

Original Research

Spatial Heterogeneity and Cause Analysis of Water Quality of Coastal City River System in Flood and Non-Flood Season: a Case Study of Haikou, China

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Abstract

Through the 26 monitoring sections established in Haikou, 7 water quality indicators were recorded. GIS spatial analysis functions were used to conduct water quality analysis and map water quality variations in Haikou. The results showed that the water quality was worse in non-flood seasons than during flood seasons. The primary pollutant is $\text{NH}_3\text{-N}$, whose average value ($4.44\text{mg}\cdot\text{L}^{-1}$) exceeds the Class V water quality standard and has a high variation coefficient (177%). There are significant spatial differences, which are greatly affected by human activities and the tertiary industry. The primary pollutant in the flood season is TP, with an average value of $0.47\text{ mg}\cdot\text{L}^{-1}$, a strong variation with significant spatial differences. From the perspective of spatial distribution, the overall water quality shows a trend of deterioration from inland to near the sea entrance. The most severe pollution is the H2 cluster, which is located in the main urban area and where many rivers enter the sea. It is a key area for water pollution prevention and control.

Keywords: Haikou, flood and non-flood season, water quality, land use, correlation analysis

Introduction

Water quality plays a vital role in human activities, the sustainable development of the social economy, and the development and utilization [1-2]. Among them, the water quality of rivers entering the sea and the flux of pollutants transported are among the most critical factors affecting coastal waters' ecological environment

[3]. In particular, China's coastal areas' rapid economic development has caused the continuous decline of the water environment quality of many rivers and their estuaries and the bay area. Rivers entering the sea as the most critical land pollution source of marine pollution are receiving widespread attention [4].

Climate, land use, and the loss of nutrients in the soil cause spatial variability in water quality in the basin [5-7]. The intensity of land use types and the different scales from the river bank also significantly affect various water quality indicators in the water body [8]. Besides, studies have shown that the basin's

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social economy also has a specific impact on the water environment's quality [9].

Due to the numerous water quality indicators, different units, and mutual influence [10-11], the comprehensive analysis of water quality is very complicated [12], so robust and straightforward statistical data and methods are needed [13]. Geospatial analysis and correlation analysis provide a reliable method for spatiotemporal identification and analysis of water quality parameters [14-15]. Ahearn et al. [16] used an optimized linear mixed-effects model to discuss land use's impact on water quality in different hydrological periods and regions. Tran et al. [17] analyzed the changes in the relationship between LUCC and water quality under other proximity through methods such as principal component analysis, correlation analysis and breakpoint regression. Wang et al. [7] used cluster analysis and stepwise linear regression model to study land use's effect on water quality under different disturbance gradients. With the rapid development of industrialization and urbanization, the impact of human activities caused the heterogeneity of land use types between basins and the types and levels of social and economic activities carried by the same land-use type. This heterogeneity makes the impact of land use types on water quality very different between different basins so that the contribution rate of land-use types to water quality is reduced [18-20]. Therefore, when analyzing the relationship between land use type and water pollutant concentration, the impact of land use on water quality may become blurred due to socio-economic differences, resulting in deviations between the analysis results and the actual results, thereby reducing the accuracy of the conclusions. It is necessary to comprehensively consider the impact of landuse types and socio-economic factors on the concentration of pollutants in water bodies, but research in this area has been carried out very little.

In summary, studying the impact of land-use types and socio-economic status of the Haikou river system on water quality is of great significance to urban water pollution control decisions. At the same time, it is also necessary to consider the impact of the above indicators on water quality in different hydrological periods. The first part of this study mainly describes the basic situation and data sources of the study area. The main research methods used in the thesis are correlation coefficient analysis, de-trend analysis, and redundancy analysis. The second part analyzes the water quality statistical parameters, spatial distribution characteristics, and the response relationship between water quality and land use and socio-economic indicators in flood and non-flood periods. Through the research of this paper, we will clarify the spatial distribution law of water quality in coastal cities and its relationship with land use types and socio-economic indicators. Provide a decision-making basis for government departments to formulate river governance plans and improve the entire Haikou and Qiongzhou Strait areas' water ecological environment.

Material and Methods

Study Area

Haikou City is located at 19°32'~20°5' north latitude and 110°10'~110°41' east longitude. It is located in the northern part of China's Hainan Province, straddling the east and west banks of the Nandu River's lower reaches, with a total area of 2304.84 km². The geographical location of the study area is shown in Fig. 1. Haikou has gentle terrain, high in the northwest and southeast, low and flat along the Nandu River in the middle, and small coastal plains in the east and northeast. The highest point in the

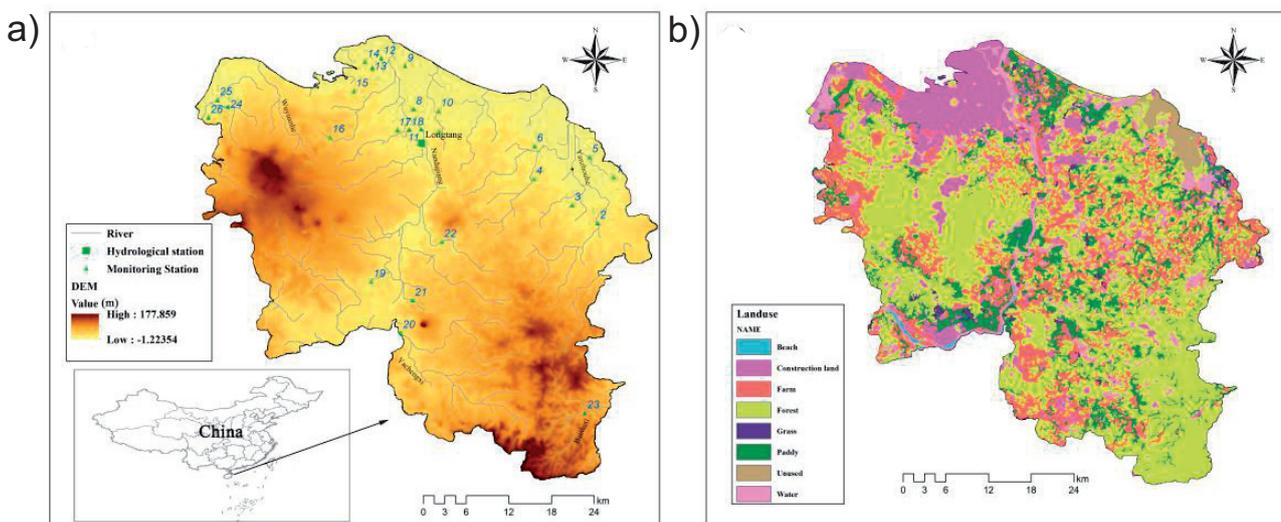


Fig. 1. Location of the study area.

territory is Ma'anling, with an elevation of 177.86 m, and the lowest point is the Nandu River's open sea mouth with a height of 0.4 m (Fig. 1a). Haikou has a tropical island climate, and the city's multi-year average precipitation is 1827 mm. May to October is the rainy season, with rainfall accounting for 78.1% of the annual precipitation; September is the peak period of precipitation, with an average precipitation of 300.7 mm, accounting for 17.8% of the annual precipitation. The average precipitation in January is only 24 mm. From December to February of the following year, the monthly average precipitation is less than 50 mm; the dry season is from November to April. The precipitation only accounts for 22% of the whole year. The river network density in the main urban area of Haikou is 0.39, and the water surface rate is 3.9%.

Data Source

The water quality data is the measured data of 26 river monitoring sections (Fig. 1b) established by the Haikou Ecological Environment Bureau from 2014 to 2017. Water quality parameters include DO, Permanganate index, $\text{NH}_3\text{-N}$, TP, F, volatile phenol, and petroleum. The frequency of water quality monitoring is once a month. The water quality standards refer to "Surface Water Environmental Standards" (GB3838-2002). The water quality parameter standards and testing methods are shown in Table 1.

The 30 m resolution image data of Landsat8 in the two phases of July and September 2018 in the study area were selected, and on the basis of geometric correction and atmospheric correction, the land use information in the room was extracted by supervised classification. According to the LUCC classification system established by Liu et al. [21] in the construction of the "China 20th Century LUCC Spatio-temporal Platform", the land use map of the study area was obtained by interpreting the 7 types of land use among forest land, grassland, paddy field, dry land, water area, construction land, and unused land (Fig. 1b).

Analytical Method

Use the descriptive statistics function of SPSS 19.0 software to analyze the data sample's structure and overall situation to reflect the actual status behind the data. The comprehensive analysis of the data of water quality elements, the average value, maximum value, minimum value, first quartile (Q1), median, standard deviation, and coefficient of variation obtained can intuitively express the central trend and current status of the Haikou river system's water quality. The coefficient of variation is classified according to the standard of variation grade: $C_v < 10\%$, weak variability, $10\% \leq C_v \leq 100\%$, medium variability, $C_v > 100\%$, strong variability. According to Haikou's meteorological conditions, we divided the whole year into two periods: flood season and non-flood season for comparative analysis. The flood season is from May to October (the annual average flow of Longtang Hydrological Station is $84.68 \text{ m}^3 \cdot \text{s}^{-1}$), and the rest months are non-flood seasons (the annual average flow of Longtang Hydrological Station is $279.55 \text{ m}^3 \cdot \text{s}^{-1}$). Spearman correlation analysis was performed on water quality and land use types in different river system clusters using SPSS190 software. In order to reflect the impact of social economy on water quality, the Canoco4.5 statistical software is used to perform detrend correspondence analysis (DCA) on water quality index data and calculate the gradient length of the sort axis. The Redundancy Analysis Method (RDA) is used to sort and analyze the water quality indicators and socioeconomic data (2016 Haikou Statistical Yearbook) matrix.

Results and Discussion

Descriptive Statistical Analysis of Water Quality

The increase of precipitation in the flood season can dilute the concentration of pollutants in the river and increase the scour of the non-point source pollution area

Table 1. Grade concentration values and detection methods of different water quality indicators.

Water quality indicators	Grade concentration values/ ($\text{mg} \cdot \text{L}^{-1}$)					Detection methods
	I	II	III	IV	V	
DO	7.5	6.0	5.0	3.0	2.0	Iodometry
Permanganate index	2.0	4.0	6.0	10.0	15.0	\
$\text{NH}_3\text{-N}$	0.15	0.50	1.00	1.50	2.00	Nessler's reagent colorimetry
TP	0.02	0.1	0.2	0.3	0.4	Ammonium Molybdate Spectrophotometry
F	1.0	1.0	1.0	1.5	1.5	Ion selective electrode method
Volatile Phenol	0.002	0.002	0.005	0.01	0.1	4-aminoantipyrine spectrophotometer after distillation
Petroleum	0.05	0.05	0.05	0.5	1.0	Infrared spectrophotometry

so that more pollutants will be collected in the river. Therefore, the water quality of rivers in different places responds differently to precipitation. The statistical analysis of the river system's water quality parameters in Haikou City is shown in Table 2.

The mean values of DO in the flood season and non-flood season are $4.18 \text{ mg}\cdot\text{L}^{-1}$ and $4.86 \text{ mg}\cdot\text{L}^{-1}$, respectively, reaching surface water quality Class IV. This may be related to the high precipitation in Haikou, the large annual runoff of the river, and sufficient water flow. The average concentration of $\text{NH}_3\text{-N}$ in non-flood season ($4.44 \text{ mg}\cdot\text{L}^{-1}$) exceeds the water quality standard of Class V, and the median is $0.47 \text{ mg}\cdot\text{L}^{-1}$, the first quartile is $0.16 \text{ mg}\cdot\text{L}^{-1}$, with a maximum value of $25.30 \text{ mg}\cdot\text{L}^{-1}$. The average is much larger than the median, which indicates that the maximum value has a more significant impact on this indicator. The variation coefficient is 177%, a strong variation with significant spatial differences; the mean value in flood season ($2.18 \text{ mg}\cdot\text{L}^{-1}$) is relatively low, close to the water quality standard of Class V, and the coefficient of variation is also high. There was little difference in the average concentration of TP in the two periods, which were $0.49 \text{ mg}\cdot\text{L}^{-1}$ and $0.47 \text{ mg}\cdot\text{L}^{-1}$, respectively, which were higher than the water quality standard of Class V. The coefficients of variation are all high, belonging to strong variation, with significant spatial differences. The average values of F, Volatile phenol, and Petroleum in the two periods can reach the water quality Class I. However, the maximum values of volatile phenols and Petroleum in non-flood season went $0.035 \text{ mg}\cdot\text{L}^{-1}$ and $0.27 \text{ mg}\cdot\text{L}^{-1}$, respectively, which belonged to the water quality standard of Class IV. The coefficient of variation of Petroleum in the non-flood season is 231%,

which is higher than all other indicators and is a strong variation with significant spatial differences. Pollutants in Haikou's rivers are mainly nitrogen and phosphorus pollution, while organic pollution such as volatile phenol and Petroleum is relatively small.

Spatial Distribution Characteristics of Water Quality

According to the "Haikou City River system Planning," referring to the river's attributes and location, we divided the city into 4 river system clusters H1-H4.

Fig. 2 shows the spatial distribution of water quality indicators during non-flood seasons (left column) and flood seasons (right column). Table 2 shows the average, maximum and minimum values of the leading water quality indicators during the flood season and non-flood season in the H1-H4 region. The analysis results show that, except for some areas of Petroleum, which have increased during the flood season, all other indicators show the characteristics of decreasing during the flood season. This may be due to the low rainfall during the non-flood season, which reduces pollutants' dilution in coastal industrial point sources, farmland, livestock and poultry breeding, and urban domestic sewage [22]. During the flood season, precipitation has diluted the N, P, and other nutrients, organic pollutants, and soluble pollutants that scoured from the surface into the river, resulting in lower concentrations. This shows that water volume is an essential driving force for the improvement of water quality in Haikou. External pollution input is the main cause of water pollution.

Table 2. Statistical characteristics of water quality of Haikou river system.

Period	Statistical Parameters	DO / ($\text{mg}\cdot\text{L}^{-1}$)	Permanganate Index/ ($\text{mg}\cdot\text{L}^{-1}$)	$\text{NH}_3\text{-N}$ / ($\text{mg}\cdot\text{L}^{-1}$)	TP / ($\text{mg}\cdot\text{L}^{-1}$)	F / ($\text{mg}\cdot\text{L}^{-1}$)	Volatile Phenol / ($\text{mg}\cdot\text{L}^{-1}$)	Petroleum / ($\text{mg}\cdot\text{L}^{-1}$)
Non-flood season	Max	11.20	36.80	25.30	5.45	0.70	0.0090	0.39
	Min	0.30	0.70	0.01	0.03	0.03	0.0002	0.01
	AVG	4.86	6.01	2.50	0.49	0.18	0.0009	0.02
	Q1	3.03	3.20	0.16	0.11	0.10	0.0002	0.005
	Me	5.05	4.40	0.47	0.20	0.15	0.0003	0.005
	Stdev	2.50	4.71	4.44	0.76	0.12	0.0013	0.04
	Cv(%)	51	78	177	156	69	149	231
Flood season	Max	11.60	23.50	18.70	4.15	0.900	0.0350	0.27
	Min	0.10	0.90	0.01	0.03	0.060	0.0002	0.00
	AVG	4.18	5.76	2.18	0.47	0.226	0.0008	0.02
	Q1	2.10	3.40	0.10	0.11	0.15	0.00015	0.005
	Me	4.20	4.75	0.41	0.24	0.20	0.00015	0.005
	Stdev	2.47	3.36	3.65	0.62	0.113	0.0033	0.03
	Cv(%)	59	58	168	131	50	226	207

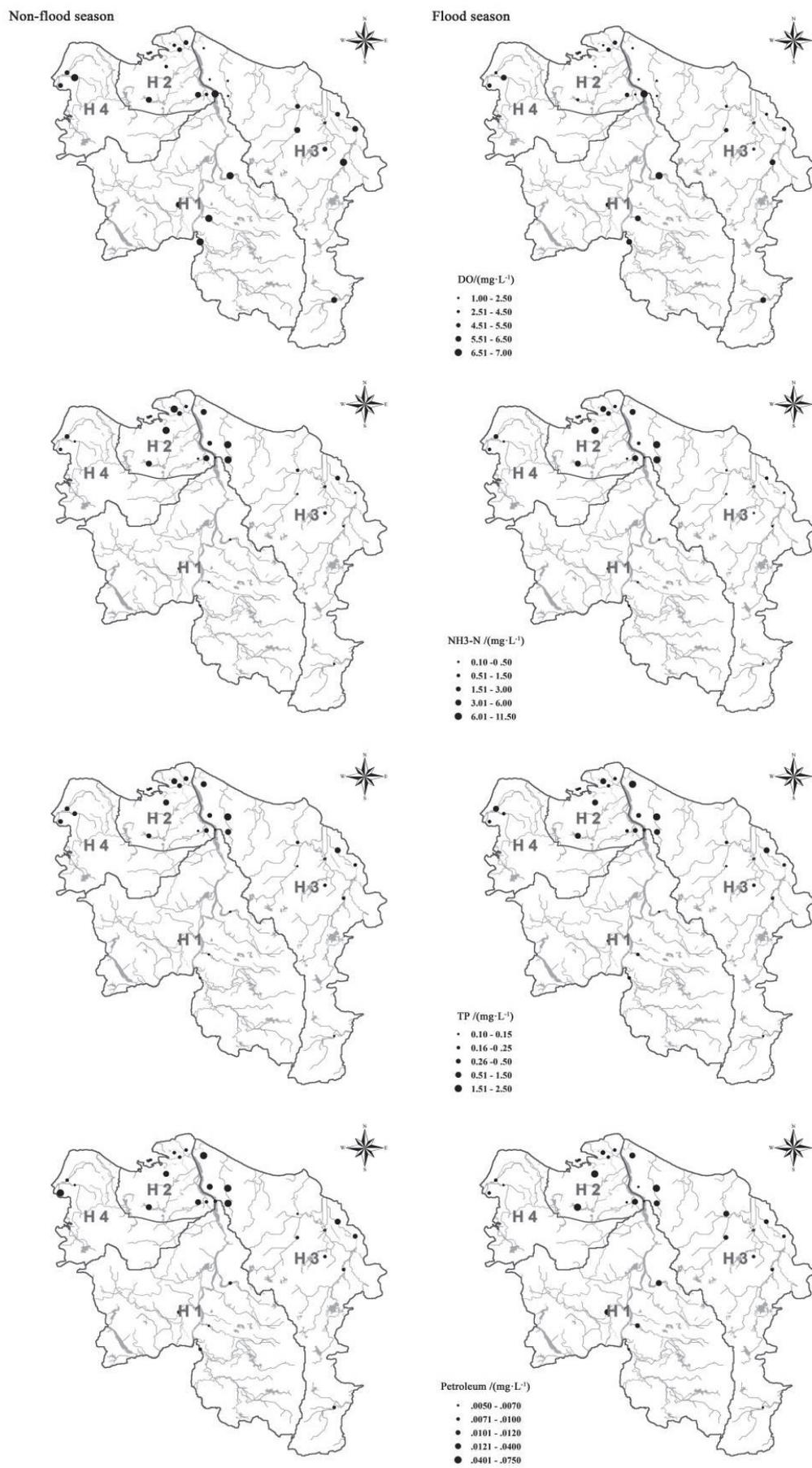


Fig. 2. Spatial distribution of water quality indicators in Haikou.

Table 3. Mean value, maximum value and minimum value of different water quality indicators in H1-H4 area during flood season and non-flood season.

Period	River system cluster	DO /(mg·L ⁻¹)			NH ₃ -N /(mg·L ⁻¹)			TP /(mg·L ⁻¹)			Petroleum /(mg·L ⁻¹)		
		Max	Min	AVG	Max	Min	AVG	Max	Min	AVG	Max	Min	AVG
Non-flood season	H1	6.88	6.16	6.67	0.28	0.12	0.18	0.14	0.10	0.12	0.01	0.01	0.01
	H2	6.04	2.67	4.29	8.45	0.15	4.02	1.28	0.11	0.56	0.02	0.01	0.01
	H3	6.70	1.33	4.13	11.10	0.19	2.98	2.38	0.12	0.66	0.07	0.01	0.03
	H4	6.70	4.90	5.51	2.12	0.40	1.23	0.46	0.27	0.36	0.08	0.01	0.03
Flood season	H1	6.82	5.27	6.17	0.31	0.08	0.17	0.20	0.11	0.15	0.02	0.01	0.01
	H2	5.32	1.57	3.34	10.08	0.22	4.00	1.21	0.18	0.60	0.06	0.01	0.02
	H3	6.09	1.29	3.68	9.53	0.09	2.18	1.85	0.06	0.56	0.04	0.01	0.02
	H4	6.18	3.19	4.64	2.63	0.15	1.26	0.65	0.17	0.35	0.01	0.01	0.01

From the perspective of spatial distribution, there are significant differences between the river system clusters. The overall water quality shows a trend of deterioration from the southern inland area to the northern coastal area. As can be seen from Table 3, the H1 river system cluster is mainly located in Haikou's inland area, with relatively few pollution sources. The average values of DO and petroleum in the two periods can reach water quality standard I, NH₃-N can reach water quality standard II or higher, and TP can reach water quality standard III or higher. And the concentration difference of each site is not significant. Simultaneously, for DO, NH₃-N, and TP, regardless of the average value or the maximum value, the H2 water system group has the worst performance in the 4 regions. This may be due to the H2 river system cluster is mainly located in Haikou's central urban area, which is the primary production and living area. Human activities are the most intensive, and the estuary of many rivers is located in this area, which is the most downstream. Due to the cumulative effect of upstream pollutants, the water quality is generally low. Among them, NH₃-N and TP are the worst indicators, and the average concentration of both during the flood season and the non-flood season is higher than the water quality class V. Most of the rivers in this area are tidal sections, and the exchange of water bodies is relatively sufficient. DO can reach surface water above the water quality class III, and petroleum is the best, which can meet the water quality class I. Due to the direct exchange between the area and the ocean water body, the site should focus on pollutant control. In the H3 river system cluster, the spatial difference of each station is noticeable. The overall performance is that the inland area's pollution is relatively good, and the water quality near the river estuary in the west and north is low. The H4 river system cluster has relatively few monitoring sites, and petroleum is the weakest among all clusters. The average DO concentration in the two periods has reached the water quality class II.

The Response Relationship between Land Use and Water Quality

It can be seen from Fig. 3 that the land use in Haikou is dominated by forest land, accounting for 50.62% of the city's total area, and beach land accounting for the smallest proportion, only 0.25%. In terms of river system clusters, the three river system clusters H1, H3, and H4 have the largest forest area ratio, accounting for about 53.1% to 54.5%. The farmland is followed, and these three clusters account for 17.9%~21.4%, respectively. H2 river system cluster is mainly based on construction land, accounting for more than 68% of the region's total area.

The correlation analysis between the proportion of land use types and water quality indicators in the flood and non-flood periods in the study area is shown in Table 4. The results show that in the non-flood season, DO is negatively correlated with the water body area. This is mainly due to the decrease of rainfall and the slowing of the water flow rate, which reduces the dynamic effect of oxygen into the water body, which causes the reduction of the water body DO concentration. NH₃-N exhibits a negative correlation with farm and forest land, which is consistent with the research conclusion of Sun et al. [23] on the Dianchi Lake Basin. The study of Tu et al. [24] showed that this negative correlation could not be used to reversely indicate that the increase and decrease of agricultural land inhibited NH₃-N pollution. This may be because the main factors causing river nitrogen pollution occur with spatial location. The rapid increase in impervious area in urban areas and the increase in point source pollution have led to an increase in the concentration of NH₃-N. Changes in the concentration of nitrogen pollutants are greatly affected by changes in the proportion of forest land because forests can effectively control the concentration of pollutants in water bodies. River pollution is an ecological process that occurs with the exchange and migration of materials and energy in

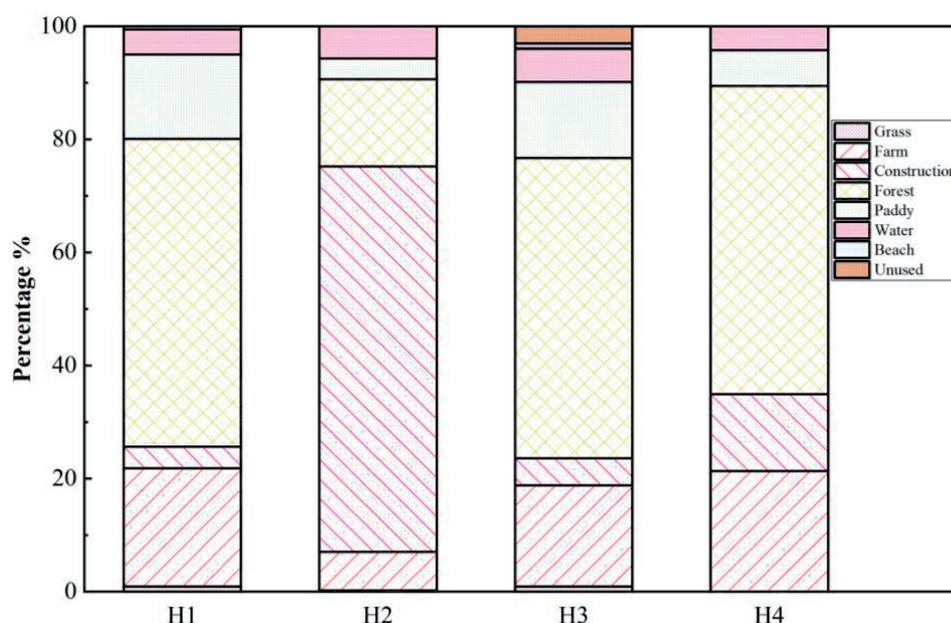


Fig. 3. River system cluster land use type area ratio.

the ecosystem, hydrological processes, and soil erosion [25]. Under the action of forest vegetation, it can effectively prevent soil erosion, reduce the degree of soil erosion caused by rainfall-runoff, and show apparent interception, filtration, absorption, and transformation of pollutants [26-27]. There is a positive correlation between TP and water area, which may be mainly concentrated in the upstream region. The upper reaches' economy is dominated by agricultural production, which

increases external phosphorus input, and pollutants migrate into the water area along with runoff. F shows a negative correlation with grassland and paddy field and a positive correlation with construction land. Volatile phenol is positively correlated with construction land and negatively correlated with beaches. Because these indicators are low in content and not representative, no specific analysis will be done.

Table 4. Spearman correlation analysis between water quality and land use.

Period	Landuse types	DO	Permanganate Index	NH ₃ -N	TP	F	Volatile Phenol	Petroleum
Non-flood season	Grass	0.1	-0.3	-0.3	-0.1	-0.9	-0.8	-0.6
	Farm	0.8	-0.4	0.9	-0.8	-0.3	-0.4	0.3
	Construction	-0.3	0.6	0.6	0.3	1.0	0.9	0.3
	Forest	0.7	-0.4	-0.9	-0.7	-0.7	-0.6	0
	Paddy	0.3	-0.6	-0.6	-0.3	-1.0	-0.9	-0.3
	Water	-0.9	0.8	0.8	0.9	0	0.2	-0.1
	Beach	0.3	-0.4	-0.4	-0.3	-0.8	-0.9	-0.7
	Unused	-0.7	0.3	0.3	0.7	-0.3	-0.2	0.3
Flood season	Grass	-0.3	0.1	0.3	0.1	0.8	0.7	\
	Farm	-0.9	0.8	0.9	0.8	0.1	0.5	0.6
	Construction	0.6	-0.3	-0.6	-0.3	-0.9	-0.9	-0.1
	Forest	0.9	-0.7	-0.9	-0.7	-0.5	-0.9	-0.6
	Paddy	0.6	-0.3	-0.6	-0.3	-0.9	-0.9	-0.1
	Water	-0.8	0.8	0.8	0.9	-0.3	0.2	0.8
	Beach	0.4	-0.3	-0.4	-0.3	-0.6	-0.5	-0.1
	Unused	-0.3	0.7	0.3	0.7	-0.7	-0.1	0.9

During the flood season, DO shows a negative correlation with farmland and a positive correlation with forest land. It shows that the non-point source pollution caused by agricultural land causes the increase of water body oxygen consumption and the slowdown of water body flow rate, which leads to the decrease of water body dissolved oxygen content. The water conservation effect of forest land makes the pollutant content of regional water bodies less and less oxygen. NH₃-N showed a positive correlation with agricultural land and a negative correlation with forest land. It indicates that agricultural activities in the flood season are the main driving factors for water bodies' eutrophication. Residual fertilizers, pesticides, and pesticides in agricultural land will enter the water body under the rain. Forest land can intercept pollution by delaying surface runoff. There is a positive correlation between TP and water area, and the reason is the same as that of the non-flood season. F shows a negative correlation with paddy fields and a positive correlation with construction land. Volatile phenol has a negative correlation with construction land, woodland and paddy field. Petroleum shows a positive correlation with unused land, which is not very representative and will not be analyzed.

The Response Relationship between Social Economy and Water Quality

This study uses the districts and counties of Haikou City as the statistical unit and selects the population density (PD), per capita GDP (GDP/ capita), the proportion of the primary industry in the GDP (PPI), the proportion of secondary industry in GDP (PSI) and the proportion of tertiary industry in GDP (PTI) are social and economic indicators that affect the quality of the water environment in the basin. Through the spatial

analysis tool of ArcGIS 10.2, according to the area weight assigned to each river system group, and then analyze the correlation between social economy and water quality.

From the RDA results in Fig. 4, it can be seen that TP, Permanganate index, Petroleum, and volatile phenols are significantly positively correlated with PTI during non-flood season. This is mainly due to the agglomeration of the catering industry and commerce, which makes the area prone to excessive sewage discharge, especially in the economically underdeveloped river basin, where the sewage treatment system is imperfect, which causes the increase in the concentration of TP and organic pollutants in the water body. There is a negative correlation with PPI and PSI, which may be due to the decrease of precipitation in non-flood seasons, which weakened the migration of phosphorus with surface runoff to some extent. Industrial point source pollution accounts for a relatively small proportion of water pollution in Haikou. F and NH₃-N are positively correlated with GDP/ capita and PD and negatively correlated with DO. This is mainly due to intensive man-made and economic activities, such as the direct discharge of domestic sewage, which caused direct pollution of nitrogen in the water body, and at the same time aggravated the activity of oxygen-consuming microorganisms in the water body and reduced the DO content in the water body. This result also validates the previous research results of Tu et al. [28] and Liu et al. [29].

During the flood season, DO, Permanganate index, and petroleum has a certain degree of positive correlation with PSI and a negative correlation with PD. This may be due to the precipitation in the flood season that caused some industrial wastewater to enter the water body without the pipe network, causing a certain degree of organic pollution. Residents' domestic

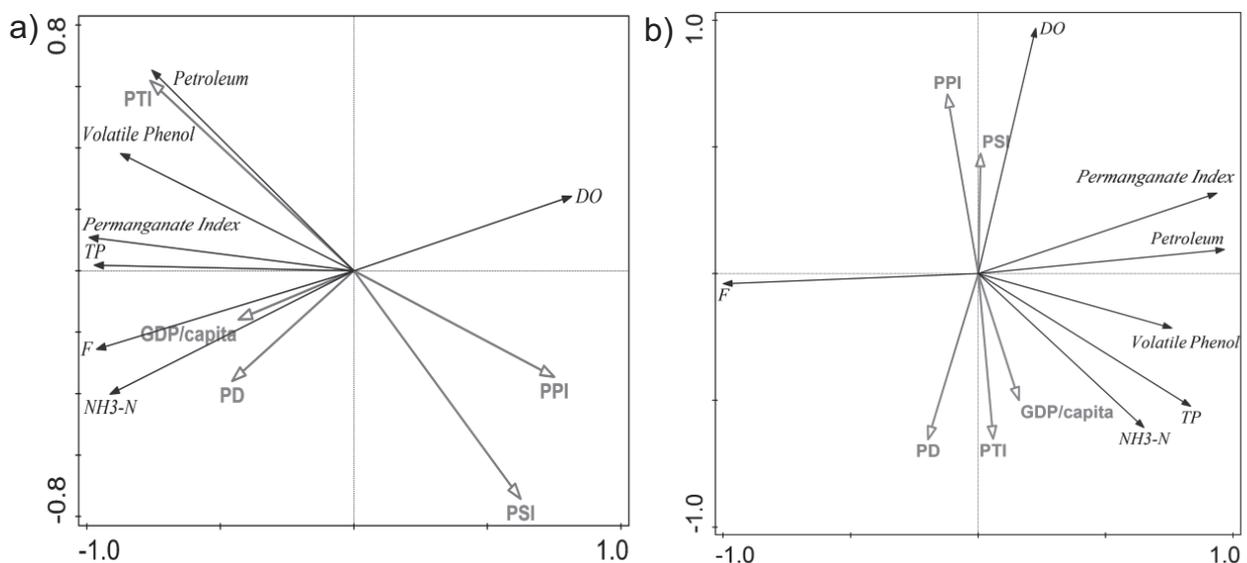


Fig. 4. RDA ranking map of water quality indicators and basin socio-economics a) Non-flood season, b) Flood season.

sewage contributes little to the Permanganate index and petroleum. $\text{NH}_3\text{-N}$, TP, and volatile phenols are significantly positively correlated with GDP/capita and PTI and significantly negatively correlated with PPI. The reason for this result is that the economic development level of each river system group is large. With the increase of GDP, the population is concentrated, and the proportion of the industrial structure's primary industry decreases. This is different from the areas where agriculture is the pillar industry [30]. Studies have also pointed out that due to a large amount of organic phosphorus and organic nitrogen in the domestic sewage of urban residents, the water body's N and P contents are higher after being discharged into the river [16, 31].

Conclusions

1) The water quality of the Haikou river system is generally poor. Water pollution in non-flood seasons is more severe than in flood seasons. The eutrophic pollution of $\text{NH}_3\text{-N}$ and TP. is strict, and the emission of external pollution far exceeds the dilution effect of precipitation. From the perspective of spatial distribution, the water pollution in the entire Haikou area shows a trend of increasing from inland to near the sea entrance. The H1 river system cluster has the least pollution, and the H2-H3 river system cluster is more serious, whether it is organic or inorganic pollutants. In particular, the H2 river system group is a key area for water pollution prevention and control.

2) From the perspective of the correlation between land use and water quality, the correlation between N, P and agricultural land in the Haikou area is weak, and non-flood season farmland non-point source pollution is not the main channel of water pollution in Haikou. Forest land plays a perfect role in intercepting pollutants, conserving water sources, and purifying water quality.

3) N and P pollutants are greatly affected by urban residents' activities and tertiary industry activities. Pollutants in water bodies mainly come from the discharge of domestic and industrial sources. Organic pollutants are also affected by pollution, as mentioned earlier, emissions. DO. is primarily influenced by population density.

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Conflict of Interest

The authors declare no conflict of interest.

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