Activity 3 of output 3.1.2:

Deliverable 12-2:

Monitoring and Acquisition Data for Sharing on Fertilizer Use in Yellow Sea coastal provinces of PR China

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Content

1. Background

The land-based non-point source pollution contributes greatly to the quality deterioration of water in coastal sea areas, especially when the point source pollution is effectively controlled. According to reports, about 30%-50% of surface water has been influenced by the non-point source pollution all over the world [1], of which the contribution of the agricultural non-point source pollution cannot be neglected. Studies have shown that the agricultural non-point source pollution has become the primary pollution source of rivers and lakes in the United States, which is a main factor resulting in groundwater pollution and wetland degradation [2]. In Europe, the agricultural non-point source pollution is also considered as the leading cause of water pollution, and the most important cause of phosphorus enrichment in surface water. For example, the concentration of phosphorus in river water exceeds 0.2 mg/L in a watershed in Germany due to the excessive use of chemical fertilizers [3]. In China, the hazards from the non-point source pollution have gradually appeared in many cities and regions and the agricultural non-point source pollution has caused the deterioration of water quality, which has hindered the further development of the national economy. Therefore, in order to achieve the expected environmental objectives, more emphasis should be placed on the control of non-point source pollution in the treatment of water environmental pollution problems. Besides, the strengthening of researches about the agricultural non-point source pollution is of great significance for the prevention and control of water pollution.

The excessive application of chemical fertilizers is the major cause resulting in the agricultural non-point source pollution [4-6]. With the development of Chinese modern agriculture in recent years, the crop yields have been continuously improved and the application amount of chemical fertilizers has been increasing. The application amount of chemical fertilizers in China has been growing rapidly since 1980, with an average annual growth rate of 3%-5% [7]. However, the effective utilization rate of the fertilizer is low, and the average annual loss rate of nitrogen fertilizer in farmland is 33.3%~73.6% [8]. The increase rate of the application amount of chemical fertilizers is far greater than

the growth rate of crop yields. The amount of chemical fertilizers consumed in China accounts for 1/3 of the total usage amount of chemical fertilizers in the world, and the application amount per unit area is more than three times of the average usage amount in the world [9]. The excessive application of chemical fertilizer leads to serious pollution of the natural resources and environment. The massive amounts of chemical fertilizers and pesticides get into water environment in many ways such as rain water, farmland irrigation, soil infiltration, etc., and the resulting non-point source pollution load has been accounting for a growing proportion, which has a serious impact on the inshore water quality. Therefore, the investigation and evaluation of the chemical fertilizers used in agriculture is a necessary to assess the agricultural non-point source pollution, and then provide the essential scientific basis and data foundation for the management and control of land-based pollution sources.

The Yellow Sea is located between the China's Mainland and the Korean peninsula, and borders China in its north and west. The Yellow Sea is a typical sea that is roughly north-south. In the north of the Yellow Sea, the connecting line between Laotie Mountain, which is located in the Lushunkou district of Dalian in the south of the Liaodong peninsula, and Tianheng Mountain, which is located in Penglai in the north of the Shandong peninsula, is the boundary between the Yellow Sea and the China's Bohai Sea. In the south of the Yellow Sea, the connecting line between Qidongzui in the north of the China's Yangtze estuary and the southwest corner of the Jeju Island is the boundary between the Yellow Sea and the East Sea. The provinces in China along the Yellow Sea include Liaoning, Shandong and Jiangsu, as shown in Fig 1, and the main coastal cities along the Yellow Sea are Dandong, Dalian, Yantai, Weihai, Qingdao, Rizhao, Lianyungang, Yancheng and Nantong, from north to south in China.

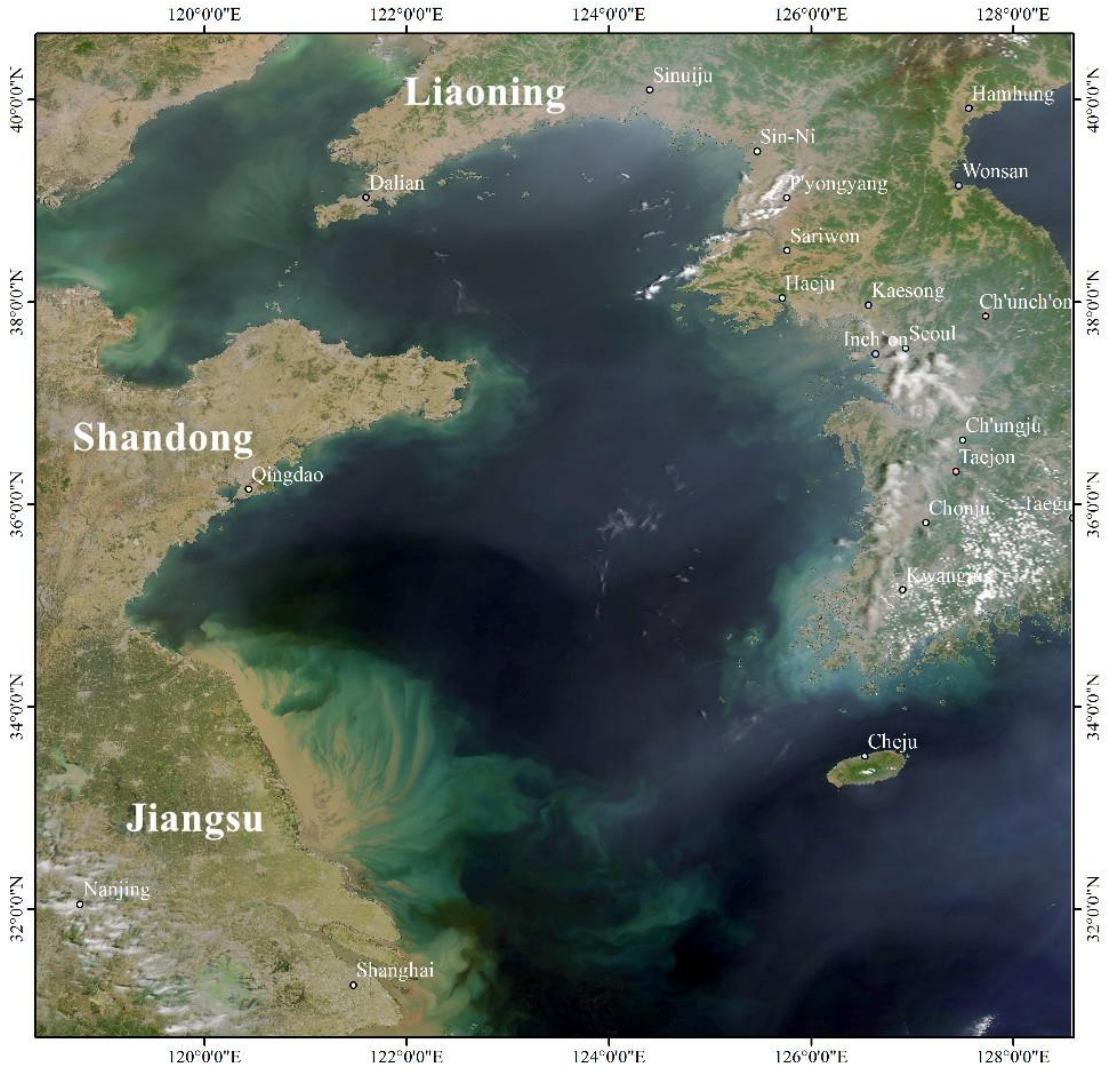


Fig 1.1. Coastal provinces along the Yellow Sea, China

Among the provinces along the Yellow Sea in China, Shandong and Jiangsu are major agricultural provinces. Shandong plays a prominent role in the production, supply, export and breeding of grain and vegetables, which is a typical province with a large amount of cultivated land, a large agricultural population, a high multiple cropping index, and a massive application amount of chemical fertilizers. Jiangsu is also a major grain-producing province, and the application amount of chemical fertilizers has increased with the gradual increase in grain output. There has been excess nitrogen in Jiangsu's agricultural production since 1990 [10]. Therefore, the investigation and evaluation of the application of chemical fertilizers in the provinces and cities along the Yellow Sea is of great significance for protecting the marine environment of the Yellow Sea, maintaining the marine ecosystem health, promoting

the coordinated development between the economic growth of regions on the coast of the Yellow Sea and the marine environmental protection, and achieving a sustainable development of the marine economy.

Outcome 3.1 of UNDP/GEF YSLME Phase II Project entitled “Ecosystem health improved through a reduction in pollutant discharges (e.g. nutrients) from land-based sources”, supports a series of activities that focus on the development and improvement of the strategies and methods to efficiently reduce the pollutant discharge from land-based sources of Yellow Sea, especially the nutrient. Output 3.1.2 specifically leads to construct an effective strategy for monitoring and acquisition of data for sharing on pollutants from atmosphere-based, fertilizer use and sea-based sources. As one of proposed activities, activity 3 of Output 3.1.2 entitled “Support for monitoring and data acquisition for sharing on fertilizer use”, is mainly focused on the data acquisition of fertilizer use of China’s three coastal provinces along the Yellow Sea, and the change tendency of fertilizer use in in recent ten years. By systematic statistics and analysis of the collected data, the basic situation of fertilizer use in the three coastal provinces can be efficiently monitored and accurately understood. Enhancement of data and information sharing on fertilizer use in coastal areas of the Yellow Sea is necessary and meaningful for better understanding of the current status of nutrient discharge in the Yellow Sea, and the implementation effect of management measures on chemical fertilizer overuse. The research result can also provide data support for the estimation of the non-point pollution in coastal areas of the Yellow Sea.

The objective underlying the proposed consultancy is to monitor and acquire data and information of fertilizer use in the coastal areas of the Yellow Sea in PR China, to provide support for evaluation of management measures and improvement of the use of chemical fertilizer. A data report is expected to delivered, which is forced on monitoring and evaluation of fertilizer use in agricultural activities in China’s coastal areas along the Yellow Sea.

2. Technical routes

Under supervision of the Chief Technical Advisor and technical guidance of the RWG-P, in close collaboration with the local project team, according to objectives given above, a series of activities are conducted, which are listed as follows:

1. Conduct a review of the current status of socio-economic development and agricultural activities in the coastal provinces along the Yellow Sea, including the geographical location, population, administrative division, GDP, agricultural economy development, and the characteristics of agricultural production activities. Information and data were collected to understand the basic situation of the survey regions in detail.
2. Collect the relevant data and information of agricultural-used fertilizer in coastal provinces along the Yellow Sea, including the total sown areas of crops, the amount of different types of fertilizers, characteristic parameters of fertilizer use in survey regions, and other information and data available currently.
3. Analyze and evaluate the characteristic of spatial-temporal variation of fertilizer use in survey regions, and assess the status and trends of environmental stresses caused by fertilizer use.
4. Summarize the agricultural policies, regulations and measures for the control of agricultural nonpoint source pollution in China and the three coastal provinces, especially for the control of fertilizer use in agricultural activities, and proposal suggestions on optimization of fertilizer use and fertilizer input structure.
5. Prepare and submit the study report of fertilizer use in the Yellow Sea.

According to objectives given above, workflow as Fig.1. was adopted.

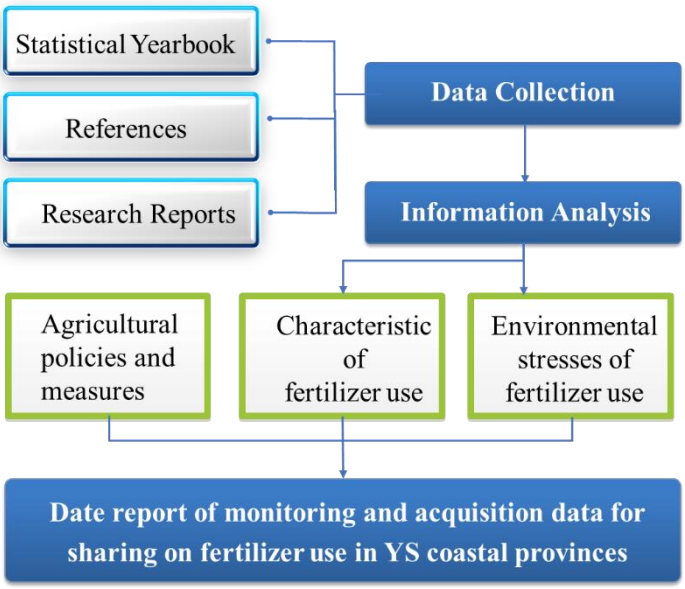


Fig 2.1. Schematic diagram of research process

The survey region in this project includes 9 prefecture-level cities along the Yellow Sea in Liaoning, Shandong and Jiangsu province of China, named Dandong, Dalian, Yantai, Weihai, Qingdao, Rizhao, Lianyungang, Yancheng and Nantong, from north to south.

The basic data used in this project are mainly collected from the statistical yearbooks and bulletins of the three coastal provinces and the 9 coastal cities, as well as data released by the website of State Statistics Bureau and the official websites of provincial and local governments. The data include the population, GDP, agricultural economic development of these provinces and cities from 2007 to 2017, and the amount of various fertilizers used in agricultural activities, such as nitrogen fertilizer, phosphate fertilizer, potash fertilizer and compound fertilizer, as well as the sown area of crops.

Table 2.1. Cities and their administrative divisions in the survey regions

Province	City	District/County/County-level City
Liaoning	Dalian	Zhongshan District, Xigang District, Shahekou District, Ganjingzi District, Lushunkou, Jinzhou, Pulandian, Changhai, Zhuanghe, Wafangdian
	Dandong	Donggang, Fengcheng, Kuandian, Yuanbao District, Zhenxing District, Zhenan District

Province	City	District/County/County-level City
Shandong	Yantai	Laishan District, Zhifu District, Fushan District, Mouping District, Laizhou, Laiyang, Zhaoyuan, Changdao, Penglai, Xixia, Haiyang, Longkou
	Weihai	Huancui District, Wendeng District, Rushan, Rongcheng
	Qingdao	Shinan District, Shibei District, Chengyang District, Licang District, Huangdao District, Laoshan District, Jimo District, Jiaozhou, Pingdu, Laixi
	Rizhao	Donggang District, Lanshan District, Wulian, Juxian
Jiangsu	Nantong	Chongchuan District, Gangzha District, Tongzhou District, Rufu, Haimen, Qidong, Haian, Rudong
	Lianyungang	Haizhou District, Lianyun District, Ganyu District, Donghai, Guanyun, Guannan
	Yancheng	Tinghu District, Yandu District, Dafeng District, Dongtai, Jianhu, Funing, Sheyang, Binhai, Xiangshui

Parameters and evaluation methods of fertilizer application：

Amount of Chemical Fertilizers used in Agriculture refers to the quantity of chemical fertilizers applied in agriculture in the year, including nitrogenous fertilizer, phosphate fertilizer, potash fertilizer, and compound fertilizer. The amount of chemical fertilizers is required in calculation to convert the gross weight into weight containing 100% effective component (e.g. 100% nitrogen content in nitrogenous fertilizer, 100% phosphorous pent oxide contents in phosphate fertilizer, 100% potassium oxide content in potash fertilizer). Compound fertilizer is converted with its major component. The formula is:

Volume of effective component = physical quantity × effective component of certain chemical fertilizer (%)

The data of compound fertilizer use in the statistical yearbooks does not clearly indicate the proportion of NPK. According to the market investigation and relevant literature, universal compound fertilizer with equal nutrient ratio has been the

mainstream product of compound fertilizer, so the ratio of NPK in compound fertilizer is uniformly converted according to experience at 1:1:1 [11-12].

Fertilization intensity refers to the quantity of chemical fertilizers used in per unit sown area of crops in agriculture in this year (kg/hm^2).

According to the construction requirements of China's ecological county and towns, the fertilization intensity (F) shall not exceed the standard value of 250 kg/hm2. According to the variation range of fertilization intensity, the situation of fertilizer application in different cities is divided into four types. Cities of $F \leq 250$ is evaluated as low intensity fertilization area, cities of $250<F \leq 350$ is evaluated as moderate intensity fertilization area, cities of $350<F \leq 450$ is evaluated as high intensity fertilization area, cities of F>450 kg/hm2 is evaluated as ultra-high intensity fertilization area.

3. Overview of the survey region

The coastal region of the Yellow Sea in China includes some counties and cities in Liaoning province and Shandong province, and the entire Jiangsu Province. The basic situation, the regional GDP and its composition of the 9 prefecture-level cities in the three provinces located in the above-mentioned regions in 2018 is shown in Table 3.1. Among all the provinces of China, the GDP of Jiangsu province and Shandong province ranks second and third, respectively, and the per capita GDP of Jiangsu and Shandong ranks fourth and eighth, respectively. In the survey region of this project, the per capita GDP of the 7 prefecture-level cities are higher than the national per capita GDP (64,600 yuan), of which Weihai, Qingdao and Nantong are the top three cities in terms of per capita GDP. From the perspective of the GDP of the three major industries, the secondary industry and the tertiary industry are developing in a balanced manner, which occupies a dominant position. The average proportion of the primary industry is 7.78%, and the proportion of the primary industry in some prefecture-level cities is more than 10%, such as 16.7% in Dandong, 11.75% in Lianyungang, and 10.45% in Yancheng.

Table 3.1. Basic situation, regional GDP and its composition of the provinces and cities in the coastal region of the Yellow Sea in China

Province/City		**Land area (km^2)**	**Population ($\times 10^4$)**	**GDP (100 million yuan)**	**GDP per capita (yuan)**	**Constitute (100 million yuan)**		
						Primary industry	**Second industry**	**Tertiary industry**
Liaoning	The entire province	148400	4359.3	25315.4	58008	2033.3	10025.1	13257
	Dalian	12574	595.2	7668.5	109644	442.7	3241.6	3984.2
	Dandong	15290	239	816.7	34193	136.4	249.6	430.8
Shandong	The entire province	157965	10047.2	76469.7	76267.0	4950.5	33641.7	37877.4
	Yantai	13854.5	712.18	7832.58	110231	510.04	3844	3478.5
	Qingdao	11293.4	939.48	12001.5	128459	386.9	4850.6	6764
	Weihai	5799.8	283	3641.48	128774	281.21	1601.2	1759.1

Province/City		Land area (km^2)	Population ($\times 10^4$)	GDP (100 million yuan)	GDP per capita (yuan)	Constitute (100 million yuan)		
						Primary industry	Second industry	Tertiary industry
	Rizhao	5371.3	306.7	2202.2	75329	166.5	1064.2	971.5
Jiangsu	The entire province	107200	8050.7	92595.4	115168	4141.7	41248.5	47205.2
	Nantong	8001	731	8427	115320	397.8	3947.9	4081.4
	Lianyungang	7615	452	2771.7	61332	325.6	1207.4	1238.7
	Yancheng	16931	720	5487.1	75987	573.4	2436.5	2477.2

Data source: Statistical Bulletin on National Economy and Social Development in 2018 of coastal provinces and cities of the Yellow Sea, China.

3.1 Agricultural Economic Development of Liaoning Province

Liaoning province is located in the south of the Northeast China region, adjacent to the Yellow Sea and the Bohai Sea. Liaoning province covers an area of 148,000 square kilometers with a total population of 42.71 million. There are 14 prefecture-level cities under the jurisdiction of Liaoning province, in which Dandong and Dalian are located along the Yellow Sea.

In 2018, the gross domestic product (GDP) of Liaoning province was 2,531.54 billion yuan, up by 5.7% over the previous year. Of this total, the value added of the primary industry was 203.33 billion yuan, that of the secondary industry was 1,002.51 billion yuan, and that of the tertiary industry was 1,325.70 billion yuan. The per capita GDP of Liaoning province in 2018 was 58,008 yuan.

The existing cultivated land area in Liaoning province is 4,971,600 hectares, accounting for 33.45% of the total land area in Liaoning and 3.69% of the total cultivated land area all over the country. The total sown area of crops in Dalian and Dandong is 515,800 hectares, accounting for 12.4% of the total sown area of crops in the entire province. There are various types of agricultural land in Liaoning. The agricultural machine-cultivated land area, the electricity consumed in the countryside, and the application amount of chemical fertilizers are higher than the national average

level. Among the gross output value of agriculture including farming, forestry, animal husbandry and fishery, the output value of farming accounted for 42.1%, forestry accounted for 3.6%, animal husbandry accounted for 33.5%, and fishery accounted for 15.4%. Besides, 86.5% of the cultivated land in Liaoning province is dry land, and the main crops of Liaoning province include corn, rice, soybeans, peanuts, and tobacco, etc.

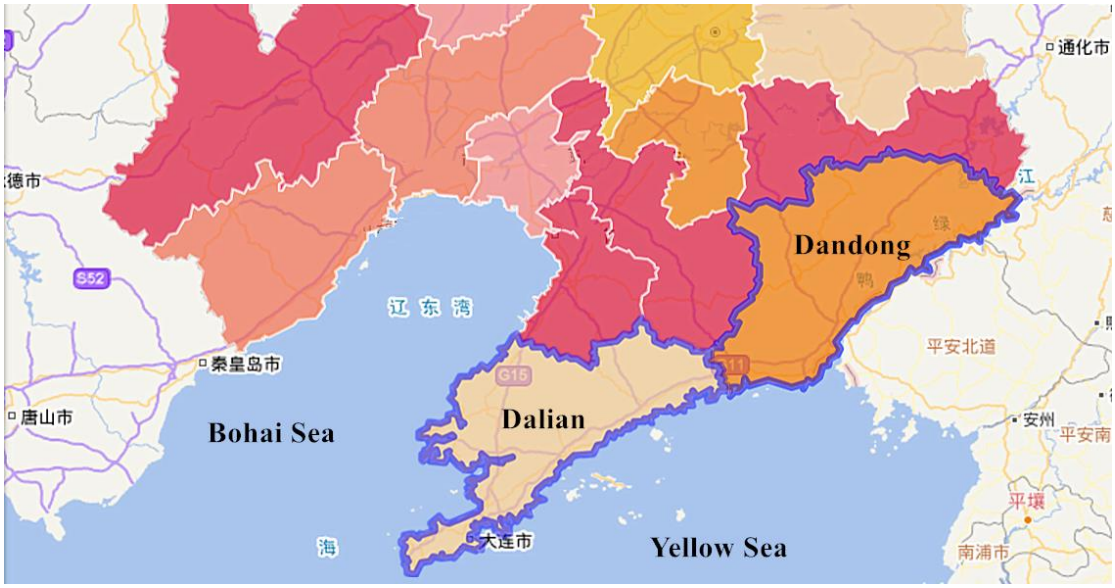


Fig 3.1. Schematic diagram of research area in Liaoning province

Dalian is located in the south of the Liaodong peninsula, and adjacent to both the Yellow Sea and the Bohai Sea. Dalian is a key coastal open port city in China and one of the cities with independent planning status under the national social and economic development. Dalian consists of 6 districts and 4 county-level cities/counties with a population of 5.95 million. In 2018, the GDP of Dalian was 766.85 billion yuan. Of this total, the value added of the primary industry was 44.27 billion yuan, accounting for 5.7% of the region's GDP. The value added of the secondary industry was 324.16 billion yuan, and that of the tertiary industry was 398.42 billion yuan. The per capita GDP of Dalian in 2018 was 109,644 yuan. The gross output value of agriculture including farming, forestry, animal husbandry, fishery and service industry in 2018 was 90.07 billion yuan. The output value of farming accounted for 29.1%, forestry accounted for 0.7%, animal husbandry accounted for 19.1%, and fishery accounted for 42.8%. Dalian has abundant agricultural resources and the main grain crops in Dalian include eight

categories, such as rice, fruit and peanuts, of which fruit production plays an important role in the country.

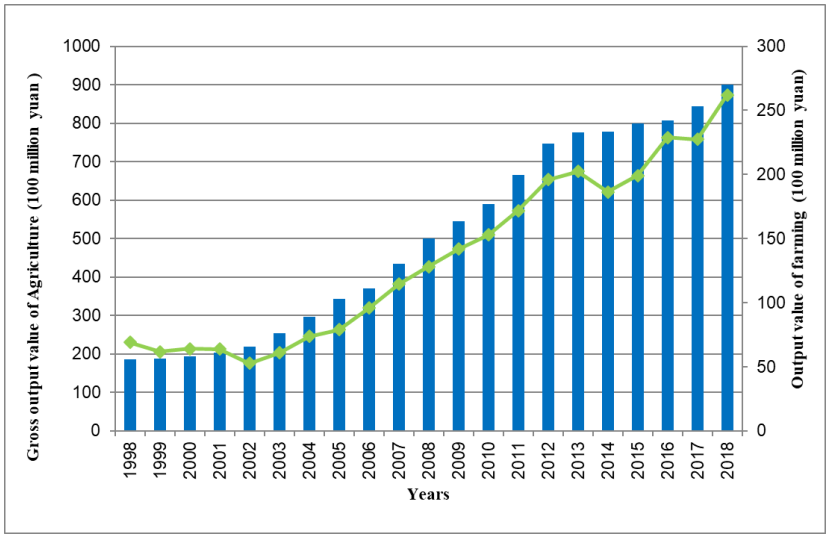


Fig 3.2. Change trend of the gross output value of agriculture and farming in Dalian, Liaoning (1998-2018).

Dandong is located in the southeast of Liaoning province, adjacent to North Korea. Dandong is the northern end of China's coastline. Dandong is a city along the Yalu River, the seacoast and the border, which is dominated by industry, commerce, port, logistics and tourism. Dandong is composed of 3 county-level cities and 3 districts with a total population of 2.39 million. The GDP of Dandong in 2018 was 81.67 billion yuan. Of this total, the value added of the primary industry was 13.64 billion yuan, accounting for 16.7% of the region’s GDP. The value added of the secondary industry was 24.96 billion yuan, and that of the tertiary industry was 43.08 billion yuan. The per capita GDP of Dandong in 2018 was 34,193 yuan. The gross output value added of agriculture in 2018 was 14.17 billion yuan, in which the output value added of farming accounted for 35.6%, forestry accounted for 4.7%, animal husbandry accounted for 14.0%, and fishery accounted for 41.8%. In addition to the featured seafood and fishery products from the Yalu River, Dandong is not only an agricultural base for producing high-quality rice, chestnut, strawberry, blueberry, etc., but also the largest production and export base for strawberry, chestnut and shellfish in China.

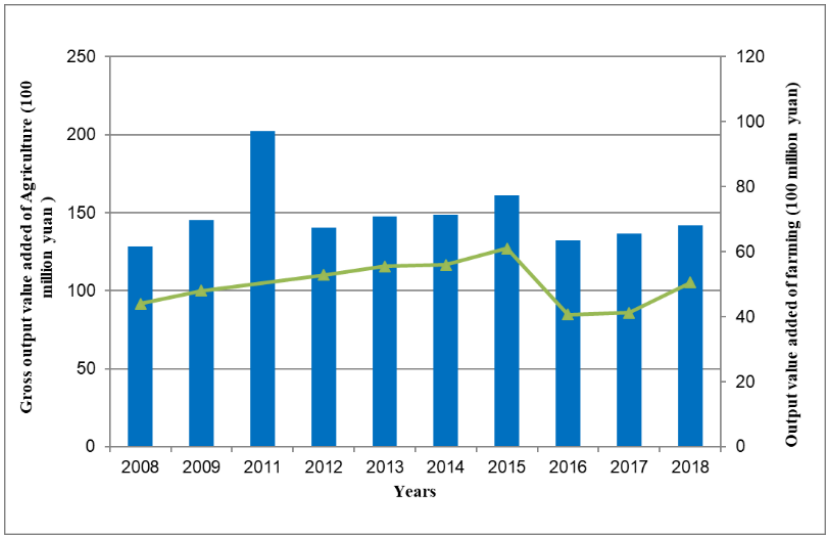


Fig 3.3. Change trend of the gross output value added of agriculture and farming in Dandong, Liaoning (2008-2018).

3.2 Agricultural Economic Development of Shandong Province

Shandong province is located in the downstream of the Yellow River, adjacent to the Yellow Sea and the Bohai Sea. Shandong covers an area of 158,000 square kilometers with a total population of 100.06 million. Shandong consists of 16 prefecture-level cities, of which 4 prefecture-level cities located along the Yellow Sea, including Yantai, Weihai, Qingdao, Rizhao.

In 2018, the GDP of Shandong province was 7,646.97 billion yuan, up by 6.4% over the previous year. Of this total, the value added of the primary industry was 495.05 billion yuan, that of the secondary industry was 3,364.17 billion yuan, and that of the tertiary industry was 3,787.74 billion yuan. The per capita GDP of Shandong province in 2018 was 76,267 yuan.

Shandong is a famous large agricultural province in China with a long history, and its agricultural added value has ranked first among all the provinces in a long term. The existing agricultural land area in Shandong province is 11,514,300 hectares, of which the cultivated land area is 7,607,000 hectares, accounting for 48% of the total land area in Shandong and 5.63% of the total cultivated land area in China. Besides, the cultivated land area in the 4 prefecture-level cities along the Yellow Sea is 1,398,066 hectares,

accounting for 18.4% of the total cultivated land area in Shandong. Among the gross output value of agriculture, the output value of farming accounted for 48%, forestry accounted for 1.8%, animal husbandry accounted for 27.4%, and fishery accounted for 16%. Shandong is an important province in terms of the production of the grain and economic crops in China. The output of grain crops of Shandong ranks second in China, and the output of vegetables, fruit, meat and aquatic products ranks the top group all over the country. The main grain crops in Shandong include wheat, corn, soybeans, sweet potatoes, sorghum, miscellaneous grains, etc., and the economic crops include cotton, tobacco, peanuts, etc. Shandong is an important cotton-producing base in northern China. Moreover, Shandong is not only the largest *vegetable basket* in China, but also the main temperate fruit producing area.

Fig 3.4. Schematic diagram of research area in Shandong province

Yantai is located in the middle of the Shandong peninsula, adjacent to the Bohai Sea in its north and the Yellow Sea in its south. Yantai is a key coastal open port city in Jiaodong region. Yantai consists of 4 districts, 1 county and 7county-level cities with a population of 7.12 million. The GDP of Yantai in 2018 was 783.26 billion yuan. Of this total, the value added of the primary industry was 51.00 billion yuan, accounting for 6.5% of the region's GDP. The value added of the secondary industry was 384.40 billion yuan, and that of the tertiary industry was 347.85 billion yuan. The per capita GDP of Yantai in 2018 was 110,231 yuan. The gross output value added of agriculture in 2018

was 54.24 billion yuan, in which the output value added of farming accounted for 42.9%, forestry accounted for 2.5%, animal husbandry accounted for 13.1%, and fishery accounted for 35.5%. Based on its special geographical location and abundant agricultural resources, Yantai has become a production base for famous and excellent agricultural products in northern China.

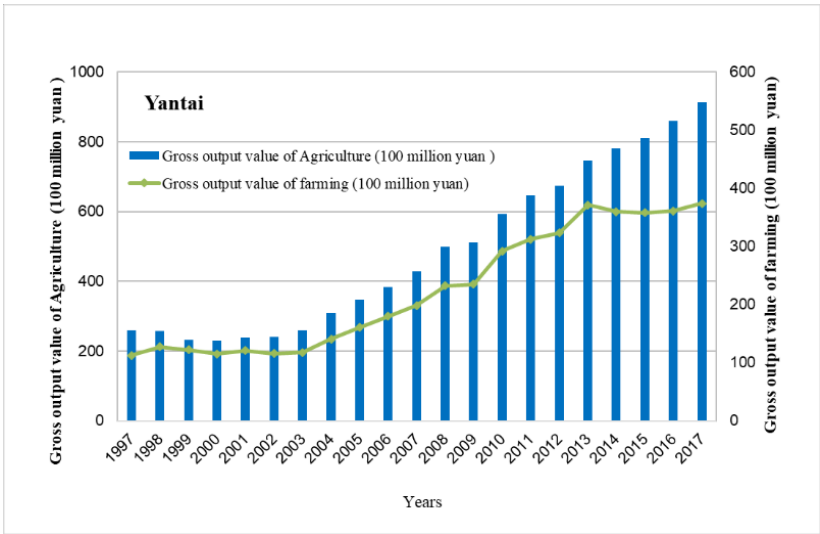


Fig 3.5. Change trend of the gross output value of agriculture and farming in Yantai, Shandong (1997-2017).

Qingdao is located in the south of the Shandong peninsula, adjacent to the Yellow Sea in its east and south. Qingdao is the largest coastal city and a key coastal open port city in the Jiaodong region, and is located in the superior region of the China-Japan-ROK free trade area. Qingdao is composed of 7 districts and 3 county-level cities with a total population of 9.39 million. In 2018, the GDP of Qingdao was 1200.15 billion yuan. Of this total, the value added of the primary industry was 38.69 billion yuan, accounting for 3.2% of the region's GDP. The value added of the secondary industry was 485.06 billion yuan, and that of the tertiary industry was 676.40 billion yuan. The per capita GDP of Qingdao in 2018 was 128,459 yuan. The gross output value added of farming in 2018 was 41.06 billion yuan, that of forestry was 0.23 billion yuan, that of animal husbandry was 7.61 billion yuan, and that of fishery was 11.45 billion yuan. Qingdao has good agricultural foundation and abundant resources, which is rich in grain, oil, forest, fruit, animal husbandry, aquatic products.

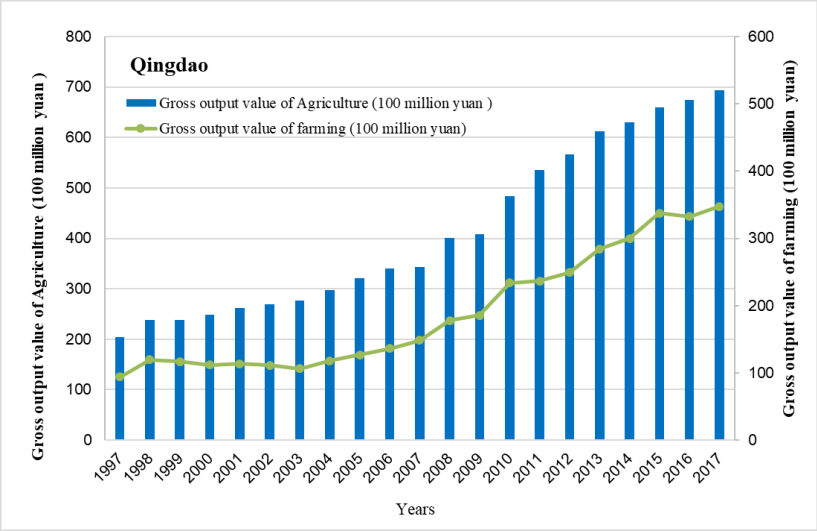


Fig 3.6. Change trend of the gross output value of agriculture and farming in Qingdao, Shandong (1997-2017).

Weihai is located in the east of the Shandong peninsula, adjacent to the Yellow Sea in its north, east and south. Weihai is one of the first coastal open cities in China. Weihai consists of 2 districts and 2 county-level cities with a population of 2.83 million. The GDP of Weihai in 2018 was 364.15 billion yuan. Of this total, the value added of the primary industry was 28.12 billion yuan, accounting for 7.7% of the region's GDP. The value added of the secondary industry was 160.12 billion yuan, and that of the tertiary industry was 175.91 billion yuan. The per capita GDP of Weihai in 2018 was 124,463 yuan. The gross output value added of agriculture in 2018 was 29.21 billion yuan, in which the output value added of farming accounted for 18.9%, forestry accounted for 0.3%, animal husbandry accounted for 9.3%, and fishery accounted for 67.8%. Weihai is one of the first modern national agricultural demonstration zones in China. Weihai is not only a production base for the raw material of green food such as apples and peanuts, but also a large city for exporting agricultural products in Shandong.

Rizhao is located in the southeast of Shandong province, adjacent to the Yellow Sea in its east. Rizhao consists of 2 districts and 2 counties with a population of 3.07 million. The GDP of Rizhao in 2018 was 220.22 billion yuan. Of this total, the value added of the primary industry was 16.65 billion yuan, accounting for 7.6% of the region's GDP. The value added of the secondary industry was 106.42 billion yuan, and

that of the tertiary industry was 97.15 billion yuan. In 2018, the per capita GDP of Rizhao was 75,329 yuan. The gross output value added of agriculture in 2018 was 17.74 billion yuan.

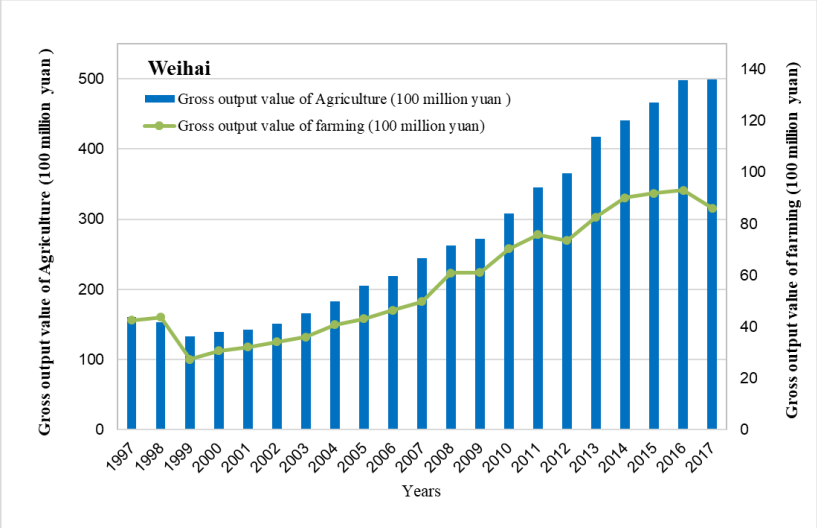


Fig 3.7. Change trend of the gross output value of agriculture and farming in Weihai, Shandong (1997-2017).

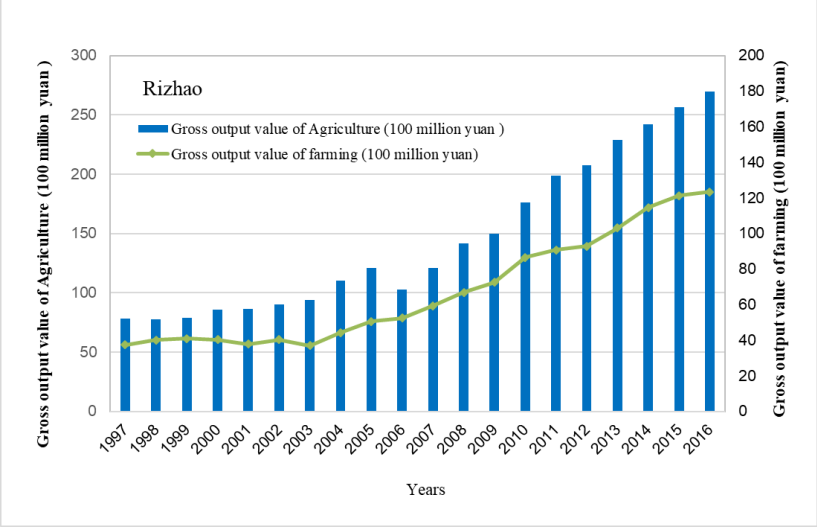


Fig 3.8. Change trend of the gross output value of agriculture and farming in Rizhao, Shandong (1997-2016).

3.3 Agricultural Economic Development of Jiangsu Province

Jiangsu province is located on the coast of the Yellow Sea, and the estuary of the Yangtze River. Jiangsu has superior geographical position and is famous for the title of "*a land flowing with milk and honey*". Jiangsu covers an area of about 107,200 square

kilometers, accounting for 1.12% of the China's total land area, which is a small province of China in area. There are 13 prefecture-level cities in Jiangsu province with a permanent resident population of 80.51 million, of which 3 prefecture-level cities located along the Yellow Sea, including Nantong, Lianyungang and Yancheng.

In 2018, the GDP of Jiangsu province was 9259.54 billion yuan, up by 6.7% over the previous year. Of this total, the value added of the primary industry was 414.17 billion yuan, that of the secondary industry was 4,124.85 billion yuan, and that of the tertiary industry was 4,720.52 billion yuan. The per capita GDP of Jiangsu province in 2018 was 115,168 yuan.

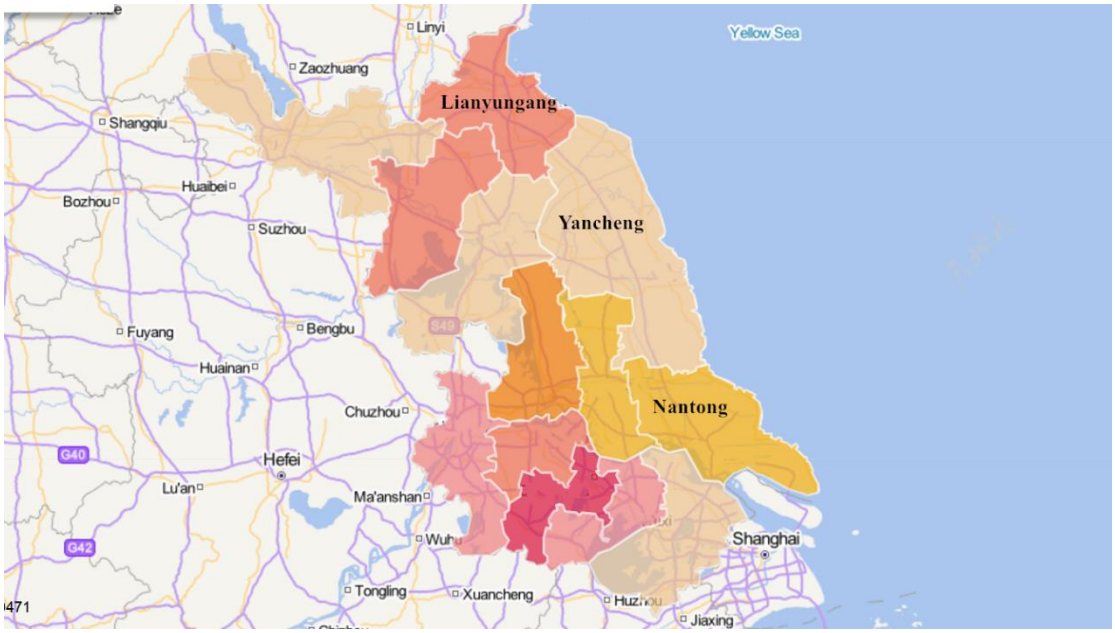


Fig 3.9. Schematic diagram of research area in Jiangsu province

Jiangsu province is located in the climate transition zone of the north and south of China, with diversified ecological type. Agricultural development in Jiangsu province has reached a high level due to its advantageous agricultural production conditions. The existing cultivated land area in Jiangsu is 4,582,700 hectares, accounting for 42.7% of the total land area in Jiangsu and 3.39% of the total cultivated land area all over the country. Besides, the cultivated land area in the 3 prefecture-level cities along the Yellow Sea is 1,671,800 hectares, accounting for 36.6% of the total cultivated land area

in Jiangsu. Among the gross output value of agriculture including farming, forestry, animal husbandry and fishery, the output value of farming accounted for 52.7%, forestry accounted for 1.9%, animal husbandry accounted for 16.2%, and fishery accounted for 22.5%. Jiangsu is one of 13 major grain producing provinces of China and the largest japonica rice producing province in southern China. Jiangsu is also an advantageous area for the production of high-quality weak gluten wheat in China. Jiangsu grows many characteristic food crops, such as corn, peanuts, oilseed rape and various miscellaneous grains and beans.

Nantong is in the southeast of Jiangsu province, adjacent to the Yellow Sea in its east. Nantong is located in the intersection between the eastern coastline of China and the Yangtze River. Nantong consists of 3 districts, 2 counties and 3 county-level cities with a population of 7.31 million. The GDP of Nantong in 2018 was 842.7 billion yuan. Of this total, the value added of the primary industry was 39.78 billion yuan, accounting for 4.7% of the region's GDP. The value added of the secondary industry was 394.79 billion yuan, and that of the tertiary industry was 408.14 billion yuan. The per capita GDP of Nantong in 2018 was 115,320 yuan. The gross output value of agriculture in 2018 was 76.12 billion yuan, in which the output value of farming accounted for 42.6%, animal husbandry accounted for 22.0%, and fishery accounted for 23.5%. Nantong has fertile soil and is suitable for a wide range of species, and it is abundant in rice, silkworm cocoons, cotton, oil plants and other crops.

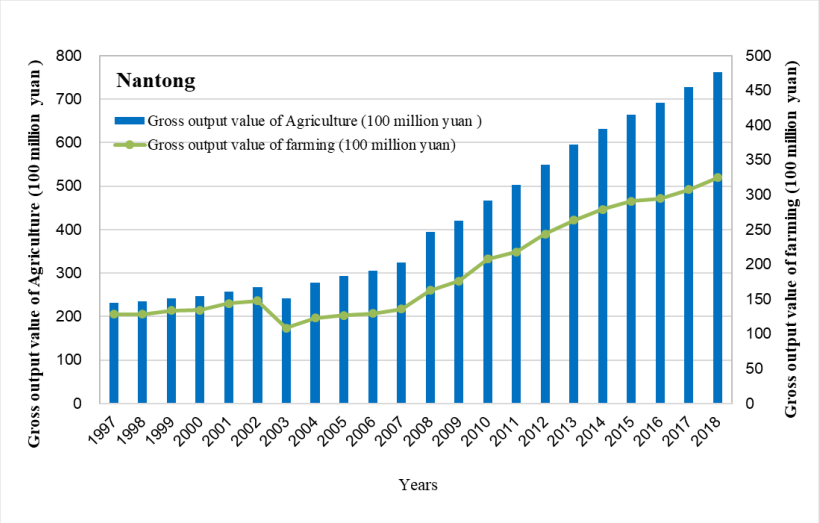


Fig 3.10. Change trend of the gross output value of agriculture and farming in Nantong, Jiangsu (1997-2018).

Lianyungang is located on the eastern coast of China, the north of the Yangtze River Delta and the northeast of Jiangsu province. Lianyungang is adjacent to the Yellow Sea in its east, facing North Korea, South Korea and Japan across the Yellow Sea. Lianyungang consists of 3 districts and 3 county-level cities with a population of 5.34 million. The GDP of Lianyungang in 2018 was 277.17 billion yuan. Of this total, the value added of the primary industry was 32.56 billion yuan, accounting for 11.7% of the region's GDP. The value added of the secondary industry was 120.74 billion yuan, and that of the tertiary industry was 123.87 billion yuan. The per capita GDP of Lianyungang in 2018 was 61,332 yuan. The gross output value of agriculture in 2018 was 63.67 billion yuan. The output value of farming accounted for 47.9%, forestry accounted for 2.5%, animal husbandry accounted for 18.2%, and fishery accounted for 24.4%. Lianyungang is abundant in rice, wheat, cotton, soybeans and peanuts, which is an important production base for agricultural and sideline products such as grain, cotton, oil, fruit, vegetables, etc.

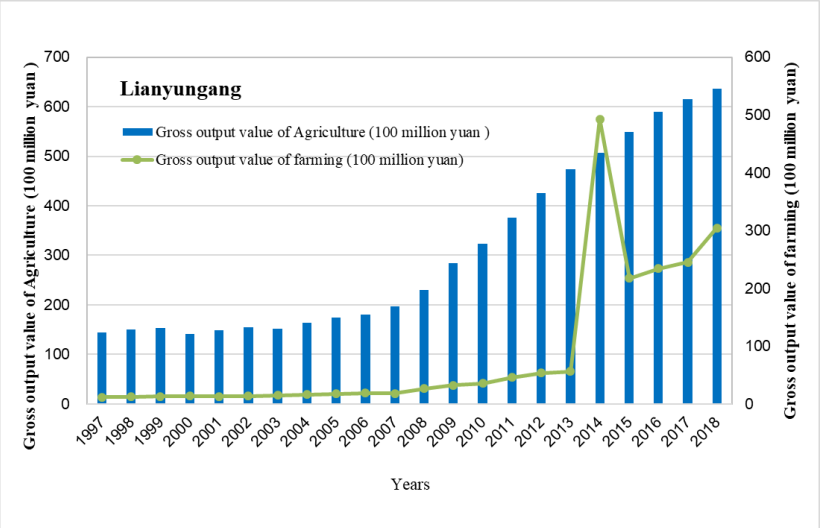


Fig 3.11. Change trend of the gross output value of agriculture and farming in Lianyungang, Jiangsu (1997-2018).

Yancheng is located in the central of coastal areas of Jiangsu province, adjacent to the Yellow Sea in its east. Yancheng has many advantageous resources, such as land,

ocean and beaches, and it is a prefecture-level city with the largest land area and the longest coastline in Jiangsu province. Yancheng consists of 3 districts, 1 county-level city and 5 counties with a population of 8.25 million. The GDP of Yancheng in 2018 was 548.71 billion yuan. Of this total, the value added of the primary industry was 57.34 billion yuan, accounting for 10.4% of the region's GDP. The value added of the secondary industry was 243.65 billion yuan, and that of the tertiary industry was 247.72 billion yuan. The per capita GDP of Yancheng in 2018 was 75,987 yuan. The gross output value of agriculture in 2017 was 113.9 billion yuan. The output value of farming accounted for 43.8%, forestry accounted for 2.5%, animal husbandry accounted for 26.7%, and fishery accounted for 19.9%.

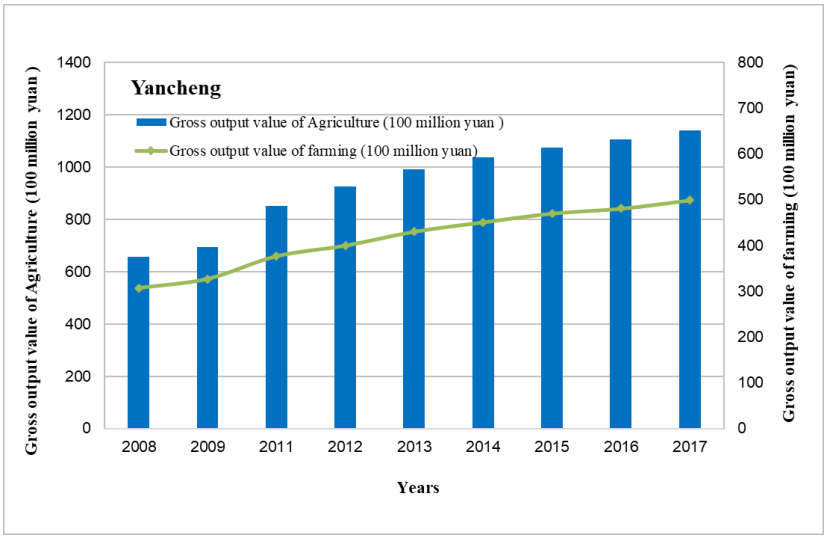


Fig 3.12. Change trend of the gross output value of agriculture and farming in Yancheng, Jiangsu (2008-2017).

4. Fertilizer use in Coastal Provinces of China

As the yield of crops increases with the development of modern agriculture, a growing number of chemical fertilizers are applied in China. It is necessary to analyze the spatial-temporal characteristics of fertilizer use in the coastal areas of the Yellow Sea and to assess its environmental risks. The research findings are conducive to understand the rationality of fertilization in the farmland of Liaoning, Shandong and Jiangsu, to strengthen the risk management and targeted guidance for fertilizer use in different regions, and to provide abundant data and information for the prevention and control of non-point source pollution in agriculture [13].

4.1 The Spatial-Temporal Variation of Fertilizer Use in Liaoning Province

4.1.1 Characteristic of Temporal Distribution for Fertilizer use in Liaoning Province

Liaoning Province is an area with moderate-intensity fertilization in China. In 2017, the total sown area of crops in Liaoning was 4,172,323 hectares, with an increase of 15.0% over 1997. Among all types of crops, the average sown area of food crops was the highest, accounting for 81.6% of the total sown areas of crops. In the past 10 years, the percentage of total sown area of food crops has remained relatively stable between 82%~83%. During 1997~2017, the sown area of food crops gradually increased after an initial decline. The sown area of food crop was 3,467,478 hectares in 2017, with an increase of 14.2% over 1997. The sown area of economic crops revealed a significant growth of 59.3% from 181,100 hectares in 1997 to 288,576 hectares in 2017. The average sown area of economic crops accounted for 11.2% in all types of crops. The sown area of other crops has remained stable in recent years, with the average value of 461,593 hectares, and its proportion in total sown area of all crops decreased from 11.3% in 1997 to 6.9% in 2017. The change trend of total sown area of all types of crops and its composition in Liaoning Province is shown in Fig 4.1.

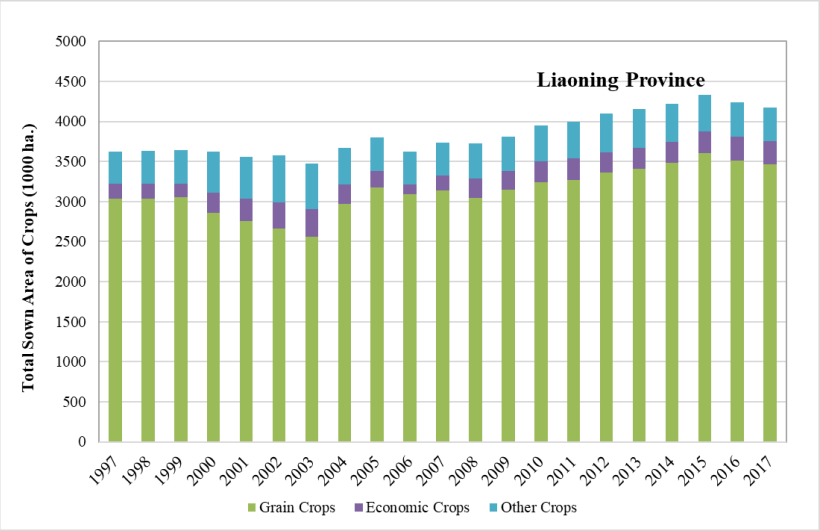


Fig 4.1. Change trend of total sown area of crops and its composition in Liaoning Province during 1997~2017

As shown in Fig 4.2, the sown area of crops in Dalian and Dandong accounted for a relatively small percentage in the whole province. Specifically, the total sown area of crops of the two cities accounted for an average percentage of 13.21% during 1997-2017, of which the total sown area of crops in Dalian accounted for 8.1% and the total sown area of crops in Dandong accounted for 5.1%. In recent years, the total sown area of crops of the two cities gradually decreased to 515,800 hectares in 2017, accounting for 12.36% in the whole province.

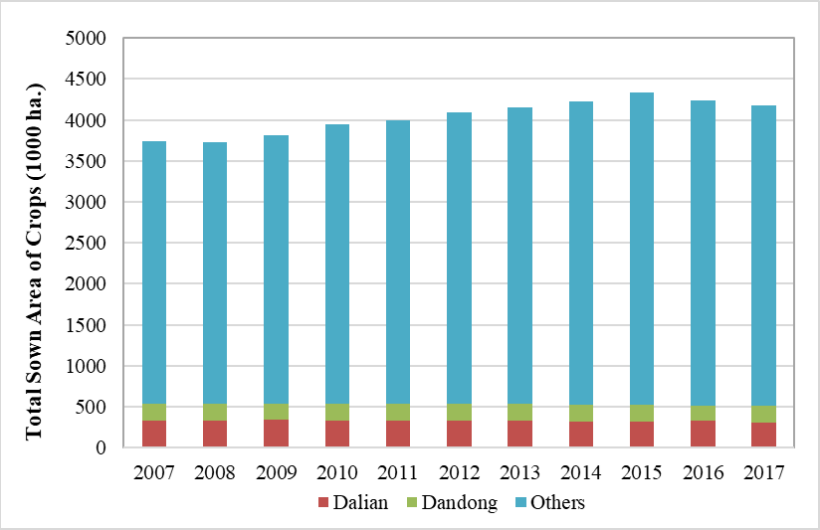


Fig 4.2. Total sown area of crops of Dalian and Dandong in Liaoning Province during 2007~2017

Fig. 4.3 shows the change trend of amount and composition of chemical fertilizers

use in Liaoning Province from 2007 to 2017. In recent 10 years, the total amount of chemical fertilizer used in Liaoning slightly increased from 1,275,000 tons in 2007 to 1,455,000 tons in 2017. In terms of the composition of fertilizer inputs, the amount of N-fertilizer showed a downward trend with a decrease of 13%, the amount of P-fertilizer and K-fertilizer remained stable in recent 10 years with the average of 115,955 tons and 121,709 tons, respectively. The amount of compound fertilizer gradually increased from 397,200 tons in 2007 to 668,000 tons in 2017, up by 68.2% in recent 10 years.

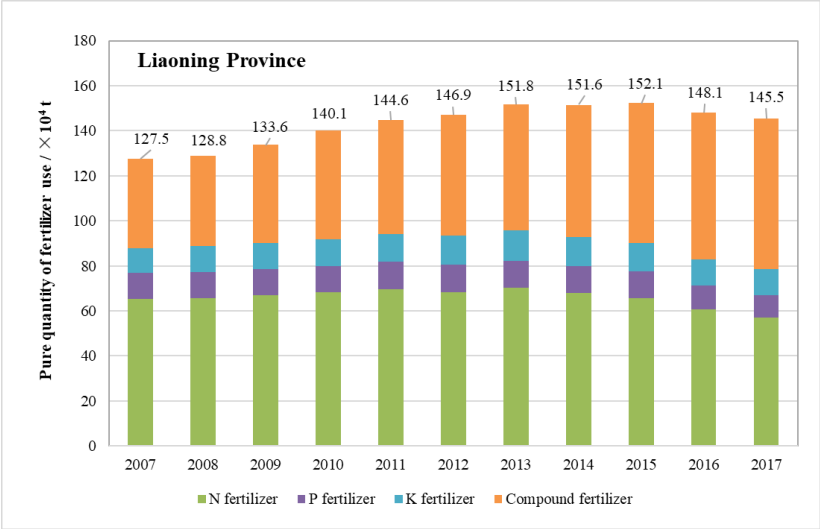


Fig 4.3. Dynamic of amount of fertilizer use in Liaoning Province from 2007 to 2017

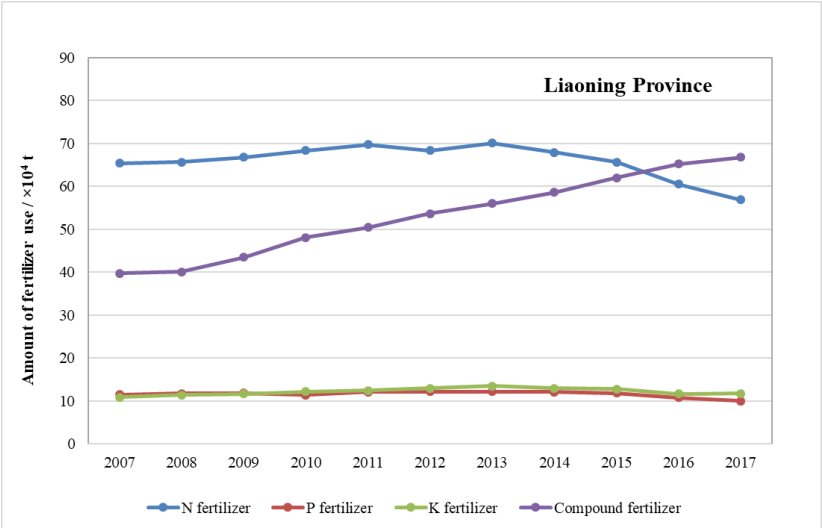


Fig 4.4. Dynamic of use of different fertilizer in Liaoning Province from 2007 to 2017

As shown in Fig 4.5, the amount of fertilizer used in Dalian and Dandong accounted for a relatively small percentage in the whole province. During 2007~2017, the total amount of fertilizer use in the two cities remained stable, accounting for an average percentage of 16.12%, of which the amount of fertilizer used in Dalian accounted for11.21% and the amount of fertilizer used in Dandong accounted for4.91%.

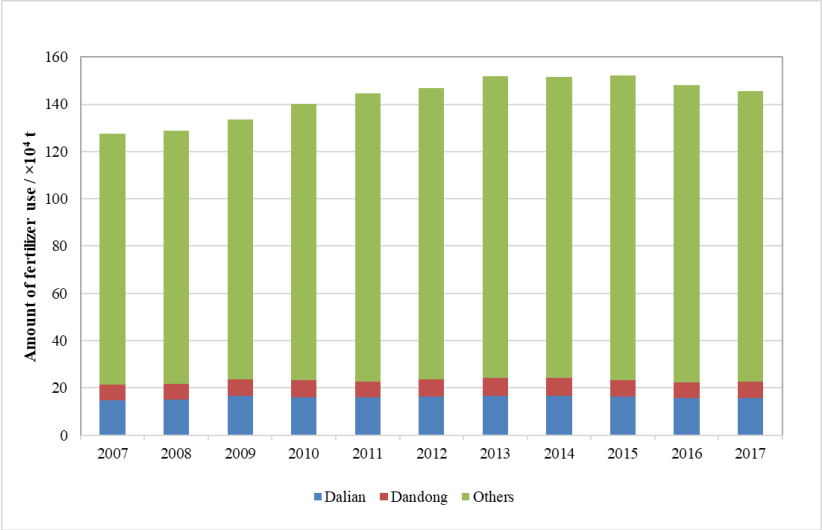


Fig 4.5. Amount of fertilizer use in Dalian and Dandong of Liaoning Province during 2007~2017

Based on the statistics data of chemical fertilizer use and the sown area of crops in Liaoning province from 2007 to 2017, the fertilization intensity was calculated and analyzed. Liaoning Province is an area with moderate-intensity fertilization, it can be seen from Table 4.1 that the total fertilization intensity of chemical fertilizer remained stable, and it was 348.73 kg/hm^2 in 2017. The fertilization intensity of nitrogen slightly decreased, while the fertilization intensity of phosphorus and potassium gradually increased. Specifically, the fertilization intensity of nitrogen in 2017 was 189.74 kg/hm^2, down by 10% over 2007. The fertilization intensity of phosphorus in 2017 was 77.34 kg/hm^2, up by 17% over 2007. The fertilization intensity of potassium in 2017 was 81.41 kg/hm^2, up by 26% over 2007. In recent 10 years, the proportion of phosphorus and potassium in chemical fertilizer gradually increased, the N:P:K was 1:0.41:0.43 in 2017. Compared with the average proportion (1:0.52:0.46) of China, the proportion of phosphorus in chemical fertilizer used in Liaoning was lower than the national average level, and the proportion of potassium was close to the national average level.

Table 4.1. Fertilization intensity (F) of Liaoning Province from 2007 to 2017 (kg/hm^2)

Years	F_T	F_N/proportion	F_P/proportion	F_K/proportion	N:P:K
2007	341.24	210.52/0.62	66.08/0.19	64.55/0.19	1:0.31:0.31
2008	345.69	211.94/0.61	67.28/0.19	66.47/0.19	1:0.32:0.31
2009	350.60	213.35/0.61	69.02/0.2	68.49/0.2	1:0.32:0.32
2010	354.67	213.49/0.6	69.45/0.2	71.47/0.2	1:0.33:0.33
2011	361.72	216.38/0.6	72.29/0.2	73.05/0.2	1:0.33:0.34
2012	358.68	210.39/0.59	73.41/0.2	75.12/0.21	1:0.35:0.36
2013	365.39	213.67/0.58	74.3/0.2	77.43/0.21	1:0.35:0.36
2014	359.26	207.2/0.58	74.96/0.21	76.86/0.21	1:0.36:0.37
2015	350.83	198.98/0.57	74.89/0.21	77.19/0.22	1:0.38:0.39
2016	349.07	193.82/0.56	76.68/0.22	78.57/0.23	1:0.40:0.41
2017	348.73	189.74/0.54	77.34/0.22	81.41/0.23	1:0.41:0.43

4.1.2 Characteristic of Temporal Distribution for Fertilizer use in Coastal Cities of Liaoning Province

(1) Dalian

The total sown area of crops in Dalian was 308,800 hectares in 2017, with a decrease of 7.7% over 2007. Fig 4.6 shows the change trend of amount and composition of chemical fertilizer use in Dalian from 2007 to 2017. The total amount of chemical fertilizer used in Dalian remained stable in recent 10 years, with an average of 159,631 tons. In terms of the composition of fertilizer inputs, fertilizer used in Dalian is mainly compound fertilizer and N-fertilizer, accounting for 47.3% and 34.0% of the total, respectively. Amount of different types of fertilizer during 2007 to 2017 remained stable, of which the amount of N-fertilizer and P-fertilizer were slightly decreased, down by 4.7% and 11.7% over 2007 respectively, and the amount of K-fertilizer and compound fertilizer were slightly increased, up by 29.3% and 12.4% over 2007, respectively.

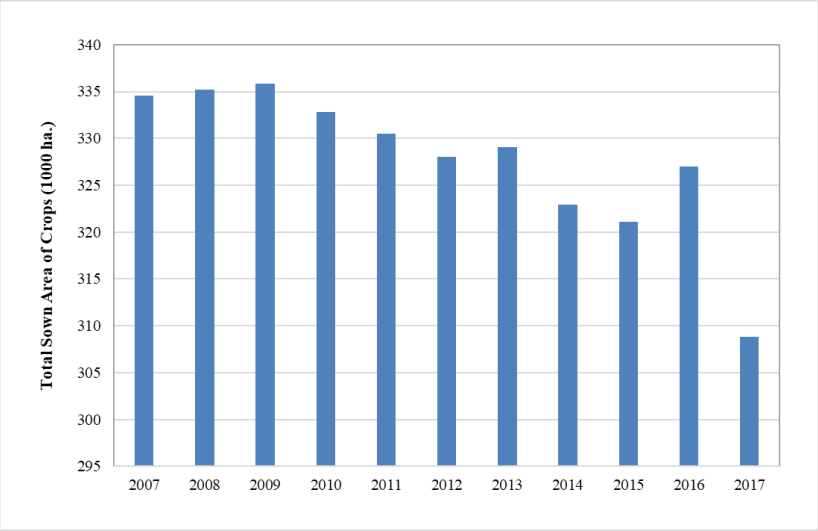


Fig 4.6. Change trend of total sown area of crops in Dalian during 2007~2017

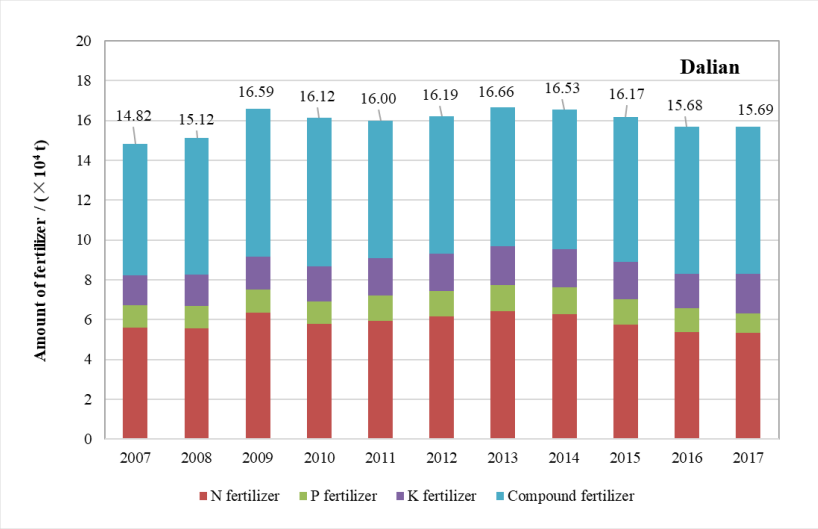


Fig 4.7. Dynamics of the amount of fertilizer use in Dalian from 2007 to 2017

Based on the statistics data of chemical fertilizer use and the sown area of crops in Dalian from 2007 to 2017, the fertilization intensity of Dalian was calculated and analyzed. As shown in Fig 4.8, the fertilization intensity of Dalian gradually increased from 443.02 kg/hm^2 in 2007 to 508.22 kg/hm^2 in 2017, up by 14.7% in recent 10 years. The fertilization intensity of nitrogen, phosphorus and potassium were increased at different level. The fertilization intensity of nitrogen in 2017 was 252.98 kg/hm^2, up by 8.5% over 2007. The fertilization intensity of phosphorus in 2017 was 111.76 kg/hm^2, up by 13.0% over 2007. The fertilization intensity of potassium in 2017 was 143.47 kg/hm^2, up by 29.2% over 2007. In recent 10 years, the proportion of

potassium in chemical fertilizer increased, the N:P:K was adjusted from 1:0.42:0.48 in 2007 to 1:0.44:0.57 in 2017. Compared with the average proportion (1:0.41:0.43) of Liaoning province, the proportion of phosphorus and potassium in chemical fertilizer used in Dalian was higher than the provincial average level.

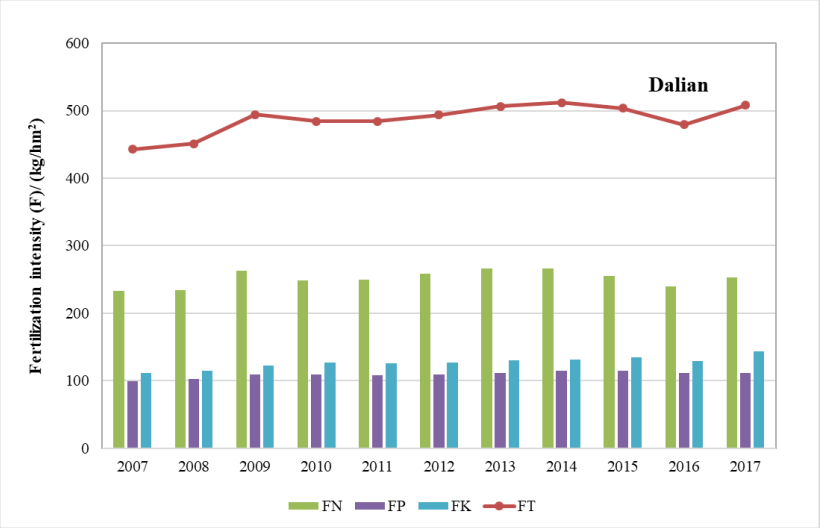


Fig 4.8. Dynamics of fertilization intensity in Dalian from 2007 to 2017

(2) Dandong

The total sown area of crops in Dandong was 207,000 hectares in 2017, with an increase of 1.4% over 2007. Fig 4.9 shows the change trend of amount and composition of chemical fertilizer use in Dandong from 2007 to 2017. The total amount of chemical fertilizer used in Dalian remained stable in recent 10 years, with an average of 70,054 tons. In terms of the composition of fertilizer inputs, fertilizer used in Dalian is mainly N-fertilizer and compound fertilizer, accounting for 52.9% and 36.8% of the total, respectively. Amount of different types of fertilizer during 2007 to 2017 remained stable, of which the amount of N-fertilizer was slightly decreased, down by 9.8% over 2007, and the amount of P-fertilizer, K-fertilizer and compound fertilizer were increased at different level, up by 7.1%, 11.1% and 35.9% over 2007, respectively.

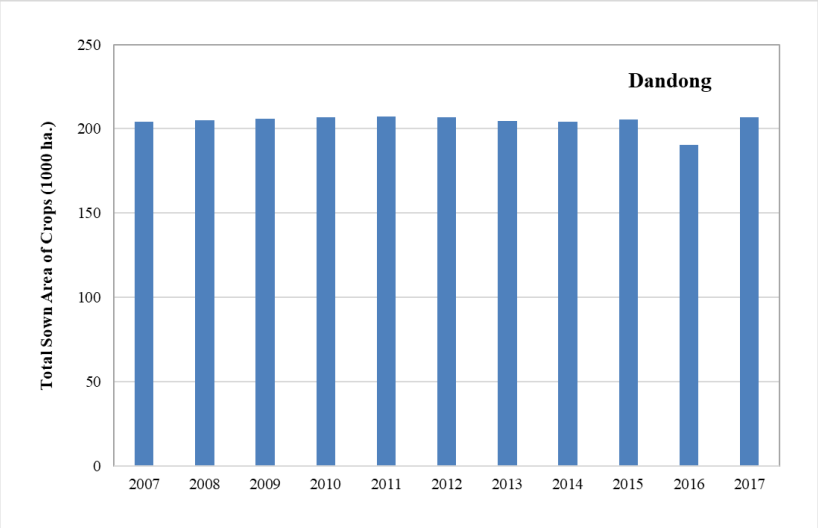


Fig 4.9. Change trend of total sown area of crops in Dandong during 2007~2017

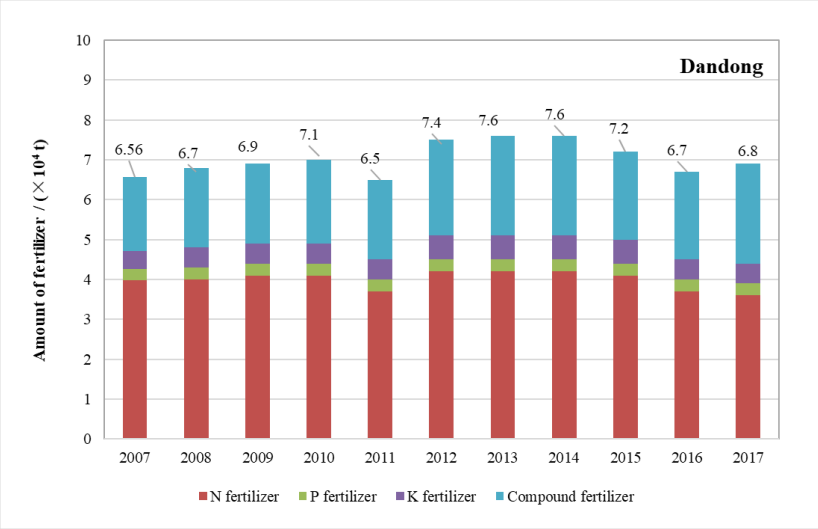


Fig 4.10. Dynamics of the amount of fertilizer use in Dandong from 2007 to 2017

Based on the statistics data of chemical fertilizer use and the sown area of crops in Dandong from 2007 to 2017, the fertilization intensity of Dandong was calculated and analyzed. As shown in Fig 4.11, the fertilization intensity of Dandong gradually decreased after an initial increase, which firstly increased from 321.25 kg/hm^2 in 2007 to 371.82 kg/hm^2 in 2014, and then decreased to 328.50 kg/hm^2 in 2017, totally up by 2.3% in recent 10 years. The fertilization intensity of nitrogen remained stable in recent years, which was 214.17 kg/hm^2 in 2017, down by 5.0% over 2007. The fertilization intensity of phosphorus and potassium were increased at different level. The fertilization intensity of phosphorus in 2017 was 54.75 kg/hm^2, up by 25.2% over 2007.

The fertilization intensity of potassium in 2017 was 64.41 kg/hm^2, up by 23.7% over 2007. In recent 10 years, the proportion of phosphorus and potassium in chemical fertilizer increased, the N:P:K was adjusted from 1:0.19:0.23 in 2007 to 1:0.26:0.30 in 2017. Compared with the average proportion (1:0.41:0.43) of Liaoning province, the proportion of phosphorus and potassium in chemical fertilizer used in Dandong was lower than the provincial average level.

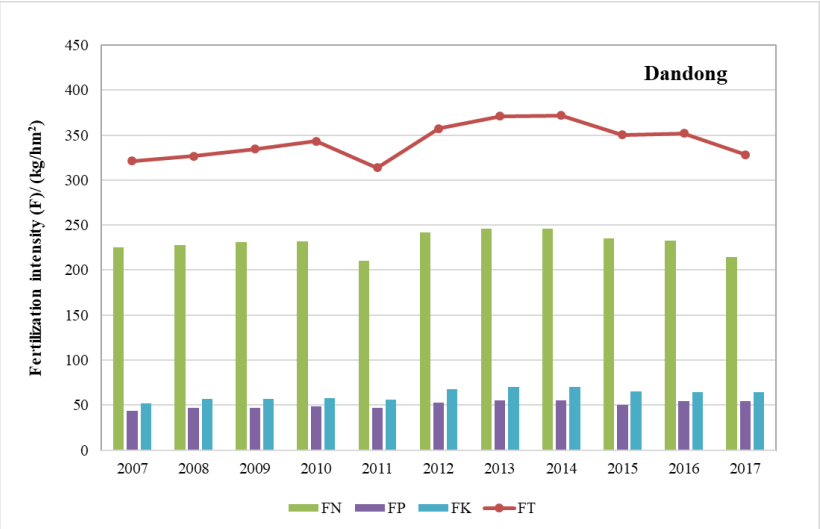


Fig 4.11. Dynamics of fertilization intensity in Dandong from 2007 to 2017

4.1.3 Spatial Variation of Fertilizer use in coastal cities of Liaoning Province

Liaoning province is located adjacent to the Yellow Sea and Bohai Sea. Most cities of Liaoning are located along the Bohai Sea, which is not in the survey regions in this project. Only Dalian and Dandong are adjacent to the Yellow Sea. Therefore, based on the data and information of fertilizer use in Liaoning province, Dalian and Dandong, the characteristics of spatial variation of fertilizer use in cities along the Yellow Sea of Liaoning province were analyzed.

In 2017, the sown area of crops in Dalian and Dandong ranked 6th and 9th among the 14 prefecture-level cities in Liaoning, accounting for 7.4% and 5.0% of the total sown area of Liaoning, respectively, ranking in the middle level of the whole the province.

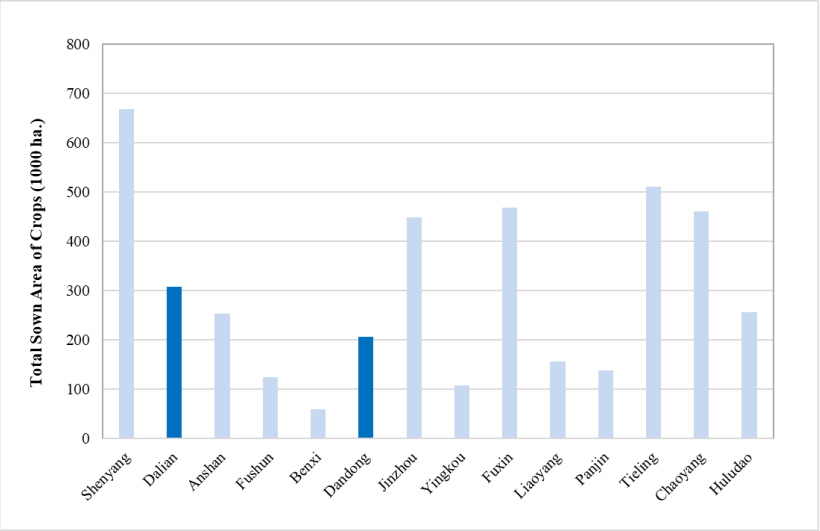


Fig 4.12. Total sown area of crops of prefecture-level cities in Liaoning Province

The amount of fertilizer used in Dalian and Dandong ranked 4th and 9th among the 14 prefecture-level cities in Liaoning, accounting for 10.8% and 4.7% of the total fertilizer use in the province, respectively.

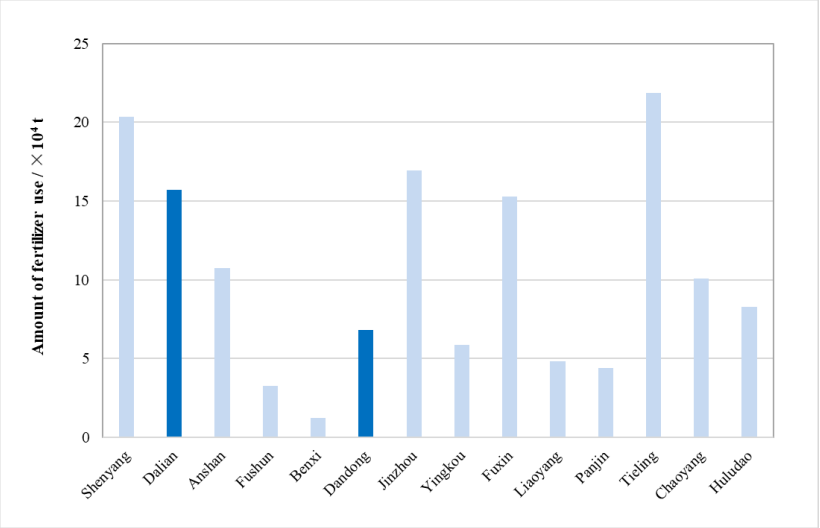


Fig 4.13. Amount of fertilizer use of prefecture-level cities in Liaoning Province

In terms of the composition of fertilizer inputs, the amount of N-fertilizer used in Dalian ranked 4th in the whole province, accounting for 9.4% of the total, and the amount of N-fertilizer used in Dandong ranked 9th in the whole province, accounting for 6.3% of the total. The amount of P-fertilizer in Dalian ranked 4th and that of Dandong ranked 13th in the whole province, accounting for 9.8% and 2.7% of the total,

respectively. The amount of K-fertilizer in Dalian ranked the second and that of Dandong ranked 10th in the whole province, accounting for 16.8% and 3.9% of the total, respectively. The amount of compound fertilizer in Dalian ranked the 5th and that of Dandong ranked the 7th in the whole province, accounting for 11.1% and 3.7% of the total province, respectively.

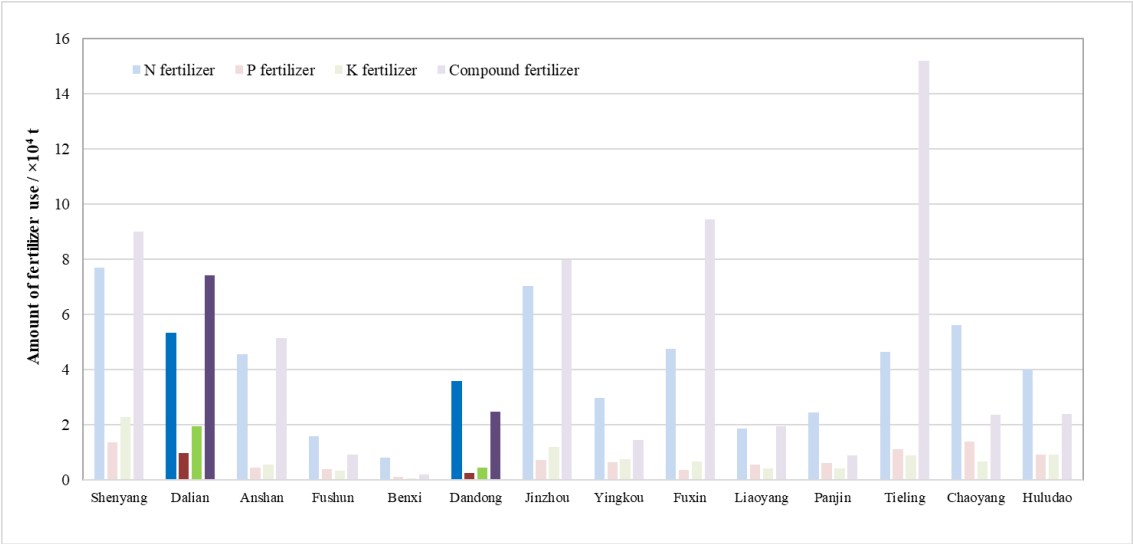


Fig 4.14. Amount of different types of fertilizer use of prefecture-level cities in Liaoning Province

In terms of fertilization intensity, Dalian is an area with ultra-high intensity fertilization, and its fertilization intensity was 508.19 kg/hm^2 in 2017. Dandong is an area with moderate intensity fertilization, and its fertilization intensity was 328.26 kg/hm^2 in 2017. Results of analysis on fertilization intensity of nitrogen, phosphorus and potassium showed that the fertilization intensity of nitrogen in Dalian ranked the second in the whole province, which was 252.97 kg/hm^2, and that of Dandong ranked the 5th in the whole province, which was 212.98 kg/hm^2.The fertilization intensity of phosphorus in Dalian ranked second and that of Dandong ranked 12th in the whole province, which was 111.76 kg/hm^2 and 53.19 kg/hm^2, respectively. The fertilization intensity of potassium in Dalian ranked first in the whole province, which was 143.47 kg/hm^2, and that of Dandong ranked 10th in the whole province, which was 62.08 kg/hm^2.

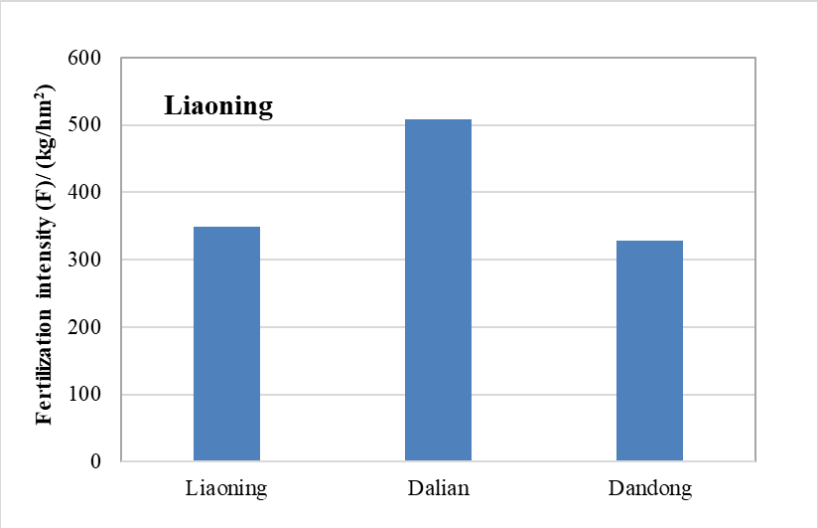


Fig 4.14-1. Fertilization intensity of coastal prefecture-level cities along the Yellow Sea in Liaoning Province

Compared with the average N:P:K ratio of fertilizers used in China (1:0.52:0.46), the proportion of phosphorus in chemical fertilizer used in Dalian (1:0.44:0.57) was lower than the national level, while the proportion of potassium was higher than the national level. The proportion of phosphorus and potassium in chemical fertilizer used in Dandong (1:25:0.29) was lower than the national level. Compared with average N:P:K ratio of fertilizers used in Liaoning (1:0.41:0.43), the proportion of phosphorus and potassium in chemical fertilizer used in Dalian were higher than the provincial level, and the proportion of phosphorus and potassium in chemical fertilizer used in Dandong were lower than the provincial level.

4.2 The Spatial-Temporal Variation of Fertilizer Use in Shandong Province

4.2.1 Characteristic of Temporal Distribution for Fertilizer use in Shandong Province

Shandong is an important agricultural province in China. Shandong is one of the main production bases of commodity grain, commodity cotton and peanut. It plays an important role in the production, supply, export and breeding of grain and vegetables. Agriculture in Shandong province is characterized by large cultivated land, large agricultural population, high multiple planting index and large amount of chemical fertilizer.

Shandong Province is an area with high-intensity fertilization in China. The total sown area of crops in Shandong was 11,107,793 hectares in 2017, which has remained stable in the recent 20 years. Among all types of crops, the average sown area of food crops was the highest, accounting for 66.1% of the total sown areas of crops. During 1999~2017, the sown area of food crops gradually increased after an initial decline. The sown area of food crop in 2017 has an increase of 4.4% over 1999, and the peak was 8,517,333 hectares in 2016. The sown area of economic crops gradually decreased after an initial increase, which firstly increased from 1332,333 hectares in 1999 to 2082,502 hectares in 2004, and then decreased to 951,745 kg/hm^2 in 2017, totally down by 28.6%. The sown area of other crops has remained stable in recent years, and a slight decline appeared in the last two years. The change trend of total sown area of all types of crops and its composition in Shandong Province is shown in Fig 4.15.

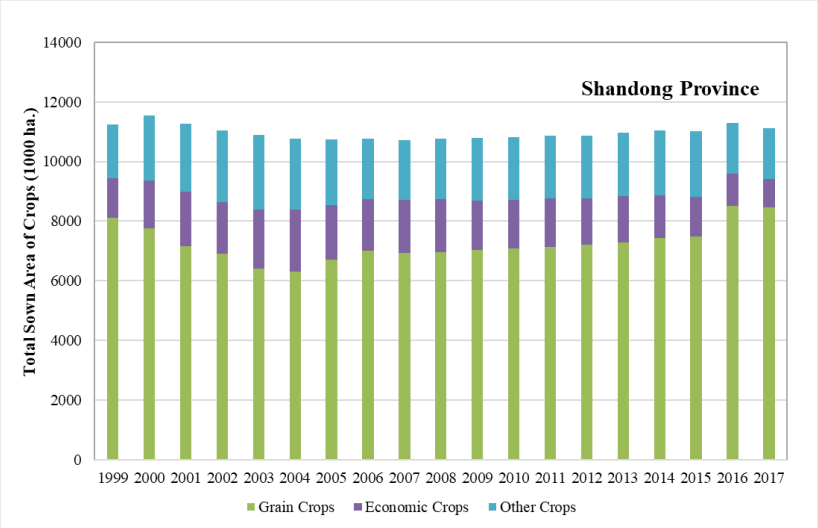


Fig 4.15. Change trend of total sown area of crops and its composition in Shandong Province during 1999~2017

Fig 4.16 shows the proportion of the sown area of crops in the 4 coastal cities along the Yellow Sea in Shandong province. From 2007 to 2017, the total sown area of crops in the 4 cities accounted for 15.97% in the whole province on average. Specifically, the sown area of Qingdao, Yantai, Weihai and Rizhao accounted for 6.6%, 4.8%, 2.2% and 2.3% in the whole province on average, respectively. In recent years, the total sown area of crops of the 4 cities gradually decreased to 1,564,908 hectares in 2017,

accounting for 14.1% in the whole province.

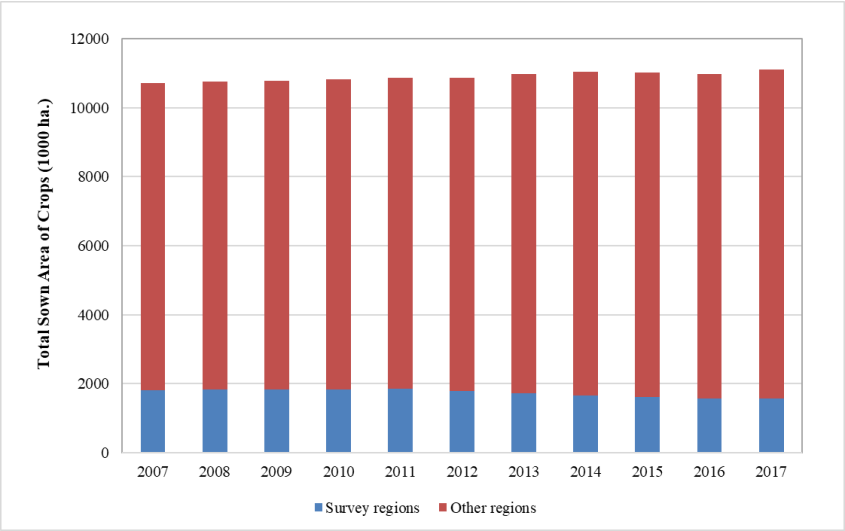


Fig 4.16. Total sown area of crops of survey regions in Shandong Province during 2007~2017

Fig. 4.17 shows the change trend of amount and composition of chemical fertilizers use in Shandong Province from 2007 to 2017. In recent 10 years, the total amount of chemical fertilizer used in Shandong gradually decreased from 5,003,447 tons in 2007 to 4,399,594 tons in 2017. In terms of the composition of fertilizer inputs, the amount of N-fertilizer, P-fertilizer and K-fertilizer gradually decreased from 1,930,922 tons, 576,702 tons, 492,708 tons in 2007 to 1,391,591tons, 452,457 tons, 383,260 tons in 2017, down by 27.9%, 21.5% and 22.2%, respectively. The amount of compound fertilizer gradually increased from 2,003,115 tons in 2007 to 2,172,287 tons in 2017, up by 8.5% in recent 10 years.

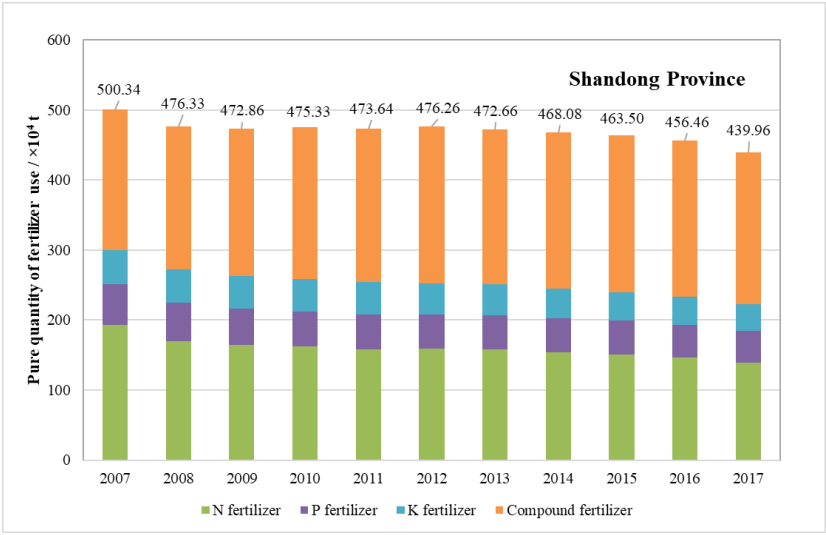


Fig 4.17. Dynamic of amount of fertilizer use in Shandong Province from 2007 to 2017

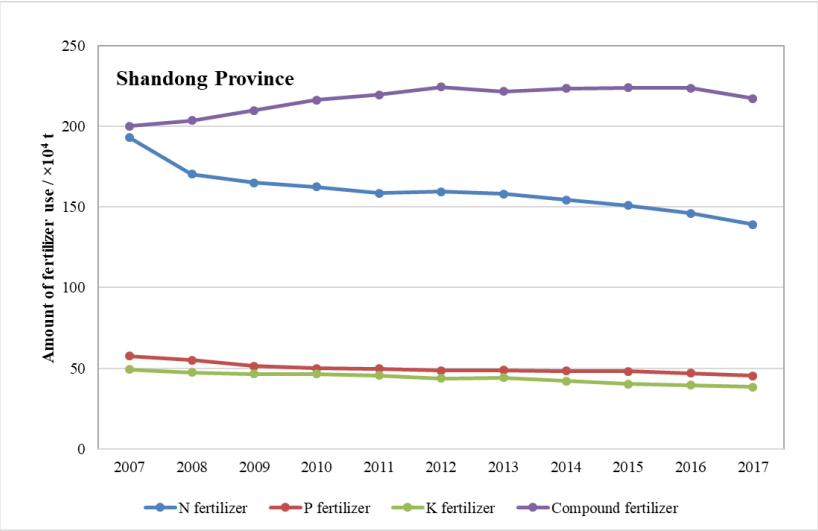


Fig 4.18. Dynamic of use of different fertilizer in Shandong Province from 2007 to 2017

As shown in Fig 4.19, the amount of fertilizer used in the 4 coastal cities along the Yellow Sea in Shandong accounted for about 25% in the whole province. During 2007~2017, the total amount of fertilizer used in the 4 cities remained stable, of which the amount of fertilizer used in Qingdao, Yantai, Weihai, Rizhao accounted for6.3%, 8.5%, 2.3% and 2.7%, respectively.

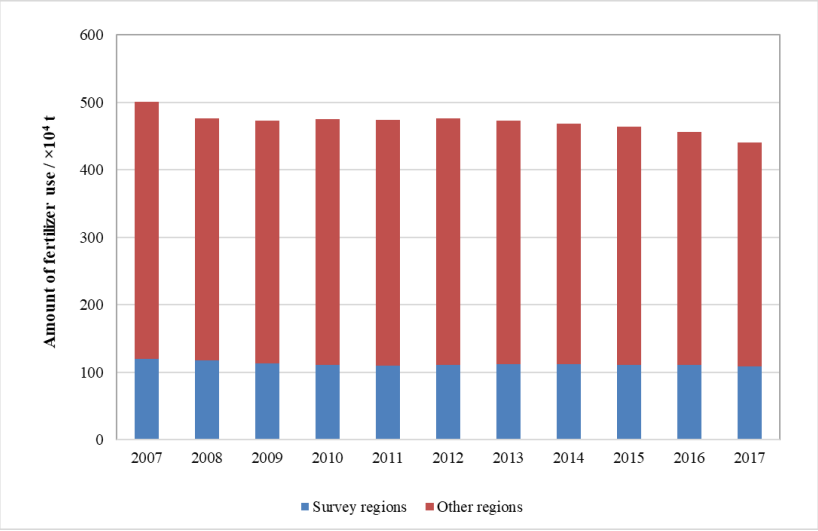


Fig 4.19. Amount of fertilizer use in survey regions of Shandong Province during 2007~2017

Based on the statistics data of chemical fertilizer use and the sown area of crops in Shandong province from 2007 to 2017, the fertilization intensity was calculated and

analyzed. Shandong Province is an area with high-intensity fertilization, it can be seen from Table 4.2 that the total fertilization intensity of chemical fertilizer gradually decreased from 466.55 kg/hm^2 in 2007 to 396.08 kg/hm^2 in 2017, totally down by 15%. The fertilization intensity of nitrogen, phosphorus and potassium were decreased at different level. Specifically, the fertilization intensity of nitrogen in 2017 was 190.47 kg/hm^2, down by 21% over 2007. The fertilization intensity of phosphorus in 2017 was 105.92 kg/hm^2, down by 9% over 2007. The fertilization intensity of potassium in 2017 was 99.69 kg/hm^2, down by 8% over 2007. In recent 10 years, the proportion of phosphorus and potassium in chemical fertilizer gradually increased, the N:P:K was 1:0.56:0.52 in 2017. Compared with the average proportion (1:0.52:0.46) of China, the proportion of phosphorus and potassium in chemical fertilizer used in Liaoning was higher than the national average level.

Table 4.2. Fertilization intensity (F) of Shandong Province from 2007 to 2017 (kg/hm^2)

Years	F_T	F_N/proportion	F_P/proportion	F_K/proportion	N:P:K
2007	466.55	242.31/0.52	116.03/0.25	108.2/0.23	1:0.48:0.45
2008	442.52	221.28/0.5	114.1/0.26	107.14/0.24	1:0.52:0.48
2009	438.71	218.03/0.5	112.59/0.26	108.09/0.25	1:0.52:0.50
2010	439.38	217.01/0.49	112.79/0.26	109.58/0.25	1:0.52:0.50
2011	435.92	213.37/0.49	113.14/0.26	109.41/0.25	1:0.53:0.51
2012	438.26	215.65/0.49	113.56/0.26	109.05/0.25	1:0.53:0.51
2013	430.61	211.4/0.49	111.76/0.26	107.45/0.25	1:0.53:0.51
2014	424.07	207.37/0.49	111.18/0.26	105.52/0.25	1:0.54:0.51
2015	420.35	204.68/0.49	111.33/0.26	104.33/0.25	1:0.54:0.51
2016	415.98	201.05/0.48	110.85/0.27	104.08/0.25	1:0.55:0.52
2017	396.08	190.47/0.48	105.92/0.27	99.69/0.25	1:0.56:0.52

4.2.2 Characteristic of Temporal Distribution for Fertilizer use in Coastal Cities of Shandong Province

(1) Qingdao

The total sown area of crops in Qingdao was 673,237 hectares in 2017, with a decrease of 7.5% over 2007. Fig 4.20 shows the change trend of amount and composition of chemical fertilizer use in Qingdao from 2007 to 2017. In recent ten years, the total amount of chemical fertilizer used in Qingdao has been decreased from 338,942 tons in 2007 to 278,251 tons in 2017. In terms of the composition of fertilizer inputs, fertilizer used in Qingdao is mainly compound fertilizer, accounting for 74.7% of the total. The amount of N-fertilizer, P-fertilizer and K-fertilizer used in Qingdao showed a downward trend. In 2017, the amount of N-fertilizer, P-fertilizer and K-fertilizer were 43,634 tons, 11,292 tons and 15,441 tons, respectively, with a decrease of 58.4%, 44.4% and 47.7% over 2007, respectively. The amount of compound fertilizer increased slightly, which was 207,885 tons in 2017, up by 12.8% over 2007.

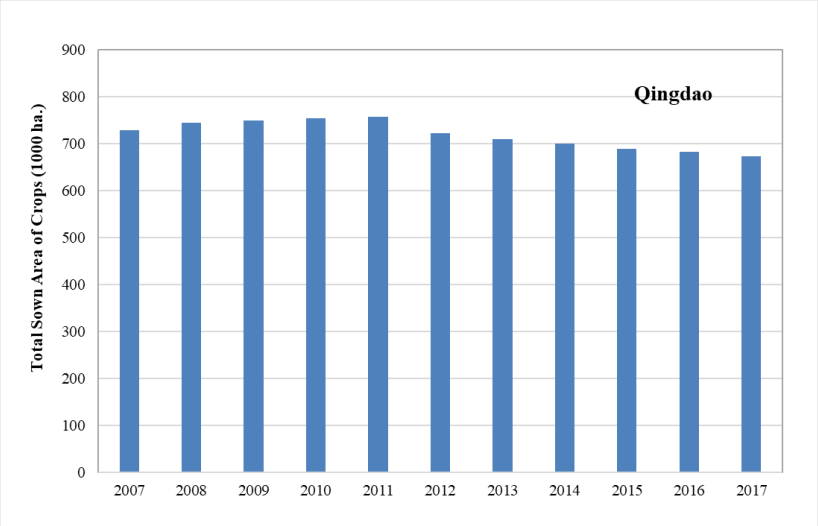


Fig 4.20. Change trend of total sown area of crops in Qingdao during 2007~2017

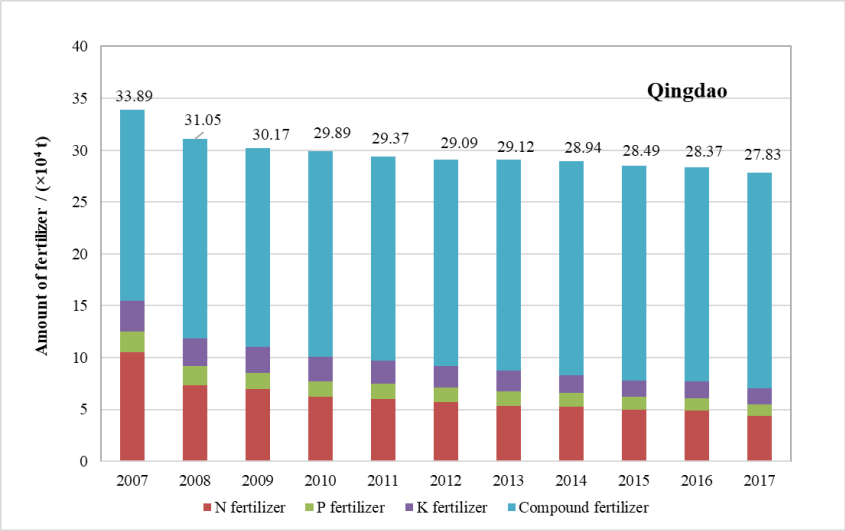


Fig 4.21. Dynamics of the amount of fertilizer use in Qingdao from 2007 to 2017

Based on the statistics data of chemical fertilizer use and the sown area of crops in Qingdao from 2007 to 2017, the fertilization intensity of Qingdao was calculated and analyzed. As shown in Fig 4.22, the fertilization intensity of Qingdao gradually increased after an initial decrease, which firstly decreased from 465.65 kg/hm^2 in 2007 to 387.98 kg/hm^2 in 2011, and then increased to 413.30 kg/hm^2 in 2017, totally down by 11.2% in recent 10 years. The fertilization intensity of nitrogen was decreased, which was 167.74 kg/hm^2 in 2017, down by 26.6% over 2007. The fertilization intensity of phosphorus and potassium remained stable in recent 10 years, which was 113.10 kg/hm^2 and 121.80 kg/hm^2 on average, respectively. In recent 10 years, the proportion of phosphorus and potassium in chemical fertilizer gradually increased, the N:P:K was adjusted from 1:0.49:0.55 in 2007 to 1:0.71:0.75 in 2017. Compared with the average proportion (1:0.56:0.52) of Shandong province, the proportion of phosphorus in chemical fertilizer used in Qingdao was higher than the provincial average level.

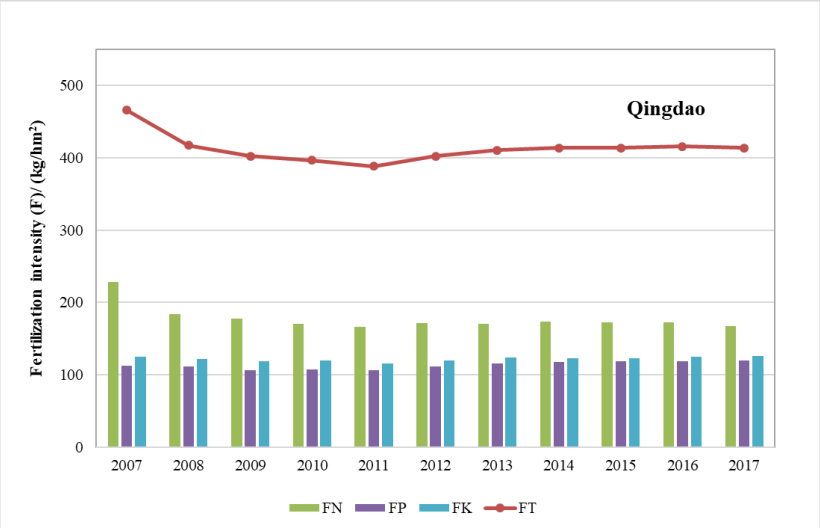


Fig 4.22. Dynamics of fertilization intensity in Qingdao from 2007 to 2017

(2) Yantai

The total sown area of crops in Yantai was 461,313 hectares in 2017, with a decrease of 18.1% over 2007. Fig 4.24 shows the change trend of amount and composition of chemical fertilizer use in Yantai from 2007 to 2017. In recent ten years, the total amount of chemical fertilizer used in Yantai has been slightly decreased from 429,919 tons in 2007 to 386,233 tons in 2017. In terms of the composition of fertilizer inputs, fertilizer used in Yantai is mainly compound fertilizer and N-fertilizer, accounting for 54.5% and 27.2% of the total, respectively. N-fertilizer, P-fertilizer and K-fertilizer use in Yantai showed a downward trend. In 2017, the amount of N-fertilizer, P-fertilizer and K-fertilizer were 104,955 tons, 28,528 tons and 42,397 tons, respectively, with a decrease of 35.1%, 36.3% and 19.3% over 2007, respectively. The amount of compound fertilizer showed an upward trend, which was 210,354 tons in 2017, up by 23.1% over 2007.

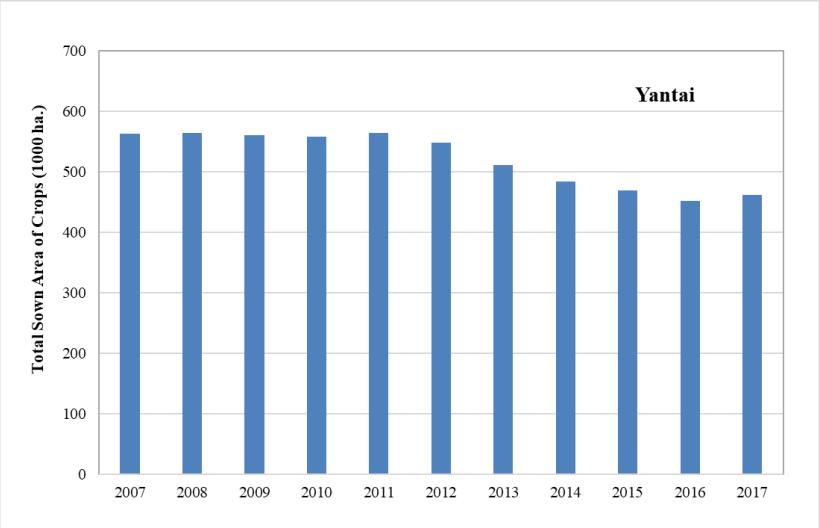


Fig 4.23. Change trend of total sown area of crops in Yantai during 2007~2017

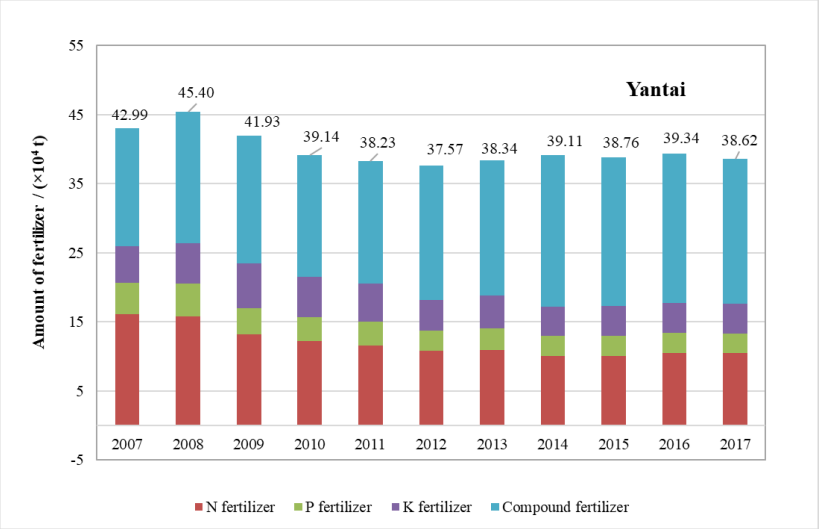


Fig 4.24. Dynamics of the amount of fertilizer use in Yantai from 2007 to 2017

Based on the statistics data of chemical fertilizer use and the sown area of crops in Yantai from 2007 to 2017, the fertilization intensity of Yantai was calculated and analyzed. As shown in Fig 4.25, the fertilization intensity of Yantai showed a wavelike increase change, increased from 763.63 kg/hm^2 in 2007 to 837.25 kg/hm^2 in 2017, totally up by 9.6% in recent 10 years. The fertilization intensity of nitrogen also revealed a trend of fluctuations, which was 379.51 kg/hm^2 in 2017, down by 2.3 % over 2007. The fertilization intensity of phosphorus and potassium showed a wavelike increase change, which were 213.84 kg/hm^2 and 243.90 kg/hm^2 in 2017 respectively, up by 18.3% and 25.4% over 2007, respectively. In recent 10 years, the proportion of

phosphorus and potassium in chemical fertilizer gradually increased, the N:P:K was adjusted from 1:0.47:0.50 in 2007 to 1:0.56:0.64 in 2017. Compared with the average proportion (1:0.56:0.52) of Shandong province, the proportion of potassium in chemical fertilizer used in Yantai was higher than the provincial average.

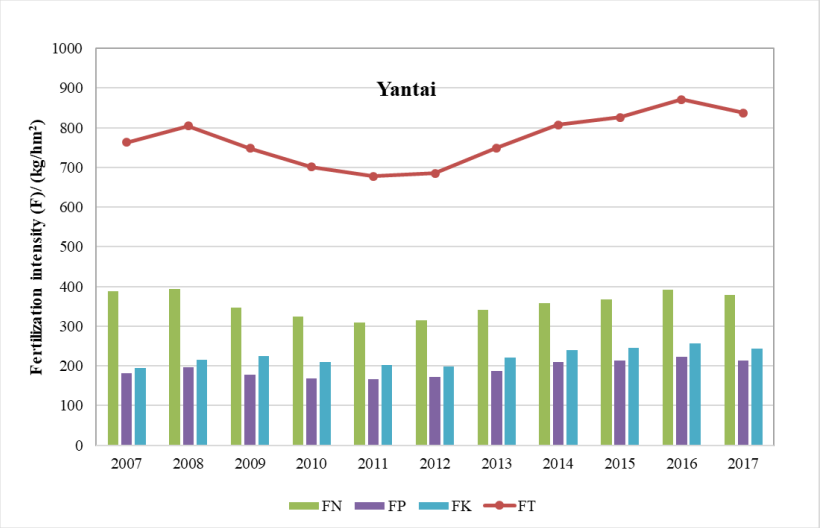


Fig 4.25. Dynamics of fertilization intensity in Yantai from 2007 to 2017

(3) Weihai

The total sown area of crops in Weihai was 203,010 hectares in 2017, with a decrease of 19.9% over 2007. Fig. 4.27 shows the change trend of amount and composition of chemical fertilizer use in Weihai from 2007 to 2017. The total amount of chemical fertilizer used in Weihai showed a wavelike decrease change during recent 10 years, which was 104,933 tons in 2017, down by 15.5% over 2007. In terms of the composition of fertilizer inputs, fertilizer used in Weihai is mainly compound fertilizer and N-fertilizer, and the proportion of N-fertilizer, P-fertilizer, K-fertilizer and compound fertilizer were 28.3%, 8.7%, 14.3% and 48.7%, respectively. The amount of N-fertilizer and P-fertilizer use in Weihai showed a downward trend, which were 29,722 tons and 9,144 tons in 2017, respectively, with a decrease of 43.1% and 50.1% over 2007, respectively. The amount of K-fertilizer remained stable in recent 10 years with the average value of 15,803 tons. The amount of compound fertilizer was increased, which was 51,072 tons in 2017, up by 34.5% over 2007.

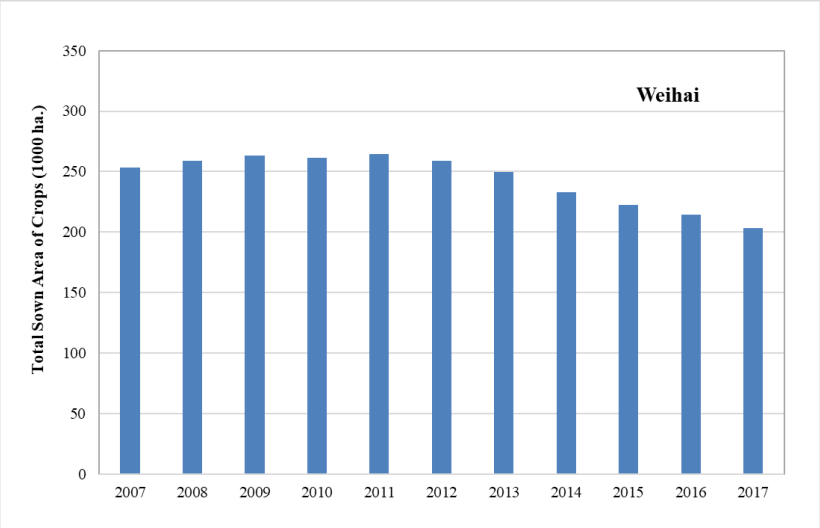


Fig 4.26. Change trend of total sown area of crops in Weihai during 2007~2017

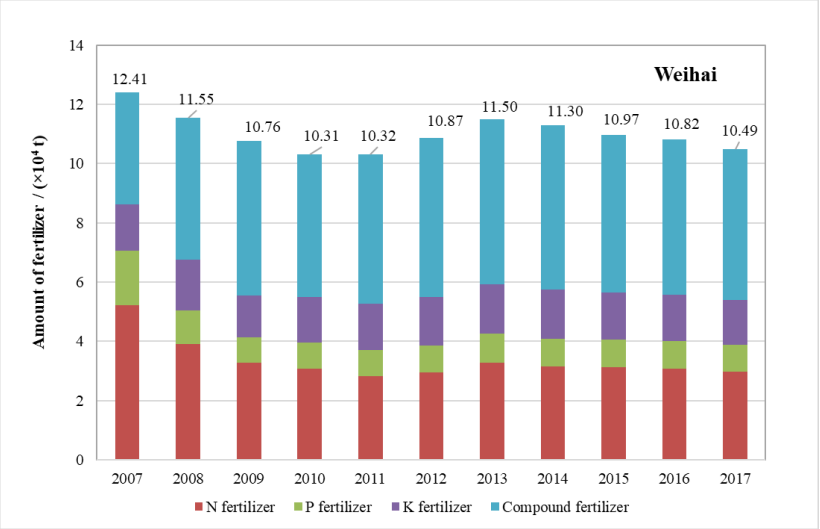


Fig 4.27. Dynamics of the amount of fertilizer use in Weihai from 2007 to 2017

Based on the statistics data of chemical fertilizer use and the sown area of crops in Weihai from 2007 to 2017, the fertilization intensity of Weihai was calculated and analyzed. As shown in Fig 4.28, the fertilization intensity of Weihai gradually increased after an initial decrease, which firstly decreased from 489.66 kg/hm^2 in 2007 to 390.23 kg/hm^2 in 2011, and then increased to 516.89 kg/hm^2 in 2017, totally up by 5.6% in recent 10 years. The fertilization intensity of nitrogen showed a downward trend, which was 230.26 kg/hm^2 in 2017, down by 10.1% over 2007. The fertilization intensity of phosphorus gradually increased after an initial decline, which was 128.90 kg/hm^2 in 2017, up by 5.4 % over 2007. The fertilization intensity of potassium was increased,

which was 157.72 kg/hm^2 in 2017, up by 41.7% over 2007. In recent 10 years, the proportion of phosphorus and potassium in chemical fertilizer gradually increased, the N:P:K was adjusted from 1:0.48:0.43 in 2007 to 1:0.56:0.68 in 2017. Compared with the average proportion (1:0.56:0.52) of Shandong province, the proportion of potassium in chemical fertilizer used in Weihai was higher than the provincial average.

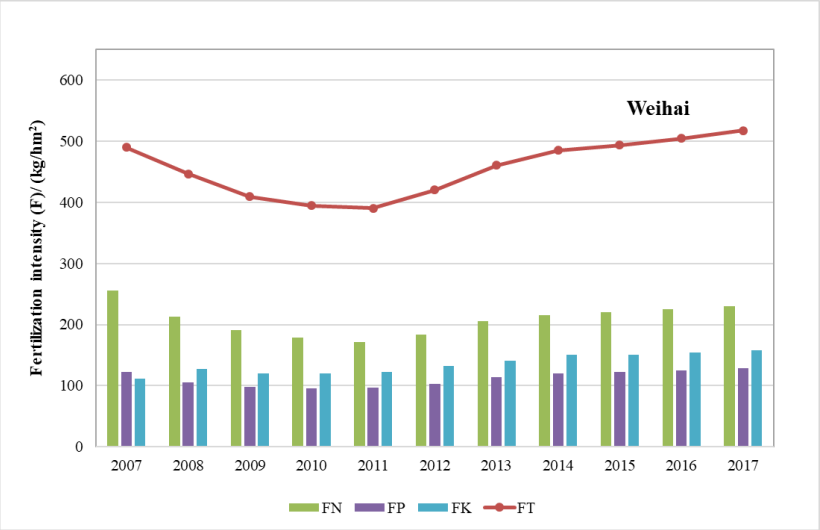


Fig 4.28. Dynamics of fertilization intensity in Weihai from 2007 to 2017

(4) Rizhao

The total sown area of crops in Rizhao was 227,349 hectares in 2017, with a decrease of 13.1% over 2007. Fig 4.30 shows the change trend of amount and composition of chemical fertilizer use in Rizhao from 2007 to 2017. In recent ten years, the total amount of chemical fertilizer used in Rizhao has been decreased from 162,325 tons in 2007 to 104,419 tons in 2017. In terms of the composition of fertilizer inputs, fertilizer used in Rizhao is mainly compound fertilizer and N-fertilizer, and the proportion of N-fertilizer, P-fertilizer, K-fertilizer and compound fertilizer were 24.7%, 8.7%, 9.3% and 57.2%, respectively. Amount of different types of fertilizer during 2007 to 2017 were decreased at different level. In 2017, the amount of N-fertilizer, P-fertilizer, K-fertilizer and compound fertilizer were 25,839 tons, 9,084 tons, 9,749 tons and 59,746 tons, respectively, with a decrease of 55.1%, 40.6%, 41.3% and 18.1% over 2007, respectively.

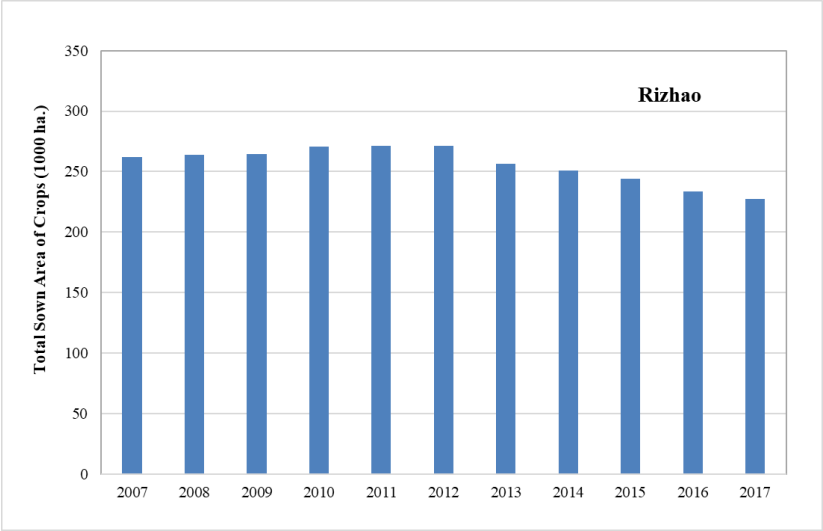


Fig 4.29. Change trend of total sown area of crops in Rizhao during 2007~2017

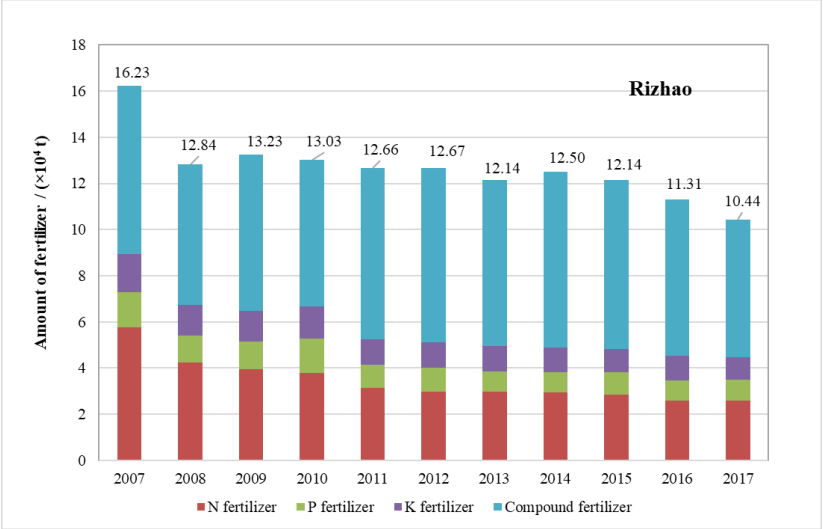


Fig 4.30. Dynamics of the amount of fertilizer use in Rizhao from 2007 to 2017

Based on the statistics data of chemical fertilizer use and the sown area of crops in Rizhao from 2007 to 2017, the fertilization intensity of Rizhao was calculated and analyzed. As shown in Fig 4.31, the fertilization intensity of Rizhao decreased from 620.21 kg/hm^2 in 2007 to 459.29 kg/hm^2 in 2017, down by 25.9% in recent 10 years. The fertilization intensity of nitrogen, phosphorus and potassium were decreased at different level. The fertilization intensity of nitrogen in 2017 was 201.25 kg/hm^2, down by 35.6% over 2007. The fertilization intensity of phosphorus in 2017 was 127.55 kg/hm^2, down by 15.7% over 2007. The fertilization intensity of potassium in 2017 was 130.48 kg/hm^2, down by 16.5% over 2007. In recent 10 years, the

proportion of phosphorus and potassium in chemical fertilizer gradually increased, the N:P:K was adjusted from 1:0.48:0.50 in 2007 to1:0.63:0.65 in 2017. Compared with the average proportion (1:0.56:0.52) of Shandong province, the proportion of phosphorus and potassium in chemical fertilizer used in Rizhao was higher than the provincial average.

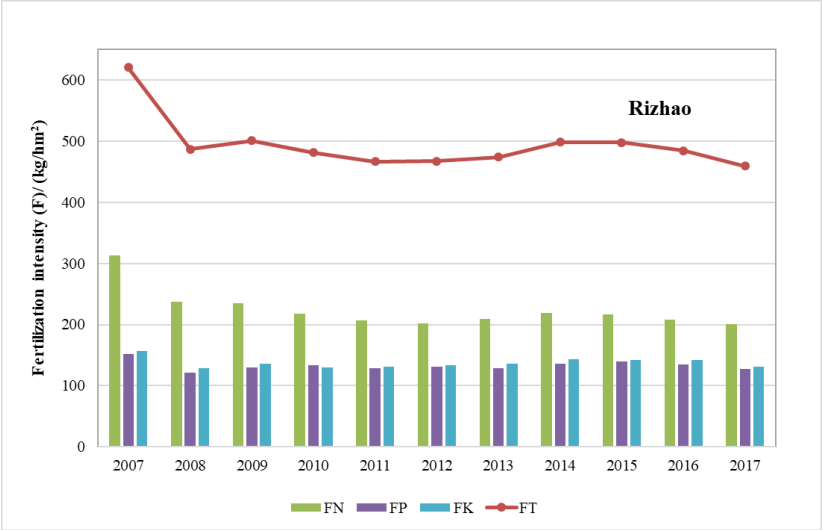


Fig 4.31. Dynamics of fertilization intensity in Rizhao from 2007 to 2017

4.2.3 Spatial Variation of Fertilizer use in coastal cities of Shandong Province

As similar as Liaoning province, Shandong province is adjacent to the Yellow Sea and the Bohai Sea. Yantai, Weihai, Qingdao and Rizhao are located along the Yellow Sea in Shandong, from north to south. Based on the data and information of fertilizer use in Shandong province and the 4 coastal prefecture-level cities, the characteristics of spatial variation of fertilizer use in coastal cities along the Yellow Sea of Shandong province were analyzed.

In 2017, the total sown area of crops of the 4 coastal cities along the Yellow Sea in Shandong accounted for 14.1% in the whole province. Specially, the sown area of crops in Qingdao ranked 8th among the prefecture-level cities in Shandong, which was 673,236 hectares, ranking in the middle level of the whole the province. The sown area of crops in Yantai, Rizhao and Weihai ranked 11th, 15th and 16th among the prefecture-level cities in Shandong, which was 461,313 hectares, 227,349 hectares and 203,010

hectares, respectively, ranking in the low level of the whole the province.

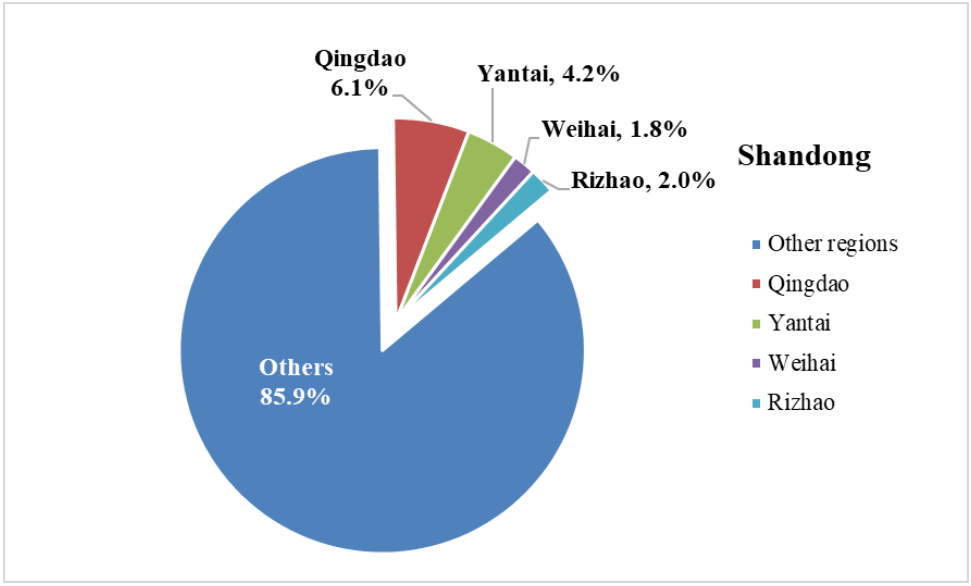


Fig 4.32. Proportion of total sown area of crops of coastal cities of the Yellow Sea in Shandong Province

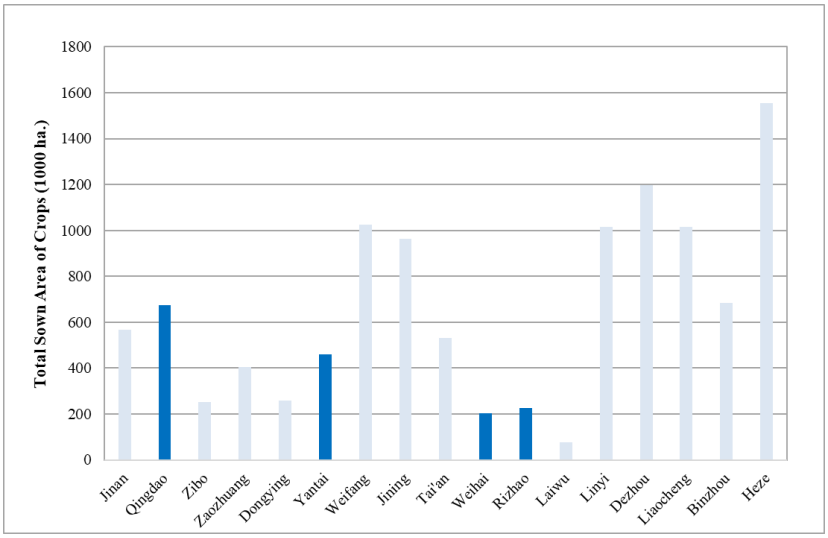


Fig 4.33. Total sown area of crops of prefecture-level cities in Shandong Province

The amount of fertilizer used in Yantai ranked 5th among the prefecture-level cities in Shandong, which was 386,233 tons in 2017. The amount of fertilizer used in Qingdao ranked 8th among the prefecture-level cities in Shandong, which was 278,251 tons in 2017, ranking in the middle level of the whole the province. The amount of fertilizer used in Weihai and Rizhao ranked 13th and 14th among the prefecture-level cities in Shandong, which were 104,933 tons and 104,419 tons in 2017 respectively,

ranking in the low level of the whole the province.

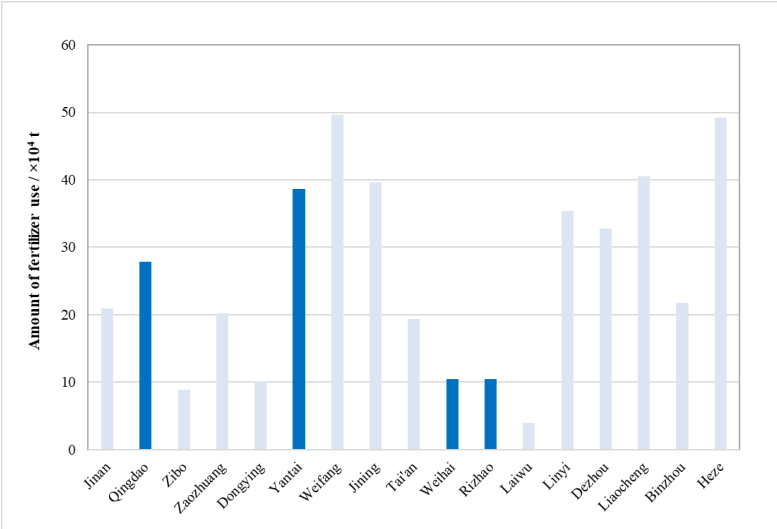


Fig 4.34. Amount of fertilizer use of prefecture-level cities in Shandong Province

In terms of the composition of fertilizer inputs, the amount of N-fertilizer used in Yantai ranked 5th in the whole province, which was 104,955 tons in 2017. The amount of P-fertilizer in Yantai ranked 7th in the whole province, which was 28,528 tons in 2017. The amount of K-fertilizer in Yantai ranked the first and it was 42,397 tons in 2017. The amount of compound fertilizer in Yantai and Qingdao ranked the 2th and 3th in the whole province, which was 210,354 tons and 207,885 tons in 2017, respectively.

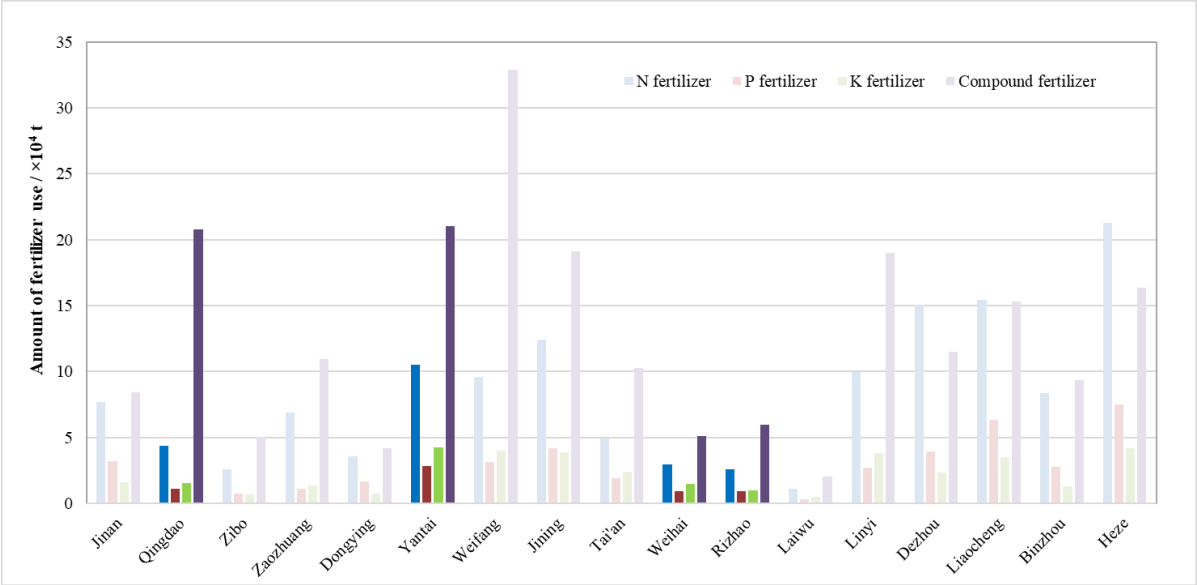


Fig 4.35. Amount of different types of fertilizer use of prefecture-level cities in Liaoning Province

In terms of fertilization intensity, Yantai, Weihai and Rizhao are areas with ultra-high intensity fertilization, and the fertilization intensity were 837.25 kg/hm^2, 516.89 kg/hm^2 and 459.29 kg/hm^2 in 2017, respectively. Qingdao is an area with high intensity fertilization, and its fertilization intensity was 413.30 kg/hm^2 in 2017.

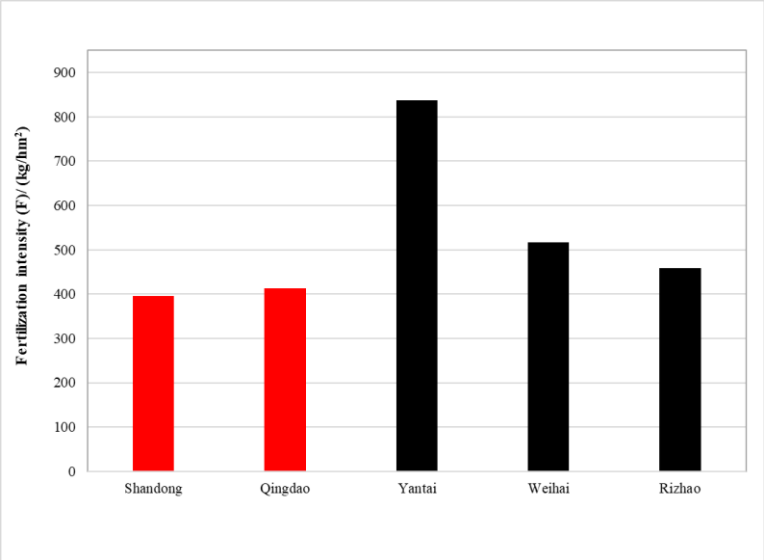


Fig 4.36. Fertilization intensity of coastal prefecture-level cities of Yellow Sea in Shandong Province

Results of analysis on fertilization intensity of nitrogen, phosphorus and potassium showed that the fertilization intensity of nitrogen in Yantai, Weihai and Rizhao were 379.51 kg/hm^2, 230.26 kg/hm^2 and 201.25 kg/hm^2, respectively, which were higher than the provincial average level. The fertilization intensity of phosphorus in Yantai, Weihai, Rizhao and Qingdao were 213.84 kg/hm^2, 128.90 kg/hm^2, 127.55 kg/hm^2 and 119.70 kg/hm^2, respectively, which were higher than the provincial average level. The fertilization intensity of potassium in Yantai, Weihai, Rizhao and Qingdao were 243.90 kg/hm^2, 157.72 kg/hm^2, 130.48 kg/hm^2 and 125.86 kg/hm^2, respectively, which were higher than the provincial average level.

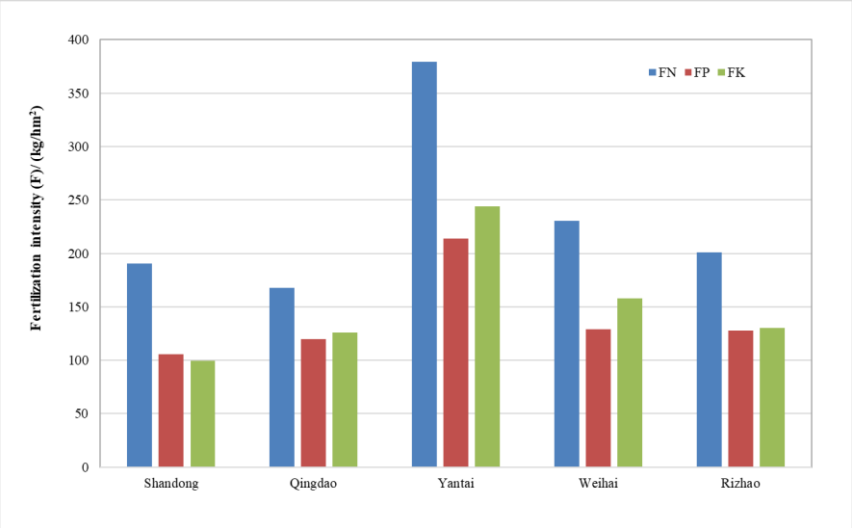


Fig 4.37. Fertilization intensity of coastal prefecture-level cities of Yellow Sea in Shandong Province

Compared with the average N:P:K ratio of fertilizers used in China (1:0.52:0.46), the proportion of nitrogen in chemical fertilizer used in coastal cities in Shandong were lower than the national level, while the proportion of phosphorus and potassium was higher than the national level. In general, the proportion of phosphorus in chemical fertilizer used in Qingdao was higher, and the proportion of potassium in chemical fertilizer used in Qingdao, Weihai, Rizhao and Yantai were higher.

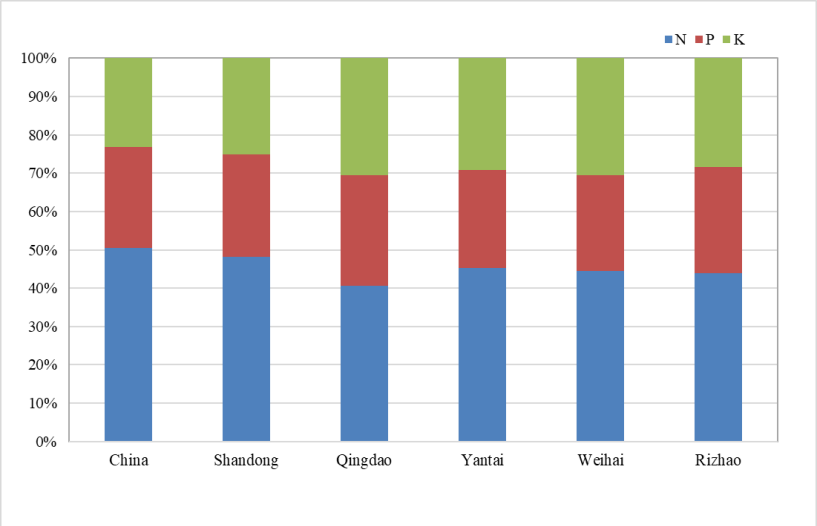


Fig 4.38. Proportion of nitrogen, phosphate, potassium in fertilizers used in coastal prefecture-level cities of Yellow Sea in Shandong Province

4.3 The Spatial-Temporal Variation of Fertilizer Use in Jiangsu Province

4.3.1 Characteristic of Temporal Distribution for Fertilizer use in Jiangsu Province

Jiangsu Province is one of the largest agricultural provinces, and it's an area with high-intensity fertilization in China [14]. In recent years, the agricultural planting structure of Jiangsu province has been continuously optimized. The total sown area of crops in Jiangsu was 7,601,250 hectares in 2017, with a decrease of 4.6% over 1997. Among all types of crops, the average sown area of food crops was the highest, accounting for 68.6% of the total sown areas of crops. During 1997~2017, the sown area of food crops gradually increased after an initial decline, and it has remained relatively stable at about 70% in the past 10 years. The average sown area of economic crops accounted for 12.2% in all types of crops, and it has been a gradual decline in recent years, which accounting 6.2% of the total. The proportion of sown area of other crops increased from 11.4% in 1997 to 22.7% in 2017. The change trend of total sown area of all types of crops and its composition in Jiangsu Province is shown in Fig 4.39.

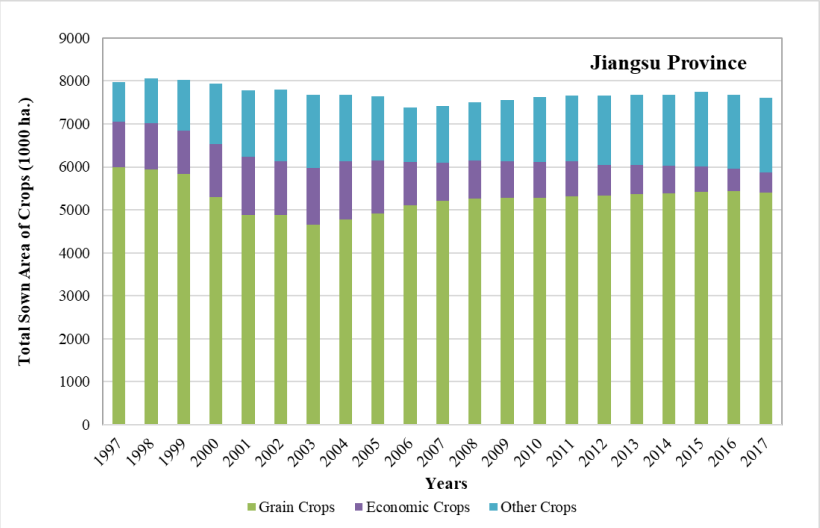


Fig 4.39. Change trend of total sown area of crops and its composition in Jiangsu Province during 1997~2017

Fig 4.40 shows the proportion of the sown area of crops in the 3 coastal cities along the Yellow Sea in Jiangsu province. From 2007 to 2017, the total sown area of crops in the 3 cities accounted for 37.8% in the whole province on average. Specifically, the sown area of Nantong, Lianyungang and Yancheng accounted for 11.1%, 8.0% and 18.8% in the whole province on average, respectively. In recent years, the total sown area of

crops of the 3 cities showed a wavelike change and it was 2,806,240 hectares in 2017, accounting for 36.9% in the whole province.

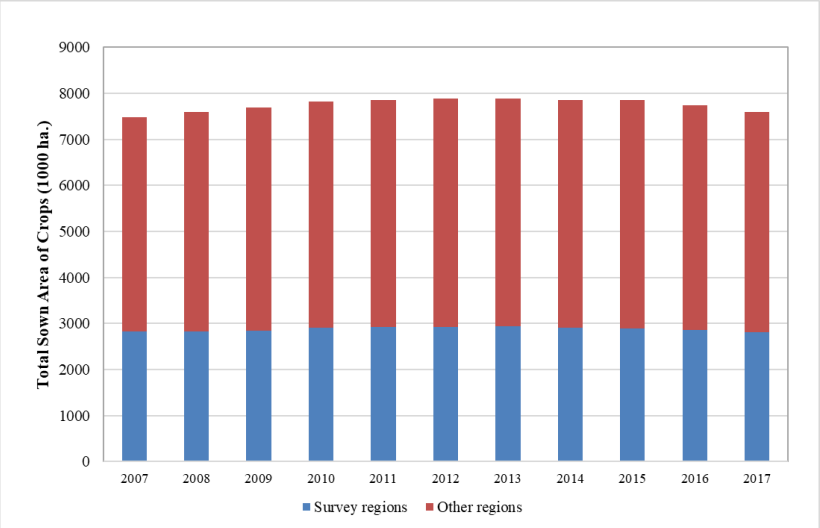


Fig 4.40. Total sown area of crops of survey regions in Jiangsu Province during 2007~2017

Fig. 4.41 shows the change trend of amount and composition of chemical fertilizers use in Jiangsu Province from 2007 to 2017. In recent 10 years, the total amount of chemical fertilizer used in Jiangsu gradually decreased from 3,420,300 tons in 2007 to 3,038,500 tons in 2017. In terms of the composition of fertilizer inputs, the amount of N-fertilizer and P-fertilizer gradually decreased from 1,828,400 tons, 480,800 tons in 2007 to 1,513,600 tons, 368,200 tons in 2017, respectively. The amount of K-fertilizer remained stable in recent 10 years with an average value of 199,145 tons. The amount of compound fertilizer gradually increased from 900,700 tons in 2007 to 974,900 tons in 2017.

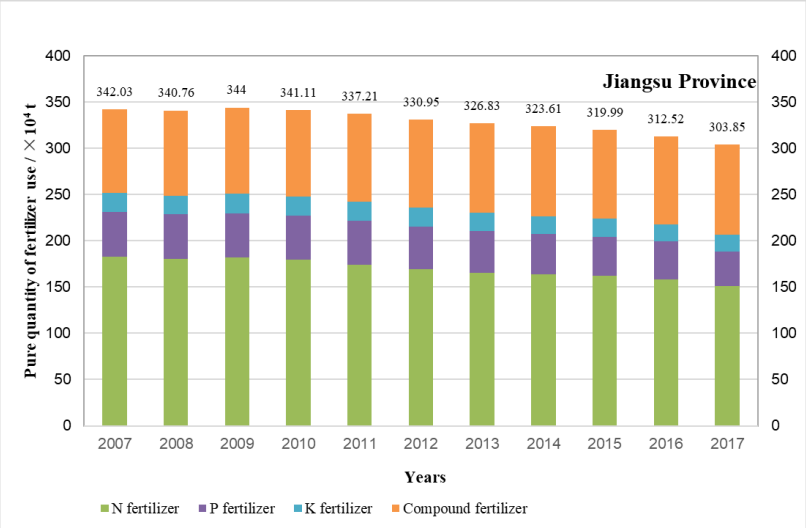


Fig 4.41. Dynamic of amount of fertilizer use in Jiangsu Province from 2007 to 2017

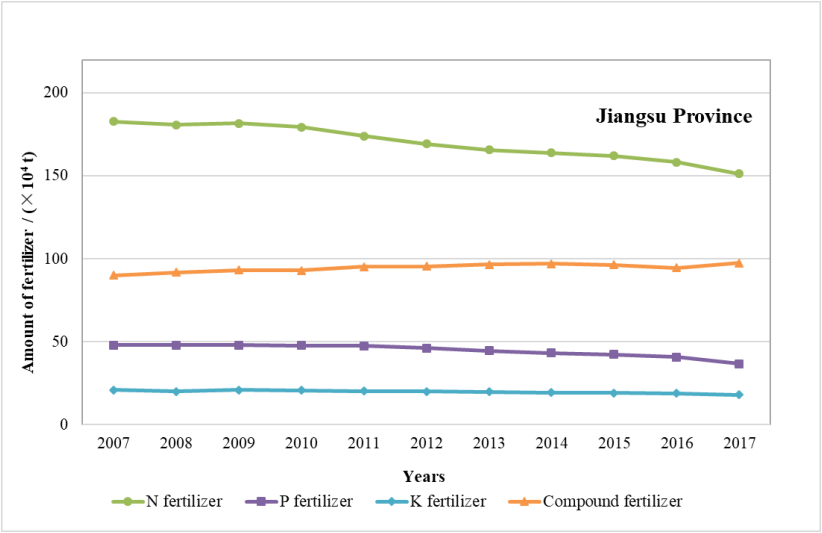


Fig 4.42. Dynamic of use of different fertilizer in Jiangsu Province from 2007 to 2017

As shown in Fig 4.43, the amount of fertilizer used in the 3 coastal cities along the Yellow Sea in Jiangsu accounted for about 35% in the whole province. During 2007~2017, the total amount of fertilizer used in the 3 cities remained stable, of which the amount of fertilizer used in Nantong, Lianyungang, Yancheng accounted for 7.3%, 10.3%, 16.9%, respectively.

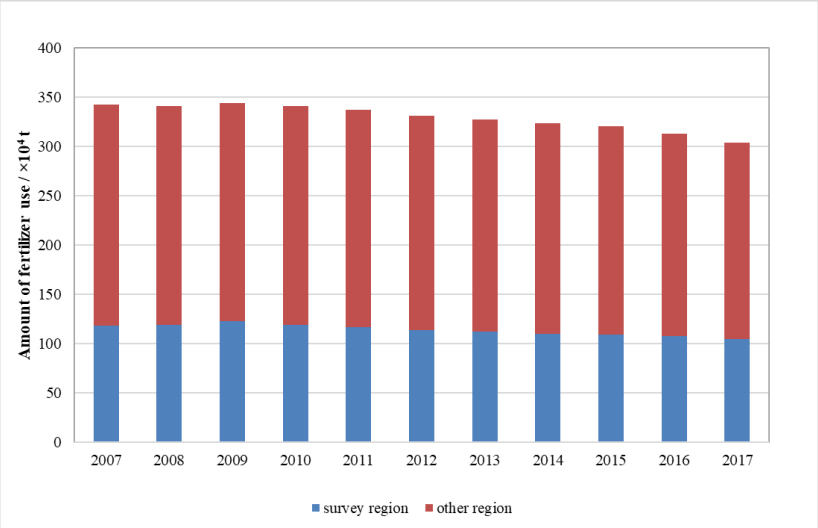


Fig 4.43. Amount of fertilizer use in survey regions of Jiangsu Province during 2007~2017

Based on the statistics data of chemical fertilizer use and the sown area of crops in Jiangsu province from 2007 to 2017, the fertilization intensity was calculated and analyzed. Jiangsu Province is an area with high-intensity fertilization, it can be seen from Table 4.3 that the total fertilization intensity of chemical fertilizer gradually decreased from 461.72 kg/hm^2 in 2007 to 399.74 kg/hm^2 in 2017, totally down by 13%. The fertilization intensity of nitrogen, phosphorus and potassium were decreased at different level. Specifically, the fertilization intensity of nitrogen in 2017 was 241.88 kg/hm^2, down by 16% over 2007. The fertilization intensity of phosphorus in 2017 was 91.19 kg/hm^2, down by 14% over 2007. The fertilization intensity of potassium in 2017 was 66.67 kg/hm^2, down by 3% over 2007. In recent 10 years, the proportion of nitrogen, phosphorus and potassium in chemical fertilizer remained stable, and the N:P:K in 2017 was 1:0.38:0.28. Compared with the average proportion (1:0.52:0.46) of China, the proportion of phosphorus and potassium in chemical fertilizer used in Liaoning was lower than the national average level.

Table 4.3. Fertilization intensity (F) of Jiangsu Province from 2007 to 2017 (kg/hm^2)

Years	F_T	F_N/proportion	F_P/proportion	F_K/proportion	N:P:K
2007	461.72	287.35/0.62	105.43/0.23	68.93/0.15	1:0.37:0.24
2008	453.73	281.43/0.62	104.77/0.23	67.53/0.15	1:0.37:0.24

Years	F_T	F_N/proportion	F_P/proportion	F_K/proportion	N:P:K
2009	455.14	281.58/0.62	104.61/0.23	68.94/0.15	1:0.37:0.24
2010	447.68	276.32/0.62	103.35/0.23	68.00/0.15	1:0.37:0.25
2011	440.04	268.46/0.61	103.48/0.24	68.09/0.15	1:0.39:0.25
2012	432.53	262.72/0.61	101.93/0.24	67.87/0.16	1:0.39:0.26
2013	425.36	257.53/0.61	100.04/0.24	67.80/0.16	1:0.39:0.26
2014	421.44	255.55/0.61	98.50/0.23	67.39/0.16	1:0.39:0.26
2015	413.15	250.69/0.61	96.14/0.23	66.32/0.16	1:0.38:0.26
2016	407.09	247.10/0.61	94.32/0.23	65.66/0.16	1:0.38:0.27
2017	399.74	241.88/0.61	91.19/0.23	66.67/0.17	1:0.38:0.28

4.3.2 Characteristic of Temporal Distribution for Fertilizer use in Coastal Cities of Jiangsu Province

(1) Nantong

The total sown area of crops in Nantong was 811,370 hectares in 2017, with a decrease of 5.1% over 2007. Fig 4.45 shows the change trend of amount and composition of chemical fertilizer use in Nantong from 2007 to 2017. In recent ten years, the total amount of chemical fertilizer used in Nantong has been decreased from 276,307 tons in 2007 to 218,600 tons in 2017, totally down by 20.9%.

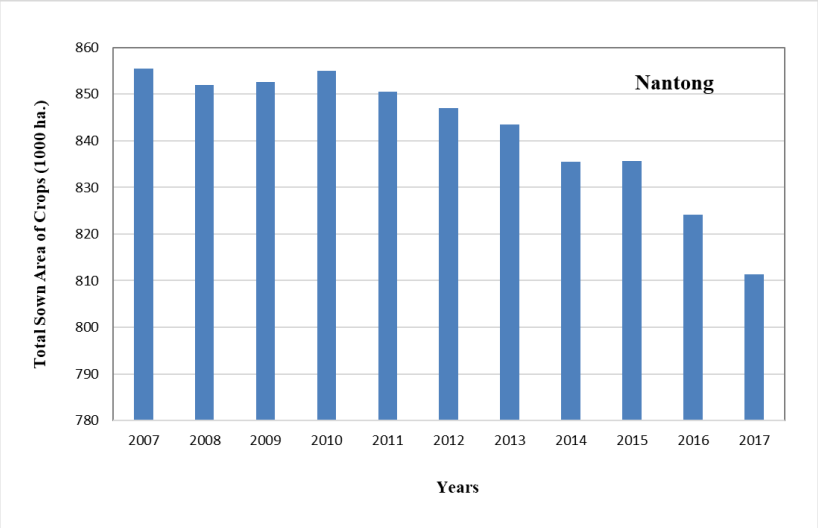


Fig 4.44. Change trend of total sown area of crops in Nantong during 2007~2017

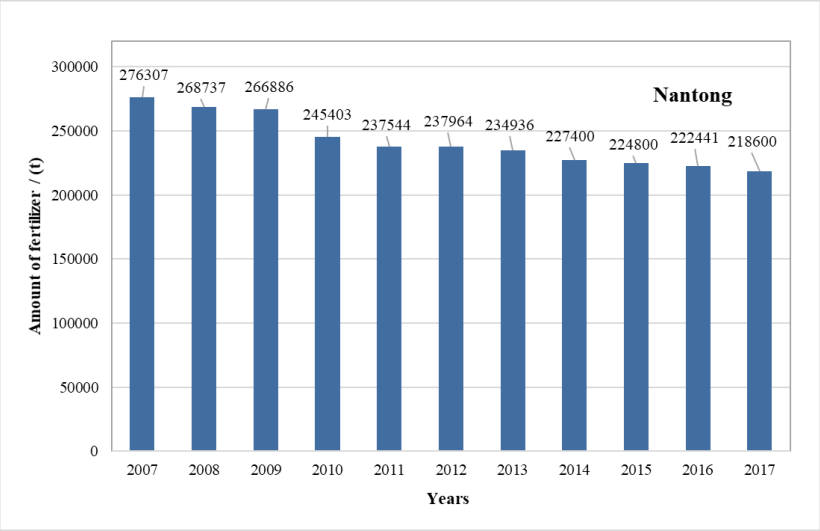


Fig 4.45. Dynamics of the amount of fertilizer use in Nantong from 2007 to 2017

Based on the statistics data of chemical fertilizer use and the sown area of crops in Nantong from 2007 to 2017, the fertilization intensity of Nantong was calculated and analyzed. As shown in Fig 4.46, the fertilization intensity of Nantong was gradually decreased from 323.01 kg/hm^2 in 2007 to 269.42 kg/hm^2 in 2017, totally down by 16.6% in recent 10 years.

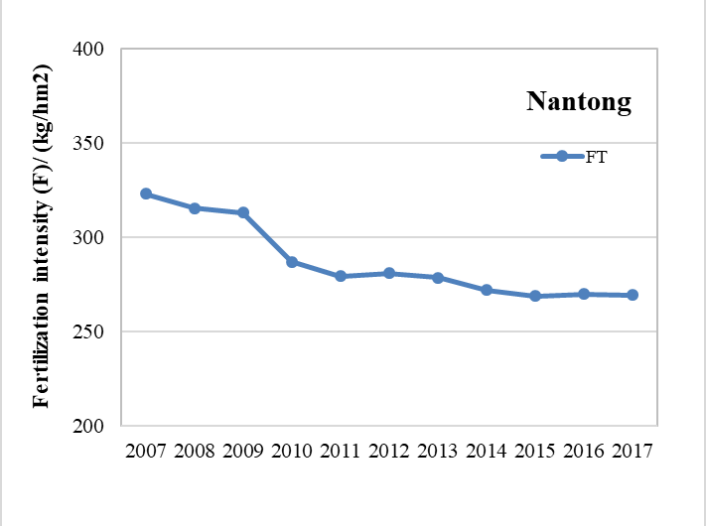


Fig 4.46. Dynamics of fertilization intensity in Nantong from 2007 to 2017

(2) Lianyungang

The total sown area of crops in Lianyungang was 628,530 hectares in 2017, with an increase of 11.6% over 2007. Fig 4.48 shows the change trend of amount and

composition of chemical fertilizer use in Lianyungang from 2007 to 2017. In recent ten years, the total amount of chemical fertilizer used in Lianyungang remained stable with an average of 338,550 tons.

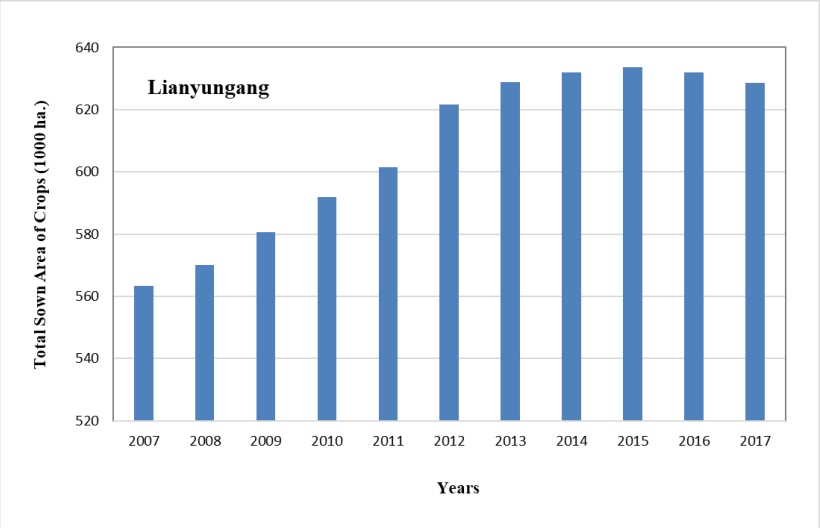


Fig 4.47. Change trend of total sown area of crops in Lianyungang during 2007~2017

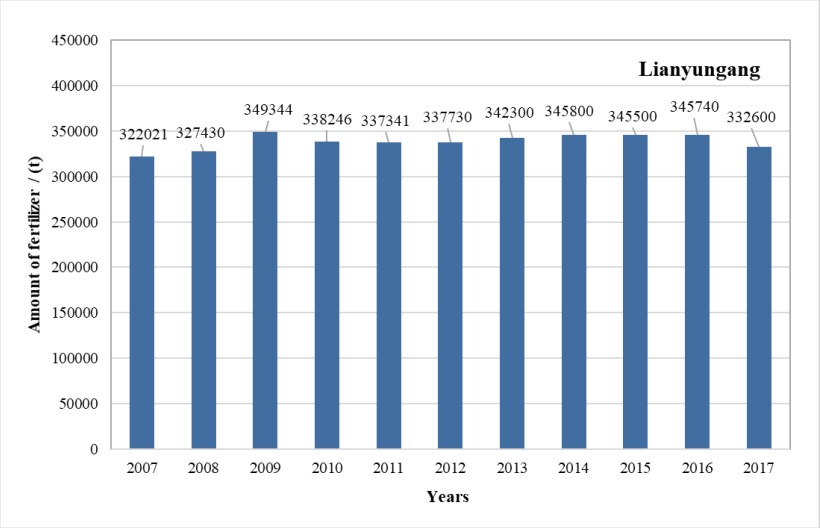


Fig 4.48. Dynamics of the amount of fertilizer use in Lianyungang from 2007 to 2017

Based on the statistics data of chemical fertilizer use and the sown area of crops in Lianyungang from 2007 to 2017, the fertilization intensity of Lianyungang was calculated and analyzed. As shown in Fig 4.49, the fertilization intensity of Lianyungang gradually decreased after an initial increase, which was increased from 571.5 kg/hm^2 in 2007 to 601.74 kg/hm^2 in 2009, and then decreased to 529.17 kg/hm^2

in 2017, totally down by 7.4% in recent 10 years.

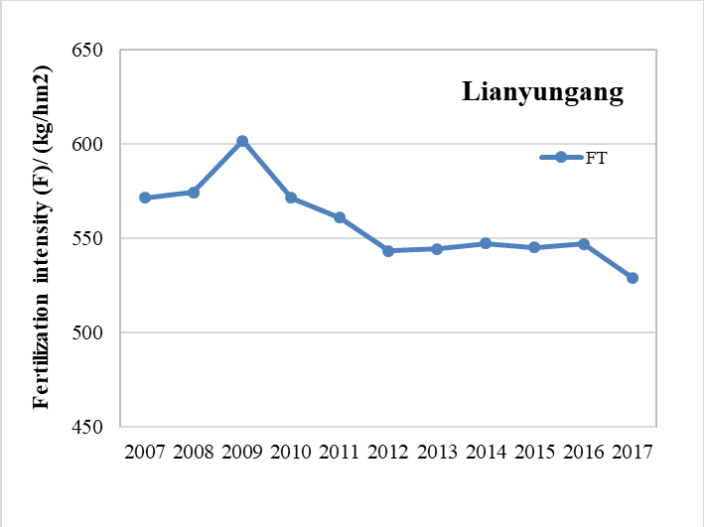


Fig 4.49. Dynamics of fertilization intensity in Lianyungang from 2007 to 2017

(3) Yancheng

The total sown area of crops in Yancheng was 1,366,340 hectares in 2017, with a decrease of 2.6% over 2007. Fig 4.51 shows the change trend of amount and composition of chemical fertilizer use in Yancheng from 2007 to 2017. In recent ten years, the total amount of chemical fertilizer used in Qingdao slightly decreased from 582,202 tons in 2007 to 496,200 tons in 2017, down by 14.8%. In terms of the composition of fertilizer inputs, fertilizer used in Yancheng is mainly N-fertilizer and P-fertilizer, and the proportion of N-fertilizer, P-fertilizer, K-fertilizer and compound fertilizer were 63.3%, 22.4%, 3.6% and 10.6%, respectively. Amount of different types of fertilizer during 2010 to 2015 were decreased at different level, with a decrease of 16.5%, 13.5%, 12.1% and 6.5% in 2015 over 2010, respectively.

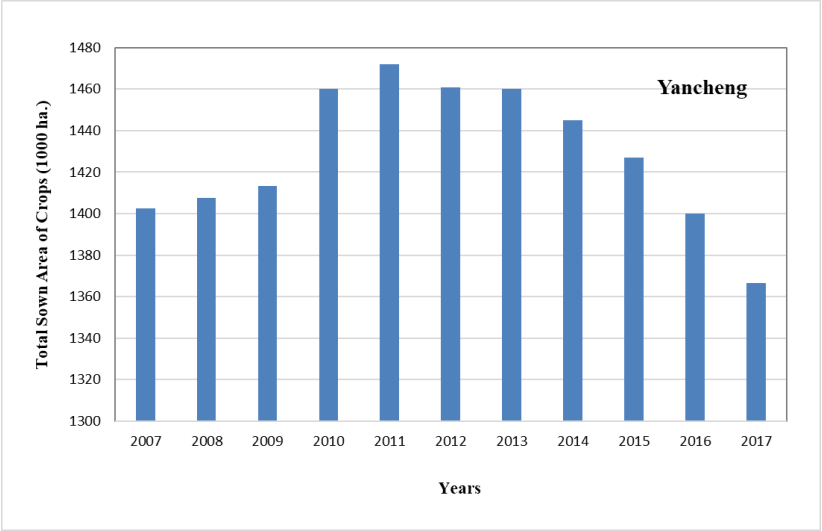


Fig 4.50. Change trend of total sown area of crops in Yancheng during 2007~2017

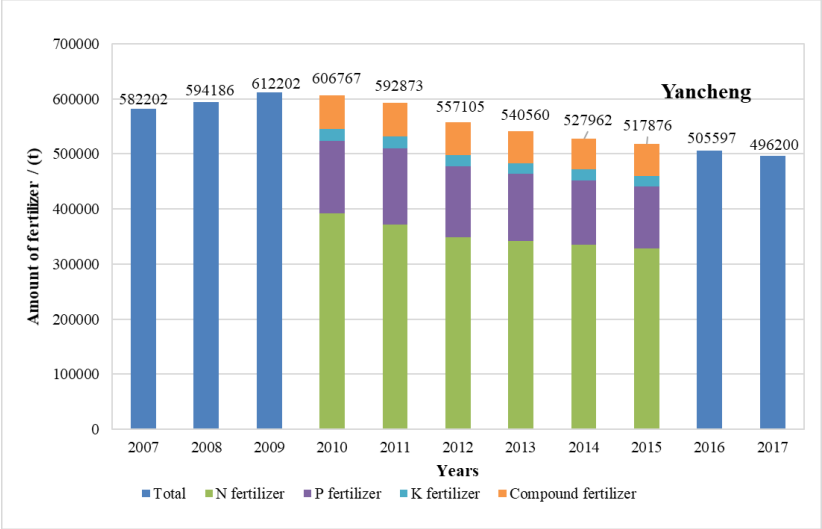


Fig 4.51. Dynamics of the amount of fertilizer use in Yancheng from 2007 to 2017

Based on the statistics data of chemical fertilizer use and the sown area of crops in Yancheng from 2007 to 2017, the fertilization intensity of Yancheng was calculated and analyzed. As shown in Fig 4.52, the fertilization intensity of Yancheng gradually decreased from 415.17 kg/hm^2 in 2007 to 363.16 kg/hm^2 in 2017, totally down by 12.5% in recent 10 years. The fertilization intensity of nitrogen, phosphorus and potassium were decreased at different level. Specifically, the fertilization intensity of nitrogen was 243.16 kg/hm^2 in 2015, down by 14.0% over 2010. The fertilization intensity of phosphorus was 93.09 kg/hm^2 in 2015, down by 10.5% over 2010. The fertilization intensity of potassium was 26.70 kg/hm^2 in 2015, down by 7.2% over 2010. In recent

10 years, the proportion of nitrogen, phosphorus and potassium in chemical fertilizer remained stable, and the N:P:K of 2015 was 1:0.38:0.11. Compared with the average proportion (1:0.38:0.28) of Jiangsu province, the proportion of potassium in chemical fertilizer used in Yancheng was significantly lower than the provincial average level.

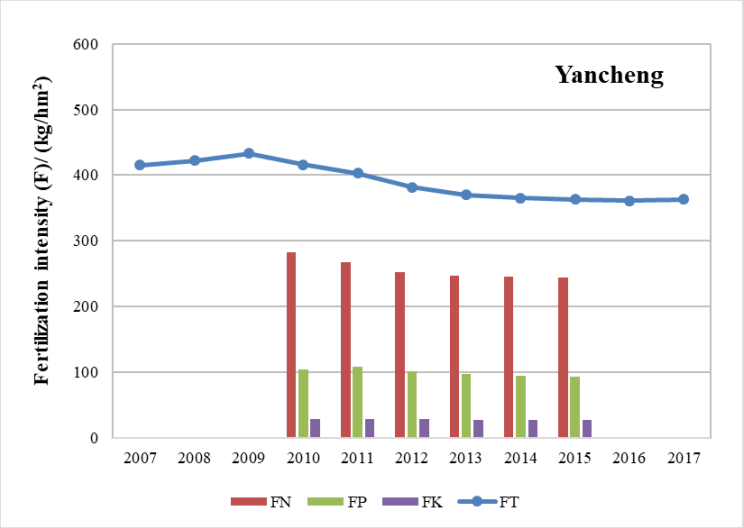


Fig 4.52. Dynamics of fertilization intensity in Yancheng from 2007 to 2017

4.3.3 Spatial Variation of Fertilizer use in coastal cities of Jiangsu Province

Because of the great differences of natural environment and social-economic development, the amount of fertilizer use and the fertilization intensity in agricultural activities has shown obvious region characters. Based on the data and information of fertilizer use in Jiangsu province and the 3 coastal prefecture-level cities, the characteristics of spatial variation of fertilizer use in coastal cities along the Yellow Sea of Jiangsu province were analyzed.

In 2017, the total sown area of crops of the 3 coastal cities along the Yellow Sea in Jiangsu accounted for 36.9% in the whole province. Specially, the sown area of crops in Yancheng ranked the first among the prefecture-level cities in Jiangsu, which was 1,366,340 hectares. The sown area of crops in Nantong ranked 3th among the prefecture-level cities in Jiangsu, which was 811,370 hectares. The sown area of crops in Lianyungang ranked 6th among the prefecture-level cities in Jiangsu, which was 628,530 hectares.

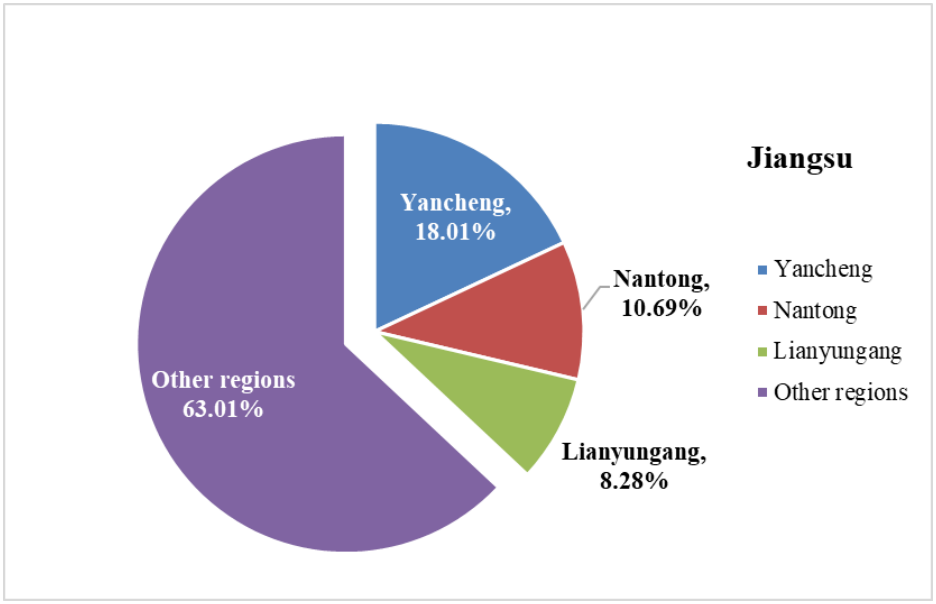


Fig 4.53. Proportion of total sown area of crops of coastal cities of the Yellow Sea in Jiangsu Province

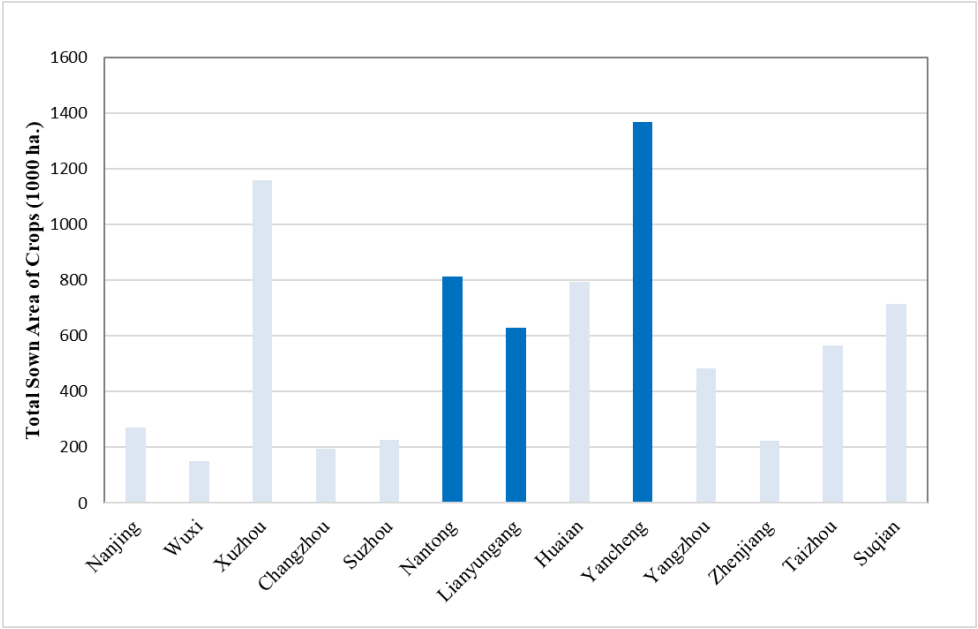
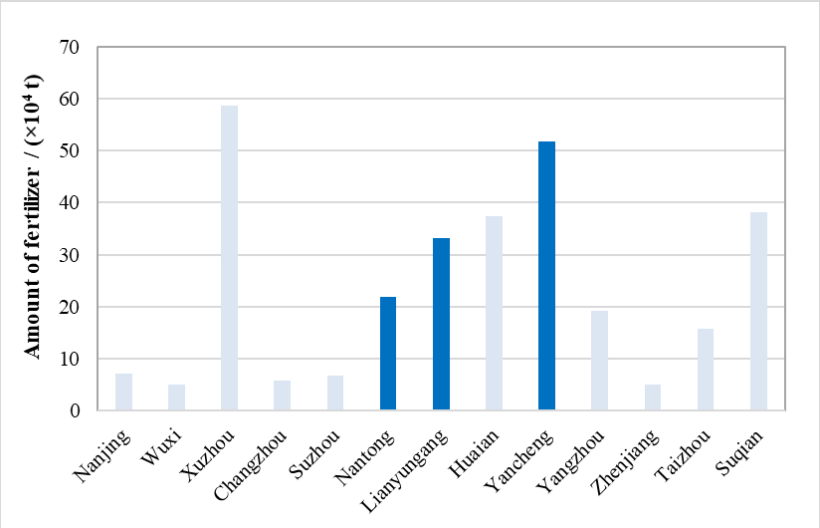


Fig 4.54. Total sown area of crops of prefecture-level cities in Jiangsu Province

The amount of fertilizer used in Yancheng ranked 2th among the prefecture-level cities in Jiangsu, which was 517,876 tons in 2017. The amount of fertilizer used in Lianyungang and Nantong ranked 5th and 6th among the prefecture-level cities in Jiangsu, which was 332,600 tons and 218,600 in 2017, ranking in the middle level of the whole the province.



* The data of Yancheng is from the statistical yearbook of Yancheng in 2015.

Fig 4.55. Amount of fertilizer use of prefecture-level cities in Jiangsu Province

In terms of the composition of fertilizer inputs, the amount of N-fertilizer and P-fertilizer used in Yancheng both ranked the first in the whole province, which was 327,680 tons and 113,563 tons in 2017, respectively. The amount of K-fertilizer in Yancheng ranked 3th in the whole province, which was 18,828 tons in 2017. The amount of compound fertilizer in Yancheng ranked the 5th in the whole province, which was 57,805 tons. Lianyungang and Nantong were not taken into account because of the data deficient of the amount of different fertilizers in the two cities.

In terms of fertilization intensity, Nantong is an area with moderate intensity fertilization, and the fertilization intensity were 269.42 kg/hm^2 in 2017. Yancheng is an area with high intensity fertilization, and its fertilization intensity was 362.95 kg/hm^2 in 2017. Lianyungang is an area with ultra-high intensity fertilization, and its fertilization intensity was 529.17 kg/hm^2 in 2017.

Compared with the average N:P:K ratio of fertilizers used in China (1:0.52:0.46), the proportion of nitrogen in chemical fertilizer used in coastal cities in Jiangsu were mostly higher than the national level, while the proportion of phosphorus and potassium was lower than the national level. In general, the proportion of phosphorus in chemical fertilizer used in Yancheng was higher and close to the national average level.

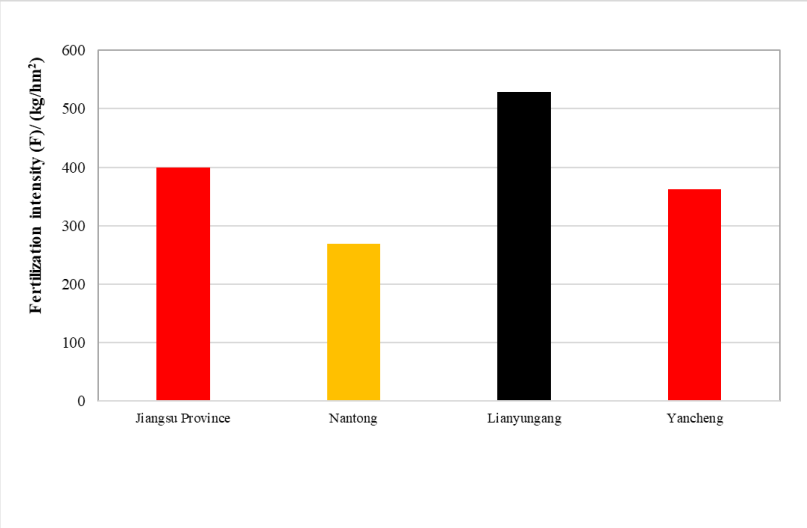


Fig 4.56. Fertilization intensity of coastal prefecture-level cities along the Yellow Sea in Jiangsu Province

4.4 Comparations of the fertilizer use in coastal cities along the Yellow Sea in China

Based on the analysis of data and information of fertilizer use in the 9 prefecture-level cities in 2017, the regional characteristics of the fertilizer use in coastal areas along the Yellow Sea in China were investigated.

In 2017, among the 9 cities along the Yellow Sea, Yancheng had the highest sown area of crops, followed by Nantong and Qingdao, while Weihai and Dandong had the lowest sown areas of crops.

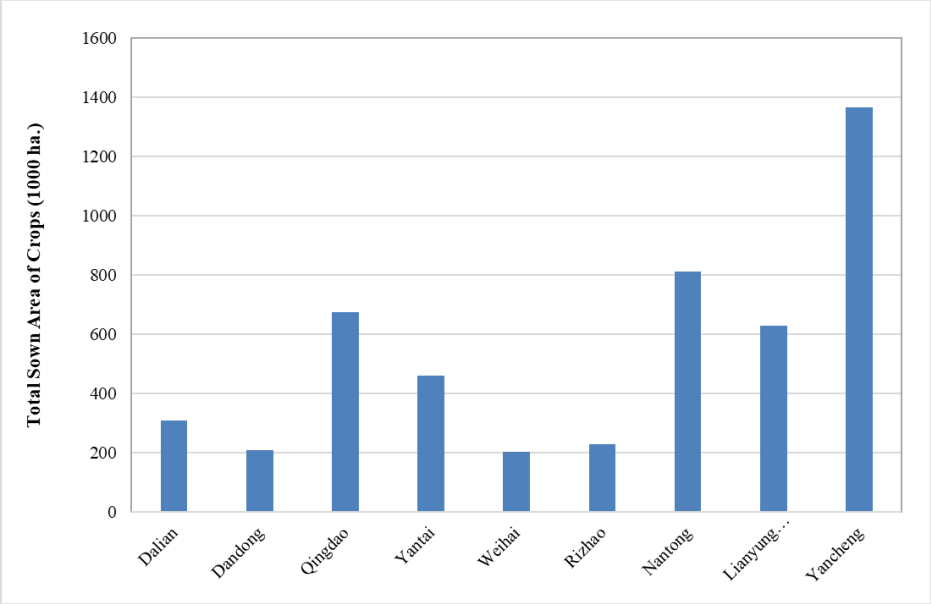


Fig 4.57. Total sown area of crops of coastal cities along the Yellow Sea in China

In terms of the total amount of fertilizer use in the survey regions, the amount of fertilizer used in Yancheng was the highest, followed by Yantai and Lianyungang. The amount of fertilizer used in Dandong was the lowest.

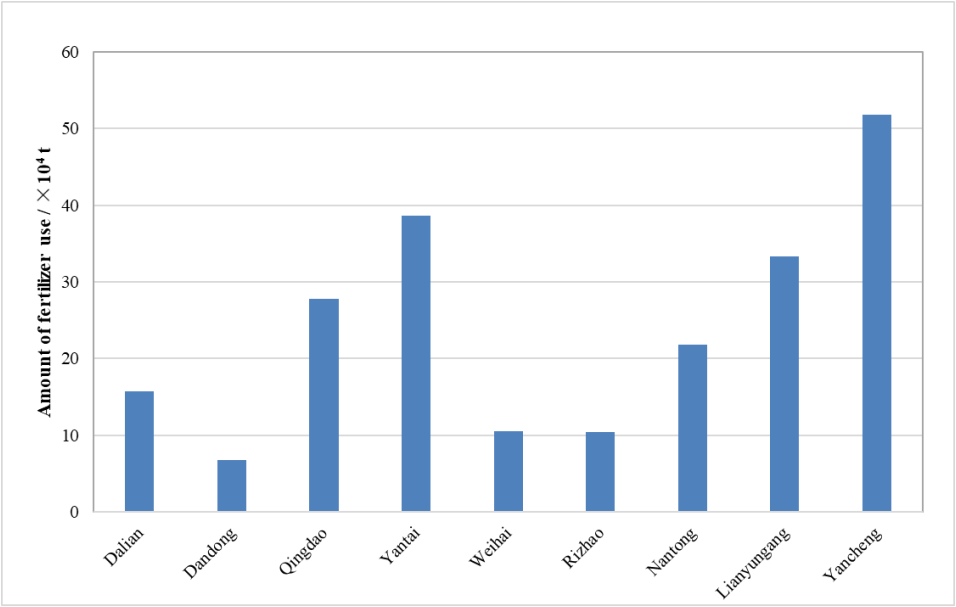


Fig 4.58. Amount of fertilizer use of coastal cities along the Yellow Sea in China

In terms of the composition of fertilizer inputs, the amount of N-fertilizer and P-fertilizer used in Yancheng was the highest in the survey region, and the amount of K-fertilizer used in Yantai was the highest, and the amount of compound fertilizer used in

Qingdao and Yantai were the highest.

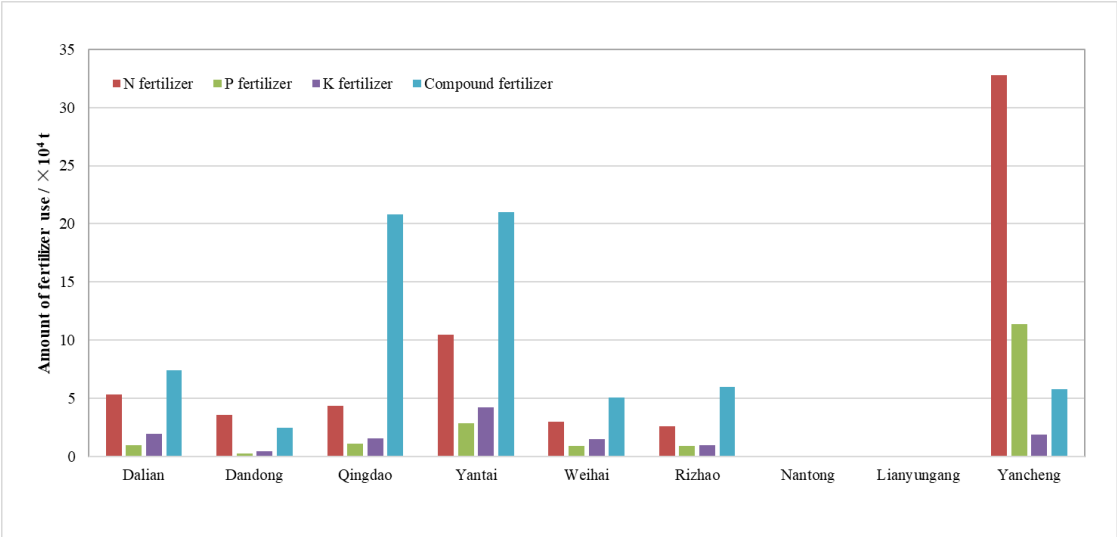


Fig 4.59. Amount of different types of fertilizer use of coastal cities along the Yellow Sea in China

The fertilization intensity of the 9 cities along the Yellow Sea was analyzed and compared. As shown in Fig 4.60, Yantai, Lianyungang, Weihai, Dalian and Rizhao are areas with ultra-high intensity fertilization, and the fertilization intensity of Yantai is the highest in the survey regions, followed by Suqian and Lianyungang. Qingdao, Yancheng are areas with high intensity fertilization, and Dandong and Nantong are areas with moderate intensity fertilization. The fertilization intensity of Nantong is the highest in the survey regions.

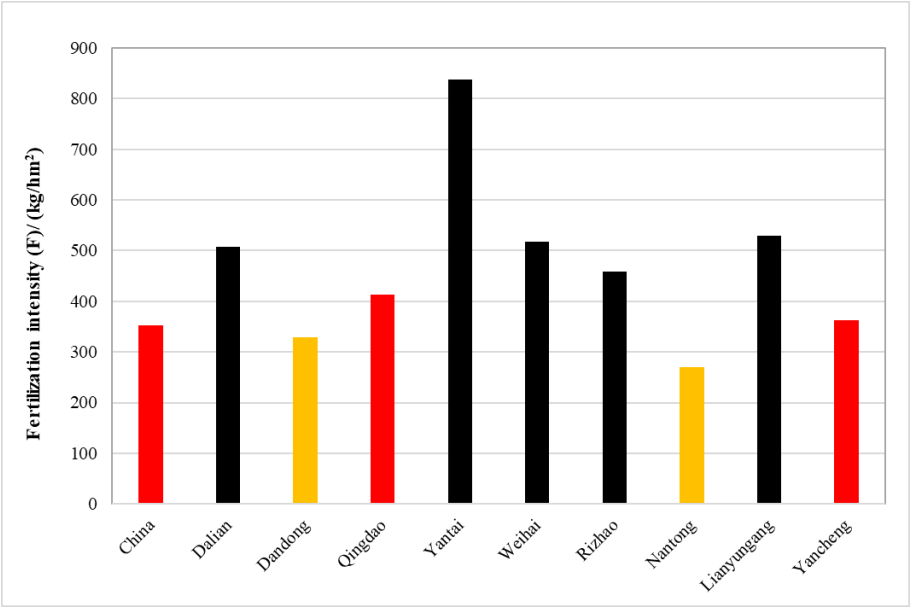


Fig 4.60. Fertilization intensity of coastal cities along the Yellow Sea in China

Results of analysis on fertilization intensity of nitrogen, phosphorus and potassium showed that high fertilization intensity of nitrogen was appeared in Yantai, Dalian and Yancheng. High fertilization intensity of phosphorus was appeared in Yantai, Weihai and Rizhao. High fertilization intensity of potassium was appeared in Yantai, Weihai and Dalian. Most of the 9 cities in survey regions have higer fertilization intensity of N, P, K than the national average level. Lianyungang and Nantong were not taken into account because of the data deficient of the amount of different fertilizers in the two cities.

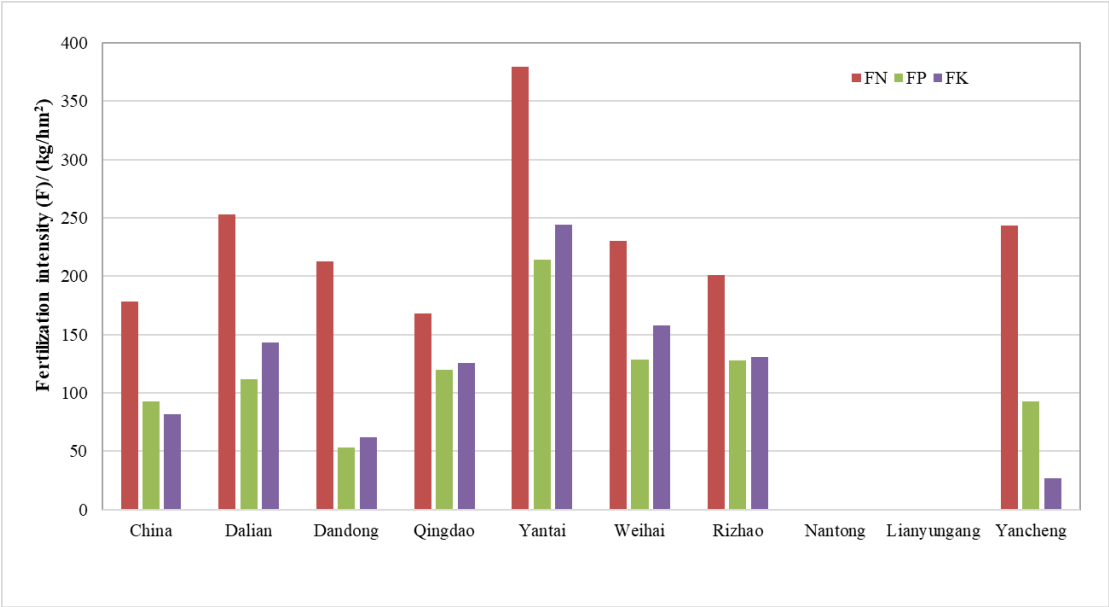


Fig 4.61. Fertilization intensity of coastal cities along the Yellow Sea in China

Compared with the average N:P:K ratio of fertilizers used in China (1:0.52:0.46), the proportion of phosphorus and potassium in chemical fertilizer used in Shandong were higher than the national level, while the proportion of phosphorus and potassium in chemical fertilizer used in Jiangsu was lower than the national level. Lianyungang and Nantong were not taken into account because of the data deficient

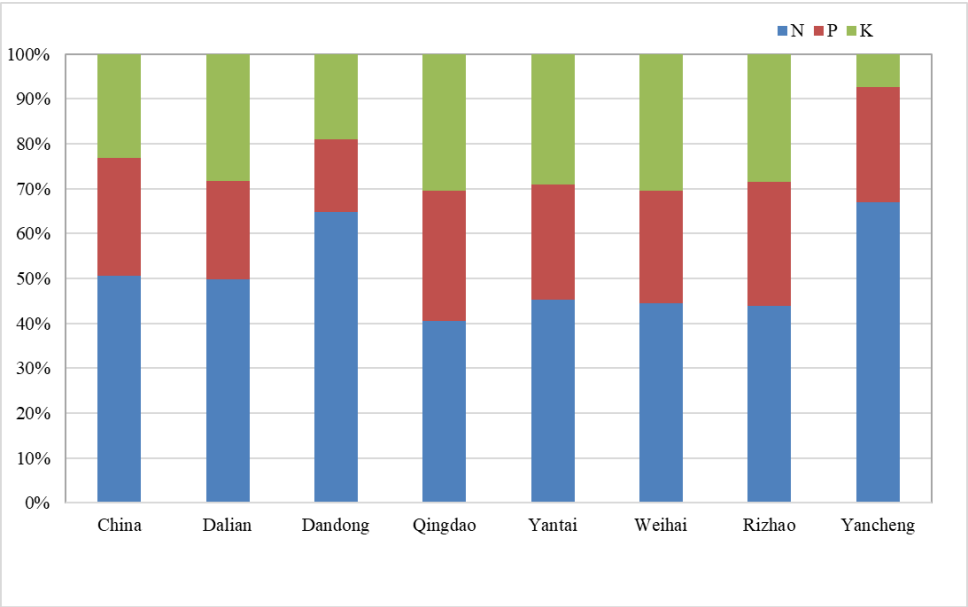


Fig 4.62. Proportion of nitrogen, phosphate, potassium in fertilizers used in coastal cities along the Yellow Sea in China

5. Management and Control measures of Fertilizer Use in China and its Coastal Provinces

5.1 National Management and Control Measures

In order to solve the current problems of over-use and haphazard use of chemical fertilizers, the relevant administrative departments of China have promulgated a series of countermeasures to achieve the reduction of fertilizer use and the increase of fertilization intensity, and have achieved considerable results.

1. Soil testing and formula fertilization.

Since 2005, the subsidy for soil testing and formula fertilization was initiated in China, and has been promoted to all agricultural counties nationwide so far. Through the soil testing and formula fertilization program, the soil nutrient status was basically analyzed, the scientific fertilization technology was popularized, the scientific fertilization consciousness of farmers was enhanced, and the increase of agricultural yield and income, the energy conservation and emission reduction were both promoted.

2. The action of zero growth in fertilizer use.

In 2015, the Ministry of Agriculture issued the “Action Plan of Zero Growth in Chemical Fertilizer and Pesticide Use by 2020” and selected 300 counties (cities) as demonstration areas to carry out actions of reducing fertilizer use and increasing fertilization efficiency, and different technical model were promoted in different areas and for different crops. Measures were also taken to accelerate integrated innovation of technologies. The action of zero growth in chemical fertilizer use is a major measure to promote “transformation and restructuring” of agriculture, and it meet the realistic needs of cost reduction and efficiency enhancement, energy conservation and emission reduction. Moreover, it is of great significance to guarantee national food security, quality safety of agricultural products and agricultural ecological security.

3. Accelerate the utilization of organic fertilizer resources and actively explore

the effective mode of nutrient utilization of organic fertilizer resources.

In order to promote the green development of agriculture, the Ministry of Agriculture issued the "Action Plan for Replacement of Chemical Fertilizer by Organic Fertilizer for Fruits, Vegetables and Tea" in 2017, in order to promote resources cyclic utilization, to achieve cost reduction and efficiency enhancement, and encourage and guide the farmers to apply farmyard manure and organic fertilizers.

In the same year, among the regions with the advantage in vegetable, fruit and tea plantation, abundant organic fertilizer resources, mature organic fertilizer application techniques and good industrial conditions, the Ministry selected 175 pilot counties which carry out both fruit, vegetable and tea plantation, and husbandry for the program of replacing chemical fertilizers by organic fertilizers. The production technology of using organic fertilizers instead of chemical fertilizers were promoted in an integrated manner. The long-term mechanism of "replacing chemical fertilizers by organic fertilizers" in fruit, vegetable and tea plantation was established.

In addition, in order to improve the comprehensive use of straws in the Northeast Region of China, the agricultural authority has formulated the "Action Plan for Straw Treatments in Northeast China", to protect the black earth and improve the cultivated land quality. It's initiated to use straw manure instead of chemical fertilizers and realize the recycling of straws.

4. Improving management and application of fertilizers.

It is advocated to use agricultural technologies and agricultural machinery, base fertilizer and topdressing coordinately, and promote the technologies of chemical fertilizer deep placement by machinery, topdressing by machinery, seeding while fertilizing, etc. The purpose is to enhance the utilization rate of fertilizers and reduce the use of chemical fertilizers.

5. Supporting innovative scientific research in agriculture.

Measures have been taken to support key scientific research projects such as

“Comprehensive Technology Research on Reduction of Chemical Fertilizers and Pesticides Use and Enhancement of Fertilization Efficiency”, to support development and transformation of new concentrated fertilizer technologies, and provide technological assurance for green agriculture.

6. Strengthen the training of new-type professional farmer training

Strengthening the construction of practical talents in rural areas is the guarantee for the sustainable development of agricultural science. Technical training and guidance services were strengthened.

In addition, according to the “National Agricultural Sustainable Development Demonstration Areas (Agricultural Green Development Pilot Zones) Management Measures (Trial)”, it’s advocated to use chemical fertilizers, pesticides and veterinary drugs in a scientific manner; gradually replace chemical fertilizers by organic fertilizers; prevent while treating the existing conditions, control the use of chemical fertilizers in a green manner; reduce the use of agricultural inputs while boosting the efficiency; and realize zero/negative growth of chemical fertilizers, pesticides and veterinary drugs.

5.2 Management and Control Measures in Liaoning

At present, the use of chemical fertilizers in Liaoning Province has achieved a negative growth for three years in succession. In order to implement the action of zero growth in chemical fertilizer use proposed by Ministry of Agriculture and Rural Affairs, and to maintain a negative growth in annual fertilizer use, Liaoning Province implements the “Village Revitalization Strategy” and “Green Development of Agriculture”, and takes active measures to develop the technical models and work mechanism for fertilizer use reduction and fertilization efficiency improvement, and guides farmers to change their fertilization habits. Significant achievements have been achieved.

1. The technical model for fertilizer use reduction and fertilization efficiency improvement was established. The utilization rate of fertilizers has been greatly

enhanced. Different technical fertilization models were applied on field crops, vegetables and fruit trees respectively. The utilization rate of fertilizers has been greatly enhanced. The situation of excessive application of chemical fertilizers have been effectively controlled. Comprehensive productivity of cultivated land has been raised. Liaoning Province goes deeper on the path of green development of agriculture.

2. Adopt “Internet+” technology to realize intelligent information services. Liaoning Province has established a big data platform of “Internet + mobile phone information” to provide locating fertilization guidance service, and established a technology promotion system of “one SIM card, one instructor, one screen, one phone, one station”, and provided soil testing and formula fertilization mobile information services in 33 counties (cities, districts). Through 12582 hotline, it offers one-to-one fertilizing services to farmers. Liaoning adopted the innovation of the promotion model, and comprehensively improved the scientific fertilization technology service level of the province.

3. Promote the soil testing and formula fertilization technology, and focus on changing farmers’ fertilization habits.

By organizing training, lectures, display and demonstration activities, Liaoning Province took activities to change the fertilization habit of farmers, which used to be emphasizing the use of inorganic fertilizers and macro-nutrients fertilizers, and ignoring organic fertilizers, medium and micro-nutrients fertilizers. Through the aforementioned measures, Liaoning effectively enhanced the comprehensive productivity of cultivated land and laid a solid foundation for future fertilization management, such as efficient fertilization and reduced use of chemical fertilizers. In 2018, Liaoning Province promoted the soil testing and formula fertilization on 4.1 million hectares, and some counties (cities, districts) realized the full coverage of these technologies. By technology promotion, the fertilization structure has been optimized, and the fertilization methods have been improved. Large-scale application of new-type efficient fertilizers were promoted.

In addition, according to “Three-Year Action Plan of Liaoning Province on Pollution Control (2018-2020)”, agricultural non-point source pollution should be prevented in order to effectively solve the agricultural pollution problem. Farmers are encouraged to use organic fertilizers and reduce the use of chemical ones. The comprehensive technology for fertilizer use reduction and fertilization efficiency improvement in apple plantation is advocated.

5.3 Management and Control Measures in Shandong

In order to implement the action of zero growth in chemical fertilizer use proposed by Ministry of Agriculture and Rural Affairs, Shandong Province successively issued the “Implementation Plan on Preventing and Controlling Agricultural Non-point Source Pollution”, the “Action Plan on Reducing the Use of Chemical Fertilizers of Shandong Province in 2016-2020”, and the “Three-Year Action Plan of Shandong Province on Strengthening Pollution Source Prevention (2018-2020)”. A series of measures to reduce fertilizer use and enhance fertilization efficiency have been taken.

1. Focus on reducing the chemical fertilizers use.

Shandong Province has taken active measures to promote the technology for reducing fertilizer use and enhancing fertilizer efficiency. By choosing the concentrated area of vegetable cultivation, Shandong promoted the integration of water and fertilizer integration technology, and organized the implementation of water and fertilizer integration demonstration projects. Trickle irrigation facilities were constructed to promote fertilization enhancement together with irrigation improvement. Measures were taken continuously to increase the use of compound fertilizers, water soluble fertilizers and slow-release fertilizers. All areas were required to strictly follow the quality standards of chemical fertilizers and other agricultural inputs. Shandong Province is accelerating its steps to develop efficient, safe and eco-friendly modern green agriculture. By 2020, the application area of ecological recycling agricultural technology is expected to reach 2 million hectares.

The application of soil testing and formula fertilization technology has been

strengthened. Cultivated land quality monitoring has been initiated. The soil testing and formula fertilization technology has been applied on wheat, corn, vegetables, fruit trees and other crops. The purpose is to enhance the utilization rate of chemical fertilizers. Shandong Province also instructs the agricultural departments of all counties (cities, districts) to issue fertilization formulas in time, guides fertilizers manufacturers to contact with new-type agricultural operators, promotes production-marketing integration, and enlarge the area of applying formula fertilizers. By 2020, more than 90% of cultivated land is expected to adopt the soil testing and formulated fertilization technology; the area of applying formula fertilizer is expected to reach 4 million hectares, and the utilization rate of chemical fertilizer is expected to reach 40%.

2. Take active measures to replace chemical fertilizers by organic fertilizers.

Shandong Province initiated several demonstration projects in the watershed areas of the east route of the South-to-North Water Diversion Project and some major fruit and vegetable plantation counties. Subsidies are given to those that apply the technology to use organic fertilizers instead of chemical fertilizers. Farmers are encouraged to use organic fertilizers, and reduce non-point source pollution to protect the water quality at the water sources and improve the quality of agricultural products. Measures have been taken to promote the use of commercial organic fertilizers, biological fertilizers, formula fertilizers and soil conditioner, and encourage planting forage in orchard; guide farmers to use farmyard manure. Shandong Province also gives priority to “toilet revolution” in rural areas, and has been taking active measures to guarantee management after toilet renovation and to increase the supply of organic fertilizers. Moreover, the “agricultural product high quality with high price guiding mechanism” will be gradually established to encourage the use of organic fertilizers. By 2020, the organic content in the soil in the major fruit, vegetable and tea plantation areas of the demonstration counties and famous brand production bases is expected to reach 5% or higher.

Promote the replacement of chemical fertilizers by organic fertilizers, and list it as a key technical training content of fertilizer use and agricultural products quality and

safety. At the same time, the application of organic fertilizers will be included in the construction projects such as “Reducing fertilizer use and enhancing fertilizer efficiency” and “Improve the quality of cultivated land”, and expand the demonstration capacity of the project. The coverage rate of organic fertilizer use in the demonstration areas of the project will reach 40%. By 2020, the province’s consumption of commercial organic fertilizer will increase to more than 4.28 million tons.

5.4 Management and Control Measures in Jiangsu

Recent years, Jiangsu has adopted the strategy of “five methods to reduce fertilizer use, five actions to promote the optimization of fertilizer use”, to carry out the action for reducing fertilizer use and enhancing fertilizer efficiency in thousands of villages and hundreds of companies. The total amount of fertilizer uses and fertilization intensity both presents a continuous decreasing trend.

1. Five methods to reduce fertilizer use

(1) Precision fertilization.

Taking soil testing and formula fertilization as the starting point, Jiangsu province establish and improve the main crop fertilization index system, by adopting a strategy of “General formula and personalized adjustment”, to release the scientific advice through the expert system of soil testing and formula fertilization to realize real-time online inquiry of the main crops, target yield and formula fertilization scheme and fertilizer management of the whole province. In 2018, the coverage rate of soil testing and formula fertilization in Jiangsu province reached 91.1%.

(2) Fertilizer replacement.

Partial replacement of chemical fertilizers and traditional fertilizers with organic fertilizers and new fertilizers, and mechanical fertilization instead of artificial fertilization. In 2018, the demonstration and promotion area of high-efficiency new fertilizers such as slow-release fertilizers, water-soluble fertilizers and biological fertilizers in Jiangsu province reached 760000 hectares.

(3) Intelligent fertilization and mechanical fertilization.

Demonstrate and promote the “Five Cloud Services” model of intelligent fertilization, and achieve “Cloud soil testing, Cloud formula fertilization, Cloud ordering, Cloud dispatching, Cloud supervision”. Implement rice lateral deep fertilization, mechanical fertilization of organic fertilizer, sowing of corn seed and fertilizer simultaneously, and so on, to improve the level of mechanized fertilization.

(4) Coupling of water and fertilizer.

Choose fruits, vegetables, tea as the main application crops, to implement the combination of irrigation and fertilization, and the coupling of water and fertilizer. The demonstration area of water and fertilizer coupling in Jiangsu province is 166667 hectares, and the rate of water and fertilizer saving in the demonstration area is more than 30%.

(5) Crop rotation fallow.

In areas with high chemical fertilization intensity, high environmental pressure, and low agricultural benefits in winter, seasonal fallow and conservation tillage are implemented, and crop rotation mode such as “Rice-Astragalus smicus”, “Rice-Silkworm peas” and “Rice-Vetch” are mainly promoted, which effectively reduces the annual fertilizer input.

2. Five actions to promote the optimization of fertilizer use.

(1) Administrative promotion.

The provincial government lists the effects of action “Reducing Fertilizer Use and Enhancing Fertilizer Efficiency” as the evaluation contents of high-quality development of agriculture at all levels of governments, and the fertilization model of economic and environmental protection was promoted in comprehensive and multiple modes.

(2) Innovation-driven.

To implement close cooperation between industry, academia and research. To develop new products, new technologies and new equipment. To promote technological

transformation and upgrading of fertilizer industry and green development of agriculture.

(3) Demonstration-promotion.

In 2018, 28 demonstration counties for improving the quality of cultivated land and reducing fertilizer use and increasing fertilization efficiency, and 7 national “fruit-vegetable-tea organic fertilizer replacement of chemical fertilizer” demonstration counties were established. To integrate the application of soil testing and formula fertilization, organic fertilizer instead of chemical fertilizer, straw returning, water-fertilizer integration technology, and so on.

(4) Encouragement policies.

Financial subsidies for the purchase of side-deep fertilizing machinery and equipment for planting large households, professional cooperatives, etc.; Suzhou and Yangzhou provide subsidies for the application of formula fertilizers; To provide subsidies for the application of organic fertilizers in projects such as upgrading of cultivated land quality and “fruit-vegetable-tea organic fertilizer replacement of chemical fertilizer”. Nanjing launched an action of “Reducing Fertilizer Use and Enhancing Fertilizer Efficiency” in a 5km area along the Yangtze River to subsidize the application of formula fertilizers and slow-release fertilizers, and to guide and encourage social capital to participate in fertilizer use reduction and fertilization efficiency improvement.

(5) Propaganda.

A conference was held to promote the province’s fertilizer use reduction and fertilization efficiency improvement, an on-site meeting was held to promote the rice side deep fertilization, and a press conference was held about the thousands of villages and hundreds of enterprises to reduce fertilizer use and increase fertilization efficiency. Through holographic media, new media propaganda reports, to do a better propaganda about fertilizer use reduction and fertilization efficiency improvement in Jiangsu.

6、Suggestions on Fertilizer Use

1. Policy guidance.

Coastal provinces should adopt different fertilization strategies according to specific conditions to correctly handle the relationship between food security and environmental protection.

(1) To promote precision fertilization. Through the subsidy project of implementation and promotion of the soil testing and formula fertilization, the fertilizer formula was released in time to guide the application of formula fertilizer, and the system of "measurement, distribution, production, supply and application" was gradually formed, which improved the utilization rate of fertilizer and reduced the total amount of fertilizer use. Provide guidance of chemical fertilizer deep placement by machinery, in order to limit the non-point source pollution caused by fertilizer over-use.

(2) Adjust the structure of fertilizer use. While stabilizing and improving crop yields, more attentions should be paid on the potential risk of chemical fertilizer pollution. Through measures such as control of total fertilizer use and zoning guidance, standards for fertilization limits for each region should be established rationally, to reduce haphazard use of chemical fertilizers, and optimize the ratio of N:P:K. Take activities to improve fertilization technology, to increase the application of organic fertilizer and biological fertilizer, and other measures to reduce environmental pollution, improve crop quality, and ensure sustainable development of agriculture.

(3) Replace chemical fertilizer with organic fertilizer. Implement the organic fertilizer substitution demonstration project, to promote the organic fertilizer to replace the chemical fertilizer technology, and to promote actions of using organic fertilizer to replace of the traditional fertilizers. Further increase the promotion of micro-organisms and organic fertilizers, guide farmers to use farmyard manure, and effectively reduce the amount of chemical fertilizers use. Gradually establish a high-quality and high-price guidance mechanism for agricultural products, and encourage the use of commercial organic fertilizer.

2. Technical support.

Increase investment in science, technology and education, and enhance farmers' awareness of science and environmental protection. Carry out education and training to improve farmers' environmental awareness, agricultural technology knowledge and farmland scale management capabilities.

3. System guarantee.

Accelerate the formulation and improvement of relevant laws and policies and technical specifications, such as soil pollution prevention and control laws, soil environmental quality standards and technical specifications for the use of chemical fertilizers, and strengthen the management of farmland and the management of fertilizer use. Exploring the organic farming subsidy mechanism and the abuse of fertilizer punishment mechanism to ensure the control of non-point source pollution and the protection of sustainable agricultural development.

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