An Empirical Study on Fertilizer Utilization Efficiency of Major Crops in the South under the Background of "Double Reduction"--Jiangxi Province as an Example

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Abstract: Based on the requirements of the general environment of "double reduction and efficiency increase", we investigated and evaluated the current situation of fertilizer utilization efficiency in Jiangxi Province, and then promoted the double reduction and efficiency increase of fertilizer in Jiangxi Province. By studying the statistical data of fertilizer application for major crops in 11 cities of Jiangxi Province from 2015 to 2020, we introduced fertilizer consumption to assist in measuring the efficiency of fertilizer utilization, and also divided the high and low levels of fertilizer consumption through hierarchical cluster analysis to study regional differences. In general, Jiangxi is a late province in the country to implement fertilizer reduction, and the intensity of fertilizer application is still at a high level; the double reduction of fertilizer in eleven cities is more effective, and most municipalities have implemented the double reduction work; the fertilizer consumption of cash crops in the province is higher than that of food crops, and the fertilizer consumption of major crops is still increasing, and half of the province is still in the middle and high input level areas, and the effect of fertilizer reduction is not so ideal. It is recommended that municipalities focus on reducing the intensity of fertilizer application and examine the underlying reasons for the higher fertilizer intensity than other municipalities, while implementing optimal strategies in light of the actual situation, such as limiting fertilizer inputs to cash crops or encouraging regional planting structure adjustment.

1. Introduction

Fertilizer application has made a great contribution to securing food production in China and is considered to be one of the important drivers of China's agricultural economic growth [1]. However, at the same time, the amount of fertilizer inputs in China's agriculture has significantly exceeded the optimal dosage range that balances economic and environmental efficiency due to low fertilizer utilization [2], and excessive fertilizer use has brought about a series of environmental problems, such as soil acidification, land fertility decline, and water resource pollution. Therefore, there is an urgent need to promote chemical fertilizer reduction, which is of great significance to ensure agricultural ecological security. During the 12th Five-Year Plan, the Ministry of Agriculture issued the "Zero Growth Action Plan for Fertilizer Use by 2020", and fertilizer reduction policies have been implemented around the world. The fertilizer reduction policy has achieved remarkable results, which is of great significance to safeguard national food and agricultural ecological security. Studies have shown that the key to effective fertilizer application reduction lies in the improvement of fertilizer utilization efficiency [3-4].

Domestic and foreign studies on the evaluation of fertilizer utilization efficiency mainly start from both agronomic and economic perspectives. The traditional fertilizer utilization efficiency (NUE) from the agronomic perspective is called absorption efficiency [5-11], which is the percentage of fertilizer nutrients absorbed by the crop (in the current season) to the total fertilizer nutrients applied, reflecting the crop's recovery efficiency of nutrients in the soil, and is mostly measured by the method of field trials. Fertilizer biased productivity (PFP) and technical efficiency of fertilizer application are

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used to characterize the efficiency of fertilizer use from an economic perspective [12-16]. Fertilizer biased productivity (PFP) is equal to the ratio of crop yield to fertilizer application under fertilizer application, and is an important indicator of the combined effect of local soil base nutrient levels and fertilizer application rates. The technical efficiency of fertilizer application is a single input efficiency, which is the ratio of the minimum fertilizer use possible for crop cultivation to the actual fertilizer application given the actual output and other input levels.

The evaluation of fertilizer use efficiency is measured by different methods, all of which are scientific and reasonable, but all of which have limitations to a certain extent at the same time. The disadvantage of the economic perspective for efficiency evaluation is that it may be influenced by some exogenous variables such as the price of agricultural products to a certain extent, but the agronomic method has the problems of high requirements for experimental conditions, difficulty in selecting highly representative experimental subjects, and high cost of data acquisition, so the economic method has certain superiority. Agricultural data mining is a relatively new research field, and the rational use of data mining and its tools, such as cluster analysis, can help us better solve various complex agricultural problems [17-20].

This study introduces the concept of "energy consumption" in the field of energy economics and uses "fertilizer consumption" to represent the amount of fertilizer input per unit of agricultural product, which avoids the disadvantages of the general method of input-output modeling and excludes the influence of factors such as exchange rate, price, and soil. Fertilizer consumption The study will investigate the spatial and temporal evolution of fertilizer application patterns, characteristics, patterns and problems, and put forward corresponding policy recommendations to provide a basis for further fertilizer reduction for major crops in southern China. The results of the study will be useful for theoretical research and practical production.

2. Data Sources and Research Methods

2.1 Data Sources

This study mainly uses the ratio of fertilizer application intensity and crop yield data of various crops in the Jiangxi Provincial Statistical Yearbook (2012-2020) to calculate fertilizer utilization efficiency (fertilizer consumption), divided by municipalities, and a total of 11 prefecture-level cities in Jiangxi Province were analyzed and studied. Based on the number of statistical yearbook statistics and the planting structure of major crops in Jiangxi Province, this study selected major crops such as late indica rice, middle indica rice, oil peanut, rapeseed, mandarin, open field tomato, open field cabbage, open field cabbage, open field cauliflower, open field pepper, open field cucumber, open field eggplant, open field radish, open field bean, etc. as the research objects.

Regarding the current situation of fertilizer application, the statistics of the Jiangxi Rural Statistical Yearbook (2012-2020) on the discounted amount of fertilizer application in each city of Jiangxi Province were chosen for this study. Regarding food calories, the data published by relevant websites were used to represent this study.

2.2 Research Methodology

2.2.1 Calculation of Fertilizer Consumption

In view of the complete range of landscape types in Jiangxi, except for the northern part, which is flat, surrounded by mountains in the east, west and south, and undulating hills in the middle. Therefore, the main crops in each city of Jiangxi are

different, and this project uses the fertilizer consumption measurement among different crops to evaluate the fertilizer utilization efficiency. In this study, the concept of fertilizer consumption is introduced to characterize the efficiency of fertilizer use, which is mainly based on the input-output ratio of physical quantity, expressed by the amount of fertilizer applied to 1t of agricultural products, and is calculated as the intensity of fertilizer application divided by the crop yield. This indicator overcomes the shortcomings of existing fertilizer utilization efficiency indicators in 2 aspects: on the one hand, fertilizer consumption does not require the determination of nutrient uptake, which is simple and easy to understand and grasp, and continuous data on yields and fertilizer application intensity are available in statistical yearbooks; on the other hand, fertilizer consumption is based on physical quantities (discounted quantities), which excludes the influence of prices, exchange rates, replanting and other factors and facilitates comparison.

Using PFP $\left(\text{Fertilizer bias productivity} = \frac{\text{Fertilizer application amount}}{\text{Crop yield}}\right)$ to represent fertilizer consumption, the amount of fertilizer used per acre of farmland for each type of crop divided by the yield per acre of farmland was substituted for the total fertilizer use per crop divided by the total yield.

The calculation formula is as follows.

$$\text{Fertilizer consumption} = \frac{\text{Fertilizer application amount}}{\text{Crop yield}} = \frac{\text{Fertilizer application intensity}}{\text{Crop unit yield}}$$

The fertilizer consumption calculated at this point is the fertilizer consumption per unit of

2.2.2 Comparative Analysis Method

Collect the data of fertilizer consumption of the same crop in different areas, fertilizer consumption of different crops in the same area, yield of the same crop with different fertilizers, changes in labor structure in recent years, and through comparative analysis, observe and discover differences between regions and commonalities of areas with high fertilizer utilization efficiency, so as to give scientific fertilizer application plans in combination with the actual situation.

2.2.3 Hierarchical Clustering Analysis

Cluster analysis is the analytical process of grouping a collection of physical or abstract objects into multiple classes consisting of similar objects; in short, it is the classification of multiple groups data based on the principle of similarity, which is mainly achieved through data modeling with the help of statistical software such as SPSS. In this study, Kmeans hierarchical cluster analysis was to cluster fertilizer consumption data from 2015-2019 in each city of Jiangxi Province, which were divided into high fertilizer consumption group, medium fertilizer consumption group, and low fertilizer consumption group according to their values, and then the regional differences in fertilizer consumption of major crops in Jiangxi Province were studied comparatively.

3. Status of Fertilizer Application in Jiangxi Province

3.1 “Double Reduction” Background, Jiangxi “Zero Growth of Chemical Fertilizers” to Achieve Certain Results

“Agricultural province” Jiangxi is located in the middle and lower reaches of the Yangtze River South, agricultural and rural resources are very rich, the province's arable land area of 43.91 million mu, is the country's main grain-producing areas, rice production ranks 3rd in the country, grain has been stable for nine years in more than 43 billion pounds of production. 2021, Jiangxi Province, the total agricultural output value of 399.81 billion yuan. Year-on-year growth of 9.0%. Promote the reduction of chemical fertilizers and pesticides to increase efficiency, is an important measure to promote the green development of agriculture.

Since 2015, China's Ministry of Agriculture and Rural Affairs organized the implementation of the “zero growth action of chemical fertilizer and pesticide use by 2020”, Figure 1 data show that from 2016, the application of chemical fertilizer in Jiangxi Province has been a significant downward trend year after year, with 2012 as the base year, the province's fertilizer application by 2020 fell by a total of 324,500 tons, Jiangxi Province to achieve the “double reduction” goal ahead of schedule.

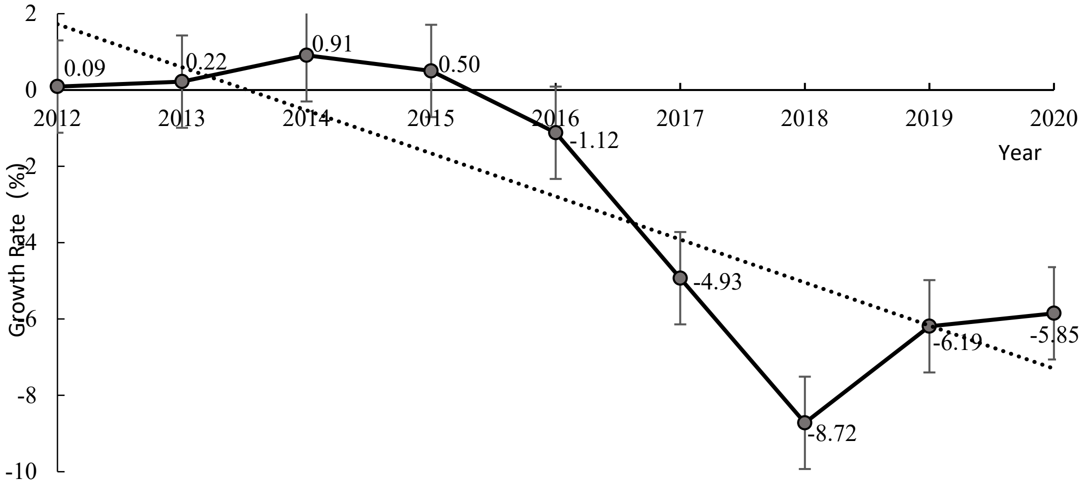

Figure 1 2012-2020 the province's fertilizer application growth rate and trend line

3.2 Apparent Regional Variability in Fertilizer Application Intensity in Jiangxi

In 2019, the fertilizer application (discounted amount) per unit crop sown area in Jiangxi Province was 209.38 kg/hm2, which is a good overall level and lower than the internationally accepted standard line of 225 kg/hm2 for safe fertilizer application, but a more obvious regional variability in fertilizer application intensity in Jiangxi Province can be found by analyzing the fertilizer application statistics of each city (county and district) in Jiangxi Province.In 2019 The highest fertilizer application intensity is in Nanchang (285.64 kg/hm2), and the lowest is in Yingtan (165.82 kg/hm2). Among them, six cities exceeded the average fertilizer application intensity in Jiangxi Province, namely Nanchang (285.64 kg/hm2), Jiujiang (243.97 kg/hm2), Xinyu (259.17 kg/hm2), Fuzhou (236.66 kg/hm2), Pingxiang (220.17 kg/hm2), and Ganzhou (216.37 kg/hm2).

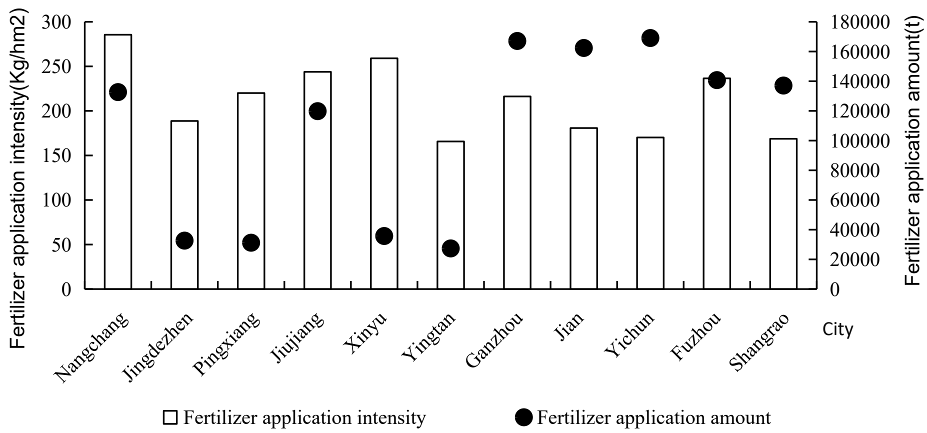

Figure 2 Fertilizer application intensity and amount by city in Jiangxi province, 2019

Since fertilizer application intensity is influenced by two variables, namely, the amount of fertilizer applied to agriculture and the area sown to crops in each city, the fertilizer application intensity does not exactly coincide with the trend of fertilizer application. For example, Figure 2 shows that Fuzhou City has the fourth highest fertilizer application intensity in the province at 236.66 kg/hm2 and its fertilizer application amount is also higher at about 140.7 thousand (the fifth highest in the province), while Xinyu City has the second highest fertilizer application intensity in the province (259.17 kg/hm2), but its agricultural fertilizer application amount is only about 35.7 thousand tons (the fourth lowest in the province). Therefore, the road to fertilizer reduction should not simply focus on fertilizer application indicators, but should also take into account the crop sowing area factor. To a certain extent, the sown area of crops reflects the market demand, and from the perspective of the need to ensure the supply of agricultural products, it is necessary and valuable to conduct research on how to improve the efficiency of fertilizer use without reducing the sown area while achieving scientific fertilizer reduction and reducing the intensity of fertilizer application.

3.3 Regional Effectiveness of Fertilizer Reduction in Jiangxi Varies

Fig.3 Data Table of the Increase or Decrease of Fertilizer Application and Fertilizer Application Intensity by Cities in Jiangxi Province Shows That.

(1) 2019 fertilizer application in the province in addition to a small increase in Xinyu City, the rest of the cities in 2019 compared to the relevant data in 2018 showed a decline in the trend. Taking 10,000 tons as the unit of measurement, Jiujiang City has the most prominent reduction of 21,000 tons, followed by Fuzhou City (13,500 tons), Ganzhou City (12,000 tons), Ji'an City (10,200 tons), Yichun City (0.8 million tons), Yingtan City (0.55 million tons), Nanchang City (0.23 million tons), Shangrao City (0.19 million tons), Jingdezhen City (0.13 million tons) and Pingxiang City (0.1 million tons).

(2) In kilograms as a unit of measurement, only Nanchang City (an increase of 8.46 kg/hm2) and Xinyu City (an increase of 0.11 kg/hm2) showed an increase in the intensity of fertilizer application in the province in 2019, and the remaining nine cities showed a significant decline compared with 2018. Among them, Jiujiang City decreased by 35.91 kg/hm2, Yingtan City decreased by 33.88 kg/hm2, Fuzhou City decreased by 20.41 kg/hm2, Ganzhou City decreased by 15.16 kg/hm2, Yichun City decreased by 12.02 kg/hm2, Jingdezhen City decreased by 10.8 kg/hm2, Pingxiang City decreased by 10.57 kg/hm2, Ji'an City decreased by 5.78kg/hm2, Shangrao City down 2.89kg/hm2.

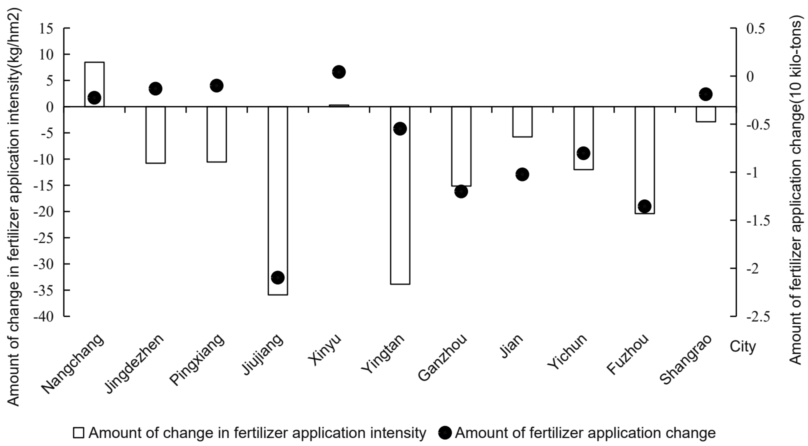

Figure 3 Amount of change in fertilizer application intensity and fertilizer application by city in Jiangxi

It can be seen that the regional effectiveness of fertilizer reduction in Jiangxi Province varies and varies widely. In this study, the 11 cities in the province are divided into 3 categories: 1) 1 city with double increase in fertilizer application and fertilizer application intensity, only Xinyu city; 2) 9 cities with double decrease in application and application intensity, respectively, Jingdezhen, Pingxiang, Jiujiang, Yingtan, Ganzhou, Ji'an, Yichun, Fuzhou and Shangrao; 3) 1 city with increase in application intensity and decrease in application intensity, only Nanchang city. of one increase and one decrease in city, only Nanchang City. [2] Among them, there is no city with increased application and decreased application intensity, because there is no significant increase or decrease in crop sown area in 2019 compared with 2018.

4. Evaluation of Fertilizer Utilization Efficiency of Major Crops in Jiangxi Province

The fertilizer consumption calculation method was used to evaluate the fertilizer use efficiency of major crops in cities (counties and districts) of Jiangxi Province from 2010 to 2020.

The project team used the fertilizer consumption calculation method and cluster analysis method to compare and analyze the fertilizer consumption of the same crop in different areas, the fertilizer consumption of different crops in the same area, and the fertilizer use per unit area in each city of Jiangxi Province from 2015 to 2019 to find the areas and crops with high fertilizer use and to provide a basis for local governments to formulate practical weight loss policies.

To ensure the representativeness and rigor of the experiment, the project team extracted the required data from the Jiangxi Statistical Yearbook and the statistical yearbooks of Jiangxi cities, and also selected grain crops (mainly: medium-grained rice and late-grown rice), oil crops (mainly: peanuts and rapeseed), fruits (mainly: mandarin), vegetables (mainly: open tomatoes, open cucumbers, open eggplants, open peppers, open cabbages, open The fertilizer consumption calculation method (fertilizer consumption = fertilizer application amount/crop yield) was used to calculate the fertilizer consumption of each type of crop in different areas, simulating the main crops in each area.

According to the different soil qualities in different parts of Jiangxi, the main crops in each municipality are different and require different amounts of fertilizer, so this study analyzes the fertilizer use per unit area with the municipality as the basic unit to facilitate the timely adjustment of fertilizer use strategies by local governments based on the data of this project.

4.1 Fertilizer Consumption of Cash Crops is Greater Than Other Crops

Table 1 Average fertilizer consumption of major crops in Jiangxi province, 2015-2020

Crop species	Crop	Fertilizer consumption per unit product(Kg/Kg)	Calories per 100g product	fertilizer consumption of equal grain volume products(Kg/Kg)
grain crop	medium indica rice	0.05	1.453	0.05
	late indica rice	0.06	1.47	0.06
oil crops	peanuts	0.1	2.357	0.06
	rapeseed	0.14	1.587	0.13
fruits	citrus reticulata	0.04	0.184	0.28
vegetable	outdoor tomato	0.01	0.084	0.17
	outdoor cucumber	0.01	0.047	0.27
	outdoor eggplant	0.02	0.116	0.21
	outdoor cooking pepper	0.02	0.092	0.39
	outdoor cabbage	0.01	0.109	0.14
	outdoor Chinese cabbage	0.01	0.076	0.2
	outdoor cauliflower	0.01	0.122	0.16
	outdoor radish	0.01	0.088	0.19
	Outdoor beans	0.02	0.13	0.22

Note: Calorie data are derived from (https://www.boohee.com/shiwu/jieganzihttp://www.shoumm.com/), the caloric value of rapeseed is calculated according to the caloric value of rapeseed oil formed from rapeseed with an oil yield of 42%.

In the calculation of fertilizer consumption per unit of product in the above table, we take an economic point of view to use PFP ($\text{Fertilizer bias productivity} = \frac{\text{Fertilizer application amount}}{\text{Crop yield}}$) to represent fertilizer consumption, Since the amount of fertilizer applied to each type of crop in each region is not yet available in each database, we use the amount of fertilizer used per acre of farmland for each type of crop divided by the yield per acre of farmland instead of the total amount of fertilizer used for each crop divided by the total crop yield, i.e.,

$$\frac{\text{Amount of chemical fertilizer used per acre of farmland}}{\text{Yield per acre of farmland}} = \frac{\text{Total fertilizer application}}{\text{Total production}}$$
$$= \text{Fertilizer consumption}$$

At the same time, the different self-calorie of the same unit of crop and the weak comparability between different crops make the comparison of fertilizer consumption lack of certain rigor, so this project team used crop calories as a bridge to determine the weight of the crop with equal calories per 100 g of grain calories, and then derived the fertilizer consumption required for the crop at that weight, and then compared the fertilizer consumption of each crop. As shown in the table above, the fertilizer consumption of equivalent grain yield products varied significantly among crops, and the top four crops with higher values were vegetable and fruit crops, which were open field peppers, mandarins, open field cucumbers, and open field beans, with fertilizer consumption of 0.39, 0.28, 0.27, and 0.22 kg/kg of equivalent grain yield products, respectively; the top four crops with lower fertilizer consumption of equivalent grain yield were medium indica rice, late indica rice, peanuts, and rapeseed The top four crops with lower fertilizer consumption in grain yield were medium indica rice, late indica rice, peanut and rapeseed, whose fertilizer consumption in grain yield was 0.05, 0.06, 0.06 and 0.13, respectively, two of which were grain crops and the other two were oilseed crops. After comparison and analysis, we know that the fertilizer consumption of cash crops (represented by vegetables and fruits) in Jiangxi Province is greater than that of grain crops. In order to reduce the large amount of fertilizer use and never better increase the efficiency of fertilizer use in Jiangxi Province, certain restrictions can be added to the use of fertilizer for cash crops.

4.2 Increase in Fertilizer Consumption of Major Crops and Other Cereal Products

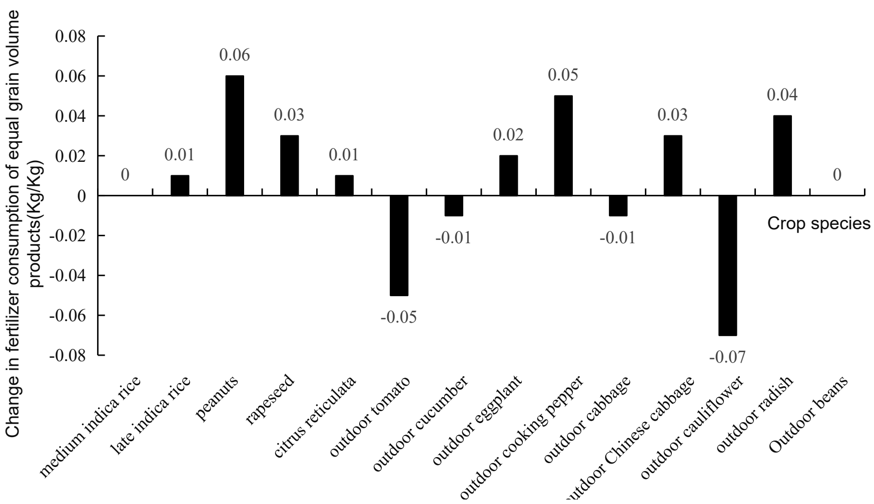

Figure 4 Change in fertilizer consumption of equal grain volume products, 2015-2020

Note: The change in fertilizer consumption of equivalent grain volume products is the change in fertilizer consumption of equivalent grain volume products in 2020 compared to 2015

Since the national fertilizer reduction policy was promulgated in 2015, fertilizer reduction was gradually implemented, so the project team took 2015 as the base year, and the average change in fertilizer consumption of equivalent grain volume products over the five-year period showed that crop fertilizer consumption was generally on an upward trend.

About 4/7 crops in Jiangxi showed an upward trend in fertilizer consumption, 2/7 showed a downward trend, and 1/7 showed no significant change. Among the crops with a decreasing trend in fertilizer consumption, the fertilizer consumption of open field cauliflower and open field tomatoes decreased the most, and the amount of fertilizer consumption of equal grain products decreased by 0.07kg/kg and 0.05kg/kg, followed by open field cucumber and open field cabbage, and the amount of fertilizer consumption of equal grain products decreased by 0.01kg/kg, and the decrease in fertilizer consumption was mainly for vegetable crops. Meanwhile, from the perspective of increased fertilizer consumption, oilseed crops (peanut, rapeseed) and some vegetable crops (open field pepper, open field radish) increased the most. From the average value of the change in fertilizer consumption of various crops, the average value of the increase in fertilizer consumption of oilseed crops and vegetables is 0.045kg/kg and 0.000kg/kg, respectively, and the average value of the increase in fertilizer consumption of grain crops is 0.005kg/kg. Overall, the fertilizer consumption of most major crops in Jiangxi Province has increased.

4.3 Evolution of Spatial and Temporal Patterns of Fertilizer Inputs on Farmland in Jiangxi Province

In order to observe the spatial distribution patterns of fertilizer inputs and their changes in farmland across Jiangxi Province, this project team successfully clustered the fertilizer input intensities of 11 municipalities in Jiangxi Province from 2015 to 2019 by using Kmeans cluster analysis to classify the samples as high-input, medium-input and low-input zones, respectively. As can be seen from Table 2: the clustering partitions showed significance ($p<0.01$) for all study items, implying that the three types of partitions obtained from the cluster analysis had significant differences in the characteristics of the study items. By and large, there are still some areas in Jiangxi Province where fertilizer input is still at a medium to high level.

Table 2 Comparison Results Of Variance Analysis of Clustering Categories

	Clustering category ANOVA variance comparison results (Mean ± standard deviation)			F	p
	High-input(n=4)	Low-input(n=4)	Medium-input(n=3)		
2015	2973.73±154.60	2031.09±110.36	2623.93±133.07	50.380	0.000***
2016	2975.98±215.22	2044.13±68.81	2556.86±117.41	38.541	0.000***
2017	2963.11±151.21	1988.51±132.63	2332.16±4.50	64.076	0.000***
2018	2619.10±222.69	1859.65±164.21	2270.46±70.92	19.282	0.001**
2019	2494.86±285.21	1687.43±139.25	2196.57±111.12	16.251	0.002**
* p<0.05 ** p<0.01 *** p<0.01					

Table 3 Clustering Results Of Fertilizer Inputs for Major Crops

Year	High-input	Medium-input	Low-input
2015	Nanchang City,Jiujiang City,Xinyu City,Ganzhou City	Pingxiang City,Yichun City	Jingdezhen City,Yingtan City,Jian City, Fuzhou City,Shangrao City
2016	Jiujiang City,Xinyu City,Ganzhou City	Nanchang City, Yichun City	Jingdenzhen City ,Pingxiang City, Yintan City,Jian City,Fuzhou City, Shangrao City
2017	Nanchang City,Jiujiang City,Xinyu City,Ganzhou City	Yichun City,Shangrao City	Jingdezhen City,Pingxiang City, Yingtan City,Jian City,Fuzhou City
2018	Nanchang City,Jiujiang City,Xinyu City	Pingxiang City,Ganzhou City,Shangrao City	Jingdezhen City, Yingtan City,Jian City, Yichun City, Fuzhou City
2019	Nanchang City,Jiujiang City,Xinyu City,Shangrao City	Pingxiang City,Ganzhou City	Jingdezhen City, Yingtan City,Jian City, Yichun City, Fuzhou City

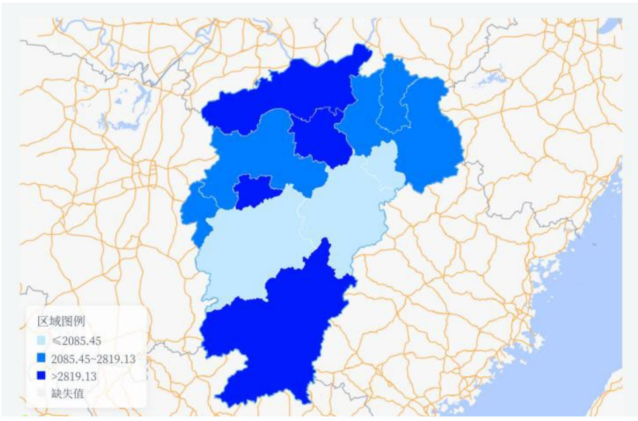

Fig.5 Average Fertilizer Use Per Unit Area in 2015

In 2015, as seen from the Figure 5, there were four municipalities with fertilizer inputs per unit area of farmland located in the high input zone, namely Nanchang, Jiujiang, Xinyu, and Ganzhou, of which the first four municipalities were in the northwest region of Ganxi and the southern region of Ganzhou, and Ganzhou was in the southern zone of Ganzhou also in the marginal region of Jiangxi Province, with the number of this part accounting for 54.55% of the total number of municipalities; the number of municipalities of this type has remained at four since 2019 , with the addition of Shangrao City, the new minus Ganzhou City,which can be known from the Figure 6. We can clearly see that fertilizer inputs have been lower in Ganzhong, while they have been kept at a higher level in Ganbei and Gannan.The municipalities that exceed the average unit area of fertilizer use in Jiangxi Province have little overall change and are mainly characterized by marginal distribution.

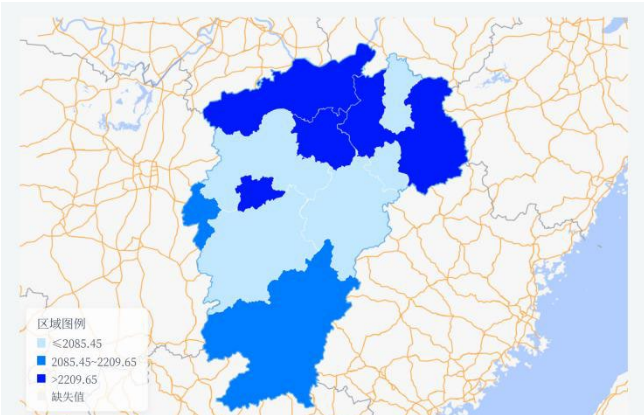

Fig.6 Average Fertilizer Use Per Unit Area in 2019

5. Conclusion and Insights

In 2015, the Ministry of Agriculture and Rural Affairs of China implemented the “zero growth action of chemical fertilizer and pesticide use by 2020”, and the growth rate of chemical fertilizer application intensity in Jiangxi Province began to have a significant downward trend. The growth rate of fertilizer application in Jiangxi Province between 2012 and 2020 shows that the fertilizer application started to grow negatively in 2015, at a rate later than that of the whole country. At the same time, the intensity of fertilizer application in Jiangxi Province shows obvious regional differences, with the intensity of application in the northwestern region being higher than that in other regions; only Xinyu City shows a double increase in fertilizer application, while all other cities except Nanchang City achieve a double decrease in fertilizer application and intensity. In terms of fertilizer utilization efficiency, the fertilizer consumption of cash crops in Jiangxi Province is greater than that of food crops, and overall, the fertilizer consumption of most major crops in Jiangxi still increased; the number of medium and high fertilizer input areas in Jiangxi Province has more than half of the total number of municipalities, and the road to fertilizer reduction still needs further efforts.

Because different urban areas differ in terms of the pace of economic development, planting structure, and the degree of arable land development, we should pay more attention to the two evaluation indicators of fertilizer application intensity and fertilizer utilization rate than to the increase or decrease of fertilizer application. The reduction of fertilizer application alone does not mean that the intensity of fertilizer application will also be reduced. Therefore, the recommendation of this paper is that each municipality should give priority to reducing fertilizer application intensity and find out the root cause of higher fertilizer application intensity than other municipalities. At the same time, the optimal strategy should be implemented in accordance with the actual situation, such as introducing a policy of limiting fertilizer inputs to cash crops in certain areas, or encouraging the restructuring of regional cropping, so as to improve the efficiency of local fertilizer use.

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