Outcome 3.1.1 "Reduced pollutant levels by enforcement and control in demonstration sites"

Deliverable 11：

Land based nutrient loading in Haizhou Bay

(Final Report)

National Marine Environmental Monitoring Center

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Content

1. Background

Coastal waters provide habitat for some of the most productive ecosystems on earth. These resources are in danger from eutrophication and other problems caused by excess inputs of nutrients, especially nitrogen and phosphorus. Nutrient over-enrichment can cause a range of economic and non-economic impacts, including eutrophication and associated anoxia and hypoxia, loss of seagrass beds and corals, loss of fishery resources, changes in ecological structure, loss of biotic diversity, and impairment of aesthetic enjoyment. Impacts resulting from nutrient over-enrichment also can cost millions of dollars in lost revenue from tourism or harm to the seafood industry(NRC,2000). Because rivers transport the vast majority of nutrients reaching coastal waters, the concentration of land-borne nutrients tends to be high from the rivers. So, watershed management offers real possibilities for reducing the nutrient runoff carried in rivers to the coastal water.

Globally, the coastal ocean can be subdivided into large marine ecosystems (LMEs) distinguished by specific physical environments and biological functioning (Sherman and Duda, 1999; Sherman et al., 2009). The LME approach for ecosystem-based management is based around the 5-modules of productivity, fish and fisheries, pollution and ecosystem health, socioeconomics, and governance. Yellow Sea Large Marine Ecosystem (YSLME) is one of the 63 LMEs.

Recently, Lee et al., estimated the nutrient load from land-based sources to the 63 LME in a global perspective (Lee et al., 2015), the result showed the smallest loads were exported to many polar and Australian LMEs, while the largest loads were exported to northern tropical and subtropical LMEs. The LMEs receiving the largest loads of land-based nutrient were the North Brazil Shelf, Bay of Bengal, Guinea Current, South China Sea, East China Sea and Gulf of Mexico LMEs. The Dissolved Inorganic Nitrogen(DIN) load to the YSLME was about 100,100~250,00 t/a, showed YSLME was a relatively lower nutrient load region compared others regions around the world, and equal to the region of the west coast of North American and Japan sea. The research also showed that most of the nutrient load was related to agricultural sources especially fertilizer and manure.

So, even we found the nutrient loading in the Yellow Sea is not the largest loads region around the world, but the increasing discharge of pollutants and eutrophication is one of the key environmental issues in the Yellow Sea according to the Transboundary Diagnostic Analysis (TDA) and reducing the pollutant levels of nutrients and identifying the source contribution based on demonstration activities is one of the goals in the YSLME phase II project.

As we can see in the figure 1, the algae bloom had been a key environmental issue in the Jiangsu coastal areas, a very high frequency of algae blooms was found in the last decades according to the monitoring data. According to report, the frequency of algae blooms in the Jiangsu Province coastal area was 33 times from 1997 to 2014, especially in Haizhou Bay, highest algae blooms frequency was recorded (OFBL, 2011).

Haizhou Bay lies on the western margin of the South Yellow Sea, near the city of Lianyungang, and receives water flow mainly from the Linhong River, Qingkou River, Longwang River and Xiuzhen River. The bay is shaped like a trumpet and has an area of approximately 876.39 km^2. The length of the coastline is about 170 km, and its maximum width is approximately 42 km. Haizhou Bay is a major fishery base, aquaculture industries boost economic growth in Lianyungang, and culture area grown by 4.3 times from 1995 to 2005 (OFBL, 2011). Also due to the significant economic development, lots of domestic sewage and industrial waste water were discharged into the sea transported with the Linhong River, according to the recent reports, the Linhong River carried 2.26 10^8t of domestic sewage and industrial wastewater to Haizhou Bay in 2010 (EPAL, 2011; OFBL, 2011).

So, for better understanding eutrophication and the algae blooms in this YSLME region，the Haizhou Bay was selected as the demonstration area for analysis the magnitudes and sources of nutrient loading to Haizhou Bay.

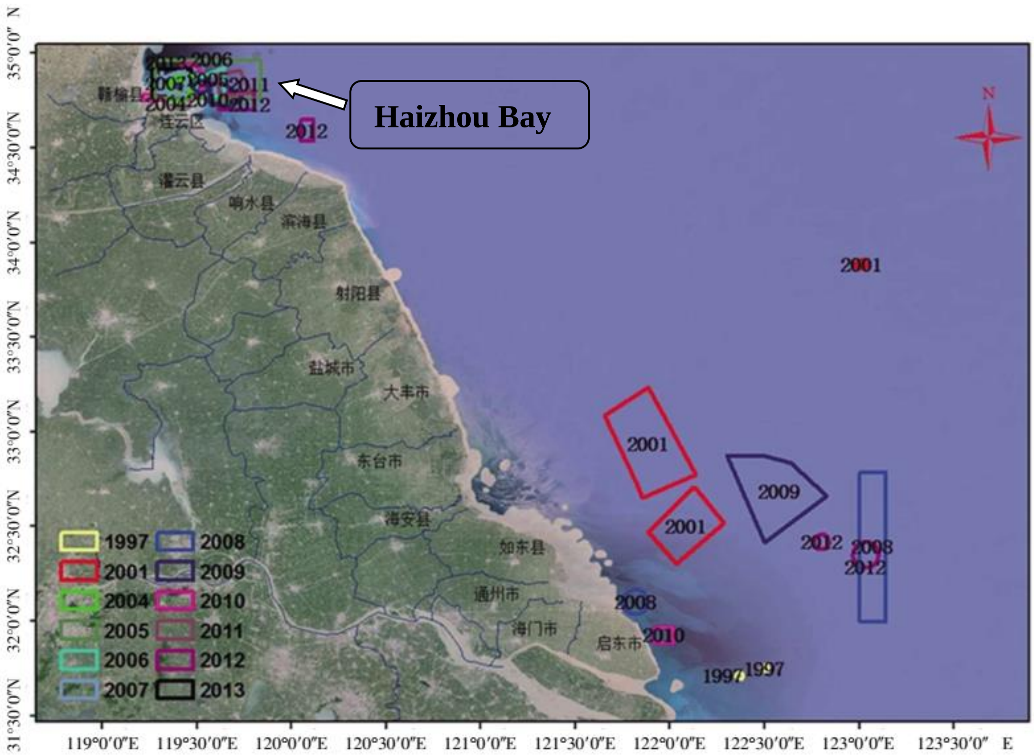

Fig.1 Records of algae blooms in Jiangsu coastal

National Research Council. 2000. *Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution*. Washington, DC: The National Academies Press

2. Objectives of the project

In Outcome 3.1 of Component 3 entitled "Ecosystem improved through reduction in pollutant discharges (Nutrients) from land-based sources", the project will generate a series of activities focusing on the reduction of nutrient discharge to Yellow Sea. Output 3.1.1 of Outcome 3.1 can specifically serve as an example to apply modelling and calculate nutrient loading in hot spots/critical habitats for local government to reduce nutrient pollutant.

The underlying objective of the proposed consultancy is to apply a watershed model and estimation of land-based nutrients loading in hot spot in PR China (i.e. Haizhou Bay). And there are two outputs expected in this project.

(1). To describe the watershed model for estimation of nutrients loading in the hot spot;

(2). To calculate the nutrients load and identify the nutrients sources, and give advice on appropriate nutrient control and reduction schemes for the local government agencies.

3. Review of Watershed model

Non-point source pollution models can be classified into functional and mechanical models. The former is mainly used to calculate the average annual pollution load of non-point source in the basin without involving the specific process and mechanism. It is not suitable for short-term calculation. The latter is based on the specific process of the occurrence, migration, transformation and influence of non-point source pollution, and covers the intermediate process or internal mechanism (Xia,2011).

3.1 Export coefficient model

In the export coefficient method, land use, fertilization amount, livestock, population and other data are used to estimate the output of land-based pollutants, and the amount of land-based pollutants entering the sea can be estimated by establishing a connection between the source of pollution and the receiving water.

Since the data requirement of export coefficient method is relatively easy to obtain, and this type of model proves to be a suitable method for estimating the pollution load from land sources with large scale, which, otherwise, is lack of monitoring data.

At present, the commonly used export coefficient method mainly includes Jones export coefficient method and improved export coefficient method etc. (Cai Ming, 2004,). The key to the application of output coefficient method is how to determine the output coefficient and the correction coefficient under various conditions, which can be based on typical sample area. The monitoring data, survey data or literature review methods are used to obtain the output coefficients of different pollution sources in the study area.

The key point of using export coefficient method is about determining which coefficient can be used and refining the coefficient under the study area, and generally, the coefficient in different pollution sources in the study area can be obtained based on the monitoring data, investigation data or literature review.

Another key point in applying the export coefficient method is about how to establish the connection between the land pollution source and the receiving water body. During the pollutant transport, loss of pollutant by physical and biochemical processes may occur, such as retention process in soil and vegetation, penetration into groundwater, sediment adsorption and degradation. Especially in large scale watersheds, the loss is more significant due to the runoff and overland flow over time, and the variety of terrain, landforms and vegetation, and land use (Cai Ming, 2004).

3.2 Distributed Watershed model introduction

The watershed models usually are applied for the land-based pollutants load in the basin-scale, usually for the nonpoint sources' estimation. The mechanism of migration and transformation of pollutants in the basin should be considered for watershed models, such as hydrological process and soil erosion etc. To build watershed model, a series of the data, in terms of topography, climate, hydrology, land use, soil, and vegetation etc, are needed.

At present, the commonly used watershed models mainly include SWAT (Soil and Water Assessment Tool), AnnAGNPS (Annualized Agricultural Non-point Source Pollution), HSPF (Hydrological Simulation Program-FORTRAN), MONRIS (Modeling of Nutrient Emission in River Systems), SPARROW (SPAtially Referenced Regressions On Watershed attributes), etc. (Yao,2012; Wang 2007; Jin 2006). A feature of this type of model is the combination of 3S and model. By using GIS spatial information management tools, a visual simulation system can be developed. For example, the ArcSWAT model developed by Arnold can be used as a component to integrate the SWAT model in ArcMap, and the HSPF model is embedded in the BASINS system developed by the US Environmental Protection Agency, and visual operation applications are also provided in the AnnAGNPS, MONRIS, and SPARROW models.

3.2.1 SWAT

SWAT is a watershed scale model developed by the US Department of Agriculture (USDA) based on the GLEAMS, CREAMS, EPIC, SWRRB, and ROTO models. The entire simulation process of the model includes two parts: land surface hydrological process (runoff generation and overland flow) and water surface process (river flow). The land surface hydrological process controls the inputs of runoff, sediment, and pollutants in the main channel of each sub-catchment, including eight modules on climate, hydrology, sediment, soil temperature, crop growth, nutrients, pesticides, and agricultural management. The water surface process determines the transport of runoff, sediment and pollutant from the river network to the outlet of the river basin, including two modules for calculation of river runoff and reservoir water balance (Tian,2009; Zhang,2009; Wang,2003).

The SWAT model has been applied to the pollutant load calculation around the world. To use the model, firstly, the hydrological characteristic parameters are extracted by DEM data in the basin, and the watershed is divided into several sub-catchments according to a certain threshold. Based on this, the hydrological response unit (HRU) is further divided according to the land use and soil area threshold. After introducing the data of meteorology, hydrology, land use, soil type, agricultural management measures, point source loading etc., a conceptual model was used to estimate the net rainfall on HRU, and the yield of flow, sediment and pollutant load.

3.2.2 AnnAGNPS

AnnAGNPS is a continuously distributed model developed by the US Department of Agriculture (USDA) based on the AGNPS model. The model is mainly composed of a hydrological sub-model, a soil erosion sub-model and a chemical transport sub-model. For the hydrological sub-model, SSO (Soil Conservation Service Curve Number) curve method (CN) is used to estimate the daily surface runoff. For the soil erosion sub-model, a corrected soil loss equation (RUSLE) is used to calculate the amount of sheet erosion and gully erosion in each sub-catchment, and soil loss equation (HUSLE) is used to simulate the migration of sediments and nutrients in the channel. And then using the pollutant transport model, the production, migration and load of nitrogen, phosphorus and organic carbon can be simulated.

According to the characteristics of watershed topography, soil type and land use, the model divides the study area into some cell units, and the contribution of each unit to the pollution load is independent. By calculating the load separately in each unit, the runoff, soil erosion and pollutant loss are connected by the river network, and the total runoff is calculated according to the average slope and aspect of the cell units, and the total amount of soil erosion and the output of non-point source pollution in the river basin can be obtained.

The AnnAGNPS model can be used to simulate and assess the surface runoff, sediment erosion and nitrogen and phosphorus nutrient loss in the watershed. The model has been successfully applied in Liaohe river basin, Dagu river basin, Taihu lake basin, , Jiulong river basin in China in recent years (Lin,2012; Wang,2014; Li,2015; Hong, 2005).

3.2.3 HSFP

HSPF model is developed for pollutant load calculation from agriculture and urban activites by USEPA in 1980 on the basis of SWM(Stanford watershed model), HSP(hydrologic simulation program), ARM (agricultural runoff management) and NPS(non-point source runoff) (Xue,2009; Li, 2012). The HSPF model mainly includes hydrological water quality module of permeable section, hydrological water quality module of non-permeable section, and hydrological water quality module of surface water body. Under the three modules, it is divided into several sub-modules according to functions to realize continuous simulation of transport and transformation of pollutants such as runoff, sediment, nitrogen and phosphorus.

BASINS system was developed by U.S. environmental protection agency in 1998, in which the HSPF model was embedded in. The system consists of GIS integrated analysis tools (BASINS GIS), analysis software (WDMUtil), watershed hydrological model (WinHSPF, etc.) and decision support analysis (GenScn). The system can automatically extract the data of terrain, landform, land use, soil, vegetation, river and other data needed for the simulation in the study area and carry out long-term continuous simulation of non-point source pollution load. Compared with the SWAT model, the HSPF model can simulate in a minimum time-scale of hours.

3.2.4 SPARROW

SPARROW is a nonlinear regression model developed by the US Geological Survey (USGS). The models can be used to estimate the amount of a contaminant transported from inland watersheds to larger water bodies by linking monitoring data with information on watershed characteristics and contaminant sources. The load of the river section is taken as the dependent variable, and the pollution source and the spatial attribute of the watershed as the independent variable to establish the nonlinear equation, which fully takes into account the relationship between the upstream and downstream of the river, and the transmission of pollutants in the land surface and river water body and can more accurately reflect the entire process from the source to the sink. The simulation equations are calibrated using the monitoring data of the river section, and the nonlinear least squares method is used as the equation parameters based on the Statistical Analysis System (SAS) (Xie,2012; Wu, 2010).

The SPARROW model is based on the mechanism of migration and loss of pollutants in the river water. The nonlinear regression technique is used to spatially correlate river water quality monitoring data with land-based pollution sources, and soil and surface water characteristics that may affect migration progress. The most prominent feature of the SPARROW model is the combination of a mechanism model and a statistical model to estimate the land-based pollution load. Compared with the mechanism model such as SWAT, SPARROW requires fewer observation data and lower monitoring frequency, and it is more suitable for the calculation of large and medium-sized watersheds. Compared with the complete statistical model, the process of generation and migration of terrestrial pollutants are associated with the loss process in the river channel.

Table 3.1 Comparison of the watershed model

Model	Time scale	Model type	GIS or RS tools used	Advantage	Disadvantage
Export coefficient model	year	/	yes	suitable method for estimating the pollution load from land sources with large scale and lack of monitoring data.	fail to take into account the transport and migration of the pollutants in the river basin
SWAT	day	Distributed	yes	can predict Long-term effects of the process of water cycle, sediment, nutrients and pesticides by the climate change, land cover, and agricultural management measures	Insufficient simulation of river channel transport process for nutrients
AnnAGNPS	day or hours	Distributed	yes	Simulation of surface runoff pollution load of nitrogen and phosphorus , continuous simulation of groundwater nutrient balance	fail to take into account the spatial difference of precipitation
HSPF	hours	Distributed	yes	Continuously simulate the migration and transformation of pollutants such as sediment, nitrogen, phosphorus and pesticides	Relatively low spatial resolution，not applicable to long-term simulations of watershed processes
SPARROW	day	Distributed	yes	estimate land and water body parameters respectively, quantitative description of pollutant migration rate and transport in river networks	The first-order attenuation equation is used in the model， and the same reduction rate is used in the same graded river section.

3. Method for nutrients loading calculation in the hot spots

3.1 Workflow

According to the comparison of the method given above, and the data availability in the study area, the exports coefficient model will be employed for the nutrient calculation in Haizhou Bay. The workflow adopted is shown as in Fig.3.1

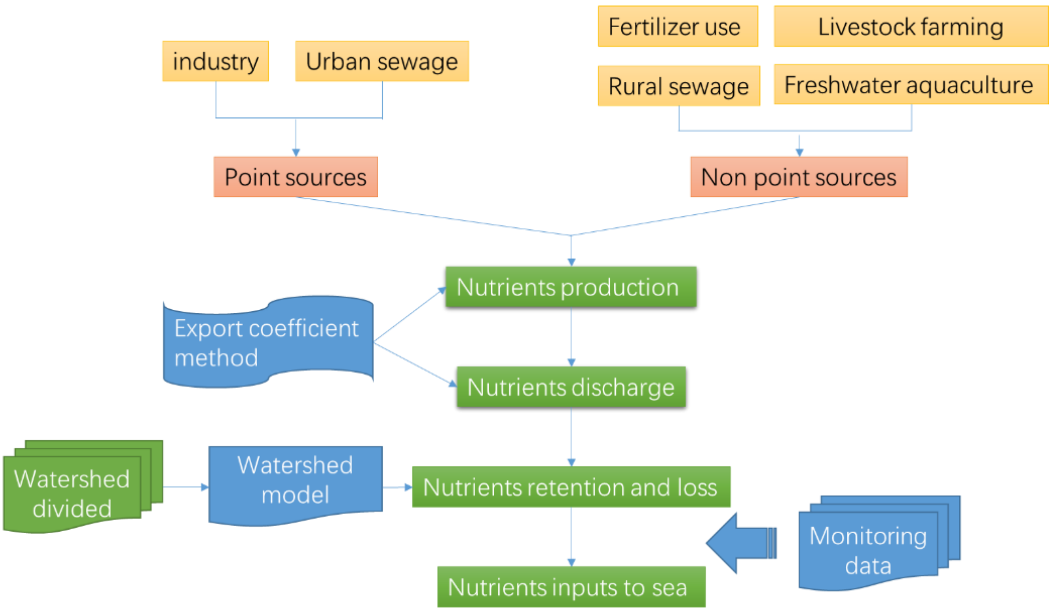

Fig.3.1 The workflow for the nutrient load calculation

According to the Also, we defined Lianyungang city as the key watershed study area. Because of most of the rivers flow into Haizhou Bay originates in Lianyungang city, and although some rivers originate in Shandong province, hydrological change may be human-controlled, such as Linhong river, the water flow is controlled by the dam of Shilianghe reservoir. So, we hoped to identify the nutrient sources by focusing on Lianyungang city as the key watershed study area. And, the total nutrient loading was defined as two parts: the loading that flows into Lianyungang city which can be calculated by the monitoring data from entry section and the loading from the production in Lianyungang city itself.

And some of the terms used in the present report are noted as follows:

(1)Nutrient production: the magnitude of original nutrient pollutants produced during a given period under normal production and management conditions.

(2) Nutrient discharge: the magnitude of original nutrient pollutants to the surface water by the runoff with the precipitation that had been reduced or utilized by treatment facilities (or not) under normal production and management conditions.

(3) Nutrient loading to the sea: In the process of pollutant transport from water body to estuary and seawater, some of the nutrient pollutant will be retained in the catchment system due to the physical and biochemical process, Nutrient loading to the sea means the portion of nutrient discharge that the magnitude of nutrient retained in the river water environment had been subtracted.

3.2 Data collection

For calculation of the nutrient loading in Haizhou Bay using the export coefficient model, the data was collected including river network, DEM, land use, river water flow, magnitude and type of livestock farming, urban and rural population, industry wastewater discharge, fertilizer use etc. all of the data was collected from the Statistical yearbook of Lianyungang City, Marine Environment Quality Bulletin of Lianyungang, Environment Quality Bulletin of Lianyungang, and published reports, literatures and online resources.

3.3 Field investigation

3.3.1 River entry section investigation

For better understanding the nutrient loading transferring to Lianyungang city by rivers, filed investigation was conducted in July 2018. Based on the field investigation, there are 5 rivers that originate from the region out of the Lianyungang city, and nutrients pollutants from other cities in the upper catchment areas may transferred with the rivers to Lianyungang city. According to the data collected from the local hydrology and water resources survey bureau, the total river waterflow into Lianyungang city in 2016 was about

13.7 $\times 10^8 m^3$, and the details of the entry sections of rivers to Lianyungang city is listed in the table 3.1.

Table 3.1 Major information of entry sections of rivers to Lianyungang city

Orders	River name	Entry section location		Waterflow into Lianyungang city in 2016（$10^8 m^3$）
		longitude	latitude	
1	Xiuzhen R	-	-	0.9299
2	Qingkou R	-	-	0.1960
3	Longwang R	119.06126	35.05812	0.244
4	Xinshu R	118.73724	34.762968	4.391
5	Shuxin R	118.832848	34.368528	7.910

3.3.2 River sea control section investigation

Based on the field investigation, there are 12 rivers to the Haizhou Bay, according to the data collected from the local hydrology and water resources survey bureau, the total river waterflow into Lianyungang city in 2016 was about 10.2 $\times 10^8 m^3$, and the details of the rivers into Haizhou Bay is listed in the table 3.2. And it can be found that the the amount of river inflow to Haizhou Bay is less than the amount of river flow to Lianyungang city, which may be mainly due to the large amount of water consumption in Lianyungang city, and the fact that for the freshwater demand and prevention of seawater erosion, almost every river is controlled by the tidal locks, there may be little water flows into the sea in the dry season, but may dramatically increase in the wet season.

Table 3.2 Major information of rivers to Haizhou Bay

Orders	River name	Sea control section location		Waterflow into Haizhou Bay in 2016（$10^8 m^3$）
		longitude	latitude	
1	Xiuzhen R	119.267	35.117	0.927
2	Tuowang R	119.219	35.062	0.078

3	Shiqiao R	119.195	35.057	0.072
4	Hankou R	119.174	34.998	0.093
5	Longwang R	119.128	34.974	0.526
6	Guanzhuang R	119.151	34.930	0.328
7	Xingzhuang R	119.159	34.894	0.089
8	Shawang R	119.161	34.852	1.043
9	Qingkou R	119.158	34.823	0.205
10	Zhuji R	119.159	34.814	0.038
11	Linhong R	119.212	34.768	6.661
12	Paidan R	119.278	34.734	0.184

3.2 Method detail for nutrient loading calculation

3.2.1 Calculation for nutrient loading flowing into Lianyungang city

The nutrient loading flowing into Lianyungang city was estimated based on the monitoring data in the entry section of the national surface water monitoring network. The calculation was estimated by the concentration in the water and waterflow of the river, showed as follows:

$$Load = K\left(\sum_{i=1}^{n}\frac{c_i}{n}\right)\overline{Q_r} = K\cdot\bar{c}\cdot\overline{Q_r}$$

In which, n means the monitoring frequency, c_i means the concentration of the nutrients in the water; $\overline{Q_r}$ means the average waterflow.

3.2.2 Export coefficient method for nutrient production

(1) Industry nutrient production

The industry nutrient production was estimated as follows:

$$P_{ind} = D_{ind} / [(1 - \lambda_{ind}) + \lambda_{ind} \times (1 - \eta_{ind})]$$

In which, P_{ind} means the nutrient production by the industry wastewater,

D_{ind} means the nutrient discharge of the industry wastewater,

λ_{ind} means the Industrial wastewater treatment rate, according to the literature, 98% of industrial wastewater treatment rate was used in the present research.

η_{ind} means the treatment rate of nutrients in the wastewater, the treatment rate of 75% and 85% was used for nitrogen and phosphorus respectively in the present research.

(2) Urban sewage nutrient production

Urban sewage nutrient production was estimated as follows, in which the permanent urban residents data was collected from the Statistical yearbook of Lianyungang City in 2016, and the nutrient production coefficient was collection from discharge coefficient manual of the first national census of domestic source pollution, and the production coefficient of 10.36 g/p.d and 0.90 g/p.d was used for the nitrogen and phosphorus respectively in the present research.

$$P_{urb} = 3.65 \times POP_{urb} \times R_{urb}$$

In which, P_{urb} means urban sewage nutrient production;

POP_{urb} means the number of permanent urban residents;

R_{urb} means the nutrient production coefficient.

(3) Fertilizer use nutrient production

In the present research, the nutrient production from fertilizer use was defined as the consumption of chemical fertilizers. The nutrient production from fertilizer use was estimated as follows:

$$P_{fertN} = M_{fertN} + 0.33 \times M_{fertNP})$$
$$P_{fertP} = (M_{fertP} + 0.33 \times M_{fertNP}) \times 43.7\%$$

In which, P_{fertN} 、 P_{fertP} means the N, P production by fertilizer use;

M_{fertN} 、 M_{fertP} 、 M_{fertNP} mean the Consumption of Nitrogen, phosphate and compound fertilizer respectively.

(4) Livestock farming nutrient production

The nutrient production from livestock farming was estimated as follows:

$$P_{pou} = 10 \times N_{pou} \times R_{pou}$$

In which, P_{pou} means livestock farming nutrient production (pig, cow, beef layers, broiler);

N_{pou} means the annual output of livestock;

R_{pou} nutrient production coefficient by livestock farming.

The data of annual output of livestock was collected from the Statistical yearbook of Lianyungang City in 2017, and the nutrient production coefficient was collection from discharge coefficient manual of the first national census of domestic source pollution, the production coefficient for the pig, cow, beef layers, broiler was listed in table 3.3.

Table 3.3 the livestock farming production coefficient

Production coefficient	pig	sow	beef	broiler	sheep
TN（kg/per livestok per year）	2.524	9.297	56.017	0.06	0.505
TP（kg/per livestok per year）	0.319	1.187	7.245	0.03	0.064

(5) Rural sewage nutrient production

In the present research, the nutrient production from rural sewage was defined as the sum of the production of rural sewage, garbage, human urine. The nutrient production from rural sewage was estimated as follows:

$$P_{ral} = P_{ralW} + P_{ralR} + P_{ralU}$$
$$P_{ralW} = 0.00365 \times POP_{ral} \times Q_{ral} \times \eta_w \times C_w$$
$$P_{ralR} = 3.65 \times POP_{ral} \times R_r \times C_r$$
$$P_{ralU} = 10 \times POP_{ral} \times R_u$$

In which, P_{ral} means the rural sewage nutrient production; P_{ralW} 、 P_{ralR} 、 P_{ralU} means the nutrients production from rural sewage, garbage, human urine; POP_{ral} means the number of permanent rural residents; Q_{ral} means water consumption per capita in rural areas; η_w , R_r , R_u means the production coefficient of rural sewage, garbage, human urine per capita in rural areas; C_w means the concentration of the nutrient in the sewage; C_r means the concentration of the nutrient in the garbage.

According to the literature, for human urine nutrient production, the production coefficient of 3.06 kg and 0.524 kg per capita per year used for nitrogen and phosphorus respectively in the present research, and for sewage nutrient production, water consumption of 95 liters per capita per day, the wastewater production rate of 0.25, and nitrogen and phosphorus concentration in the wastewater of 34.21mg/L and 4.88mg/L was used, and for garbage nutrient production, the garbage production coefficient of 0.28kg per capita per day, the nitrogen and phosphorus concentration in the garbage of 27.85 g/kg and 11.7 g/kg was used.

(6) Freshwater aquaculture nutrient production

$$P_{aqu} = M_{aqu} \times R_{aqu} \times 10^{-3}$$

In which, P_{aqu} means freshwater aquaculture nutrient production; M_{aqu} means annual freshwater aquaculture Yield; R_{aqu} means the production coefficient of freshwater aquaculture.

The data of annual freshwater aquaculture Yield was collected from the Statistical yearbook of fishery in Jiangsu province in 2016. From the data, in 2016, the freshwater aquaculture output in Lianyungang was 263,400 tons, including 189,400 tons for pond aquaculture and 36,800 tons for intensive aquaculture, which accounted for 71.9% and 14.0% of the total freshwater aquaculture output respectively. And the nutrient production coefficient was collection from discharge coefficient manual of the first national census of fishery source pollution, the production coefficient for each culture breed was listed in the table 3.4.

Table 3.4 Freshwater aquaculture nutrient production coefficient

Culture breed		Production coefficient of TN (g/Kg)	Production coefficient of TP (g/Kg)
Fishes	Black carp	1.388	0.256
	Grass carp	7.975	1.188
	Silver carp	3.501	0.607
	Bighead carp	4.035	0.455

	Carp		1.388	0.256
	Crucian		2.321	1.089
	Gurnard		1.636	0.125
	Loach		8.216	0.601
	Ricefield eel;		22.319	5.431
	Siniperca chuatsi		5.755	2.219
	Hypomesus olidus		4.035	0.455
	Weever		27.237	4.417
	Snakehead		27.237	4.417
	Mossambica tilapia		6.485	0.859
	Sturgeon		8.716	1.422
	Others		8.716	1.422
Crustacea	Prawns	giant freshwater prawn	0.301	0.044
		freshwater shrimp	2.713	0.577
		Turtle shrimp	2.713	0.577
		South America prawns	1.311	0.106
	Crab		2.679	0.472
Others		Turtle	6.73	0.814

3.2.3 Export coefficient method for nutrient discharge

(1) Industry nutrient discharge

$$D_{ind} = D_{ind0} \times (1 + \varepsilon\beta)^{(t-t_0)}$$

In which, D_{ind} means N, P discharge in the base year;D_0 means N, P discharge in the reference year;ε means reference coefficient; βmeans annual growth rate of industrial production.

(2) Urban sewage nutrient discharge

$$D_{urb} = P_{urb} \times [\lambda_p \times (1 - \eta_p) + (1 - \lambda_p) \times \delta_{urb}]$$

In which, D_{urb} means urban sewage N, P discharge; P_{urb} means urban sewage N, P production; λ_p means sewage treatment rate; η_p means N, P treatment rate; δ_{urb} means loss rate of nontreatment.

The loss rate of nontreatment sources was collection from discharge coefficient manual of the first national census of domestic source pollution, and the treatment rate of 15.4% and 14.7% was used for nitrogen and phosphorus respectively in the present research, and for the treatment sources, the data was collected from the discharge standards of pollutants from urban sewage treatment plants(GB 18918-2002), and a treatment rate of 71.6% and 73.97% was used for nitrogen and phosphorus respectively in the present research.

(3) Fertilizer use nutrient discharge

$$D_{fert} = P_{fert} \times (\delta_{rof} + \delta_{lec} + \delta_{vol})$$

In which, D_{fert} means fertilizer use N, P discharge; P_{fert} means fertilizer use N, P production; δ_{rof}, δ_{lec}, δ_{vol} means discharge coefficient due to the loss of runoff, leaching, and volatilization.

(4)Livestock farming nutrient discharge

$$D_{pou} = 10 \times N_{pou} \times \{[E_{pouM} \times (1 - \eta_m) + E_{pouU}] \times (1 - \eta_u) + E_{pouM} \times \eta_m \times \delta_m\}$$

In which,D_{pou} means Livestock farming N, P discharge ;N_{pou} means annual slaughter of pig, cow, cattle, chicken etc. E_{pouM}, E_{pouU} means discharge coefficient of faeces and urine; $\eta_m$means faeces collection rate; $\eta_u$means wastewater treatment rate;$\delta_m$means loss rate during faeces.

(5) Rural sewage nutrient discharge

$$D_{ral} = P_{ralW} \times \delta_w + P_{ralR} \times \delta_R + P_{ralU} \times \delta_U$$

In which, D_{ral} means rural N, P discharge; P_{ralW}, P_{ralR}, P_{ralU} means rural N, P production of wastewater, domestic waste and faeces; δ_W , δ_R ,δ_U means discharge coefficient of wastewater, domestic waste and faeces discharge.

(6) Freshwater aquaculture nutrient discharge

$$D_{aqu} = M_{aqu} \times E_{aqu} \times 10^{-3}$$

In which, D_{aqu} means freshwater aquaculture N, P discharge; M_{aqu} means yield increase; E_{aqu} means discharge coefficient.

3.3.4 Nutrient load to the sea

(1) Retention coefficient assessment

According to the law of conservation of substance, the retention of nitrogen and phosphorus in the basin (R) is equal to the discharge of nutrients in the basin (D) minus the loading of nutrients at the outlet of the basin (L)， i.e. $R = D - L$. and the retention coefficient is calculated as follows:

$$\frac{R}{D} = 1 - \frac{1}{1 + \alpha HL^{\beta}}$$

In which, α 、 β means empirical coefficient of the model； HL means Hydraulic loading, Represents the volume of water passing through the unit area per unit time, $HL = Q / (A_{L,R} + 0.001 \times A^{1.185})$, Q means the annual river flow, $A_{L,R}$ means the area of reservoir and lake, A means the area of sub-catchment.

(2) Nutrient load to the sea

The retention of the nutrients in a river basin is caused by the land surface and water body of river and reservoir. In order to calculate the retention coefficient in the watershed, it is necessary to calculate the land surface retention coefficient and the river and reservoir retention coefficient for each sub-catchment respectively. And then the loading coefficients of the point and non-point sources in each sub-catchment are calculated according to runoff and confluence characters in the whole basin. Nutrient pollutant load to the sea can be acquired by the loading coefficients and the discharge of the point and non-point sources.

4. Result and discussion

4.1 Catchment delineation

A catchment is the topographic area from which all water runoffs finally reach one single given point, known as the pit. Watersheds are referred to as the topographic barriers that divide catchments from each other. DEMs are a popular source for hydrological modeling and watershed characterization because of their simple data structure and widespread availability. Based on the DEMs, using the ArcHydro module that was developed by the Center for Research in Water Resources (CRWR) based on ARC/INFO, the model is a combination of hydrological surface water flow simulation and GIS data structure. The model consists of five parts: Drainage, Hydrographic, Channel, Network, and Time Series.

ArcGIS can obtain the data of total area flowing into this specific point, also called pour point. In order to obtain the watershed delineation, certain predefined steps are followed to obtain the Flow direction and the Flow accumulation and obtain the for each cell in the DEM the number of cells that are flowing into them.

The recommended steps for watershed delineation using ArcGIS are as follows:

Step 1: Fill sinks. In this step, the sinks in the DEM will be filled to create a depressionless DEM.

Step 2: Flow direction. In this step, the flow direction of each cell in the raster will be calculated. There are eight valid output directions.

Step 3: Flow accumulation. In this step, the number of cells that are flowing into them for each cell in the DEM can be calculated.

Step 4: Catchment delineation. In this step, as the flow accumulation grid was outputted, it is possible to determine the drainage network of the area and the area where the most of the water will be accumulated. Now we can establish a point along the high value accumulation cells for which we will delineate the contributing/catchment area.

Step 5: Watershed. Finally, the data of the contributing area to a point using the Watershed tool can be obtained.

The original DEM data showed in the figure 4.1, and the delineated catchments in Haizhou bay showed in the figure 4.2. The watershed was delineated to 23 catchments in Lianyungang city, and because Haizhou Bay is located in the Huaihe Plain, the crisscross river and canal network formed a very complex drainage systemin, so in the delineation progress, the catchment must be manually adjusted to accord with the real river and canal network.

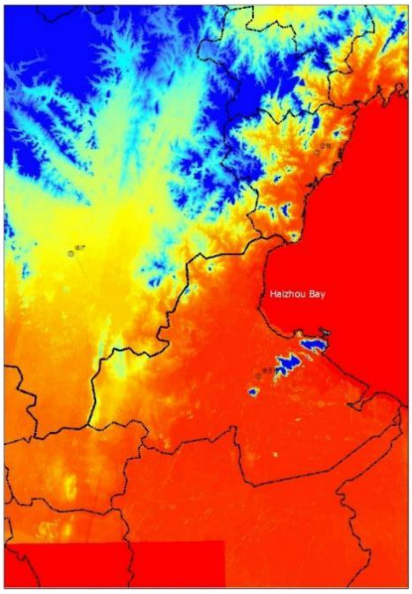

Fig 4.1 Original DEM data of the study area

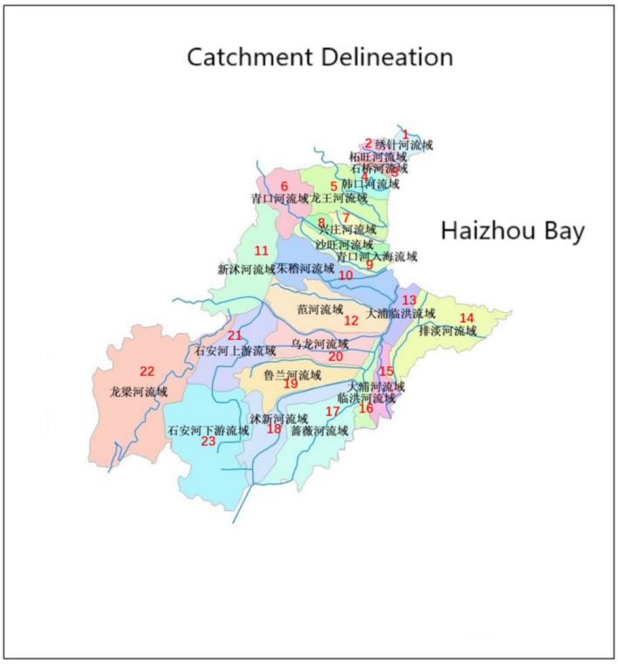

Fig 4.2 Delineated catchment cells in Haizhou Bay

(1. Xiuzhen R, 2. Tuowang R, 3. Shiqiao R, 4. Hankou R, 5. Longwang R, 6. Qingkou R, 7. Xingzhuang R, 8. Xingwang R, 9. Qingkou R, 10. Zhuji R, 11. Xinshu R, 12. Fan R, 13. Dapulinhong R, 14. Paidan R, 15. Dapu R, 16. Linhong R, 17. Linwei R, 18. Shuxin R, 19. Lulan R, 20. Wulong R, 21. Upstream Shian R, 22. Longliang R, 23Downstream Shian R)

4.2 Nutrient production

4.2.1 Total nitrogen production

According to the calculation result (table 4.1), magnitude of TN production in Lianyungang city was about 118,156 tons/year, among which industrial nitrogen production was 4,432 tons, urban sewage nitrogen production was 7,170 tons, fertilizer use nitrogen production was 89,224 tons, livestock farming nitrogen production was 10,029 tons, rural sewage nitrogen production is 6,116 tons, and freshwater aquaculture nitrogen production was 1,186 tons. As showed in the figure 4.3, the fertilizer use was the major source for production of TN, account for 76%, and next was the livestock farming, urban sewage, rural sewage, account for 8%, 6%, 5% and 4% respectively, and only 1% of TN production was from freshwater aquaculture. And if we applied fertilizer use and livestock farming as the agricultural sources, more than 80% of TN were from the agricultural sources.

As showed in the figure 4.4, the largest TN production exported to catchment cells of Longling R, Shian R, Linwei R, Fan R, Wulong R (catchment cell No 22, 23, 17, 12, 20), all of these catchment located in the upstream of the Linhong River, where the dominated land use type is farmland, and high intensive of the agricultural activates may be the reason that largest TN production was from fertilizer use.

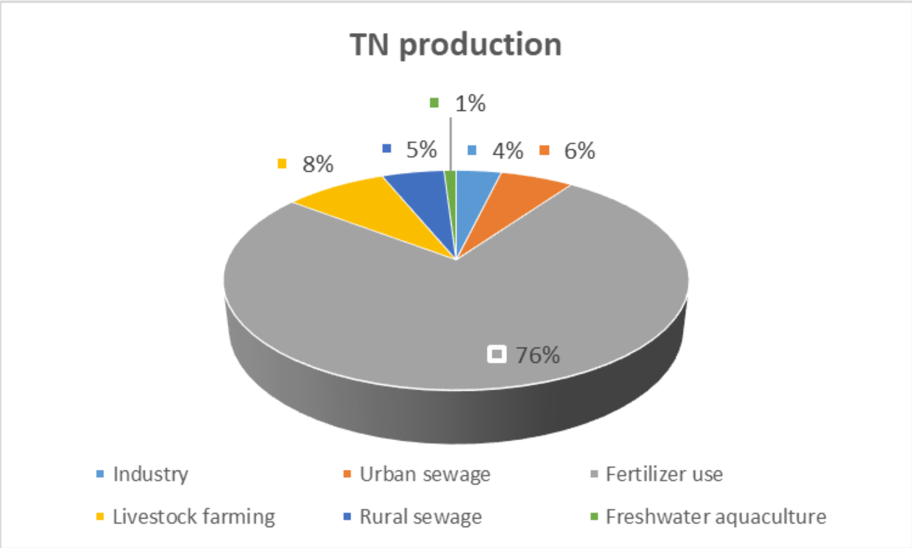

Fig 4.3 Sources of TN production in Lianyungang city

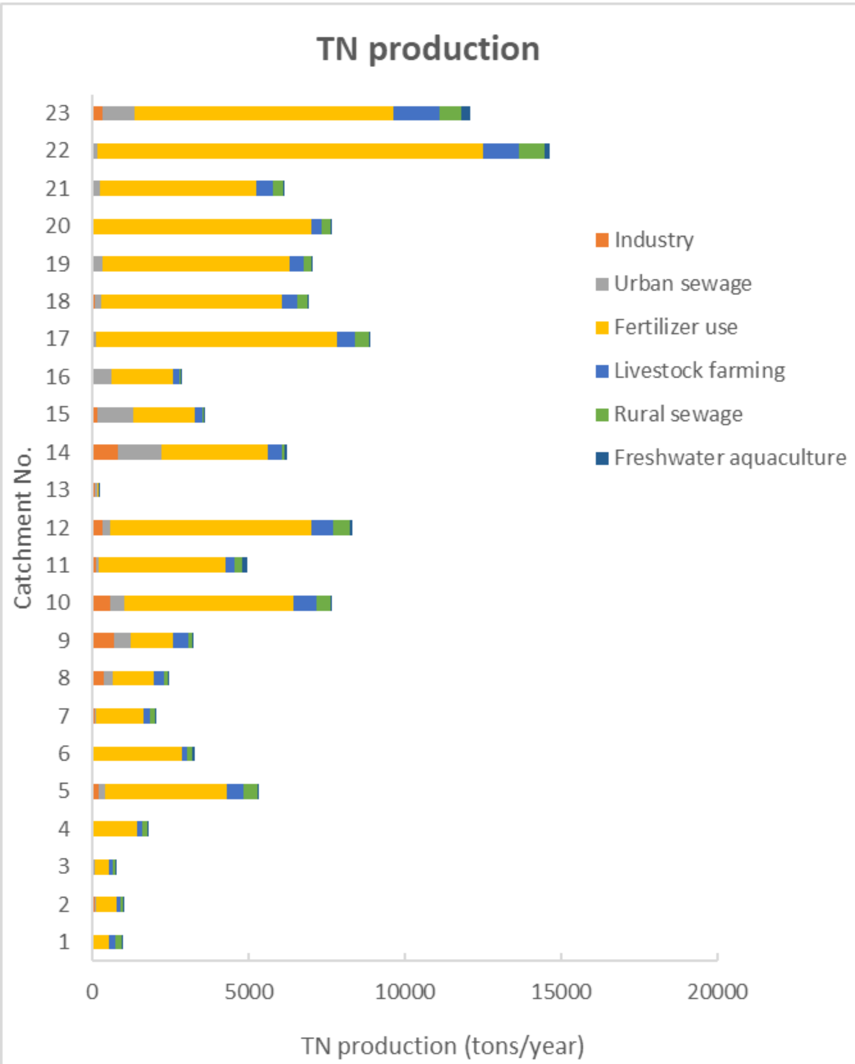

Fig 4.4 Magnitude of TN production in each catchment cells

Table 4.1. TN production in Lianyungang city of each Catchment

Catchment name	Catchment No	TN production （tons/year）						
		Industry	Urban sewage	Fertilizer use	Livestock farming	Rural sewage	Freshwater aquaculture	Subtotal
Xiuzhen R	1	0	0	560	192	209	16	978
Tuowang R	2	88	65	660	119	73	6	1011
Shiqiao R	3	59	44	447	114	87	9	760
Hankou R	4	0	0	1441	161	175	9	1787
Longwang R	5	237	177	3891	557	454	35	5351
Qingkou R	6	0	0	2890	148	161	73	3272
Xingzhuang R	7	81	60	1520	192	157	4	2014
Xingwang R	8	376	280	1342	325	113	16	2452
Qingkou R	9	708	527	1341	524	117	12	3229
Zhuji R	10	606	451	5375	754	433	15	7633
Xinshu R	11	131	108	4019	312	245	161	4977
Fan R	12	333	248	6445	694	543	73	8336
Dapulinhong R	13	92	87	24	29	0	44	276
Paidan R	14	820	1401	3404	459	85	71	6241
Dapu R	15	179	1151	1951	274	29	10	3593
Linhong R	16	59	586	1956	178	66	25	2869
Linwei R	17	36	119	7674	591	428	24	8871
Shuxin R	18	80	235	5748	506	305	55	6929
Lulan R	19	71	268	5970	447	274	5	7036
Wulong R	20	16	43	6957	324	287	54	7681
Upstream Shian R	21	66	190	5009	515	321	44	6145

Longliang R	22	44	125	12336	1134	843	147	14628
Downstream Shian R	23	350	1005	8264	1480	711	278	12087
Subtotal		4432	7170	89224	10029	6116	1186	118156

4.3.2 Total phosphorus production

According to the calculation result (table 4.2), magnitude of TP production in Lianyungang city was about 20,842 tons/year, among which industrial phosphorus production was 449 tons, urban sewage phosphorus production was 623 tons, fertilizer use phosphorus production was 16,043 tons, livestock farming phosphorus production was 1,810 tons, rural sewage phosphorus production is 1,739 tons, and freshwater aquaculture phosphorus production was 180 tons. As showed in the figure 4.5, as same as the production of TN, the fertilizer use was also the major source for production of TP, account for 77%, and next was the livestock farming, rural sewage, urban sewage and industry, account for 9%, 8%, 3% and 2% respectively, and only 1% of TP production was from freshwater aquaculture. Also, if we applied fertilizer use and livestock farming as the agricultural sources, more than 80% of TP were from the agricultural sources.

Same as TN production, the largest TP production also exported to catchment cells of Longling R, Shian R, Linwei R, Fan R, Wulong R (catchment cell No 22, 23, 17, 12, 20. Fig 4.6).

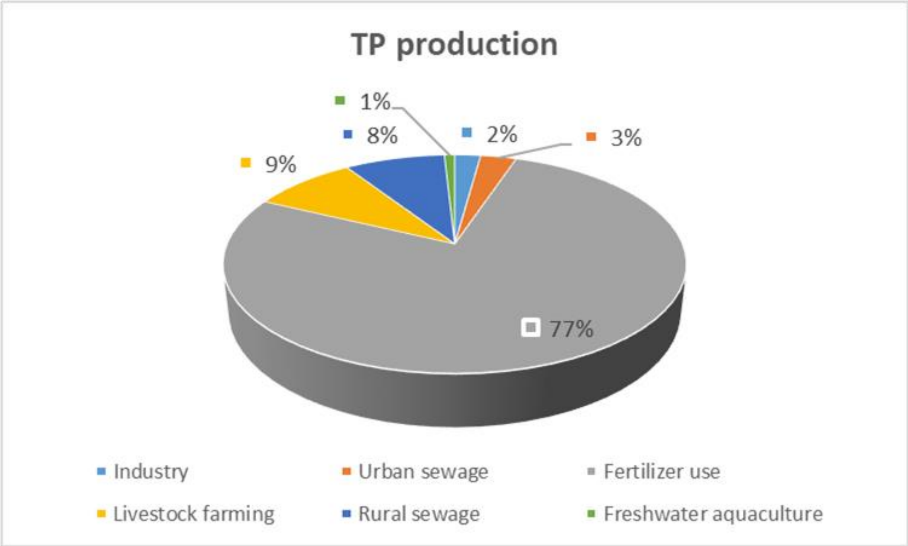

Fig 4.5 Sources of TP production in Lianyungang city

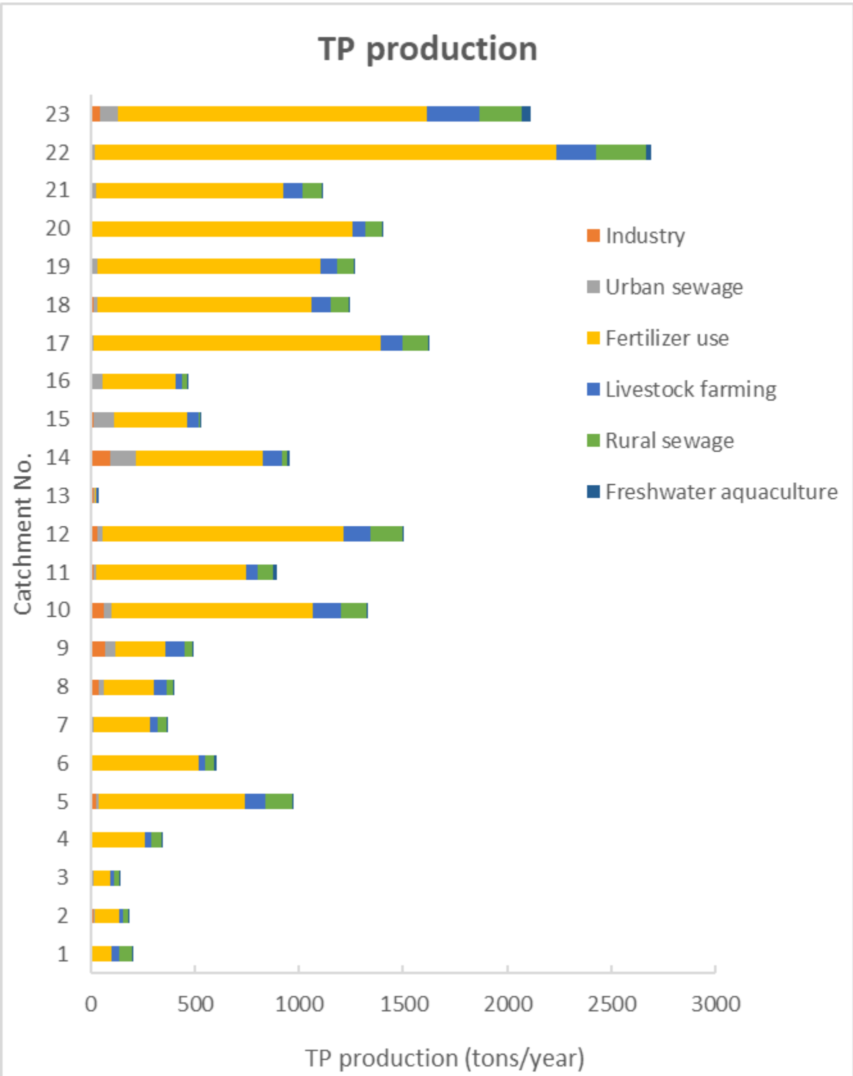

Fig 4.6 Magnitude of TP production in each catchment cells

Table 4.2 TP production in Lianyungang city of each Catchment

Catchment name	Catchment No	TN production （tons/year）						
		Industry	Urban sewage	Fertilizer use	Livestock farming	Rural sewage	Freshwater aquaculture	Subtotal
Xiuzhen R	1	0	0	101	35	59	2	198
Tuowang R	2	9	6	119	22	21	1	176
Shiqiao R	3	6	4	80	21	25	1	137
Hankou R	4	0	0	259	30	50	1	340
Longwang R	5	23	15	700	102	129	5	974
Qingkou R	6	0	0	520	27	46	10	603
Xingzhuang R	7	8	5	273	35	45	1	367
Xingwang R	8	37	24	241	60	32	2	397
Qingkou R	9	69	46	241	96	33	2	488
Zhuji R	10	59	39	966	139	123	2	1329
Xinshu R	11	13	9	723	57	70	24	895
Fan R	12	33	22	1159	128	154	10	1505
Dapulinhong R	13	11	8	4	6	0	7	35
Paidan R	14	91	122	612	94	24	11	953
Dapu R	15	11	100	351	56	8	1	527
Linhong R	16	1	51	352	36	19	4	463
Linwei R	17	4	10	1380	102	122	4	1622
Shuxin R	18	9	20	1033	88	87	9	1246
Lulan R	19	8	23	1073	79	78	1	1262
Wulong R	20	2	4	1251	59	82	8	1406
Upstream Shian R	21	8	17	901	89	91	7	1112

Longliang R	22	5	11	2218	195	239	23	2692
Downstream Shian R	23	42	87	1486	254	202	44	2115
Subtotal		449	623	16043	1810	1739	180	20842

4.3 Nutrient discharge

4.3.1 Total nitrogen discharge

According to the calculation result (table 4.3), magnitude of TN discharge in Lianyungang city was about 9,469 tons/year, among which industrial nitrogen discharge was 93 tons, urban sewage nitrogen discharge was 301 tons, fertilizer use nitrogen discharge was 237 tons, livestock farming nitrogen discharge was 290 tons, rural sewage nitrogen discharge is 90 tons, and freshwater aquaculture nitrogen discharge was 255 tons. As showed in the figure 4.7, the fertilizer use was the major source for discharge of TN, account for 27%, and next was the urban sewage, livestock farming, industry, freshwater aquaculture and rural sewage, account for 22%, 20%, 12%, 11% and 8% respectively. And if we compared the result of the production and discharge of TN, only 8% of the TN production in the Lianyungang city can be transported into the water body, more than 90% of the TN may be stored in the land. And as showed in the figure 4.8, the largest TN discharge exported to catchment cells of upstream of the Linhong River(catchment cell No 23, 22, 14, 10, 12).

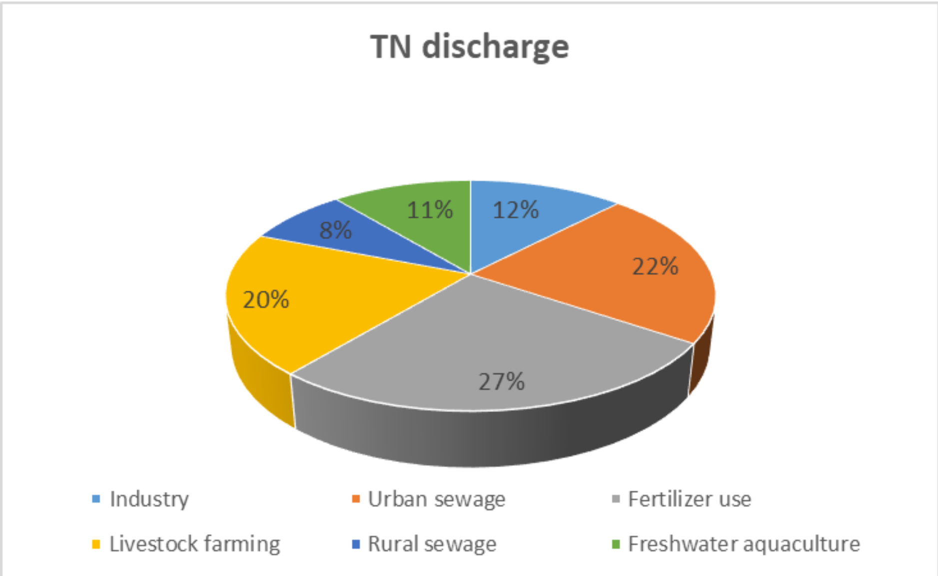

Fig 4.7 Sources of TN discharge in Lianyungang city

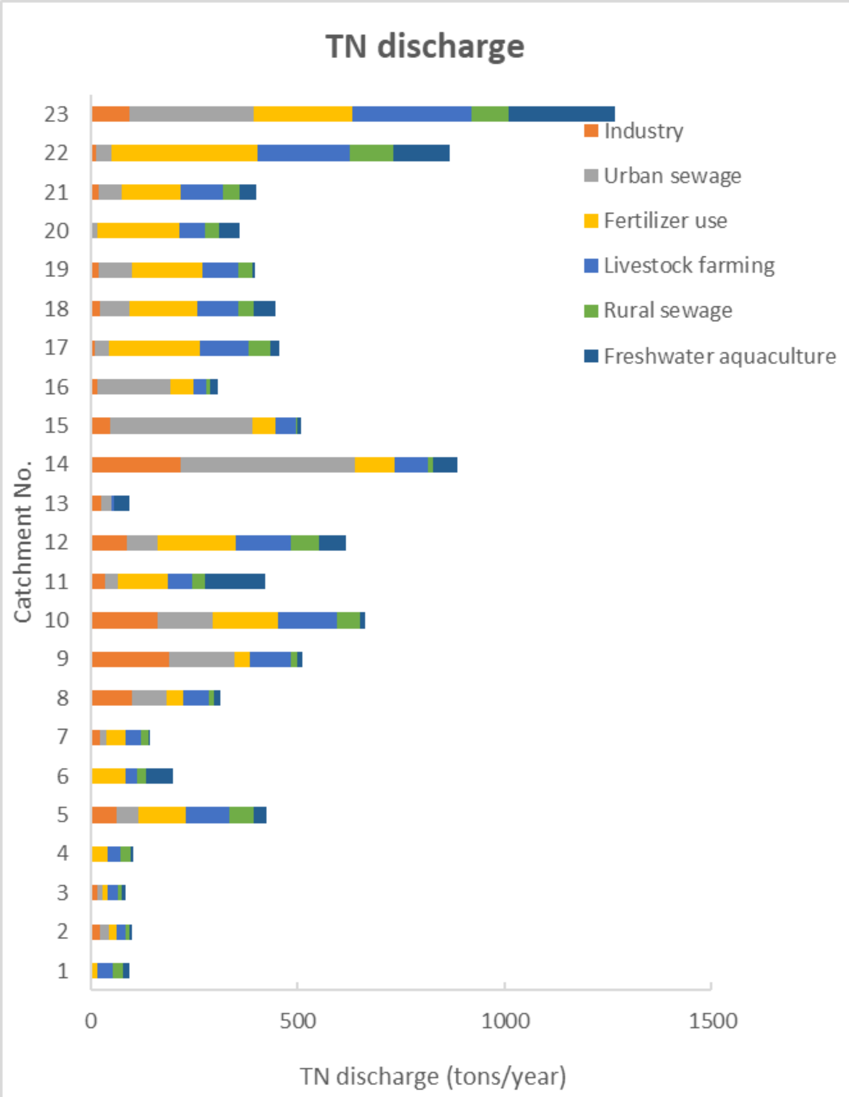

Fig 4.8 Magnitude of TN discharge in each catchment cells

Table 4.3 TN discharge in Lianyungang city of each Catchment

Catchment name	Catchment No	TN production (tons/year)						
		Industry	Urban sewage	Fertilize use	Livestock farming	Rural sewage	Freshwater aquaculture	Subtotal
Xiuzhen R	1	0	0	16	36	26	14	94
Tuowang R	2	23	20	19	23	9	5	99
Shiqiao R	3	16	13	13	22	11	8	83
Hankou R	4	0	0	42	31	22	8	103

Longwang R	5	63	53	114	106	58	31	424
Qingkou R	6	0	0	85	28	20	65	198
Xingzhuang R	7	21	18	45	36	20	3	144
Xingwang R	8	100	84	39	62	14	14	313
Qingkou R	9	188	158	39	99	15	11	510
Zhuji R	10	161	135	157	143	55	13	664
Xinshu R	11	35	32	118	59	31	145	420
Fan R	12	88	74	189	132	69	65	617
Dapulinhong R	13	24	26	1	5	0	37	94
Paidan R	14	217	420	96	82	11	60	886
Dapu R	15	47	345	55	49	4	8	508
Linhong R	16	16	176	55	32	8	21	307
Linwei R	17	9	36	219	116	54	21	455
Shuxin R	18	21	71	164	99	39	51	443
Lulan R	19	19	80	170	87	35	5	395
Wulong R	20	4	13	197	61	36	48	360
Upstream Shian R	21	18	57	143	101	41	40	400
Longliang R	22	12	38	353	222	107	135	866
Downstream Shian R	23	93	301	237	290	90	255	1266
Subtotal		1175	2150	2566	1921	775	1063	9649

4.3.2 Total phosphorus discharge

According to the calculation result (table 4.4), magnitude of TP discharge in Lianyungang city was about 828 tons/year, among which industrial phosphorus discharge was 74 tons, urban sewage phosphorus discharge was 175 tons, fertilizer use phosphorus discharge was 140 tons, livestock farming phosphorus discharge was 135 tons, rural sewage phosphorus discharge is 142 tons, and freshwater aquaculture phosphorus discharge was 163 tons. As showed in the figure 4.9, the urban sewage was the major source for discharge of TP, account for 21%, and next was the freshwater aquaculture, fertilizer use, rural sewage, livestock farming, and industry, account for 20%, 17%, 17%, 16% and 9% respectively, almost each source had the equal contribution. Meanwhile, if we compared the result of the production and discharge of TP, only 4% of the TP production in the Lianyungang city can be transported into the water body, and more than 95% of the TP may be stored in the land. And as showed in the figure 4.10, the largest TP discharge exported to catchment cells of upstream of the Linhong River(catchment cell No 23, 22, 14, 10, 12), that was consistent with the TN.

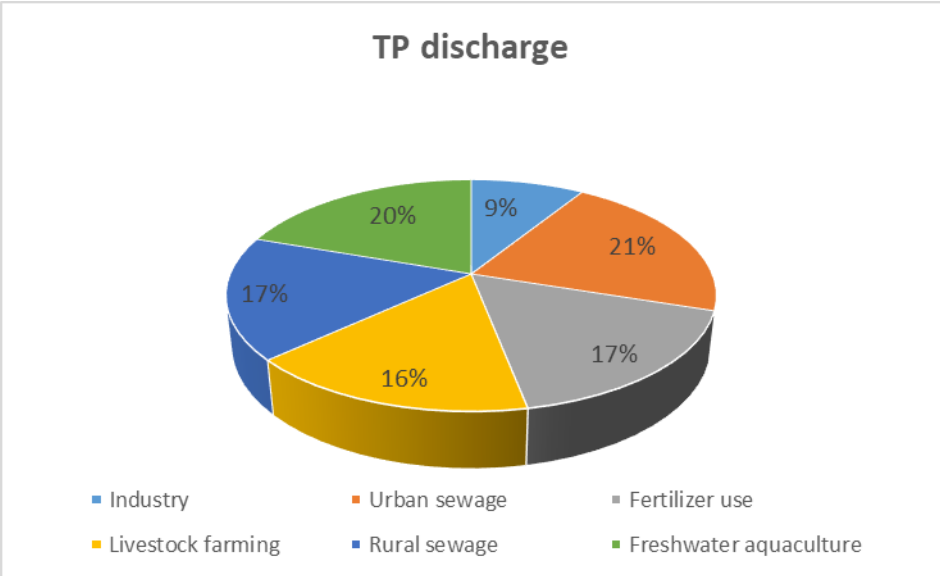

Fig 4.9 Sources of TP discharge in Lianyungang city

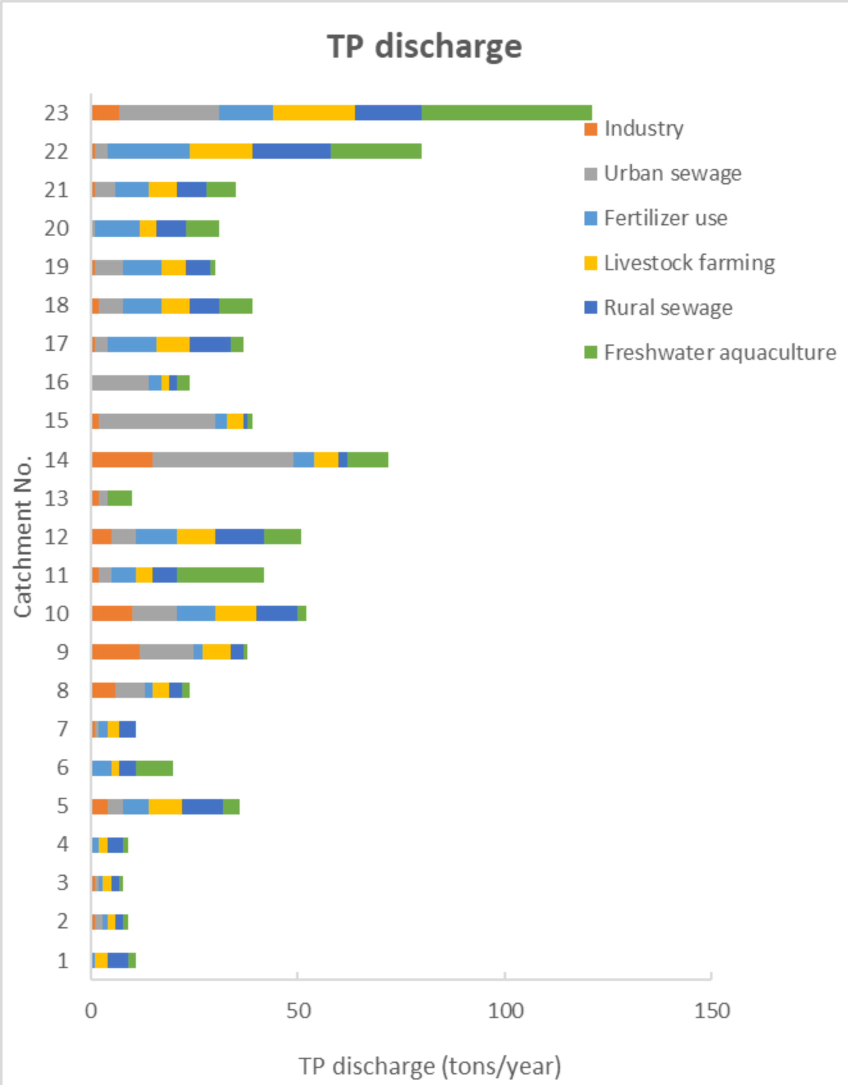

Fig 4.10 Magnitude of TP discharge in each catchment cells

Table 4.4 TP discharge in Lianyungang city of each catchment

Catchment name	Catchment No	TN production （tons/year）						
		Industry	Urban sewage	Fertilize use	Livestock farming	Rural sewage	Freshwater aquaculture	Subtotal
Xiuzhen R	1	0	0	1	3	5	2	10
Tuowang R	2	1	2	1	2	2	1	8
Shiqiao R	3	1	1	1	2	2	1	7
Hankou R	4	0	0	2	2	4	1	10

Longwang R	5	4	4	6	8	10	4	37
Qingkou R	6	0	0	5	2	4	9	19
Xingzhuang R	7	1	1	2	3	4	0	12
Xingwang R	8	6	7	2	4	3	2	24
Qingkou R	9	12	13	2	7	3	1	38
Zhuji R	10	10	11	9	10	10	2	51
Xinshu R	11	2	3	6	4	6	21	42
Fan R	12	5	6	10	9	12	9	53
Dapulinhong R	13	2	2	0	0	0	6	10
Paidan R	14	15	34	5	6	2	10	72
Dapu R	15	2	28	3	4	1	1	38
Linhong R	16	0	14	3	2	2	3	25
Linwei R	17	1	3	12	8	10	3	37
Shuxin R	18	2	6	9	7	7	8	38
Lulan R	19	1	7	9	6	6	1	30
Wulong R	20	0	1	11	4	7	8	30
Upstream Shian R	21	1	5	8	7	7	7	35
Longliang R	22	1	3	20	15	19	22	80
Downstream Shian R	23	7	24	13	20	16	41	122
Subtotal		74	175	140	135	142	163	828

4.4 Nutrient loading to the Haizhou Bay

4.4.1 Total nitrogen loading in Lianyungang city

According to the calculation result (table 4.5), magnitude of TN loading in Lianyungang city was about 4,175 tons/year, among which industrial nitrogen loading was 543 tons, urban sewage nitrogen loading was 990 tons, fertilizer use nitrogen loading was 1,097 tons, livestock farming nitrogen loading was 826 tons, rural sewage nitrogen loading is 332 tons, and freshwater aquaculture nitrogen loading was 387 tons. As showed in the figure 4.11, the fertilizer use was the major source for TN loading, account for 26%, and next was the urban sewage, livestock farming, industry, freshwater aquaculture and rural sewage, account for 24%, 20%, 13%, 9% and 8% respectively. And as showed in the figure 4.12, the largest TN loading exported to catchment cells of Paidan R, Longliang R, Qingkou R, Linwei R, Downstream Shian (catchment cell No 14, 22, 9, 17, 23). Different from the distribution characteristics of TN production and discharge, the large TN loading area mainly located in the coastal area, because of the loading coefficient is largely affected by the flow and distance from the sea.

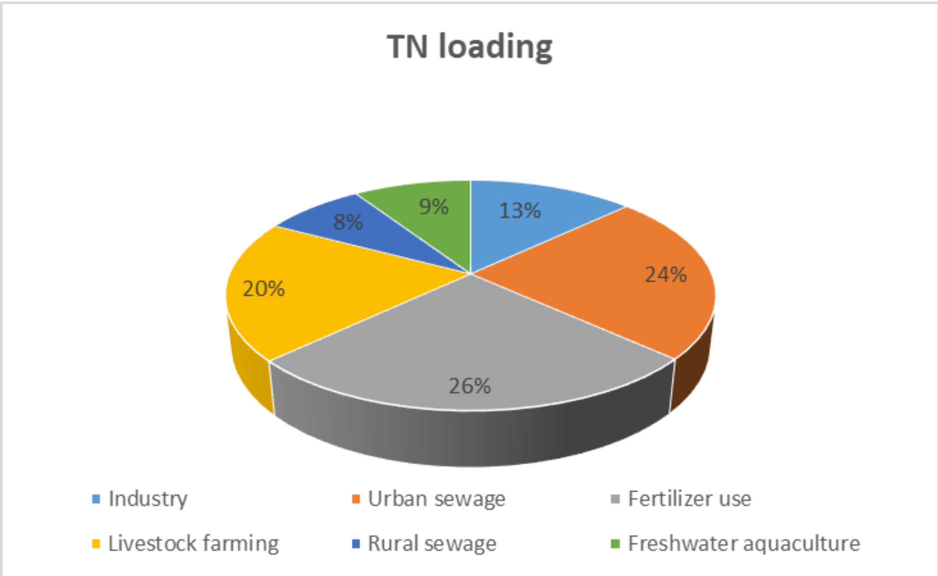

Fig 4.11 Sources of TN loading in Lianyungang city

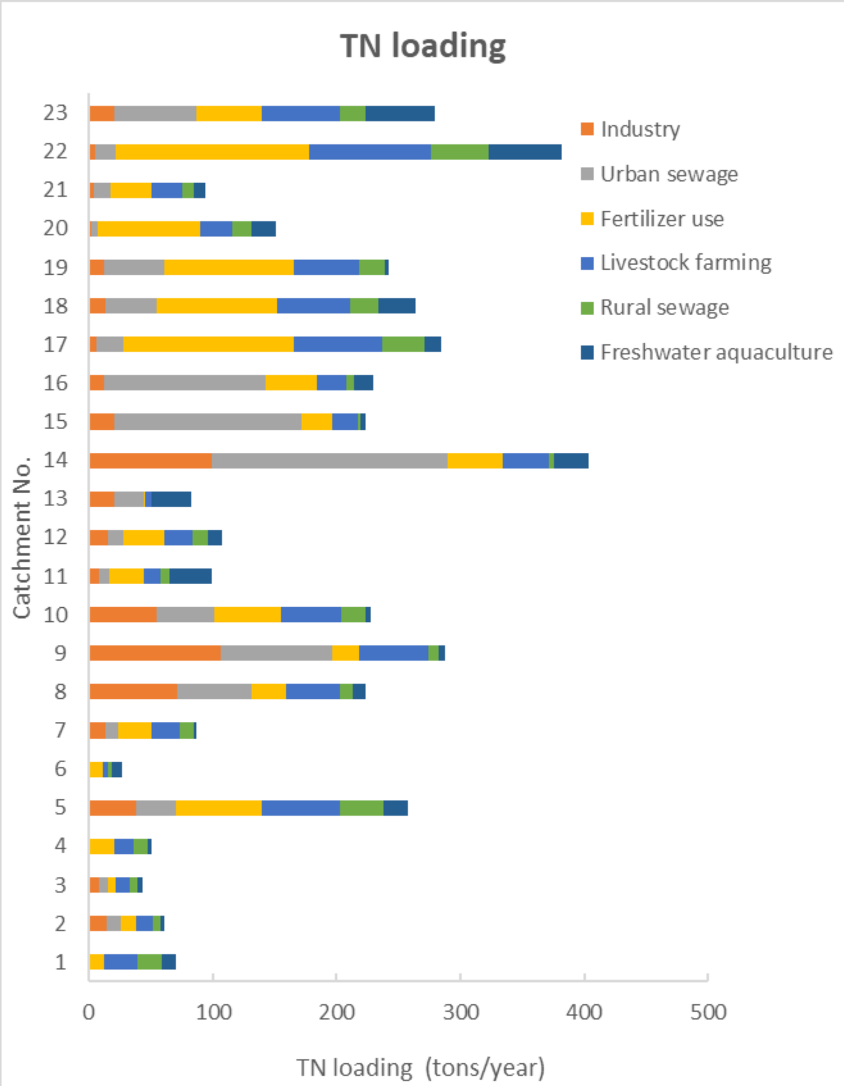

Fig 4.12 Magnitude of TN loading in each catchment cells

Table 4.5 TN loading in Lianyungang city of each catchment

Catchment name	Catchment No	TN production （tons/year）						
		Industry	Urban sewage	Fertilize use	Livestock farming	Rural sewage	Freshwater aquaculture	Subtotal
Xiuzhen R	1	0	0	12	27	20	11	70
Tuowang R	2	14	12	12	14	6	3	61
Shiqiao R	3	8	7	7	11	6	4	43
Hankou R	4	0	0	21	15	11	4	51

Longwang R	5	38	32	69	64	35	19	257
Qingkou R	6	0	0	11	4	3	9	27
Xingzhuang R	7	13	11	27	22	12	2	87
Xingwang R	8	71	60	28	44	10	10	223
Qingkou R	9	106	90	22	56	8	6	288
Zhuji R	10	55	46	54	49	19	4	227
Xinshu R	11	8	8	28	14	7	34	99
Fan R	12	15	13	33	23	12	11	107
Dapulinhong R	13	21	23	1	5	0	33	83
Paidan R	14	99	191	44	37	5	27	403
Dapu R	15	21	151	24	21	2	4	223
Linhong R	16	12	131	41	24	6	16	230
Linwei R	17	6	22	137	72	34	13	284
Shuxin R	18	13	42	97	59	23	30	264
Lulan R	19	12	49	104	53	21	3	242
Wulong R	20	2	5	83	26	15	20	151
Upstream Shian R	21	4	13	34	24	10	9	94
Longliang R	22	5	17	156	98	47	59	382
Downstream Shian R	23	20	67	52	64	20	56	279
Subtotal		543	990	1097	826	332	387	4175

4.3.2 Total phosphorus loading in Lianyungang city

According to the calculation result (table 4.6), magnitude of TP loading in Lianyungang city was about 199.3 tons/year, among which industrial phosphorus loading was 17.9 tons, urban sewage phosphorus loading was 46.4 tons, fertilizer use phosphorus loading was 35.7 tons, livestock farming phosphorus loading was 33.4 tons, rural sewage phosphorus loading is

34.6 tons, and freshwater aquaculture phosphorus loading was 31.3 tons. As showed in the figure 4.13, the urban sewage was the major source for TP loading, account for 23%, and next was the fertilizer use, rural sewage, livestock farming, freshwater aquaculture and industry, account for 18%, 17%, 17%, 16% and 9% respectively, almost each source had the equal contribution. And as showed in the figure 4.14, the largest TP loading exported to catchment cells of Linwei R, Shuxin R, Linhong R, Lulan R, Xingwang R (catchment cell No 17, 18, 16, 19, 8). According to the loading distribution of TN and TP, the largest TN and TP loading mainly export to the Linhong estuary.

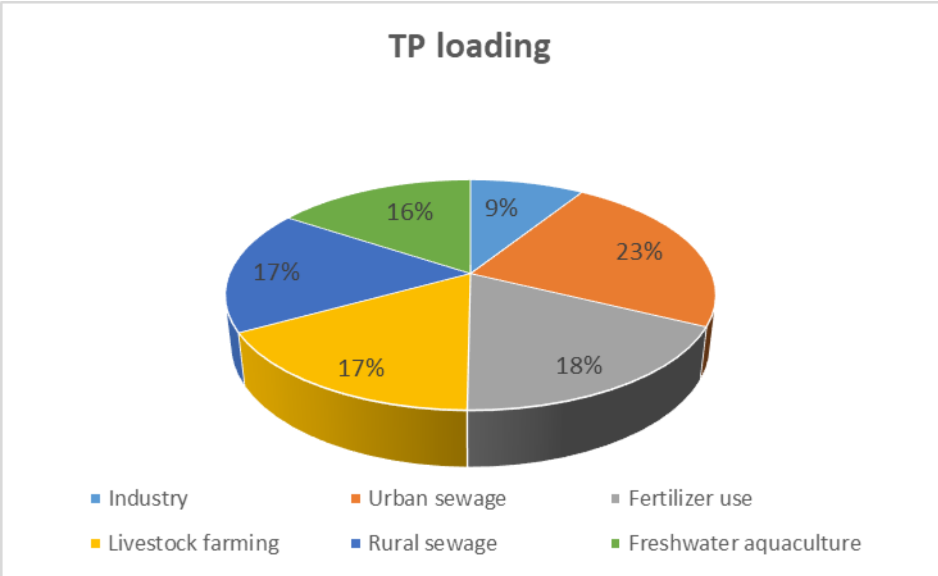

Fig 4.13 Sources of TP loading in Lianyungang city

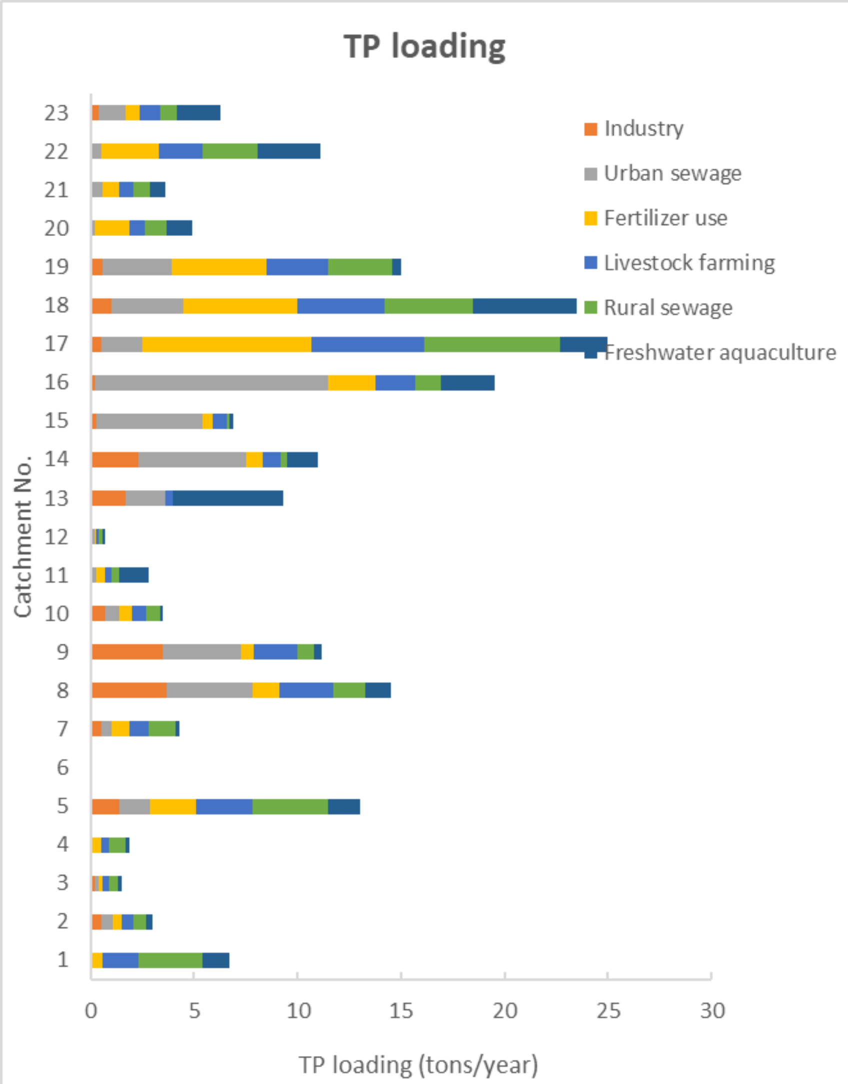

Fig 4.14 Magnitude of TP loading in each catchment cells

Table 4.6 TP loading in Lianyungang city of each catchment

Catchment name	Catchment No	TN production （tons/year）						
		Industry	Urban sewage	Fertilize use	Livestock farming	Rural sewage	Freshwater aquaculture	Subtotal
Xiuzhen R	1	0	0	0.6	1.7	3.1	1.3	6.7
Tuowang R	2	0.5	0.6	0.4	0.6	0.6	0.3	3
Shiqiao R	3	0.2	0.2	0.2	0.3	0.4	0.2	1.5
Hankou R	4	0	0	0.5	0.4	0.8	0.2	1.9

Longwang R	5	1.4	1.5	2.2	2.7	3.7	1.5	13
Qingkou R	6	0	0	0	0	0	0.1	0.1
Xingzhuang R	7	0.5	0.5	0.9	0.9	1.3	0.2	4.3
Xingwang R	8	3.7	4.1	1.3	2.6	1.6	1.2	14.5
Qingkou R	9	3.5	3.8	0.6	2.1	0.8	0.4	11.2
Zhuji R	10	0.7	0.7	0.6	0.7	0.7	0.1	3.5
Xinshu R	11	0.1	0.2	0.4	0.3	0.4	1.4	2.8
Fan R	12	0.1	0.1	0.1	0.1	0.2	0.1	0.7
Dapulinhong R	13	1.7	1.9	0	0.4	0	5.3	9.3
Paidan R	14	2.3	5.2	0.8	0.9	0.3	1.5	11
Dapu R	15	0.3	5.1	0.5	0.7	0.1	0.2	6.9
Linhong R	16	0.2	11.3	2.3	1.9	1.2	2.6	19.5
Linwei R	17	0.5	2	8.2	5.4	6.6	2.3	25
Shuxin R	18	1	3.5	5.5	4.2	4.3	5	23.5
Lulan R	19	0.6	3.3	4.6	3	3.1	0.4	15
Wulong R	20	0	0.2	1.7	0.7	1.1	1.2	4.9
Upstream Shian R	21	0.1	0.5	0.8	0.7	0.8	0.7	3.6
Longliang R	22	0.1	0.4	2.8	2.1	2.7	3	11.1
Downstream Shian R	23	0.4	1.3	0.7	1	0.8	2.1	6.3
Subtotal		17.9	46.4	35.7	33.4	34.6	31.3	199.3

4.4.3 Nutrient loading to the Haizhou Bay

When we combine the loading from the entry section and loading that produced in Lianyungang city itself and applying the loading of all 23 subcatchments to the 12 rivers, then the total loading of the nutrient to Haizhou Bay was achieved, see in the table 4.7.

According to the result, magnitude of TN and TP loading to haizhou Bay was about 6411 tons/year and 403.4 tons/year. And the Linhong river was the major nutrient source to Haizhou Bay(figure 4.15), account for 56% and 59% of total loading for TN and TP respectively, and next is Xiuzhen river, account for 9% and 18% of total loading for TN and TP respectively.

Table 4.7 Nutrient total loading to Haizhou Bay

order	river name	Total loading to Haizhou Bay (tons/year)	
		TN	TP
1	Xiuzhen R	551	71.5
2	Tuowang R	61	3
3	Shqiao R	43	1.5
4	Hankou R	51	1.9
5	Longwang R	303	15.7
6	Guanzhuang R	107	0.7
7	Xingzhuang R	87	4.3
8	Shawang R	223	14.5
9	Qingkou R	323	17.2
10	Zhuji R	227	3.5
11	Linhong R	4032	258.6
12	Paidan R	403	11
subtotal		6411	403.4

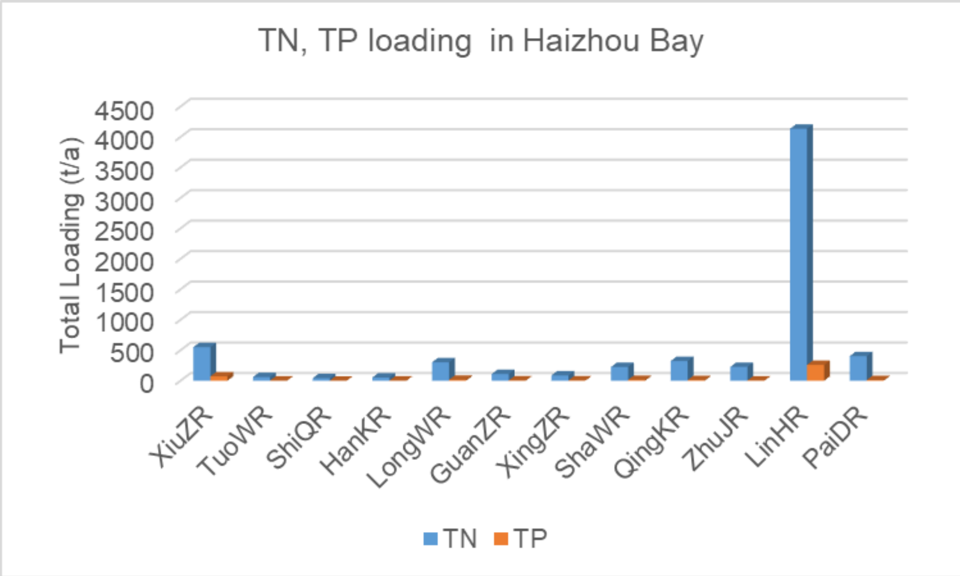

Fig 4.15 Distribution of TN and TP loading to Haizhou Bay

4.5 Major sources of nutrient in the Haizhou Bay

According to the calculation result, the production, discharge and total loading of TN,TP in Lianyungang was about 11800t and 2100t, 9600t and 800t, 4200t and 200t per year respectively, and total loading of TN,TP to Haizhou Bay was about 6400t and 400t when the loading that flow into Lianyungang city was involved. According to the result of production and discharge, as we can see in the table 4.8, only less than 10% of the TN, TP production might discharge into water body, and the loading to Haizhou bay mainly from the production in Lianyungang city itself, account for 66% and 50% for TN and TP respectively.

From the result in chapter 4.3 and 4.4, the fertilizer use was concluded as the major sources in the study area, and if we applied fertilizer use and livestock farming as the agricultural sources, nearly 50% of TN and TP were from the agricultural sources. Even more, for the production of TN and TP, more than 75% of TN and TP production was from fertilizer use, showed fertilizer use was the most definitely contribution, but for the discharge of TN and TP, there showed a nearly equal contribution between the fertilizer use, livestock farming, urban sewage. The significant difference indicated that only small part of TN and TP production from fertilize use can discharge into water body, see in the table 4.9.

Table 4.8 Comparison the nutrient production, discharge and loading to sea

parameters	TN, TP in Lianyungang city itself (tons/year)			total loading to the sea (tons/year)
	production	discharge	loading to sea	
TN	118156	9649	4175	6406
TP	20842	828	200	398

Table 4.9 Comparison sources of the nutrient production and discharge

	Industry	Urban sewage	Fertilizer use	Livestock farming	Rural sewage	Freshwater aquaculture
TN discharge/ TN production	26.51%	29.99%	2.88%	19.15%	12.67%	89.63%
TP discharge/ TP production	16.48%	28.09%	0.87%	7.46%	8.17%	90.56%

5. Conclusion and suggestion

As discussed in previous chapters, the major conclusion in the present showed as:

(1) Linhong river was the major nutrient pollutant source to Haizhou Bay.

(2) The nutrient load to Haizhou Bay mainly from the production in Lianyungang city itself, account for 66% and 50% for TN and TP respectively.

(3) The agricultural sources were the dominated sources to Haizhou Bay, that was consistent with the results of other studies

(4) Although the fertilizer use, livestock farming, urban sewage had the same contribution on TN,TP loading, the potential loading from the fertilizer use should not be ignored, the large magnitudes of the nutrients reserved in the farmland might discharge into the water body, especially in the wet year or in the flood season, nutrient loading may dramatically increase.

Based on the result, some of the suggestion for the nutrient reduction for the local government is:

(1) In order to control nutrient input to haizhou bay, nutrient reduction scheme should focus on Linhong river basin.

(2) Non-point agricultural sources pollution control is the most important way for the nutrient reduction, especially the reduction of fertilize use and livestock farming. To achieve the goal of nutrient reduction, the suggestion showed as:

1) Sources reduction, like point source pollution control, source reduction is the key and most effective strategy for agricultural non-point source pollution control. The reason that excessive nitrogen and phosphorus emissions in farmland usually due to low nutrient utilization efficiency and excessive fertilizer input. Therefore, strategies for source reduction mainly include reducing fertilizer input, improving nutrient utilization efficiency, and implementing water-saving irrigation and runoff control.

2) Process blocking. Process control technologies include ecological ditches, buffer zones, ecological ponds and constructed wetlands. Generally, ecological ditches are one of the most effective nutrient retention technologies in agriculture, nitrogen, phosphorus and other nutrients in the drainage can be effectively removed by means of

interception, adsorption, assimilation and denitrification, and have been widely used in taihu lake area of China.

3) Nutrient reuse. There are many ways to reused nutrients. Nitrogen, phosphorus and other nutrients from non-point source sewage can be re-entered into the crop production system to provide nutrients and achieve the purpose of recycling. For nitrogen and phosphorus nutrients in livestock manure and crop straw can be returned to the field directly, also the cultivation wastewater and biogas slurry can be returned to the field after pretreatment. Nitrogen and phosphorus nutrients in rural sewage, farmland drainage and eutrophic river water can be absorbed, purified and reused through the paddy field wetland system.

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