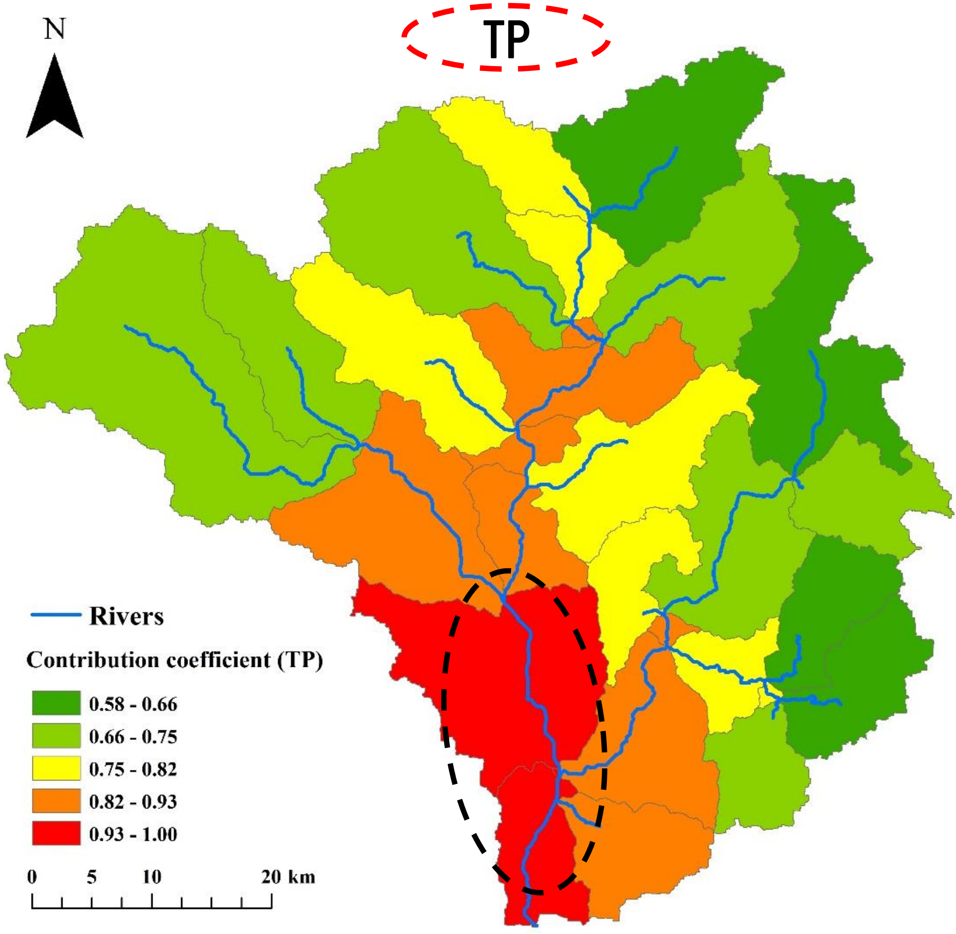



**pollution contribution coefficient = product of channel migration coefficient of each sub basin**

**For example： pollution contribution coefficient of sub basin 1 =$L_1$*$L_2$**

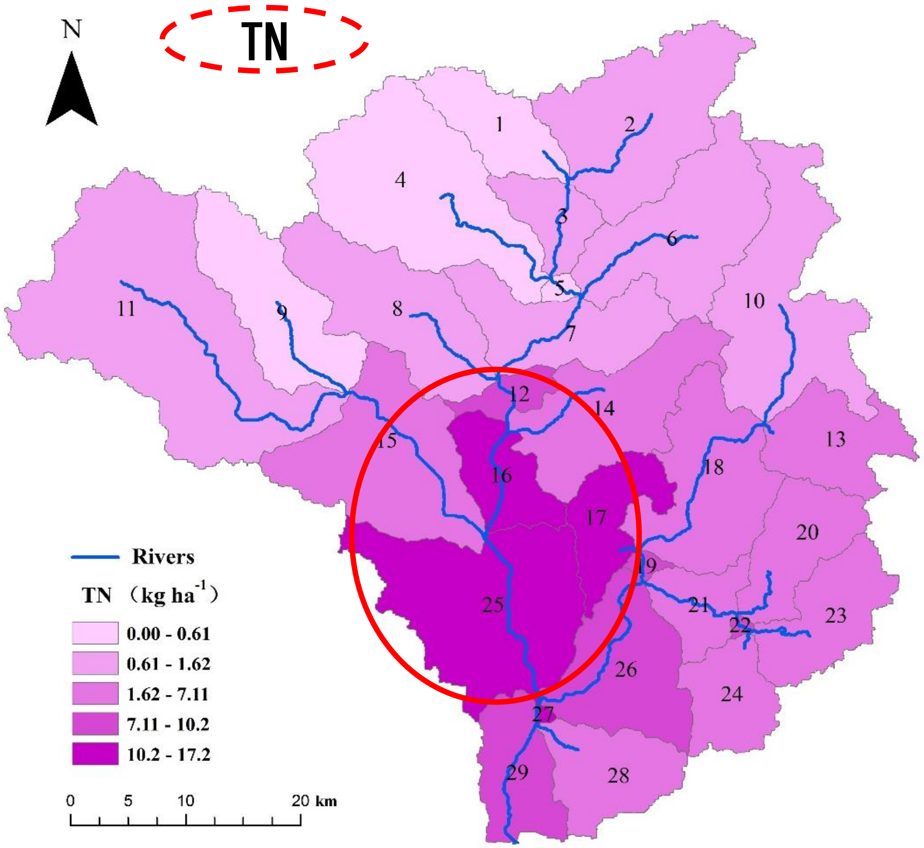
# Pollution contribution coefficient:

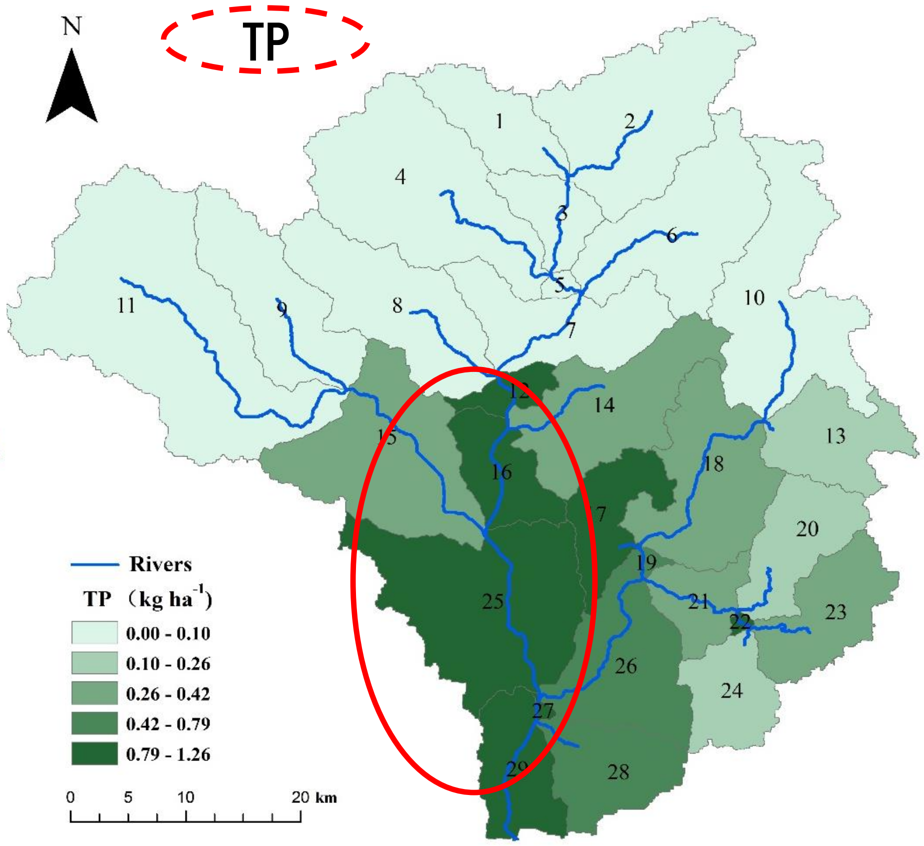



**TN contribution coefficients of each sub basin varied from 0.70 to 1.12 and TP varied from 0.59 to1.00. The average of TN and TP contribution coefficient of the whole basin were 0.92 and 0.82, respectively.**

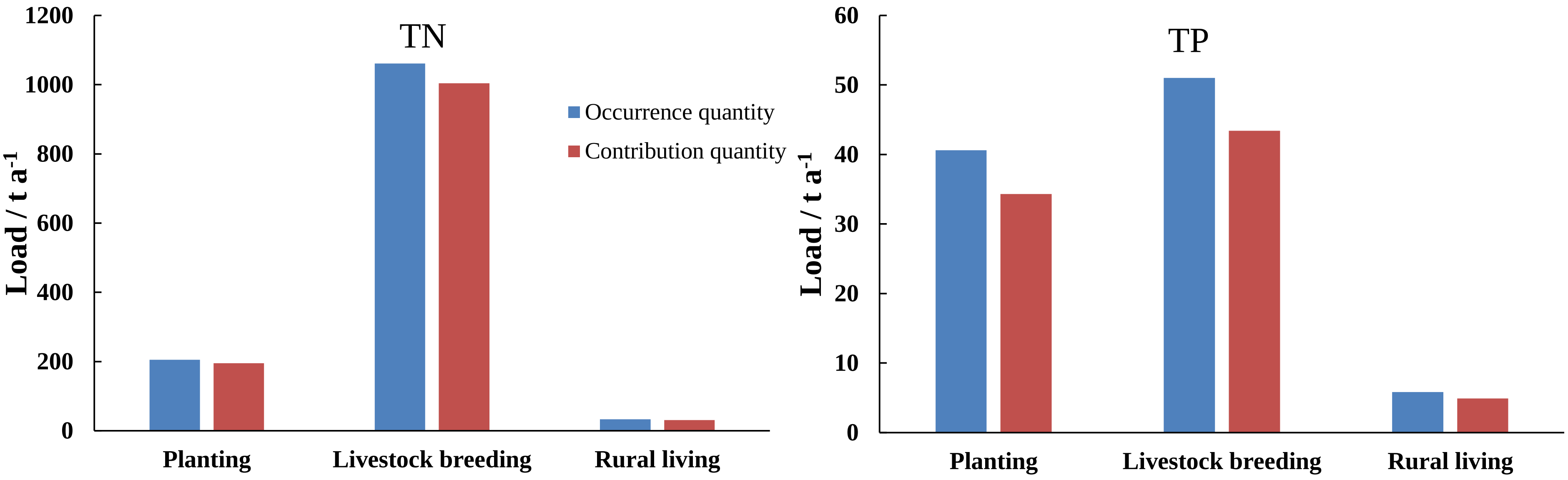
# Contribution intensity of TN and TP :




- **It has a small difference between the distribution of TN and TP load contribution intensity and the generation intensity around the whole basin.**
- **The critical source area for agricultural non-point source pollution is in the southwest of Xiangxi River Basin.**

# Emission loads of TN and TP at watershed outlet:




- **TN and TP from agricultural source contributed 1229.5 t $a^{-1}$ and 82.4 t $a^{-1}$ at the watershed outlet, accounted for 40% and 38% of the total pollution, respectively.**
- **The contribution amount of planting source, livestock breeding source and rural living source is 195.2, 1004 and 30.7 t $a^{-1}$ of the TN emission.**
- **TP load from three agricultural sources were 34.3, 43.4 and 4.9 t $a^{-1}$ at the watershed outlet.**

# Conclusions

- TN and TP load releasing into the reservoir area from agricultural source were 1229.5 t $a^{-1}$ and 82.4 t $a^{-1}$, accounted for 40.2 and 37.6 percent of the whole contribution content, respectively.
- Livestock breeding was the main source of TN load, accounted for 81.7 percent of agricultural TN load in the study area.
- Livestock breeding and cropland farming were the main source of TP load, accounted for 52.3 and 41.5 percent respectively.

# Thanks for your attention!