Chin. Geogra. Sci. 2013 Vol. 23 No. 2 pp. 203–215
doi: 10.1007/s11769-013-0593-x

Springer Science Press
www.springerlink.com/content/1002-0063

Industrial and Agricultural Effects on Water Environment and Its Optimization in Heavily Polluted Area in Taihu Lake Basin, China

ZHAO Haixia[1], YOU Bensheng[1], DUAN Xuejun[1], Stewart BECKY [2], JIANG Xiaowei[3]

(1. *State Key Laboratory of Lake Science and Environment*, *Nanjing Institute of Geography and Limnology*, *Chinese Academy of Sciences*, *Nanjing* 210008, *China*; 2. *White Clay Editorial*, *Newark*, *Delaware* 19711, *USA*; 3. *College of Territorial Resources and Tourism*, *Anhui Normal University*, *Wuhu* 241003, *China*)

Abstract: The deteriorating water quality in the Taihu Lake Basin has attracted widespread attention for many years, and is correlated with a sharp increase in the quantity of pollutant discharge such as agricultural fertilizers and industrial wastewater. In this study, several factors were selected for evaluating and regionalizing the water environmental capacity by ArcGIS spatial analysis, including geomorphologic characteristics, water quality goals, water body accessibility, water-dilution channels, and current water quality. Then, the spatial optimization of agriculture and industry was adjusted through overlay analysis, based on the balance between industrial space and water environmental capacity. The results show that the water environmental capacity gradually decreases from the west to the east, in contrast, the pollution caused by industrial and agricultural clustering is distributes along Taihu Lake, Gehu Lake and urban districts. The analysis of the agricultural space focuses on optimizing key protected areas of the Taihu Lake Basin, and the shores of Gehu Lake, optimally adjusting the second protected areas of the Taihu Lake Basin, and generally adjusting the urban areas of Changzhou and Wuxi cities. The analysis of industrial space focuses on optimizing the downtowns of Changzhou and Wuxi cities, optimally adjusting key protected areas and second protected areas of the Taihu Lake Basin, and generally adjusting the south and southwest of Gehu Lake. Lastly, some schemes of industrial and agricultural layouts and policies for the direction of industrial and agricultural development were proposed, reflecting a correlation between industry and agriculture and the water environment.

Keywords: water environmental capacity; industrial and agricultural pollution; spatial optimization; heavily polluted area

Citation: Zhao Haixia, You Bensheng, Duan Xuejun, Becky Stewart, Jiang Xiaowei, 2013. Industrial and agricultural effects on water environment and its optimization in heavily polluted area in Taihu Lake Basin, China. *Chinese Geographical Science*, 23(2): 203–215. doi: 10.1007/s11769-013-0593-x

1 Introduction

With fast economic growth, water pollution has been a serious problem throughout China (Qin *et al*., 2004). Growing pollutant discharges such as agricultural fertilizers, industrial wastewater and domestic sewage, coupled with limited wastewater treatment capacity, are principal drivers of water pollution. About two-thirds of the total waste discharged into rivers, lakes and the sea derives from industry, and about 80% of that is untreated (Wang *et al*., 2008). The water environment has been deteriorating continuously and has become a restricting factor to regional development (Deng and He, 1999; Li *et al*., 2002; Huang *et al*., 2009; Sun *et al*., 2011). Many economically developing regions still strategically depend on fast industrialization. However, the relationship between industry′s spatial distribution and regional water environmental capacity was neglected (Zhao *et al*., 2009), which has resulted in a rapid deterioration of water quality, and has on occasion depleted

Received date: 2012-07-11; accepted date: 2012-10-22
Foundation item: Under the auspices of National Natural Science Foundation of China (No. 41130750, 70703033), ′135′ Strategic Development Planning Project of Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences (No. 2012135006)
Corresponding author: ZHAO Haixia. E-mail: hxzhao@niglas.ac.cn

the water resources supply capacity.

Many studies have shown a close relationship between water quality and industrial development. Freeman (1993) proposed that it was necessary for industrial optimizing development to study its interaction with environmental externalities, and to consider relationships between environmental pollution and other factors, such as the location of the facility. At present, domestic and international research on industrial development and environmental issues can be summarized as two aspects. First, industrial development and its spatial layout affected the regional ecological environment. However, this research was restricted to the qualitative identification of a relationship between industry and environmental pollution, and did not examine the internal impact mechanism between industry and environment (Coyle, 1997; Virkanen, 1998; Ottaviano *et al*., 2002; Verhoef and Nijkamp, 2002; Ren *et al*., 2003; Jiang, 2005; Duc *et al*., 2007). Second, researchers on water environmental capacity constraining the industrial layout believed that the location choice of the industrial area needs to account for water environmental capacity. After evaluating the environmental capacity from water resources quality and hydrological characteristics, industry development would be constrained according to the total amount of discharges control (Bao *et al.*, 1996; Bao, 1998; Tian *et al*., 1998; Zeng and Wang, 2010). Furthermore, some scholars partitioned the water ecological environment based on water environment integrated management (Xia, 1989), and then distributed a macro layout of productivity according to the special differences of water environmental capacity (Han and Wang, 2005). These works focused on the large watershed scale and industrial development control from the macroscopic scale (Wilson, 1995; Li *et al*., 2000; Sun *et al*., 2011). However, large spatial scale (trans-jurisdictional) basin management can hardly be achieved in China, as it is a country in transition (Webber *et al*., 2008). Moreover, at present, on a smaller scale, such as the small watershed or administrative unit of township (street), there have been few quantitative studies on water pollution effects or the optimization of industrial development according to the partition evaluation of water environmental capacity. And an integrated perspective with spatial consciousness is important when focusing on a regional socio-economic development and water pollution issue (Zhao *et al*., 2009).

The Taihu Lake Basin is one of the most developed areas in China (Hu *et al*., 2008). Recently, the area has been in the forefront of industrialization process in China, while at the same time it is a pivotal ecologically sensitive zone. Even after years of comprehensive treatment, the water quality of the Taihu Lake Basin is unstable and knocking its ecosystem out of balance (Stone, 2011). River inflows are the main source of pollutants to the lake watershed, thereby inducing serious ecological and sanitary problems (Gibert and Wendy, 2003; Kunwar *et al*., 2005). Surface water pollution in the Taihu Lake Basin has become increasingly serious, restricting the sustainable development of local economies (Li *et al*., 2000; Jin and Hu, 2001; Li, 2005). With the rapid formation of economic zones, led by Shanghai, the pace of industrialization and urbanization in the Taihu Lake Basin will also accelerate. As a result, loads on the ecology and environment will be aggravated, and the potential crises for river water environmental deterioration will increase (Li, 2005). Thus, the improvement of the water environment is an important issue moving into the future. The deteriorating water quality is becoming a topic of increasing concern. In order to stop this deterioration, local governments have enacted a series of integrated water environment restoration regulations, including ecological dredging, sewage interception, dynamic water-transfer, ecological restoration, and shore protection. While these measures might have helped to control water pollution, they have still not reversed the deteriorating trend completely (Sun *et al*., 2007).

In order to improve the water quality fundamentally and restore ecological health, it is important to not only focus on the restoration of the polluted water body, but also reduce pollutants by integrated regulation and management (Yang, 2004). Therefore, the research on constraint regionalization of the water environment plays a critical role in guiding the spatial layout of industry and agriculture scientifically so as to improve water quality as well as to achieve the goal of sustainable development. From the perspective of township units, this paper used ArcGIS spatial analysis tools to optimize industrial and agricultural developing space according to the water environmental constraints, which takes an innovative and completely different approach. Case studies on water quality related to industry and agriculture in the heavily polluted area of the Taihu Lake Basin, China, will be useful as a reference for other developing regions with similar environmental problems caused by rapid industrialization. The main idea of this study highlights water environmental constraints exerting on the industrial and agricultural layout, and provides a more scientific basis for both the pollutant discharge regulation and industrial and agricultural planning policy.

2 Materials and Methods

2.1 Study area

The study area is located in the western Taihu Lake Basin. It is named the heavily polluted area, due to its pollutant discharges being heavily influenced the water environment, through most of rivers flowing into the Taihu Lake. It covers parts of two prefecture-level cities, Changzhou and Wuxi, among which the parts of Changzhou City include five districts, i.e., Xinbei, Zhonglou, Tianning, Qishuyan and Wujin, and the parts of Wuxi City cover 6 districts and one county-level city, i.e., Huishan, Beitang, Chong′an, Nanchang, New District, Binhu and Yixing City (Fig. 1). The total area is approximately 5271.6 km^2, accounting for 14.3% of the whole Taihu Lake Basin (36 895 km^2). In recent years, especially after 2000, the heavily polluted area began a rapid development phase with an annual GDP increase of 20.0%, that is, its gross domestic product (GDP) grew from 1.63×10^{10} dollars (USD) in 2000 to 6.91×10^{10} dollars (USD) in 2008. Moreover, there were 7.44×10^6 inhabitants (20.6% of the local total) in 2007 and the population density was 1412 person/km^2, up to 1.16 times that of the Taihu Lake Basin as a whole and more than 10 times that of the average for China (134 person/km^2). In 2007, the total wastewater discharge in the whole area was 4.47×10^9 t accounting for 0.8% of China. In the same time, the wastewater discharge per capita was 60.1 t, but that of China only 42.1 t/person, moreover, the wastewater discharge per square kilometers was 8.5×10^4 t and was 14.6 times than that of China (5.8×10^2 t). Additionally, this area is densely covered by a water network, including Taihu Lake and 18 rivers, and numerous other water bodies. Among the 18 rivers, Wuyi Canal, Caoqiao River, Taige Canal, Xilicao River, Wujin Port, Cailing Port, Zhihu Port, Zhandu Port, and Hengtang River contribute most of the water and pollution inputs to Taihu Lake, the third largest freshwater lake in China (Li *et al.*, 2000). During the rapid economic growth and industrialization, surface water pollution has become a serious issue.

2.2 Methods

The following passage uses the concept of environmental geography to do the divisional evaluation on water environmental capacity and analyze the spatial distribution. Through the superposition analysis, the industrial and agricultural space is partitioned according to the corresponding relation between the potential of the environmental capacity and the pressure of the industry and agriculture layout.

2.2.1 Evaluation of water environmental capacity

The capacity of water environment is also called the pollutant total. It refers to the amount of pollutants that can be contained in the water environment under certain functional requirements, defined by hydrological conditions and required water quality goals. Its internal factors are the hydrological conditions and the water′s physical, chemical and biological characteristics, and the external factors are the water quality requirements and the water using function of the water environment functional partition. Additionally, the geographical condition and river basin, which is open to the outside, also have great influence on the water environmental capacity. Operationally, it is a multivariate function of both natural parameters and social parameters.

(1) Evaluation indexes.

For the same river basin, many featured indexes have similarities (for example, the degradation ability of featured pollutants). Therefore, the relative water environmental capacity is calculated, which is based on the difference of multiple indicators′ assessment (Chen *et al.*, 2008; Sun *et al.*, 2011). Based on the characteristics of the water environment in the Taihu Lake Basin, five evaluation indexes are applied to analyze the capacity of the water environment: geomorphologic characteristics, water quality goals, water body accessibility, water-dilution channels, and current water quality (Zhao *et al.*, 2012).

1) Morphological characteristics. Different types of morphological characteristics have different capacities for retention and drainage, and also have differing influence on the water environmental capacity. As runoff influx and strong erosion always happen in hilly areas, water and soil are likely to leach and the water environment of these areas is rather sensitive. Since the

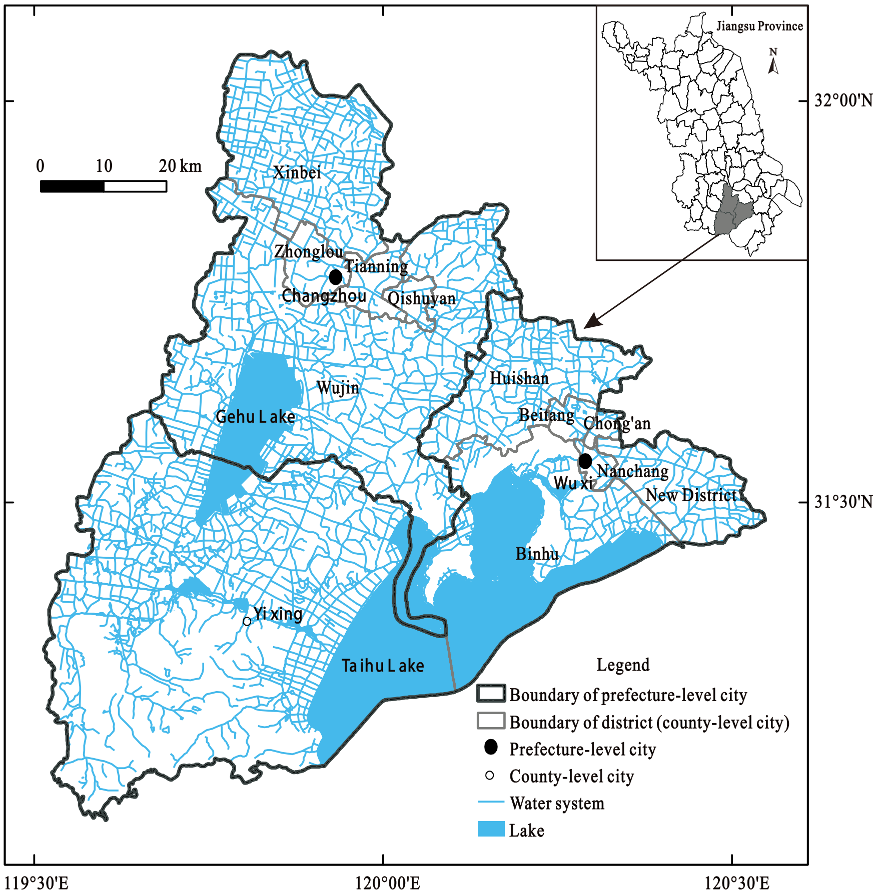

Fig. 1 Location of study area

low-terrain area has a poorer ability to treat wastewater efflux and weaker self-purification ability than water bodies in other areas, the water environment is also sensitive, but better than that of the hilly areas. Compared with them, the plains area has a much smoother water flow, so the water sensitivity is less distinctive.

2) Water quality goals. A water quality goal is a specified target of water quality that is to be achieved in a certain time period in a particular area. According to the standards of 'the Functional Division of Surface Water (Environment) in Jiangsu Province', the different targets of water qualities should be evaluated holistically. In other words, in evaluating achievement of water quality goals, the analyst needs to examine both the progress towards the target and the water environment that may or may not be impeding progress. The partitions that have the higher quality goal have lower abilities in holding the pollution in water environment, whose pressure of water environmental capacity is also bigger.

3) Water body accessibility. This index refers to the accessibility between the river system and the peripheral water systems, which is an indirect measurement of the degree of patency of the pollution discharge path for human activities. The region with a better opportunity of exchanging water with an external large water body often has a stronger ability to hold and eliminate pollutants, so the corresponding water environment will be less sensitive.

4) Water-dilution channels. Water-dilution channels are the delivery channels between inter-basin water diversion and clean water sources, which demand higher water quality and better protection than other water sources. Higher water flow of the water-dilution channels decreases the water environmental capacity.

5) Current water quality. The current water quality is the density of pollutants in the water environment, showing the extent of water function used. The higher the density of the present pollutants is, the more pressure is placed on the capacity of the water environment to control pollutants.

(2) Index weight

Heterogeneity and essentiality are considered as the most significant elements in choosing the index weights. In order to achieve more accurate and scientific results, Delphi method is applied to define the index weight (Table 1).

Table 1 Weight and standard of index for water environmental capacity

Evaluation index	Weight	Criteria	Value
Water quality goals	0.30	Above Class III	0
		IV-V class	1
		VI class	2
Current water quality	0.25	Above Class III	2
		IV-V class	1
		VI class	0
Water body accessibility	0.20	No river pass	0
		River pass indirectly	1
		River pass directly	2
Water-dilution channels	0.15	Pass	0
		No pass	1
Morphological charac-terristics	0.10	Hill	0
		Mound	1
		Low-lying water network	2
		Polder	3
		Plain	4

Note: According to literature (Zhao *et al*., 2012)

Using a geographic information system (GIS) spatial analysis method, taking into account the index value and weight, the comprehensive evaluation score of the water environmental capacity in each township unit is calculated by the weighting factor method (Chen *et al*., 2008):

$$S_i = \sum_{k=1}^{5} B_{ki} W_k \qquad (1)$$

where S_i is the comprehensive evaluation score of the water environmental capacity in township i; B_{ki} is the observation of index k in township i; W_k is the weight value of index k.

2.2.2 Overlaying method of administrative and natural boundaries

Remote sensing (RS) and GIS were used to divide the watershed into smaller units. In order to adjust the evaluation unit to make the zoning scheme and industrial and agricultural layout management more operable, the evaluation results of water environmental capacity, which take small basins as evaluation units, need to be transformed to municipal units by using a polygon overlay analysis method. The conversion formula is as follows (Sun *et al*., 2011):

$$W_i = \sum_{j=1}^{n} S_j \times \frac{AW_{ij}}{A_i} \qquad (2)$$

where W_i is the water environmental capacity of township i; AW_{ij} is the area of small basin unit j located in township i; A_i is the total area of township i; and S_j is the water environmental capacity of small basin unit j.

2.2.3 Division of industrial and agricultural spatial optimization

Using the ArcGIS spatial analysis tools, three types of partitions are applied in two different analyses, a superposition analysis of water environmental capacity and agricultural pollution discharges and a superposition analysis of water environmental capacity and industrial pollution discharges. The three partitions are optimized adjustment partitions, key adjustment partitions and common adjustment partitions.

2.3 Data acquisition and processing

Through the field investigation, the administrative map of the Taihu Lake Basin in 2011, the data on the water environment including the objectives and the status of water quality, and the pollution discharges of local industry and agriculture were collected. The objectives and the status of water quality were mainly from 'the Resource Bulletin of Taihu Lake Basin and Southeast Rivers' released by Taihu Bureau in 2009, and 'the Functional Division of Surface Water (environment) in Jiangsu Province' prepared by water conservancy and environmental protection departments of Jiangsu Province in 2003. Pollution data content the agricultural nonpoint source pollution discharges and the industrial point source pollution discharges, which were found in the census of pollution sources from Environmental Protection Department of Jiangsu Province in 2007. The data for the present situation of water quality were measured at 40 monitored sections on 18 rivers connecting to Taihu Lake.

Additionally, in order to eliminate the dimensional differences between various indicators, a maximum difference standardization method is used, which is calculated as follows:

$$X_{ij} = \frac{x_{ij} - x_{j\min}}{x_{j\max} - x_{j\min}} \qquad (3)$$

where X_{ij} is the standardized value of index j in township i; $x_{j\max}$ is the maximum value among index j; $x_{j\min}$ is the minimum value among index j ; and x_{ij} is the initial value of index j in township i.

3 Results

3.1 Industrial and agricultural effects on water environment

From this study, the industrial clustering pattern of the Taihu Lake Basin becomes clear. The pollution-intensive enterprises along the sides of rivers or the Taihu Lake show distinct spatial concentrations, which then put pressure on the water environment, especially on the protection of the Taihu Lake. From the distribution patterns of agricultural nonpoint source pollution and industrial point source pollution (Fig. 2 and Fig. 3), it can be seen that the most agriculturally polluted areas are distributed in rural townships, while less in urban areas. Industrial pollution is somewhat more concentrated, with the highest concentrations in Tianning District of Changzhou City, and west of Huishan District, Beitang District, and Chong'an District of Wuxi City. Generally, the most polluted areas are distributed along Taihu Lake, Gehu Lake and urban districts which put greater pressure on the protected areas in the Taihu Lake Basin, such as lake wetlands and water-dilution channels.

3.2 Evaluation of water environmental capacity

Through the cluster analysis method, the study area is divided into five types of water environmental capacity regions: lowest, lower, medium, higher and highest (Fig. 4). Overall, the water environmental capacity gradually decreases from the west to the east.

The areas of highest and higher water environmental capacity are mainly located in the northwest areas in Changzhou City and southwest areas in Wuxi City. Among them, east of Xinbei District and downtown of Yixing City are the regions with the highest water environmental capacity; the center of Wujin District, north of Xinbei District, west of Huishan District and areas around Yixing downtown have higher water environmental capacity. The water environmental capacity is relatively high in areas along the river and the lake, due to the water accessibility and powerful exchange capability. The regions where the capacity of the water environment is lowest and lower are mainly distributed along Taihu Lake and Gehu Lake. Affected by the

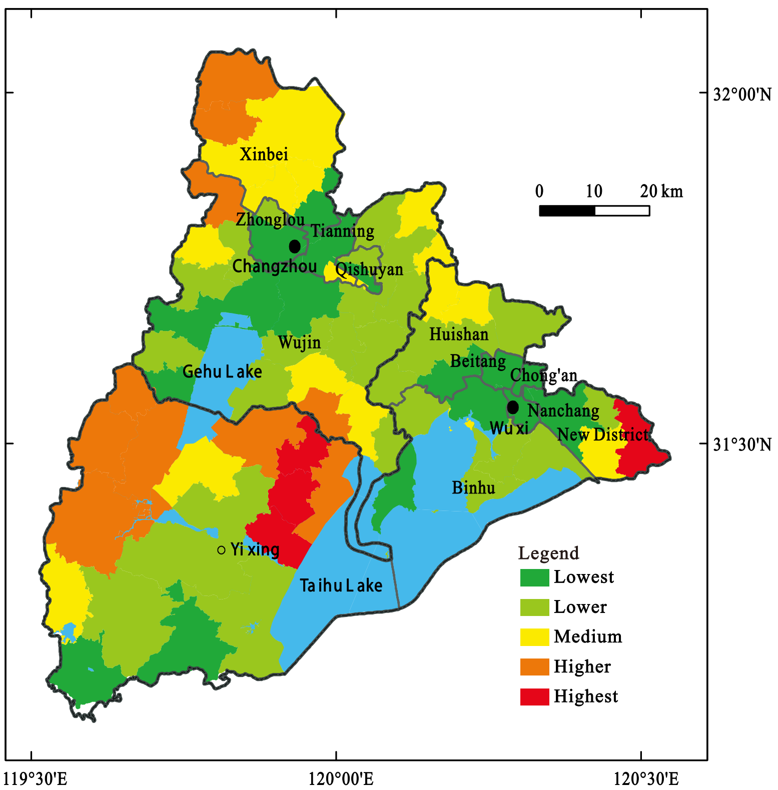

Fig. 2 Spatial distribution of agricultural pollution

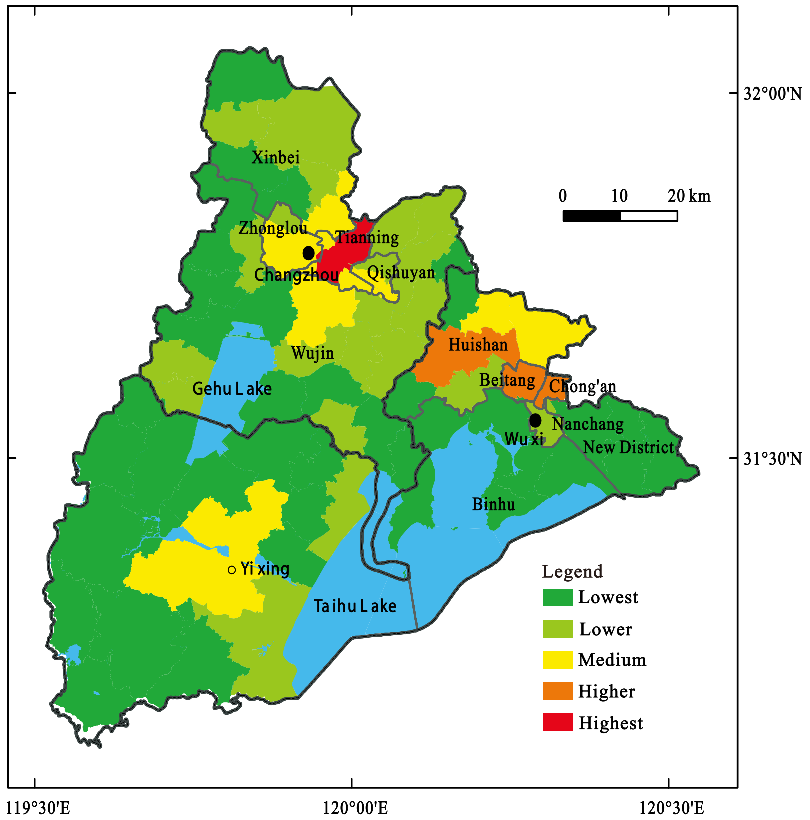

Fig. 3 Spatial distribution of industrial pollution

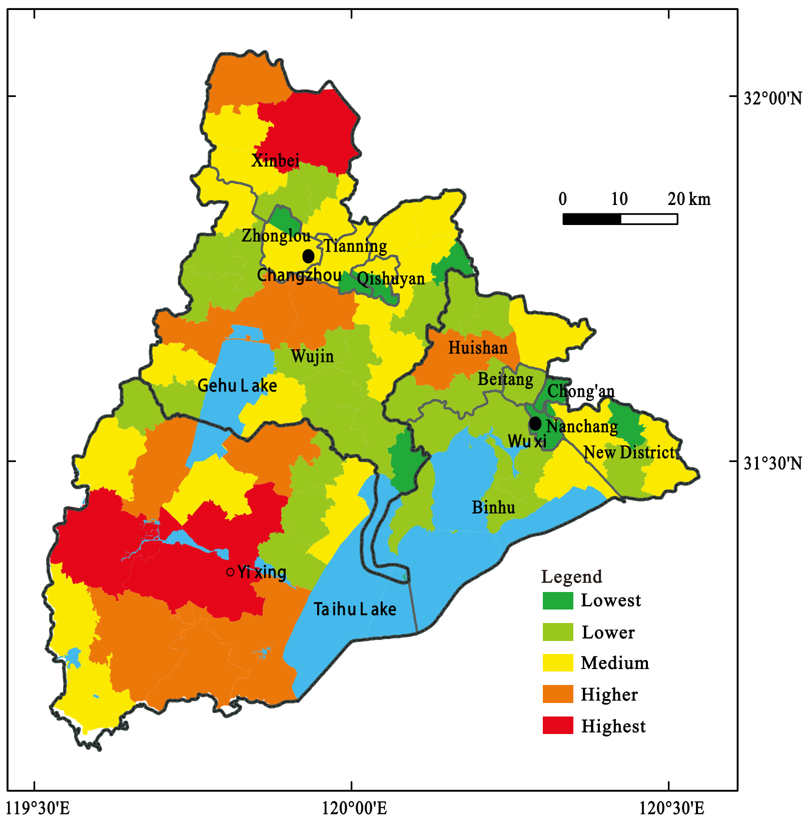

Fig. 4 Subregion of water environmental capacity

source of drinking water, the water-dilution channels and the important wetland, the water environment is more sensitive, and its carrying capacity is low. Regions where the water environmental capacity rates as medium are scattered in the urban areas, mainly in Wuxi City. Above all, the spatial distribution of the water environmental capacity does not correlate with the distribution of industrial pollution. Therefore, it is possible to further optimize industrial space based on the water environmental capacity constraints for the heavily polluted area of the Taihu Lake Basin.

3.3 Optimization based on water environmental capacity constraints

Through overlay analysis, the study area is divided into three types of areas: key adjustment areas, optimal adjustment areas, and general adjustment areas, according to the corresponding relations between the water environmental capacity support and either agricultural or industrial pollution pressure.

3.3.1 Optimization and guidance for agricultural layout

According to the water environmental capacity and agricultural pollution discharges, units with low capacity and heavy pollution are key adjustment areas; units with high capacity and heavy pollution or low capacity and less pollution are optimal adjustment areas, and units with high capacity and less pollution are general adjustment areas (Fig. 5). Each of these adjustment areas is explained in detail as follows.

(1) Key adjustment areas

Mainly located in key protected areas of the Taihu Lake Basin and the shores of Gehu Lake, key adjustment areas cover 1075.61 km^2, 25.2% of the total area, including the north and east of Yixing City, south of Wujin District and east of Binhu District (Fig. 5). In these areas, agriculture is well developed. However, as a result of the widespread use of fertilizers and pesticides, agricultural nonpoint source pollution is large. The sensitivity of the water environment is high, and as a result, agricultural activities have had significant impact on the water environment. In order to control agricultural nonpoint source pollution, the development of efficient, ecological and safe agriculture should be encouraged. This includes promoting the use of bio-organic fertilizer and low-residue and efficient pesticides and practicing

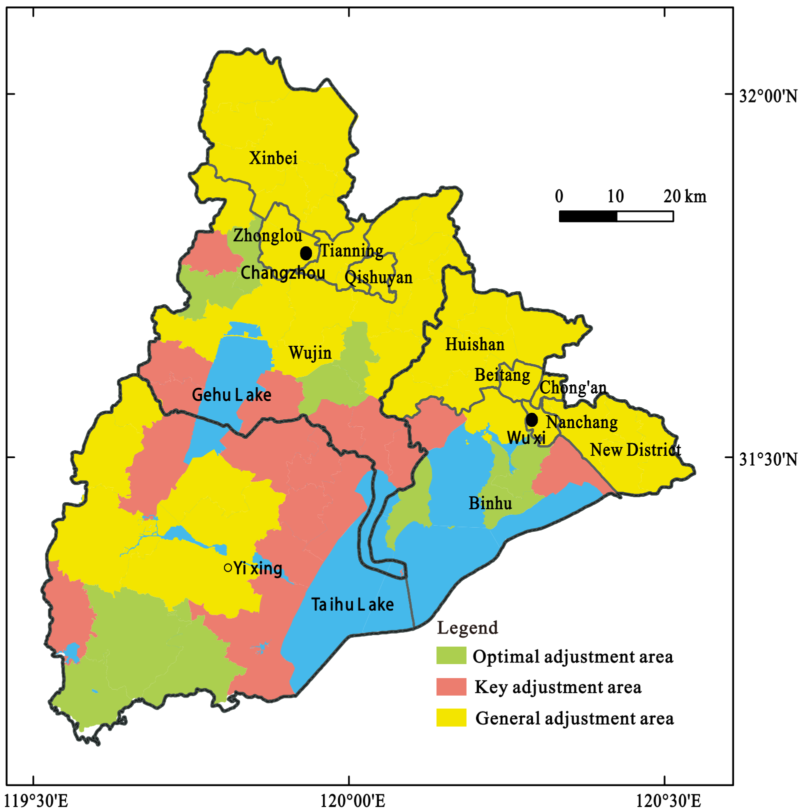

Fig. 5 Optimization of agricultural subregion

clean cultivation on a largescale.

(2) Optimal adjustment areas

Optimal adjustment areas cover 638.18 km^2, 14.9% of the total land area, and are mainly located in the second protected areas of the Taihu Lake Basin, including the south of Yixing City, the west of Binhu District, the south and west of Wujin District (Fig. 5). Farming is developed, though as yet it has not had a large impact on the water environment. However, the risk of water pollution is great because of the poor recovery ability of aquatic ecosystems. In the future, it will be necessary to encourage efficient, ecological and safe agriculture in the suburbs, focus on the development of green, organic agricultural products, highlight the forestry economy with water conservation and ecological protection functions, control large-scale cultivation in the reservoirs and embankments, and reduce the feeding intensity of bait to effectively control nitrogen and phosphorus pollution on the surface runoff.

(3) General adjustment areas

Mainly located in the urban areas of Changzhou and Wuxi cities, general adjustment areas cover 2517.43 km^2, accounting for 58.9% of the total land area. In these partitions, the capacity of the water environment is higher. In order to effectively protect the water environment, constructing a green food base, standardizing the agricultural products processing base, optimizing the existing planting structure, reducing the use of agricultural chemicals, implementing an improved scale of cultivation, and adjusting measures to local conditions to develop horticulture at the same time should all be encouraged.

3.3.2 Optimization and guidance for industrial layout

According to the water environmental capacity and industrial point source pollution discharges, units with low water environmental capacity and heavy pollution belong to optimal adjustment areas; units in which capacity is high and there is heavy pollution or in which capacity is low and there is less pollution are the key adjustment areas; and units in which capacity is high and there is less pollution are general adjustment areas (Fig. 6).

(1) Key adjustment areas

Mainly located in the downtown of Changzhou and Wuxi cities, along the Jiangnan Canal and the Shanghai-Nanjing railway, and the north of the Yili River in

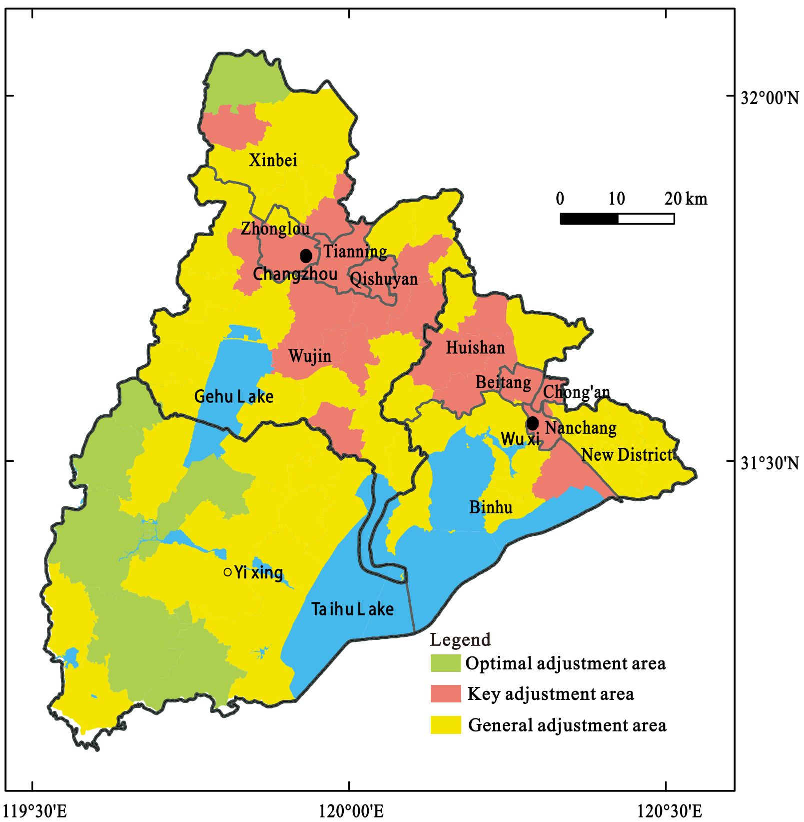

Fig. 6 Optimization of industrial subregion

Yixing City, key adjustment areas cover 1238.51 km^2, accounting for 29.3% of the total land area. In this area, the traditional pollution-intensive enterprises are concentrated, such as textiles, chemicals, paper making, steel, electroplating, and food manufacturing, and consequently their strong intensity of sewage discharges has great impact on water ecosystems. The most urgent tasks to combat this are to focus on renovating the heavily polluting industrial enterprises, transforming and enhancing the level of production technology of major polluting enterprises above a designated size using improved technology, and adopting the comprehensive improvement of eliminating, transforming and concentrating on renovating the polluting enterprises under the scale.

(2) Optimal adjustment areas

Mainly located in the key protected areas, the second protected areas of the Taihu Lake Basin, and outside of key adjustment areas, the optimal adjustment areas cover 2272.82 km^2, accounting for 53.7% of the total area. The water environment is sensitive, but the capacity of the water environment is not high. In order to improve this before the deadline, it is urgent to optimize industry structure, concentrate industries to the industrial park, conduct a mandatory audit of clean productions, construct the eco-industrial park, develop the circular economy, raise the industry environmental threshold and make sure that the industrial enterprises along the Wangyu River, Desheng River and other water corridors relocate before the Chinese government′s deadline for treatment.

(3) General adjustment areas

General adjustment areas cover 719.88 km^2, accounting for 17.0% of the total area, mainly located in the agro-ecological zones. Their hydrological functions are regulation and storage, and their ecological functions are soil and water conservation. They are distributed in the south and southwest townships of Gehu Lake and generally belong to the restricted development zones. These areas can be improved by limiting the ability of concentrated industrial parks in townships to blindly expand, altering, relocating or shutting down the enterprises with serious pollution in order to improve the environmental capacity and development space, relaxing the industry access threshold appropriately, and putting prohibitions or restrictions on the quarry layout of the mine sites.

4 Conclusions and Discussion

This paper used the theory and methods of environmental geography. It is represented by the water environmental capacity constraint index, which is calculated by measuring five things: geomorphologic characteristics, water quality goals, water body accessibility, water-dilution channels and current water quality. Using ArcGIS spatial analysis tools the water environmental capacity was calculated from the spatial analysis of the townships and the watershed. The degree of industrial or agricultural pollution discharge was also measured. Utilizing overlay analysis of potential environmental capacity and two measures′ pressures, the study area was divided into three types of areas: key adjustment areas, optimal adjustment areas and general adjustment areas. In order to optimize the space layout of industrial and agricultural agglomeration, a scheme of industrial and agricultural development was proposed to minimize water pollution based on the constraints of the capacity of the water environment. As a result of the above research, the following conclusions have been drawn:

(1) The water environmental capacity has obvious spatial differences in the study area. The areas of water environmental capacity rated highest and higher are mainly located in the northwest areas in Changzhou and southwest areas in Wuxi. As a result of the water accessibility and powerful exchange capacity, the water environmental capacity is relatively high. The regions mainly distributed along Taihu Lake and Gehu Lake are affected by the source of drinking water, the water-dilution channels and the important wetland, and the capacity of the water environment is rated lowest and lower.

(2) The pollution caused by industrial agglomeration of the study area is mainly distributed in the townships along Taihu Lake, Gehu Lake and urban districts, which has an effect on protection of the wetland reserve in the Taihu Lake Basin and the water-dilution channels. The spatial distribution of the water environmental capacity does not correlate with the distribution pattern of industrial pollution.

(3) For the agricultural optimization, it is urgent to focus on adjusting the key protected areas of the Taihu Lake Basin and shores of Gehu Lake by developing efficient, ecological and safe agriculture so as to control agricultural pollution. It is needed to optimally adjust

the second protected areas of the Taihu Lake Basin by developing suburbs sustainably, growing organic agricultural products, and effectively controlling surface runoff pollution. The urban districts in Changzhou and Wuxi cities can be generally adjusted by optimizing the existing planting structure and reducing agricultural chemicals.

(4) For the industrial optimization, the priority is to focus on renovating the heavily polluting industrial enterprises in the downtown areas of Changzhou and Wuxi cities. To optimally adjust key protected areas and second protected areas of the Taihu Lake Basin, it is necessary to raise the environmental threshold and ensure industrial enterprises are relocated before the deadline for treatment along the Wangyu River, the Desheng River and other water corridors. The south and southwest townships of Gehu Lake can be improved by alternating, relocating or shutting down the enterprises with serious pollution and widening the industry accessing threshold appropriately for the others.

Water environmental capacity is an important measure to evaluate the suitability of industrial structure and layout in a region. Previous studies showed a close relationship between the regional division and space organization of industry and changes in the environment (Lin and Feng, 2008). Therefore, the choice of industrial location needs to take into account the constraints of the environmental capacity (Cao and Bao, 1998). As an important part of the environment, water environmental capacity could restrict the amount of sewage discharge based on the self-purification ability and pollutant bearing capacity of the water environment given a certain objective of water quality and quantity (Chen *et al.*, 2008), and thus also restrict the industrial pattern in specific regions (Tian *et al.*, 1998). Some studies have shown that the industrial space layout is the main reason behind shortages of water resources, increasingly severe environmental pollution, and the threatened ecological security in the Changjiang (Yangtze) River Delta (Wang *et al.*, 2003), so a reasonable industrial layout is an important measure to coordinate industrial development and water pollution (Wang and Liang, 1995). Therefore, in order to propose effective strategies of water pollution control and management, it is necessary to distinguish the regional water environmental capacity according to the differentiation of the main rivers′ water environmental capacity (Bao *et al.*, 1996). The most heavily polluted areas, therefore, need to develop a strict threshold based on the constraint functions of the water environmental capacity and the water pollution control target, to guide the optimal adjustment of industrial structure and layout. If an area′s pollutant bearing capacity is still good but there are significant resource or environmental problems, a mandatory industry access threshold should be developed based on the aspects of water consumption, water environmental impact, production scale, technology and other criteria deemed appropriate for a specific case, according to the short board for water environmental capacity. While still supporting characteristics of industries in line with the dominant function of an area, pollution-intensive industries should be distributed in the areas with a larger capacity in the water environment, however, the areas short of water environmental capacity or more sensitive to the water ecosystem should be shifted to develop high-tech and high value-added industries. It is necessary to form an industrial spatial structure that takes into account relative concentrations and is appropriate to the water environmental capacity.

Based on the balance between potential environmental capacity and industrial or agricultural pressure, the spatial optimization of agriculture and industry is adjusted in this research, which provides a new perspective for the discussion of the mechanism between industry agglomeration and the water environmental capacity of an area, and also provides a theoretical basis about how the industrial cluster space is optimized in the Taihu Lake Basin during the transformation period. However, the following areas would benefit from further research. First of all, because of the material and data source, there are some limitations in quantity and representative aspects about the characterization index of water environmental capacity. Therefore it would be beneficial to do further research to obtain more precise numbers. Second, because of the availability of the data, this analysis was only able to consider the indexes of the water environmental capacity and industrial and agricultural pollution discharge, but was not able to subdivide the industrial agglomeration elements that have an impact on the water environmental capacity, which have been identified in research on the optimization scheme of industrial cluster space. Future studies should seek to establish a feasible association mechanism for the mutual coupling mechanism between industrial space and water environmental capacity.

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