Spatial-temporal Features of Nitrogen and Phosphorus Losses of Jingui River Watershed in the upstream of Lijiang River

Linyan Pan1, Junfeng Dai 23*, Chenwenjiong Yu1, Xiaolin Xie1, Zhiqiang Wu23*

1College of Environmental Science and Engineering, Guilin University of Technology, Guilin, China;
2Guangxi Key Laboratory of Environmental Pollution Control Theory and Technology, Guilin University of Technology, Guilin 541004, China;
3Collaborative Innovation Center for Water Pollution Control and Water Security in Karst Region, Guilin University of Technology, Guilin 541004, China

Email: ann-fred@163.com; whudjf@163.com; 1335754629@qq.com; 1135635231@qq.com; zqwu@gxu.edu.cn
TEL: +86-139-7739-6045; +86-187-7718-0208

Abstract: To find out the nitrogen and phosphorus concentration and load emission regularity and its effect during the rainy season + irrigation period and dry season + non-irrigation period in the small watershed, five spatial scales (3.35 ~27.25 km²) nested in the Jingui river watershed are selected and regularly monitored from October 2017 to September 2018. The results showed that the nitrogen and phosphorus concentrations in the rainy season + irrigation period and dry season + non-irrigation period increased with the increase of the scale. The total nitrogen and total phosphorus load per unit area in the rainy season + irrigation period decreased with the increase of the scale; the dry season + non-irrigation period increased slightly. The same nitrogen and phosphorus index concentration was significantly different at different spatial scales. The main reason for the scale effect was the distribution pattern of land-use. Affected by this, scale D, the critical scale of nitrogen and phosphorus load in Jingui river watershed, its average load of total nitrogen, ammonium nitrogen, total phosphorus and total dissolved phosphate reached the highest value of the watershed. The contribution rate of nitrogen and phosphorus load in rainy season + irrigation period and dry season + non-irrigation period of research areas with different area depends on precipitation and the distribution pattern of land-use. Therefore, the nitrogen and phosphorus emission control and pollutant reduction in the rice irrigation districts of Lijiang river basin should consider the spatial-temporal features and effects of nitrogen and phosphorus pollutant transport.

1. Introduction

Agricultural non-point source pollution is the main source of non-point source pollutants for surface water. Nitrogen and phosphorus are the main components of agricultural non-point source pollutants [1-3], which are also the main factors causing water eutrophication and wetland degradation [4,5]. The research on the transport characteristics of nitrogen and phosphorus pollutants in different typical regions has become one of the hotspots of non-point source pollution research at home and abroad. As one of the typical areas in the southwestern region, the Lijiang river basin has gradually attracted the attention of researchers [6-13]. Studies have shown that, due to the influence of topography, irrigation
water management, water system distribution, removal of ditch/pond /wetlands, reuse of discharge, aquaculture, domestic sewage and other sources of pollution, the difference in nitrogen and phosphorus pollution load at different scales in irrigation districts does not present a single increase or decrease trend [14]. The Qingshitan reservoir irrigation district of the Lijiang river basin located in the humid area, the surface water systems such as ditches, ponds, wetlands and rivers are relatively developed, which is conducive to the rapid flow of water and nitrogen and phosphorus, and also promotes the accumulation or reuse of nitrogen and phosphorus in local areas, affecting the emission process of nitrogen and phosphorus in the irrigation district, and even harms the ecological environment and water safety of the irrigation district. This paper selects the representative Jingui river watershed in the Qingshitan reservoir irrigation district in the upper reaches of the Lijiang river basin, and studies the nitrogen and phosphorus concentrations and load emission patterns and their effects in the rainy season + irrigation period and dry season + non-irrigation period with different area scale, with a view to provide reference for the prevention and control of agricultural non-point source pollution in irrigation districts and the ecological security of the Lijiang river basin.

2. Material and Methods

2.1 Study area
Jingui river (25°17′ ~ 25°22′N, 110°09′ ~ 110°14′E) is located in the north of Lingui District, Guilin City, Guangxi Province, China. The total area of the watershed is 27.25 km². Jingui river is one of the branch canals of the West Main Canal belonging to the Qingshitan reservoir irrigation district in the upper reaches of the Lijiang river basin (Figure 1). The West Main Canal replenishes water to Jingui river about 0.5m³/s from April to October every year. It flows through villages such as Tianhua village, Xiaqiao village and Fengxue village, with a total length of 13.8km and finally flows into the Taohua river. The terrain in the watershed is high in the north and lower in the south. This area is influenced by typical subtropical monsoon climate, with an average annual precipitation of 1853.7mm, and the rainy season is generally from April to September every year, accounting for about 80% of the annual precipitation. The annual average evaporation is about 1300mm and the annual average temperature is 20 °C. The soil in this area is mainly red soil, which is acidic and rich in aluminum. The Jingui river watershed is a representative small watershed in the Qingshitan reservoir irrigation district with good sealing and the only discharge outlet. The arable land in the watershed is mainly planted with rice ripe once a year, and the orchard is planted with tangerines and summer oranges. Rice production mainly uses nitrogen fertilizer (mainly urea with a nitrogen content of 46%) and compound fertilizer (mainly a fertilizer with a nitrogen, phosphorus and potassium content of 15% respectively).

2.2 Sub-watershed division
The river network data is generated by digitalization of the rivers in the Jingui river watershed by Google Earth. With the measured river network data as the standard, the Jingui river watershed is divided into 5 sub-watersheds using the ArcGIS and SWAT, based on the digital elevation model (DEM, resolution 30m×30m) data, and five research areas at different scales with relatively closed hydraulic connection and nested step by step were selected (Table 1 and Figure 1).

| Scale | Sub-watershed included | Total area (km²) | Area (km²) | Arable land | Orchard | Ditch/pond/wetland | Water | Residential land | Woodland | Grassland |
|-------|------------------------|-----------------|------------|-------------|---------|-------------------|-------|-----------------|----------|-----------|
| A     | 1                      | 3.35            | 0.68       | 2.09        | 0.24    | 0.30              | 0.04  | 0               | 0        | 0         |
| B     | 1~2                    | 5.05            | 1.12       | 3.32        | 0.25    | 0.30              | 0.06  | 0               | 0        | 0         |
| C     | 1~3                    | 12.23           | 2.00       | 8.28        | 0.61    | 0.94              | 0.06  | 0.18            | 0.16     | 0         |
| D     | 1~4                    | 15.56           | 2.86       | 10.59       | 0.64    | 0.94              | 0.13  | 0.20            | 0.20     | 0         |
### 2.3 Data collection

From October 2017 to September 2018, the water volume at the outlet of each scale area was regularly monitored, and the discharge water samples were collected for nitrogen and phosphorus concentration analysis.

The flow velocity of the water is measured in field by Stalker II SVR hand-held Electric Wave Flow Meter. The cross-section of the runoff is measured by a five-point aliquot method using a ruler to measure the cross-sectional area and water depth. The calculation equation for the outlet flow and the discharge per unit area can be expressed as:

\[ Q = VS \]  
\[ q = \frac{Q}{A} \]

Where: \( Q \) is the runoff flow of each scale outlet (m\(^3\)/s); \( q \) is the discharge per unit area (m\(^3\)/km\(^2\)); \( V \) is the flow velocity of each scale outlet (m/s); \( S \) is the cross-sectional area of the outlet of each scale (m\(^2\)); \( A \) is the control area of each scale (km\(^2\)).

The water samples at various scales are collected once every 15~30 days, taking into account the growth period of the rice and precipitation. The samples were analyzed in the laboratory within 24 hours after they had been collected. The total nitrogen (TN) of the water sample is determined by alkaline potassium persulfate digestion ultraviolet spectrophotometry (HJ636-2012), and the ammonium nitrogen (NH\(_4^+\)-N) is measured by Nessler reagent (HJ535-2009). The total phosphorus (TP) and total dissolved phosphate (TDP) are measured by ammonium molybdate spectrophotometry (GB11893-89).

The equation for calculating the nitrogen and phosphorus load of each scale outlet is as follows:

\[ L = \frac{CQT \times 10^3}{A} \]

Where: \( L \) is the nitrogen and phosphorus load per unit area (kg/km\(^2\)); \( C \) is the nitrogen and phosphorus concentration (mg/L) of the runoff in each scale; \( Q \) is the runoff flow of each scale outlet (m\(^3\)/s); \( T \) is the time, in seconds (s); \( A \) is the control area of each scale research area (km\(^2\)).
3. Results

3.1 Discharge

The monthly discharge per unit area of different scales presented two peaks within the year. The first low peak appears in April, and the second peak appears in June, which is similar to the trend of precipitation variation (Figure 2). According to Figure 3, due to the influence of water replenishment and precipitation in the West Main Canal of the Qingshitan reservoir during the rainy season + irrigation period, except for scales C and E, the average water discharge per unit area of the rainy season + irrigation period is significantly greater than that of the dry season + non-irrigation period; The average discharge per unit area in the two periods is affected by factors such as runoff, storage and water consumption, and the overall decline with the increase of the area. In sub-watershed 3 of the C, there is a ditch/pond/wetland and water area of about 1 km² in total, which is used for fish farming. During the dry season, the villagers drained the fish pond water to clean up the silt, resulting in that the average discharge per unit area of the C in dry season + non-irrigation period is higher than that of the B, and the large-area water storage of the fish pond in the rainy season also causes the average discharge per unit area during the rainy season + irrigation period to be smaller than the B. In E, the percentage of
arable land (mainly planted rice) area of the research area increases from the previous D 18.4% to 28.7%, and the percentage of orchard area of the research area decreases from 48.0% to 46.2%. During the rainy season, the water consumption of irrigation in the paddy field is high and the reusing rate is high. At the same time, the large-scale livestock breeding industry, which is concentrated in the downstream sub-watershed 5 along the river, consumes a large amount of water during the rainy season. Due to the reasons mentioned above, even if the precipitation in the rainy season is sufficient, the discharge per unit area of the E is reduced to the lowest point of $3.69 \times 10^4$ m$^3$/km$^2$, which is close to $3.06 \times 10^4$ m$^3$/km$^2$ of the dry season + non-irrigation period.

3.2 Laws of nitrogen and phosphorus emission of different scales and periods

The change trend of ammonium nitrogen concentration is similar to that of total nitrogen (Figure 4(a)). Due to the influence of total nitrogen and ammonium nitrogen accumulation and species aggregation effects, the average concentration of total nitrogen and ammonium nitrogen in different irrigation periods increases with the increase of area. The E is the largest research area scale, which not only accumulates the amount of nitrogen loss in the upstream, but also faces the increase of the arable land area in the sub-watershed 5 and the emission of large-scale livestock breeding waste liquid, making the total nitrogen and ammonium nitrogen concentration of E increase sharply; the average emission of total nitrogen and ammonium nitrogen in the rainy season + irrigation period of C increases significantly compared with that in D, which is caused by the high content of total nitrogen and ammonium nitrogen in fishpond sewage water in the rainy season in sub-watershed 3 [15]. In terms of time, the average emission of total nitrogen and ammonium nitrogen in the dry season + non-irrigation period is generally greater than that in the rainy season + irrigation period and the difference increases with the increase of the area. Because the number of residents increases with the increase of the area (Table 1). And, the Spring Festival is in the dry season, the number of migrant workers returning to the countryside increases, the living sewage discharged into the river increases. The precipitation in the dry season is small and the West Main Canal stops the water supply of the Jingui river (the branch canal), so the river flow decreases sharply.

The change trend of the average emission load per unit area of total nitrogen and ammonium nitrogen is similar to that of the rainy season + irrigation period, and the overall trend of decrease fluctuates from decrease to increase with the increase of area (Figure 4(b)). Under the combined action of unit area discharge and concentration, the total nitrogen and ammonium nitrogen load per unit area in the rainy season + irrigation period in D reach the highest values of 687.8 kg/ km$^2$ and 217.2 kg/ km$^2$, which is the critical scale. The discharge per unit area of E drops sharply, the reusing rate of farmland water increases, and part of total nitrogen and ammonium nitrogen are removed by sediment adsorption, plant absorption and microbial degradation and synergy in pond/ditches, resulting the total nitrogen and ammonium nitrogen load per unit area decrease to the lowest values 162.7 kg/km$^2$ and 73.0 kg/km$^2$. The total nitrogen and ammonium nitrogen load per unit area in the dry season + non-irrigation period
generally fluctuate and increase with the increase of the area scale, which is similar to the overall change trend of the average concentration. There are no obvious pollutants discharged along the ditches of B and D, and the total nitrogen and ammonium nitrogen load per unit area are slightly decreased. The C and E are affected by the discharge of pollutants from livestock and fish farming, and the total nitrogen and ammonium nitrogen load per unit area increase slightly.

Figure 4. Average concentration and load per unit area of total nitrogen and ammonium nitrogen in different period.

Figure 5(a), together with Figure 4(a), shows that the overall trend of total phosphorus and total dissolved phosphate load per unit area in different periods of irrigation is similar to that of total nitrogen and ammonium nitrogen, and both increase with the increase of the area. The difference is that the concentration of total phosphorus and total dissolved phosphate is smaller. Combined with Table 1, in the A-D, it can be seen that the area of orchard accounts for more than 62.2% of the area, the amount of fertilization of the fruit trees is small, and the emission of phosphorus pollutants is also less [16].

The change trend of the average load of total phosphorus and total dissolved phosphate is similar to that of the rainy season + irrigation period (Figure 5(b)). The total phosphorus and total dissolved phosphate load per unit area in the rainy season + irrigation period show a fluctuating trend of increase, decrease, increase and then decrease, and the overall trend is downward. The B has rebounded and the D reaches the highest value of 66.2 kg/km$^2$ and 36.8 kg/km$^2$, which is the critical scale of the total phosphorus and total dissolved phosphate load per unit area in the rainy season + irrigation period. The E is reduced to the lowest value of 13.4 kg/km$^2$ and 9.6 kg/km$^2$; the average emission load of total phosphorus and total dissolved phosphate in dry season + non-irrigation period fluctuates and increases with the increase of area, which is similar to the trend of concentration variation.
3.3 Analysis of nitrogen and phosphorus concentration

The pollutant concentration of runoff in a watershed is affected by various factors such as precipitation, precipitation intensity, type of precipitation, underlying surface, and the number of gully and ditch/ponds along the watershed. Due to the different hydrological factors, underlying surface conditions and the number of ditch/ponds in different scales in the watershed, the pollutant concentrations at different area scales also change, showing the effect of pollutant emission. The average concentration of nitrogen and phosphorus in the research area of different area scales is shown in Figure 6.

The nitrogen and phosphorus average concentrations all increase with the increase of the area, and the E has the highest nitrogen and phosphorus concentration at the outlet of the whole watershed. At the same time, it was found that the total nitrogen and ammonium nitrogen in the watershed fluctuate greatly with the change, while the fluctuation of total phosphorus and total dissolved phosphate is smaller, mainly because that the total phosphorus and total dissolved phosphate in the study area are mainly from the application of compound fertilizer during agricultural activity. Compared with total nitrogen and ammonium nitrogen, total phosphorus and total dissolved phosphate are single source and less applied. Phosphorus migrates poorly in the soil, and is easily adsorbed by the sediments in the ditches and rivers during the movement with runoff, so that the monitoring concentrations of total phosphorus and total dissolved phosphate in the outlets of different area scale are lower. At the same time, the extent of change is also small.
In order to further analyze the effects of different spatial scales on nitrogen and phosphorus concentrations, with the total nitrogen, ammonium nitrogen, total phosphorus and total dissolved phosphate concentrations as the dependent variables and different spatial scales as factors, the monthly concentration of nitrogen and phosphorus pollutants at different spatial scales is analyzed by one-way analysis of variance (ANOVA). The results of ANOVA show that the significance level of concentrations of total nitrogen, ammonium nitrogen, total phosphorus and total dissolved phosphate of different area scales is all 0.000 (Table 2), both less than 0.05, indicating that there are significant differences for the concentrations of the same nitrogen and phosphorus index in different spatial scales, and spatial changes have a certain impact on the concentration of nitrogen and phosphorus emissions.

| Index          | Sum of square | df  | Mean square | F     | Significance |
|----------------|--------------|-----|-------------|-------|--------------|
| TN concentration | Between groups | 182.65 | 4     | 45.663 | 26.419 | 0.000        |
|                | Within groups | 95.065 | 55    | 1.7283 |       |             |
|                | Total         | 277.718 | 59    |       |       |             |
| NH₄⁺-N concentration | Between groups | 50.238 | 4     | 12.559 | 24.765 | 0.000        |
|                | Within groups | 27.892 | 55    | 0.507  |       |             |
|                | Total         | 78.130 | 59    |       |       |             |
| TP concentration | Between groups | 0.710  | 4     | 0.177  | 18.225 | 0.000        |
|                | Within groups | 0.536  | 55    | 0.010  |       |             |
|                | Total         | 1.246  | 59    |       |       |             |
| TDP concentration | Between groups | 0.478  | 4     | 0.120  | 27.843 | 0.000        |
|                | Within groups | 0.236  | 55    | 0.004  |       |             |
|                | Total         | 0.714  | 59    |       |       |             |

Note: Significant difference level greater than 0.05 is not significant.

On the basis of ANOVA, in order to further analyze the degree of difference of nitrogen and phosphorus concentrations between the two spatial scales, the monthly nitrogen and phosphorus concentrations of different spatial scales are analysis by LSD, and the differences of nitrogen and phosphorus concentration between two spatial scales are compared with each other. The significance level is set at 0.05, the difference in nitrogen and phosphorus concentrations between the scales a, b, c and d is not significant, while there is significant difference in nitrogen and phosphorus concentration between scales e and a, b, c and d, and the significance is all below 0.001 (Table 3). According to the Table 1 comprehensively, the proportion of the orchard and arable land area of research area in the A-D is similar, and mainly the orchard (the orchard area is 62.38%, 65.71%, 67.69% and 68.06%, respectively, and the arable land area percentage is 20.2%, 22.2%, 16.3% and 18.4%). Orchard is sloping planting, generally pumping irrigation, water consumption and fertilization amount are small, and nitrogen and phosphorus emissions are also less; while in E, the area of the orchard accounts for 46.2% of the area, and the area of arable land (mainly farmland) accounted for 28.7% of the area. At the same time, the livestock breeding industry developed along the river in the sub-watershed 5 in E has the characteristics...
of centralization and scale, and the contribution rate of the aquaculture industry and farmland to the nitrogen and phosphorus pollution index is greater than that of the orchard [17]. In summary, the land-use distribution pattern is the main factor for the effect of nitrogen and phosphorus concentrations.

Table 3. LSD analysis of nitrogen and phosphorus concentrations at different spatial scales.

| Index                     | Scale | A       | B       | C       | D       | E       |
|---------------------------|-------|---------|---------|---------|---------|---------|
| Total nitrogen concentration | A     | —       | 1.000   | 0.427   | 0.104   | 0.000   |
|                           | B     | —       | 0.420   | 0.101   | 0.000   |         |
|                           | C     | —       |         | 0.935   | 0.000   |         |
|                           | D     | —       |         |         | 0.000   |         |
|                           | E     | —       |         |         |         |         |
| Ammonium nitrogen concentration | A     | —       | 1.000   | 0.759   | 0.515   | 0.000   |
|                           | B     | —       | 0.743   | 0.497   | 0.000   |         |
|                           | C     | —       |         | 0.995   | 0.000   |         |
|                           | D     | —       |         |         | 0.000   |         |
|                           | E     | —       |         |         |         |         |
| Total phosphorus concentration | A     | —       | 0.994   | 0.468   | 0.053   | 0.000   |
|                           | B     | —       | 0.726   | 0.136   | 0.000   |         |
|                           | C     | —       |         | 0.785   | 0.000   |         |
|                           | D     | —       |         |         | 0.000   |         |
|                           | E     | —       |         |         |         |         |
| Total dissolved phosphate concentration | A     | —       | 0.842   | 0.100   | 0.123   | 0.000   |
|                           | B     | —       | 0.570   | 0.629   | 0.000   |         |
|                           | C     | —       |         | 1.000   | 0.000   |         |
|                           | D     | —       |         |         | 0.000   |         |
|                           | E     | —       |         |         |         |         |

Note: Significant difference level greater than 0.05 is not significant.

3.4 Laws of nitrogen and phosphorus load changing with spatial scale
It can be seen from Figure 7(a) and Figure 7(b) that the non-point source pollution in the study area is mainly nitrogen pollution, and the average emission load of nitrogen and phosphorus increases first and then decreases with the increase of the area. The D is the critical scale of the nitrogen and phosphorus load in the Jingui river watershed. The average emission load of total nitrogen, ammonium nitrogen, total phosphorus and total dissolved phosphate in D reaches the highest value in the whole watershed, which is 1337.96kg/km², 421.51kg/km², 125.86kg/km² and 66.32kg/km², respectively. From the previous analysis, the land-use distribution pattern of scales A-D is similar. The main land-use type is orchard, where the nitrogen and phosphorus emissions are stable and the water demand is small, and the nitrogen and phosphorus pollutants in the river are collected at the downstream D. D is the inflection point: from D to E, the land-use distribution pattern changes; the percentage of arable land (mainly farmland) increases by 10.3%, and the discharge per unit area is reduced by 85%; the average emission load of total nitrogen, ammonium nitrogen, total phosphorus and total dissolved phosphate decreases by 57.0%, 38.1%, 67.3% and 57.2%, respectively. From A to E, the average emission load of total nitrogen, ammonium nitrogen and total phosphorus decreases by 56.2%, 2.8% and 40.5%, respectively, and total dissolved phosphate increases by 38.8%, indicating that in the process of production and confluence of non-point source pollution in Jingui river watershed, the nutrient adjustment function of watershed ecosystems such as adsorption, degradation and filtration has obvious effects on the removal of total nitrogen and total phosphorus.
(a) total nitrogen and ammonium nitrogen
(b) total phosphorus and total dissolved phosphate

Figure 7. Monthly average concentration and load of nitrogen and phosphorus in different spatial scales.

ANOVA of total nitrogen, ammonium nitrogen, total phosphorus and total dissolved phosphate load at different spatial scales (Table 4) shows that there is no significant difference in nitrogen-phosphorus load variation at each spatial scale (significance > 0.05). It is speculated that the area of each scale is small and does not reach a certain scale of spatial scale.

Table 4. ANOVA analysis of nitrogen and phosphorus load at different spatial scales.

| Index                        | Sum of square | df  | Mean square | F      | Significance |
|------------------------------|---------------|-----|-------------|--------|--------------|
| Total nitrogen concentration | Between groups| 379658.8 | 4  | 94914.7 | 0.63 | 0.643        |
|                              | Within groups | 8281531.7 | 55 | 150573.3|        |              |
|                              | Total         | 8661190.5 | 59 |         |        |              |
| Ammonium nitrogen concentration | Between groups| 26588.6   | 4  | 6647.2  | 0.61 | 0.655        |
|                              | Within groups | 595831.6  | 55 | 10833.3 |        |              |
|                              | Total         | 622420.2  | 59 |         |        |              |
| Total phosphorus concentration | Between groups| 3715.5    | 4  | 928.87  | 0.92 | 0.459        |
|                              | Within groups | 55524.5   | 55 | 1009.54 |        |              |
|                              | Total         | 59240     | 59 |         |        |              |
| Total dissolved phosphate concentration | Between groups| 1539.9   | 4  | 384.967 | 1.00 | 0.413        |
|                              | Within groups | 21074.5   | 55 | 383.172 |        |              |
|                              | Total         | 22614.4   | 59 |         |        |              |

Note: Significant difference level greater than 0.05 is not significant.

4. Discussion

4.1 Impact of precipitation and land-use patterns on nitrogen and phosphorus load in irrigation district

Precipitation is the direct driving force for non-point source pollution. The runoff from precipitation has a transporting effect on nitrogen and phosphorus pollutants. The greater the precipitation, the more pollutants are carried and the greater the degree of pollution generated [18]; however, the migration process of runoff is mainly affected by land-use patterns, thus affecting the output of non-point source
pollutants [19]. In this study, in the small spatial scale (3.35 km$^2$–27.25 km$^2$), the contribution rate of nitrogen and phosphorus load is positively correlated with precipitation in the research areas with similar land-use distribution pattern. The nitrogen and phosphorus load contribution rate at the same precipitation is different in the research area with different land-use distribution pattern. The scales A-D have similar land-use distribution pattern. When the precipitation in the rainy season is significantly greater than that in the dry season, the nitrogen and phosphorus elements in the soil are easily lost by the effects of precipitation erosion and runoff erosion. At the same time, the arable land in the watershed is mainly planted with rice ripe once a year. The irrigation period is in the rainy season, and the fertilization on the farmland increases the nitrogen and phosphorus load input of the soil. Due to the action of precipitation erosion and agricultural irrigation, the surplus nitrogen and phosphorus elements on the surface are lost to the water with runoff discharge [20]. Due to the combined effects, the contribution rate of nitrogen and phosphorus load of A-D in rainy season + irrigation period is between 80.1% and 95.0%, which is significantly greater than that in dry season + non-irrigation period. In contrast, during the rainy season + irrigation period, the contribution rate of nitrogen and phosphorus load of E decreases to 50.2% and 58.6%, which is significantly smaller than that of the A-D. The main reason is that the migration process of runoff at E is affected by the change of land-use distribution pattern such as the increase of arable land area and the scale of livestock breeding industry. The runoff has plummeted and runoff discharge has been reused many times in farmland ditches, so some nitrogen and phosphorus have been removed, and the emission load has decreased; same in the dry season + non-irrigation period, the contribution rate of the nitrogen and phosphorus load in E increases to 41.4% and 49.8%, which is significantly greater than the A-D. The main reason is the increase of the returning population during the Spring Festival and the changes in the land-use distribution pattern such as livestock breeding industry; the domestic sewage and breeding wastewater discharged into the runoff increase, and the emission load increases.

4.2 Effect of nitrogen and phosphorus emissions
Due to the uneven distribution of precipitation, different underlying surface conditions and hydrological factors, a series of hydrological phenomena, such as runoff, will change with the scale in different spatial and temporal, thus showing effect. In the southwest irrigation district, the effect of agricultural non-point source pollution emissions is mainly derived from the effects of runoff discharge and underlying surface. This study result shows that affected by the distribution of land-use pattern, in small watershed (27.25 km$^2$) at different space scale, the same index of nitrogen and phosphorus emissions concentration has significant difference, but has no significant difference in nitrogen and phosphorus discharge load, probably because the research area at different scale is too small to reach a certain scale of spatial scale, which is greatly affected by human intervention. Zhang Xifeng [21] studied the effects of precipitation on runoff processes and nitrogen migration characteristics in four cascade watersheds in the purple soil region of Sichuan Province and found that compared with the small watersheds with strong human intervention, the nitrogen concentration in the larger basins was significant reduced, and the nitrogen load in cascade basins was significantly reduced. PM Haygarth et al. [22] selected 20ha–834km$^2$ small watersheds nested at different scales in the southwestern part of the UK to study the migration of phosphorus under different precipitation conditions. It also shows that phosphorus is easy to diffuse at small scales, while its attenuation and dilution mostly occur at large scales. Therefore, when studying the effect of nitrogen and phosphorus load in this region in the future, it can be considered to select a typical region with a relatively closed and larger spatial scale to carry out the nitrogen and phosphorus emission monitoring test on the basis of research in small watershed.

5. Conclusions
(1) The emission of agricultural non-point source pollution in small watershed shows different characteristics in different irrigation periods and spatial scales: in the rainy season + irrigation period and dry season + non-irrigation period, the concentration of total nitrogen, ammonium nitrogen, total phosphorus and total dissolved phosphate increases with the increase of the area; the nitrogen and
phosphorus load per unit area of the rainy season + irrigation period decrease with the increase of the area, while it increases slightly in dry season + non-irrigation period. The nitrogen and phosphorus load per unit area of E in the two periods is not much different; the same nitrogen and phosphorus index concentration is significantly different at different spatial scales; the D is the critical scale of nitrogen and phosphorus load in Jingui river watershed; in the whole runoff process, the average emission load of total nitrogen and total phosphorus decreases significantly. From A to E, the average emission load of total nitrogen, ammonium nitrogen and total phosphorus decreases by 56.2%, 2.8% and 40.5%, respectively, and total dissolved phosphate increases by 38.8%.

(2) The main factor contributing to the effect of nitrogen and phosphorus concentrations is precipitation and the land-use distribution pattern. The contribution rate of nitrogen and phosphorus load in rainy season + irrigation period and dry season + non-irrigation period in different area scale depends on precipitation and land-use distribution pattern: In the research area where the land-use distribution pattern is similar, the contribution rate of nitrogen and phosphorus load is positively correlated with precipitation, and the contribution rate of nitrogen and phosphorus load during rainy season + irrigation period is greater than that of dry season + non-irrigation period. The nitrogen and phosphorus load contribution rate at the same precipitation is different with different land-use distribution pattern. In the rainy season + irrigation period, the contribution rate of nitrogen and phosphorus load in E is significantly lower than that of A-D, while in the dry season + non-irrigation period, E was significantly higher than that of A-D.

Acknowledgements
This project was financially supported by the National Natural Science Foundation of China (Nos. 51569007), and the Natural Science Foundation of Guangxi Province, China (Grant No. 2018GXNSFAA294087, No. 2018GXNSFAA050022).

References
[1] Barton L ., Colmer T. D . (2006)Irrigation and fertiliser strategies for minimising nitrogen leaching from turfgrass. Agricultural Water Management, 80(1-3):160-175.
[2] Zhang W.L., Xu A.G., Ji H. J., et al.(2004) Estimation of agricultural non-point source pollution in china and the alleviating strategies III. A review of policies and practices for agricultural non-point source pollution control in China. Scientia Agricultura Sinica, 37(7): 1026-1033. (in Chinese with English abstract)
[3] Zhu Z.L., Sun B . (2008) Current situation, causes and control countermeasures of agricultural non-point source pollution in China. Chinese agricultural science bulletin, 24 (supplement):1-2. (in Chinese)
[4] Scanlon T M ,Kiely G, Xie Q. (2004) A nested catchment approach for defining the hydrological controls on non-point phosphorus transport. Journal of Hydrology (Amsterdam), 291(3-4): 218-231.
[5] Xiao F.P., Wang Y., Li H. (2014) Impact of different land use modes on soil nutrients of Huixian karst. GUANGXI WATER RESOURCES & HYDROPOWER ENGINEERING, (3):75-79. (in Chinese with English abstract)
[6] Wen J.H., Li J., Xu R., et al. (2018) Analysis of Water Pollution in the Lijiang River Basin Based on GIS and Linear Structural Equation Model. The Administration and Technique of Environmental Monitoring, 30(1): 27-30. (in Chinese with English abstract)
[7] Lin P ., Chen Y.D ., Xia Y. (2016) Types and causes of water pollution under different land use types in Lijiang river Basin. Journal of Guilin University of Technology, 36(3):539-544. (in Chinese with English abstract)
[8] Guo P ., Li X.J. (2017) Techniques and Application of Farmland Non-point Source Pollution Control in Typical Small Watershed of Lijiang River. Water Resources and Power, (09): 55-58+95. (in Chinese with English abstract)
[9] Yang L.Y., Xia Y. (2017) Analysis and reduction strategies of non-point source pollution in small
watershed of Lijiang tributaries. Journal of Guilin University of Technology, 37(01):177-181. (in Chinese with English abstract)

[10] Dai J.F., Quan Q.H., Fang R.J., et al. (2017) Estimation of non-point source pollution load in upstream of Lijiang River. Advances in Science and Technology of Water Resources, 37(05):57-63. (in Chinese with English abstract)

[11] Zhang D.D., Wang D.M., Ren Y., Zhou S.S. (2015) Interception effect of riparian vegetation zone on floats and factors affecting it. Journal of Beijing forestry university, 37(04):98-103. (in Chinese with English abstract)

[12] Lu L., Li W. L., Pei J.G., Wang J. (2014) A Quantitative Study of the Sources of Nitrate of Zhaiadi Underground River in Guilin Based on IsoSource. Acta Geoscientica Sinica, 35(2): 248-254. (in Chinese with English abstract)

[13] Wang Y.W., Guo C.Q., Mao Z., et al. (2016) Sewage purification effect of multi-series surface flow constructed wetland. Transactions of the Chinese Society of Agricultural Engineering, 32(3) : 220-227. (in Chinese with English abstract)

[14] Yang B.L., Cui Y.L., Zhao S.J., et al. (2014) Scale Effects of the Emission Laws of Nitrogen and Phosphorus from Paddy Fields in South China's Hills. China Rural Water & Hydropower, 7: 85-88.

[15] Luo W., Li W.H., Pang Y.Y., et al. (2016) Principal Component Analysis of Pollution in Freshwater Fish Ponds. Fisheries science, (2), 136-141. (in Chinese with English abstract)

[16] Yu C.M., Lai C.Y., Zong Z.S., et al. (2016) Scale Effects of Agricultural Non-point Source Pollution Based on SWAT Model. China Rural Water & Hydropower, 9: 187-191.

[17] Zhang L.H., Dai J.F., Mo X.L., et al. (2018) Effects of Different Underlying Conditions on Nitrogen and Phosphorus Pollution Load in Small Watershed of Lijiang River. Water Saving Irrigation, 2: 66-70. (in Chinese with English abstract)

[18] Lin M., Ding X.W., Lu P.X. (2015) Review of researches on influence mechanism of rainfall, topography on the production and transportation of non-point source pollution. Water Pollution Control, 33(6): 19-23. (in Chinese with English abstract)

[19] Jiang J., An N., Zhang Y., et al. (2012) Influence of Rainfall Run-off in Hydrologic Process on Non-Point Pollution. Agricultural Science & Technology, 13(2): 380-383.

[20] Xiao J., Zong L.G., Cao D., et al. (2012) Research on Distribution of Soil Nitrogen and Phosphorus Content under Different Types of Land Usage in Yixing. Chinese Journal of Soil Science, 2: 347-352. (in Chinese with English abstract)

[21] Zhang X.F., Shen D., Tang J.L., et al. (2018) Scale Effects on Characteristics of Runoff Processes and Nitrogen Losses in a Small Agricultural Catchment in Purple Soil Region. Research of soil and water conservation, 25(2): 72-79. (in Chinese with English abstract)

[22] Haygarth P M, Wood F L, Heathwaite A L, et al. (2005) Phosphorus dynamics observed through increasing scales in a nested headwater-to-river channel study. Science of the Total Environment, 344(1-3): 83-106.