The Youth Leadership Camp of World Food Prize

Current Status and Analysis of Factors Influencing Agricultural Fertilizer Non-point Source Pollution - Evidence from China's Major Grain Producing Areas

Name: Haosen Huo

Grade: Grade 10

Class: Class 2

Advisor: Zhao Na

Date: May 2023

Shijiazhuang Foreign Language School

Abstract

The surface source pollution triggered by chemical fertilizers has exerted a significant repercussion on the ecological environment, and the amount of fertilizer application pertains closely to the intensity of surface source pollution. This paper analyzes the total amount of fertilizer application and the use of nitrogen-phosphorus-potassium compound fertilizers in thirteen major grain-producing regions in China from a temporal and spatial perspective. Using a two-way fixed effects model, it analyzes multiple factors that influence the amount of fertilizer usage and proposes suggestions for reducing surface source contamination caused by chemical fertilizers based on this analysis.

Key words: surface source pollution of chemical fertilizers; fertilizer usage per unit of arable land

The low efficiency in land use and soil pollution have long constrained the development of the agricultural economy. Relevant surveys and studies have shown that soil quality in China continues to deteriorate, and the contribution rate of soil to agricultural production today is only 50% to 60%, which is a 10% decrease compared to that in 40 years ago and at least 10% to 20% lower than that in Western countries. In the past 30 years, the actual increase in grain production stemming from the input of unit quality of chemical fertilizers in China has been decreasing, indicating that the space for increasing production purely relying on chemical fertilizers is shrinking. However, the agricultural surface source pollution (referred to as fertilizer surface source pollution) derived from this has been increasing. Furthermore, this has led to ecological problems such as land infertility and compaction, as well as water pollution primarily caused by nutrient enrichment. In the context of tightening natural resources, it has severely restricted the sustainable development of agriculture. The 19th National Congress Report pointed out, "Promote green development in rural areas, strengthen soil pollution control and restoration, strengthen the prevention and control of agricultural surface source pollution, and create a new pattern of harmonious coexistence between humans and nature." Based on this, the State Council has put forward the requirement to "improve fertilization methods, promote the application of mechanized fertilization, simultaneous application of seed and fertilizer, and integrated water and fertilizer management measures to reduce nutrient volatilization and loss and improve the efficiency in fertilizer utilization ." Therefore, effectively preventing and controlling agricultural surface source pollution, improving the rural ecological environment, and enhancing the quality of the rural environment are issues of common concern for governments at all levels and the academic community.

This paper takes the agricultural surface source pollution caused by chemical fertilizers in China's major grain-producing regions as the research object. It aims to illustrate the current status of agricultural fertilizer usage in China in recent years, discover the relationship between fertilizer usage and surface source pollution, and explore the impact of policy implementation on the amount of fertilizer application, providing scientific basis for the formulation of pertaining policy tactics for controlling regional agricultural surface source pollution.

1. Literature Review

Agricultural non-point source pollution refers to the extensive pollution caused by improper use of chemical fertilizers, agricultural activities, livestock and poultry manure, and rural solid waste in the process of agricultural production. Currently, the main sources of agricultural non-point source pollution include excessive use of agricultural fertilizers, agricultural waste, and excreta from livestock and poultry farming. Scholars have conducted research on agricultural non-point source pollution from five aspects, including fertilizer pollution, livestock and poultry farming pollution, aquaculture pollution, agricultural solid waste, and rural domestic pollution.

Academic research has focused on studying the influencing factors of agricultural non-point source pollution from three perspectives: (1) From a macro perspective, the growth-oriented agricultural development strategy leads to the excessive use of agricultural chemicals, resulting in extensive non-point source pollution and affecting the sustainability of agricultural development. The phenomenon of "pollution-for-growth" exists in agricultural input companies, and the agricultural structure and economic growth impact the governance of agricultural non-point source pollution. (2) From a meso perspective, researchers analyze the influencing factors of non-point source pollution from the perspective of environmental regulations and agricultural industry clustering. (3) From a micro perspective, studies have found that the continuous increase in the use of agricultural chemicals by farmers is directly responsible for the non-point source pollution. Short-term and diversified farming practices exacerbate non-point source pollution, and declining income is the fundamental cause of its exacerbation. Increasing the proportion of non-agricultural income can promote urbanization and mitigate pollution.

Based on the literature review, this study focuses on the non-point source pollution caused by overly use of agricultural fertilizers in China's major grain yielding areas. By analyzing the usage of agricultural fertilizers and the resulting pollution from both temporal and spatial perspectives, it aims to provide scientific evidence for formulating policy strategies to improve agricultural fertilizer non-point source pollution in China, drawing on the experience from developed countries in controlling such pollution while taking the Chinese context into consideration.

2. Research Methods and Data Sources

2.1 Introduction to Research Methods

Based on the research objectives, this study selects five variables, including the total amount of agricultural fertilizer use (in 10,000 tons), nitrogen fertilizer use (in 10,000 tons), phosphate fertilizer use (in 10,000 tons), potash fertilizer use (in 10,000 tons), and compound fertilizer use (in 10,000 tons) as dependent variables. Building upon existing literature, and considering the availability of data from major grain producing areas, the study selects agricultural machinery power (in 10,000 kw), irrigated area of cultivated land (in 1,000 hectares), agricultural output value (in billion yuan), total output value of agriculture, forestry, animal husbandry, and fishery (in billion yuan), and total sown area of crops (in 1,000 hectares) as independent variables. A two-way fixed effects model is constructed to analyze the influencing factors of fertilizer use. The specific model is as follows:

$$CF_{it} = a_0 + a_1Mac_{it} + a_2Irr_{it} + a_3Arg_{it} + a_4Afa_{it} + a_5Sow_{it} + \gamma_i + \varepsilon_t + e_{it}$$

$$CF_{N_{it}} = a_0 + a_1Mac_{it} + a_2Irr_{it} + a_3Arg_{it} + a_4Afa_{it} + a_5Sow_{it} + \gamma_i + \varepsilon_t + e_{it}$$

$$CF_{P_{it}} = a_0 + a_1Mac_{it} + a_2Irr_{it} + a_3Arg_{it} + a_4Afa_{it} + a_5Sow_{it} + \gamma_i + \varepsilon_t + e_{it}$$

$$CF_{K_{it}} = a_0 + a_1Mac_{it} + a_2Irr_{it} + a_3Arg_{it} + a_4Afa_{it} + a_5Sow_{it} + \gamma_i + \varepsilon_t + e_{it}$$

$$CF_{NPK_{it}} = a_0 + a_1Mac_{it} + a_2Irr_{it} + a_3Arg_{it} + a_4Afa_{it} + a_5Sow_{it} + \gamma_i + \varepsilon_t + e_{it}$$

Where i represents individual prefecture-level cities and t represents the year; $a_1 \sim a_5$ represent the estimated coefficients, and a_0、γ、ε、e、 represent the intercept term, control for individual fixed effects, control for time fixed effects, and random error term, respectively. The model clearly reflects the types of influences on each dependent variable and uses regression coefficients to explain their magnitudes. (The p-values are generally presented for interpretation at the end.)

2.2 Data Sources and Utilization

By referring to the "China Statistical Yearbook," "China Rural Statistical Yearbook," provincial statistical yearbooks, and rural statistical yearbooks of various provinces, the study compiles the change curves of total fertilizer use and individual fertilizer use in China's major grain-producing provinces (Jiangsu, Shandong, Hubei, Hebei, Jilin, Liaoning, Hunan, Heilongjiang, Henan, Anhui, Sichuan, Jiangxi) from 2005 to 2020. Through data investigation and model analysis of the influencing factors (independent variables) such as grain crop sown area, agricultural machinery power, irrigated area of cultivated land, agricultural output value, rural population, etc., relevant data tables are summarized. The study analyzes the fertilizer usage and its trends, spatial changes, and further explores the influencing factors and their strengths on various fertilizer uses in China's major grain-producing provinces.

3. Analysis of Changes in Agricultural Fertilizer Application

3.1 Trend in Total Fertilizer Application

(i) Based on Figure 1, "Changes in Fertilizer Application in China's 13 Major Grain-Producing Areas from 2005 to 2020," the following observations can be made:

The total fertilizer application shows an initial increase followed by a decrease trend during the observation period. From 2005 to 2015, there was an upward trend, with fertilizer application reaching 40.166 million tons in 2015. From 2016 to 2020, it declined to a low point, with fertilizer application amounting to 35.934 million tons in 2020. However, upon examining the data, it is found that the per unit sown area fertilizer usage increased from 304.77 kg/ha in 2005 to 394.48 kg/ha. Compared to the safe threshold of 225 kg/ha set by developed countries to prevent fertilizer pollution of water bodies (no land-source pollution data available), even the lowest year (2005) exceeded this threshold. Especially from 2007 onwards, the per unit sown area fertilizer application exceeded 1.5 times the international threshold level each year. Further investigation revealed that while the total fertilizer application growth rate in the region increased by only 2.3% since 2013, the per unit sown area fertilizer usage increased by 3.5%. The growth rate per unit exceeded the overall growth rate. It can be seen that the excessive use of fertilizers in China's major grain-producing areas remains a concern when considering the per unit sown area fertilizer usage.

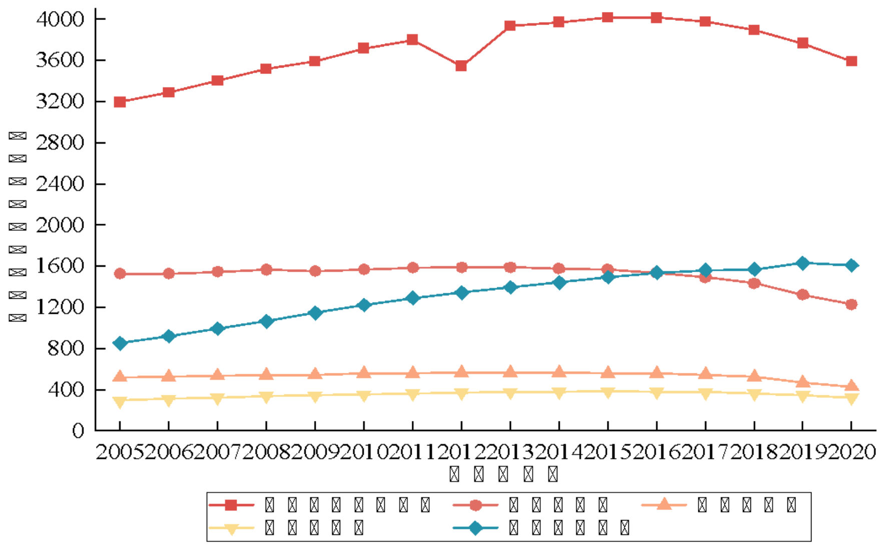

Figure 1: Fertilizer Application in China's 13 Major Grain-Producing Areas from 2005 to 2020

(ii) Variation in Individual Fertilizer Application

Different types of fertilizers show varying application quantities: (1)From 2005 to 2020, nitrogen fertilizer accounted for the majority of fertilizer application, with compound fertilizer surpassing it in usage in 2016. (2)Phosphate and potash fertilizer usageremained low, with potash fertilizer having the lowest usage. (3)The usage of compound fertilizer exhibited a slow upward trend and surpassed nitrogen fertilizer usage in 2016.

(iii)Trends in the Usage of Different Types of Fertilizers: (1) Decreasing trend in the use of nitrogen fertilizers; (2) Consistently low usage of potassium fertilizers; (3) Slow increase in the usage of compound fertilizers, surpassing nitrogen fertilizers. Different crops have varying requirements for nitrogen, phosphorus, and potassium. Compound fertilizer, which is a scientifically formulated fertilizer guided by agricultural experts, contains multiple trace elements and provides various nutritional values. Therefore, the application of compound fertilizer ensures that different crops absorb the necessary nutrients, achieves balanced nutrient supply, meets crop needs, improves fertilizer efficiency, reduces usage, increases crop yield, and enhances the quality of agricultural products. As a result, the usage of compound fertilizer has gradually increased, surpassing the usage of nitrogen fertilizers.

After 2007, due to rising fertilizer prices, farmers encountered difficulties in fertilizer application. Multiple factors such as agricultural overcapacity, high production costs, international high prices, and adjustments in the national tariff policies for nitrogen, phosphorus, and potassium fertilizers have led to a gradual decline and stabilization in the usage of these three types of fertilizers, while the usage of compound fertilizer has shown some increase. Additionally, organic fertilizer, which is considered more environmentally friendly, has gained popularity among more farmers. Overall, the usage of nitrogen, phosphorus, and potassium fertilizers in China has exhibited a downward trend.

3.2 Regional Disparities in Fertilizer Usage in China's 13 Major Grain-Producing Regions

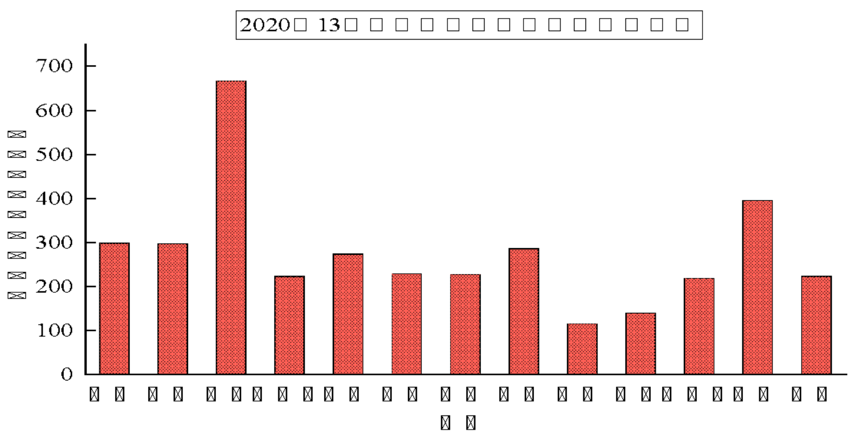

Figure 2 Distribution of Total Fertilizer Application in China's 13 Major Grain-Producing Regions in 2020

(i) By analyzing Figure 2, "Total Fertilizer Application in China's 13 Agricultural Grain-Producing Provinces in 2020," the following observations can be made: (1) Henan Province had the highest total fertilizer application, reaching 6.667 million tons; (2) Shandong Province followed with a total fertilizer application of 3.953 million tons; (3) Jiangxi Province and Liaoning Province had the lowest total fertilizer application, with 1.156 million tons and 1.399 million tons, respectively. The total fertilizer application in other provinces was around 3 million tons.

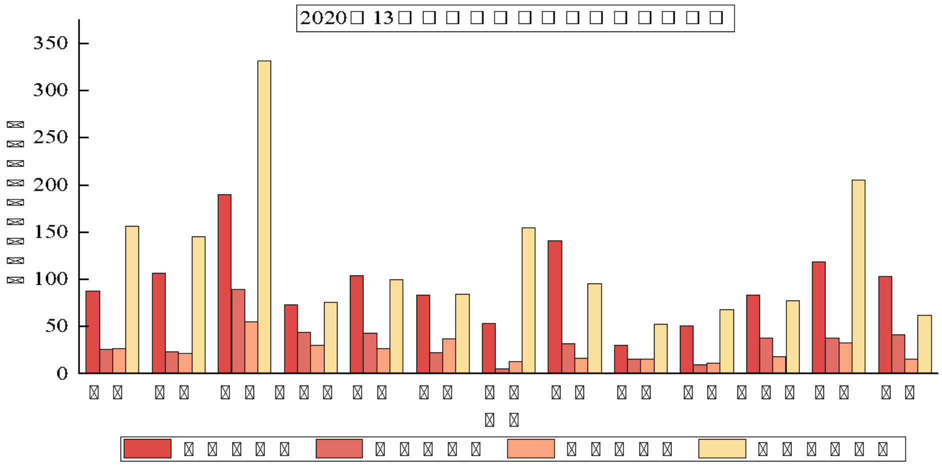

Figure 3 Distribution of Fertilizer Usage in China's 13 Major Grain-Producing Regions in 2020

(ii) By analyzing Figure 3, "Distribution of Nitrogen, Phosphorus, and Potassium Fertilizer Usage in China's 13 Provinces in 2020," the following observations can be made: (1) Henan, Jiangsu, and Shandong provinces had higher nitrogen fertilizer usage. Henan, Heilongjiang, and Hubei provinces had higher phosphorus fertilizer usage. Henan, Hunan, and Shandong provinces had higher potassium fertilizer usage. However, compound fertilizer remained the primary choice in all provinces. It is worth noting that potassium fertilizer usage was generally lower than the usage of the other three types of fertilizers. This is mainly due to the uneven distribution of potassium resources, and China has not been able to achieve self-sufficiency in potassium fertilizer production. Similar to phosphorus fertilizer resources, the global distribution of potassium fertilizer is highly uneven, with significant resources concentrated in regions such as Canada, Russia, and Belarus. China, with its vast territory, suffers from severe potassium resource shortages. Therefore, not with standing the attempts to develop internal resources, China still heavily relies on imports for potassium fertilizer. This results in an imbalance in the proportion of fertilizer application when international potassium fertilizer prices rise or production decreases. In response, the government has implemented corresponding policies. Unlike other fertilizers, China has specifically established a national reserve for potassium fertilizer, with 1.5 million tons stored in port inventories, ensuring a stable supply to the market during the fertilizer application process. This indicates that international conditions still have a significant impact on fertilizer usage. In such circumstances, macroeconomic regulation and policy support from the government are particularly crucial, especially in regions where agriculture is a major industry.

4. Analysis of Factors Influencing Agricultural Non-Point Source Pollution from Fertilizers

Based on the research objectives of this study, five variables, namely total fertilizer application (in 10,000 tons) CF_{it}, nitrogen fertilizer usage (in 10,000 tons) $CF_{N_{it}}$, phosphorus fertilizer usage (in 10,000 tons)$CF_{P_{it}}$, potassium fertilizer usage (in 10,000 tons) $CF_{K_{it}}$, and compound fertilizer usage (in 10,000 tons) $CF_{NPK_{it}}$, are selected as dependent variables. Building upon existing literature and considering the availability of data for grain-producing regions, the explanatory variables selected are total agricultural machinery power (in 10,000 kilowatts) Mac, cultivated land irrigation area (in 1,000 hectares) Irr, agricultural output value (in 100 million yuan) Arg, total output value of agriculture, forestry, animal husbandry, and fishery (in 100 million yuan) Afa, and total sown area of crops (in 1,000 hectares) Sow. A fixed-effects model is constructed to analyze the influencing factors of fertilizer usage. The regression results of the model are presented in Table 1.

Table 1: Regression Results of Factors Influencing Total Application of Agricultural Fertilizers

Explanatory Variables	Coefficient	P-value
Total Agricultural Machinery Power	0.0147***	0.000
Cultivated Land Irrigation Area	-0.0150***	0.003
Agricultural Output Value	0.0600***	0.000
Total Output Value of Agriculture, Forestry, Animal Husbandry, and Fishery	-0.0423***	0.000
Total Crop Cultivation Area	0.0251***	0.000
Constant	51.2097*	0.068

Sample Size	273
	0.9729

Note: P-value represents the probability of the estimated coefficient being significant at 0, as well as the significance levels *** (1%), ** (5%), and * (10%). A smaller P-value indicates a more significant impact of the independent variable on the dependent variable.

Based on the analysis of the data in Table 1, it can be observed that all five explanatory variables in the model have a significant impact on the total application of agricultural fertilizers. Among them, the agricultural output value (in billion yuan) has the most significant influence on the total application of agricultural fertilizers. For every unit increase in agricultural output value, the total application of agricultural fertilizers increases by 0.06 units. Additionally, it can be noted that the cultivated land irrigation area and the total output value of agriculture, forestry, animal husbandry, and fishery have a negative impact on fertilizer application. Therefore, in order to reduce excessive use of agricultural fertilizers, it is advisable to develop animal husbandry and fishery industries appropriately according to local conditions. Furthermore, increasing irrigation levels can dilute the pollution caused by fertilizer use.

Agricultural fertilizers can be classified into nitrogen, phosphorus, potassium, and compound fertilizers. Therefore, this study explores the factors influencing the application of different types of fertilizers separately. The regression results are presented in Tables 2~5.

Table 2: Regression Results of Factors Influencing Nitrogen Fertilizer Application

Explanatory Variables	Coefficient	P-value
Total Agricultural Machinery Power	0.0016*	0.072
Cultivated Land Irrigation Area	0.0020	0.227
Agricultural Output Value	0.0129***	0.000
Total Output Value of Agriculture, Forestry, Animal Husbandry, and Fishery	-0.0140***	0.000
Total Crop Cultivation Area	0.0100***	0.000
	19.2867**	0.036

Constant

Sample Size 273

Note: *** (1%), ** (5%), and * (10%) represent the significance levels.

Table 2 reports the regression results of factors influencing nitrogen fertilizer application. From the data, it can be observed that the agricultural output value is the most significant factor affecting nitrogen fertilizer application, with a regression coefficient of 0.0129 and a significant level of 1%. This indicates that for every unit increase in agricultural output value, the nitrogen fertilizer application increases by 0.0129 units. Additionally, the total output value of agriculture, forestry, animal husbandry, and fishery also has a significant impact on nitrogen fertilizer application at the 1% level, suggesting that an increase in the total output value can effectively control the use of nitrogen fertilizers. Therefore, appropriate expansion of animal husbandry and fishery industries can help mitigate soil erosion caused by nitrogen fertilizers.

Table 3: Regression Results of Factors Influencing Phosphorus Fertilizer Application

Explanatory Variables	Coefficient	P-value
Total Agricultural Machinery Power	0.0010**	0.029
Cultivated Land Irrigation Area	-0.0003	0.659
Agricultural Output Value	0.0051***	0.006
Total Output Value of Agriculture, Forestry, Animal Husbandry, and Fishery	-0.0047***	0.000
Total Crop Cultivation Area	0.0060***	0.000
Constant	16.6459***	0.001
Sample Size		273
	0.9808	

Note: *** (1%), ** (5%), and * (10%) represent the significance levels.

Table 3 presents the regression results of factors influencing phosphorus fertilizer application. From the data, it is evident that the total crop cultivation area is the most significant factor influencing phosphorus fertilizer application, with a regression coefficient of 0.0060 and a significant level of 1%. This suggests that for every unit increase in the total crop cultivation area, the phosphorus fertilizer application increases by 0.0060 units. Similar to the results for nitrogen fertilizer, the total output value of agriculture, forestry, animal husbandry, and fishery has a negative regression coefficient and is statistically significant at the 1% level, indicating a decrease in phosphorus fertilizer application with an increase in the total output value.

Table 4: Regression Results of Factors Influencing Potassium Fertilizer Application

Explanatory Variables	Coefficient	P-value
Total Agricultural Machinery Power	0.0011***	0.000
Cultivated Land Irrigation Area	0.0013***	0.008
Agricultural Output Value	0.0059***	0.000
Total Output Value of Agriculture, Forestry, Animal Husbandry, and Fishery	-0.0034***	0.000
Total Crop Cultivation Area	0.0024***	0.000
Constant	-5.9618**	0.031
Sample Size	273	
	0.9733	

Note: *** (1%), ** (5%), and * (10%) represent the significance levels.

Table 4 reports the regression results of factors influencing potassium fertilizer application. The data indicates that all five explanatory variables in the model have passed the statistical significance test at the 1% level. Among them, the agricultural output value is the most significant factor influencing potassium fertilizer application, with a regression coefficient of 0.0059. This suggests that for every unit increase in agricultural output value, the potassium fertilizer application increases by 0.0059 units. Additionally, an increase in the total output value of agriculture, forestry, animal husbandry, and fishery can effectively reduce the application of potassium fertilizers. The regression coefficient for the total output value is -0.0034, indicating that for every unit increase in the total output value, the potassium fertilizer application decreases by 0.0034 units. This implies that appropriately expanding industries other than small-scale agriculture, such as animal husbandry and fishery, is beneficial for reducing surface runoff pollution caused by excessive fertilizer use and protecting the agricultural ecological environment.

Table 5: Regression Results of Factors Influencing Compound Fertilizer Application

Explanatory Variables	Coefficient	P-value
Total Agricultural Machinery Power	0.0111***	0.000
Cultivated Land Irrigation Area	-0.0178***	0.008
Agricultural Output Value	0.0368***	0.000
Total Output Value of Agriculture, Forestry, Animal Husbandry, and Fishery	-0.0205***	0.000
Total Crop Cultivation Area	0.0063*	0.055
Constant	56.7099**	0.015
Sample Size	273	
	0.9116	

Note: *** (1%), ** (5%), and * (10%) represent the significance levels.

Table 5 presents the regression results of factors influencing compound fertilizer application. Similar to the regression results for the total application of agricultural fertilizers, all five explanatory variables in the model have passed the statistical significance test. The agricultural output value is the most significant factor influencing compound fertilizer application, with a regression coefficient of 0.0368. This indicates that for every unit increase in agricultural output value, the compound fertilizer application increases by 0.0368 units. Furthermore, an increase in cultivated land irrigation area and the total output value of agriculture, forestry, animal husbandry, and fishery can effectively reduce the application of compound fertilizers. The regression coefficient for cultivated land irrigation area is -0.0178, suggesting that for every unit increase in the irrigation area, the compound fertilizer application decreases by 0.0178 units. Similarly, the regression coefficient for the total output value is -0.0205, indicating that for every unit increase in the total output value, the compound fertilizer application decreases by 0.0205 units. This highlights that appropriately increasing cultivated land irrigation area and developing industries other than small-scale agriculture are favorable for diluting the concentration of surface runoff pollution and reducing the scope of fertilizer-induced pollution, ensuring an environmentally friendly and sustainable agriculture.

In conclusion, whether considering the total application of agricultural fertilizers or focusing on specific types of fertilizers, both the agricultural output value and the total output value of agriculture, forestry, animal husbandry, and fishery have passed the statistical significance test at the 1% level. This suggests that the agricultural output value exacerbates surface runoff pollution, while the total output value of agriculture, forestry, animal husbandry, and fishery mitigates it. This means that appropriately expanding animal husbandry and fishery activities can alleviate surface runoff pollution caused by excessive fertilizer use. Additionally, targeted measures can be implemented to address the surface runoff pollution caused by different types of fertilizers, such as expanding cultivated land irrigation area and reducing the total crop cultivation area, based on local conditions.

5. Conclusion and Recommendations

5.1 Conclusion:

(i) Over the past decade, the total emissions of fertilizer-related pollutants in China have shown an overall increasing trend, indicating a gap between China and developed countries in terms of fertilizer application, with pollution emissions exceeding international warning standards. The main factors contributing to the continuous increase in emissions of fertilizer-related pollutants are the growth of agricultural output value and the expansion of crop cultivation scale. In terms of fertilizer application, the dominant use of nitrogen fertilizers remains unchanged, while the application of potassium fertilizers is still constrained by spatial limitations, and the fertilizer application structure has not been significantly adjusted.

(ii) The application of fertilizers is influenced by international situations and market demands. Uneven distribution of fertilizer resources leads to different fertilizer application levels among countries, and fluctuations in the international market can also affect fertilizer application, resulting in varying degrees of pollution and reduced grain yields. Additionally, the country's economic conditions and foreign exchange policies can also influence fertilizer usage. Generally, when the price of a certain fertilizer decreases, its application tends to be on the rise. Therefore, controlling fertilizer prices within an appropriate range is an effective method to prevent pollution caused by fertilizers. This indicates the differences in the total amount of fertilizer and the demand for specific types of fertilizers based on crops and land characteristics.

(iii) With the development of rural economy and non-agricultural industries, the focus of rural residents' work is gradually shifting to non-agricultural sectors. Farmers may increase fertilizer application to enhance agricultural productivity, leading to severe agricultural surface runoff pollution. Furthermore, the transfer of agricultural labor results in a significant reduction in the number of young laborers in rural areas. Currently, the rural permanent population is predominantly composed of the elderly, women, and children, whose labor productivity is relatively low. To increase crop yields and household income, farmers tend to use large amounts of fertilizers to ensure stable grain production. Additionally, land transfer in rural areas may also increase fertilizer application. Due to short contracting periods, farmers may not consider long-term land utilization or the long-term benefits of land protection and environmental conservation. Therefore, they apply large amounts of fertilizers, pursuing short-term high yields without reducing fertilizer use from the perspective of farmland and ecological environment protection.

(iv) The amount of fertilizer application varies in the same direction as agricultural output but in the opposite direction to the total output value of agriculture, forestry, animal husbandry, and fishery. This indicates that China has excessive fertilizer input in the process of agricultural cultivation, while the development of forestry, fishery, and animal husbandry can reduce fertilizer input and improve the ecological level of rural areas. The amount of fertilizer application also changes in the same direction as the level of agricultural mechanization, indicating that with technological development, fertilizer application is gradually becoming mechanized and information-based.

5.2 Recommendations

(i) Due to the significant regional differences in fertilizer-related pollution emissions in China, it is necessary to further enhance the research, development, and promotion of environmentally friendly technologies and reduce the use of fertilizers in future agricultural development. Transformation from traditional agriculture to technology-intensive modern agriculture should be pursued. Moreover, each region should implement differentiated agricultural development policies based on its own geographical characteristics, emphasizing ecological environmental protection while ensuring stable grain production, thus promoting sustainable development of agriculture and rural areas.

(ii) The experience of developed countries in Europe and America suggests that reducing fertilizer usage and improving efficiency in ecological agriculture require comprehensive measures such as laws, policies, technology, and education. Technological approaches can learn from the experience of France in promoting satellite-based agricultural management technology, monitoring crop growth conditions, providing farmers with information on fertilizer application, irrigation timing, and optimal harvesting seasons to effectively prevent excessive use of fertilizers and pesticides. The combined farming and animal husbandry methods and techniques of residue returning and no-tillage in the United States should be studied, focusing on the mutual promotion and coordination between livestock farming and crop cultivation in terms of feed and fertilizers, increasing the use of organic fertilizers, and adopting a combination of organic and inorganic approaches. Additionally, the government should increase support in terms of technology and funding, encourage and guide farmers to participate in agricultural social services, and attract various talents, such as university graduates, entrepreneurs, agricultural scientists, and returned overseas students, to join agricultural social service organizations. This will foster the growth of diverse service organizations and enhance their capacity to provide comprehensive organic fertilizer services and promotion. Furthermore, regular training programs conducted by environmental experts in rural areas can be organized to promote farmers' in-depth understanding of fertilizer application through face-to-face technical demonstrations and guidance.

(iii) Currently, during the fertilization period of crops, there are issues such as tight timing and relatively low efficiency. According to relevant surveys, the mechanization rate of fertilizer application in China is only 30%. Therefore, it is necessary to focus on the research and development of crop fertilizer machinery, vigorously promote more suitable fertilizer machinery and technologies, and ensure precise mechanized fertilizer application. Furthermore, throughexperimental demonstrations, farmers should be made aware of the advantages of mechanized fertilizer application and guided to choose and purchase new types of machinery and high-performance fertilization equipment. This will not only promote the effective application of mechanized fertilizer technology but also enhance the efficiency and effectiveness of crop fertilization. Therefore, in crop fertilizer application, it is essential to prioritize the use of mechanized fertilization methods to address the existing issues and further promote the development of agricultural production in China.

Bibliography

[1] Shi Huaping, Yi Minli Environmental Regulation, Non agricultural and Non agricultural Non point Source Pollution: A Case Study of Fertilizer Application [J] Rural Economy, 2020 (7): 127-136

[2] Lv Jie, Liu Hao, Xue Ying, Han Xiaoyan Risk Avoidance, Social Networks, and Farmers' Excessive Fertilizer Application Behavior: A Survey Data from Corn Planting Farmers in Three Northeast Provinces [J] Agricultural Technology and Economy, 2021 (7): 4-17

[3] Zhao Chang, Kong Xiangzhi, Qiu Huanguang Does the expansion of agricultural operation scale contribute to the reduction of fertilizer production—— Quantitative analysis based on 1274 family farms nationwide [J] Agricultural Technology and Economy, 2021 (4): 110-121

[4] Liang Zhihui, Zhang Lu, Zhang Junbiao Land transfer, plot size, and fertilizer reduction: an empirical analysis which is based on the major rice producing areas in Hubei Province [J] China Rural Observation, 2020 (5): 73-92

[5] Wan Lingxiao, Cai Hailong Research on the Impact of Cooperative Participation on the Adoption of Soil Testing and Formula Fertilization Technology by Farmers - Based on the Perspective of Standardized Production [J] Agricultural Technology and Economy, 2021 (3): 63-77

[6] Rice Yun, Du Pengfei, Chen Jining Investigation and assessment method of non Point source pollution based on unit analysis [J] Journal of Tsinghua University (Natural Science Edition), 2004 (9): 1184-1187

[7] Liang Liutao, Study on the spatiotemporal characteristics and evolution laws of rural ecological environment [D] Nanjing Agricultural University, 2009

[8] Liu Gensong, Problems and Countermeasures in the Application of Crop Fertilizers

[9] Yang Wanjiang, Li Qi. Influencing factors of rice farmers' behavior of reducing fertilizer use. Journal of South China Agricultural University (Social Science Edition), 2017, (3): 58~66

[10] Ma Yila, Tu Erxun, Fu Qinayi, Yulvas, Asya, Tuohuti. Analysis of the influencing factors of excessive fertilizer application behavior among farmers - Taking Xinjiang cotton growers as an example. Journal of Cotton, 2016, 28 (6): 619-627

[11] Liu Yu. Empirical analysis on the influencing factors of farmers' scientific fertilization -- Taking Jianghan Plain in Hubei Province as an example. Science and Technology and Management, 2011, 13 (2): 48~50

[12] Liang Liutao, Qu Futian, Feng Shuyi Economic Development and Agricultural Non point Source Pollution: Decomposition Model and Empirical Study [J] Resources and Environment of the Yangtze River Basin, 2013 (10): 1369-1374

[13] Les Yun, Du Pengfei, Chen Jining Investigation and assessment method of non Point source pollution based on unit analysis [J] Journal of Tsinghua University: Natural Science Edition, 2004 (9): 1184-1187

[14] Chen Minpeng, Chen Jining, Lai Yun Inventory analysis and spatial feature recognition of agricultural and rural pollution in China [J] China Environmental Science, 2006 (6): 751-755

Acknowledgments

After more than two-month preparation, the thesis is finally completed. Here, I would like to express my gratitude to every teacher and classmate who guided me in writing this thesis. It is owing to all of them that my thesis could be improved.

Firstly, I would like to thank my classroom teacher, Mr. Lang Rongxiao. She encouraged me to participate in the Youth Leadership Symposium of World Food Prize and helped me balance my research and study. Her rigorous academic attitude and peaceful mindset allowed me to stay grounded and complete each step of the research solidly.

Additionally, I want to thank my advisor, Ms. Zhao Na. The revision and improvement of the thesis would not have been possible without her responsible attitude. She provided valuable suggestions for the logical flow of my thesis, which helped me make significant progress in terms of rigor and logic. Through discussions with Mr. Lv Jianheng, I also learned the importance of seeking truth in academic research and the need for evidence-based arguments.

My parents played an indispensable role in the creation of this thesis. They provided me with many resources and opportunities to engage with professionals and discuss ideas. I would also like to extend special thanks to Professor Liu Xiaoqian, who provided guidance on the direction and specific data analysis methods for my thesis, greatly enhancing its professionalism and rigor.

Finally, I would like to thank Shijiazhuang Foreign Language School and all the teachers as well as classmates who gave me this valuable opportunity to immerse myself in thesis research and improve my academic level.