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Analysis on the Spatial and Temporal Distribution of Rice Planting in Maoming Paddy Soil and Its Agricultural Role from the Perspective of Agrogeography

BY

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Abstract

Rice is one of the main crops in grain production. The spatial-temporal distribution of rice planting, area, and other related factors can affect grain production. At the same time, paddy soil is the main soil for planting rice, which has a great influence on rice. In this study, the paddy soil distributed in Maoming City is taken as a study area. In terms of agrogeography, this study aims to realize the spatial-temporal relation between paddy soils and rice planting, as well as its production. Thus, this study taking 2001, 2005, 2011, 2016, and 2021 as the five-year time span, the spatial-temporal distribution and area data of rice planting in paddy soil were analyzed. On this basis, the correlation analysis between rice planting area of paddy soil and rice output value was also explored. Finally, the rice yield prediction model of paddy soil was made by taking the rice planting area of paddy soil as the variable.

KEYWORDS: *Paddy soil; Spatial-temporal distribution of rice planting; agriculture role; Yield prediction model; Agrogeography.*

1. Introduction

Agriculture is closely related to geography and has a natural connection. Agrogeography is to study the characteristics and causes of regional differences in agricultural production and to explore the trend of its change and development. Through the research, people can plan agricultural production according to local conditions, and realize the rational layout of agricultural production process and rational utilization of natural resources. Therefore, it is the foundation of the development of agrogeography to explore agriculture from the perspective of geography. Agrogeography is a science that studies the structure of agricultural production and the law of regional differentiation. It mainly studies the formation conditions, process, structure of agricultural economic activities and the law of spatial-temporal development and change from the regional perspective (Wu, 1998)。 Rice planting is one of the main development directions of agrogeography, so the research on rice-related factors has great value in the times.

China is a populous country, and food security is a top national priority. At present, the self-sufficiency rate of grain in China has been reduced to below 90%, which shows that the problem of food security is worthy of attention. Maoming is the largest agricultural producing area and the largest grain production base in Guangdong Province. The biological characteristics of rice can be widely adapted to the climate and soil in Maoming and its paddy soil are widely distributed, which is one of the main soils in Maoming, so the rice planting is relatively extensive. With the rapid development of economy, the agricultural development speed has accelerated, but the contradiction between population and resources is aggravated, which also affects the agricultural development of our country (Ma, 2019). People's unreasonable use of land and the soil has not been adapted to local conditions, resulting in a lot of crops, although the sown area is wide, but the yield is difficult to raise, even backward situation. Therefore, in the era of emphasis on agricultural development, it is more necessary to study and analyze the agricultural function of soil.

Soil is an important component of natural systems and an important contributor to human well-being. It is essential for crop production through its own contribution to crop cultivation (Xu, 2021)。 Soil promotes sustainable agricultural development by improving crop yield and quality, and is an important part of sustainable agricultural development. It can be seen that the agricultural role of soil is reflected in the planting state of soil on crops, yield, and other aspects.

Based on the above background, this paper takes paddy soil in Maoming as the research area and analyzes paddy soil planting from the perspective of spatial-temporal distribution according to the perspectives and methods of agrogeography on rice planting. It aims to analyze the relevant laws of paddy soil planting in Maoming through the spatial-temporal distribution patterns, such as suitable planting conditions, spatial-temporal changes of planting area, etc. Based on these rules, the correlation between rice planting area and yield of paddy soil was analyzed, and the agricultural function was reflected through the correlation between planting area and yield. Finally, the predictive yield model was fitted according to the correlation between the two, so as to further analyze the spatial-temporal distribution of rice planting and its agricultural function in Maoming paddy soil.

2. STUDY AREAS

Maoming is located in the southwest of Guangdong Province. Its geographical coordinates are 110°20 '~ 111°40' east longitude and 21°25 '~ 22°43' north latitude. It borders the South China Sea to the south, Yunfu and Yulin and Wuzhou of Guangxi Zhuang Autonomous Region to the north, Yangjiang to the east, and Zhanjiang to the west (show as Figure 1). The land area of Maoming area was continuously expanded and its landform gradually developed in the late Paleozoic Mudpan Period to Cretaceous period. In the process of geological development, organic matter accumulates continuously, and soil material elements are also formed on this basis. The quality of soil development environment is an important material basis for the formation of cultivated land resources.

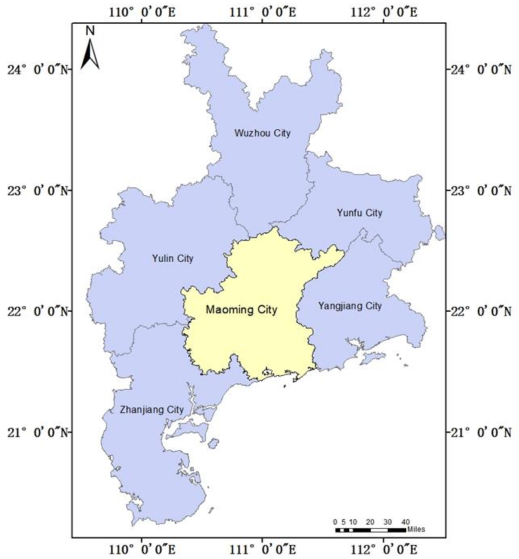

Figure 1 Map of Maoming City Administrative

According to the geographical coordinates, Maoming is located in the south of the Tropic of Cancer, a subtropical monsoon climate zone with obvious monsoon and diverse climate types, prevailing northerly wind in winter and southeast wind in summer. The average daily temperature ranges from 21℃to 29℃, the accumulated temperature of rice ranges from 3150℃ to 5220℃, and the average annual precipitation is 1870 mm.

The growth of rice needs more than 10°C and the heat resources required by accumulated temperature are 2000℃-5000℃, and the water requirement of rice during the whole growth period is 500-800 mm. In each growth period, the change of heat and water has a huge impact on the growth of rice and the full rate of fruit (Li and Li, 2021). It can be seen that the Maoming area is very suitable for the development of rice in terms of heat and water conditions.

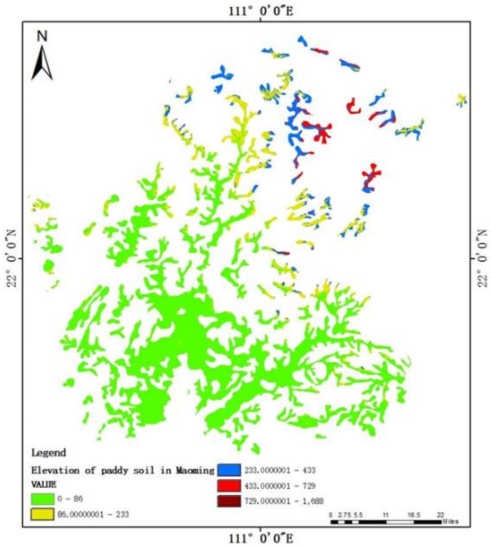

Figure 2 Distribution elevation of paddy soil in Maoming

Maoming is located in the southeastern hilly region; the terrain is high in the north and low in the south. It slopes from northeast to southwest, making rivers crisscrossed and cut in Maoming City, forming a topography and landform of mountains, hills, platforms, and plains (show as Figure 2). Paddy soil in Maoming is widely distributed, mainly in the south of Maoming region, namely in the plain and hilly areas, and a small part in the north in a scattered form. The southern part of paddy soil in Maoming City has become the main area for paddy soil planting due to the characteristics of rice planting in the gentle terrain.

3. RESEARCH METHODS

Based on the spatial analysis of agrogeography, this paper proposes a framework for analyzing the spatial-temporal distribution of rice planting and its agricultural role in Maoming (show as Figure 3). At first, this study collecting relevant data and obtaining relevant image information, including the second national soil census data, paddy soil vector map, and so on. In addition, ArcGIS software was used to process the collected data with its functions such as superposition and extraction, so as to obtain the distribution range of paddy soil and rice planting area of paddy soil in Maoming City and other relevant information. According to the above information, the spatial-temporal distribution of rice planting and its agricultural function in Maoming paddy soil were analyzed.

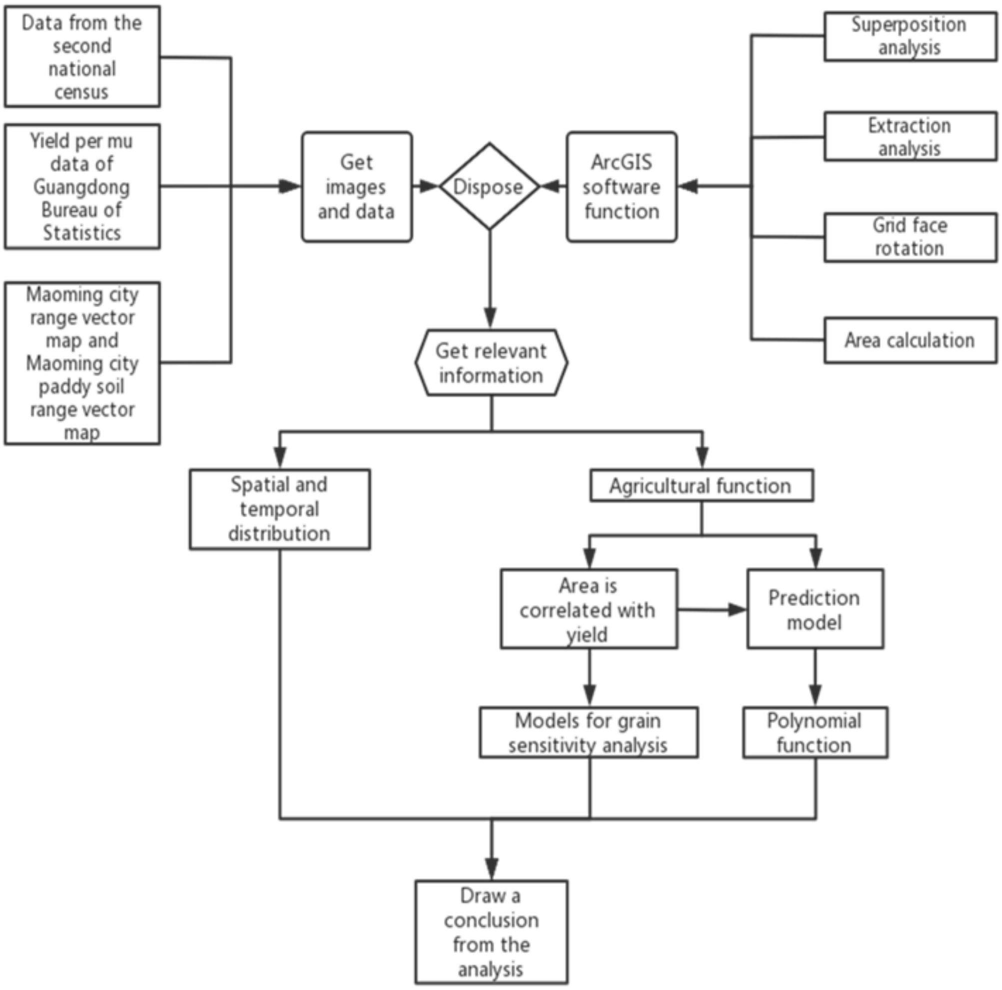

Figure 3 The diagram of analysis framework

The agricultural function of this paper, represented by crop yield, explores the correlation analysis between the area of rice planted in paddy soil and the production of rice on this soil, analyzes the correlation between the area of rice planted and the production, and explores its agricultural function and value. In addition, through five years of planting area from small to large and corresponding yield data, the paddy soil's rice planting area as a variable to make a yield prediction model for short-term rice yield prediction. Finally, the spatial-temporal distribution of rice planting and its agricultural function in the Maoming region were concluded.

4. DATA PROCESSING AND ALALYSIS

Spatial distribution analysis of rice planting in paddy soil of Maoming

Since crop planting differences are less apparent in similar years, this study selected every few years, which makes the spatial-temporal differences of crops significant. Therefore, this paper selects the rice planting distribution data of 2001, 2005, 2011, 2016, and 2021 from the "2000-2021 Rice Planting Area Data Set of Major Countries in the Asian Monsoon Region" (Han and Zhang, 2022) to analyze the spatial-temporal differences of rice planting in the paddy soil of Maoming. The region with paddy soil in Maoming, its rice-growing region, and Maoming region were extracted and superimposed for analysis, thereby the rice planting distribution map was made (show as Figure 4-8). From the distribution map, we can recognize directly the rice planting distribution on paddy soil in Maoming area

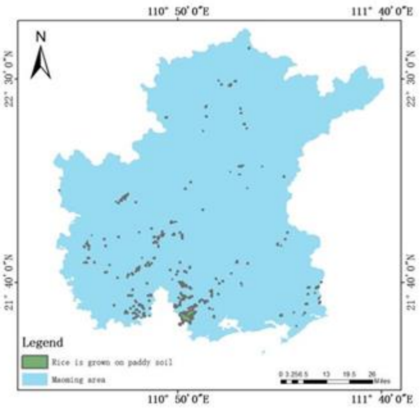

Figure 4 Rice planting distribution on paddy soil in 2001

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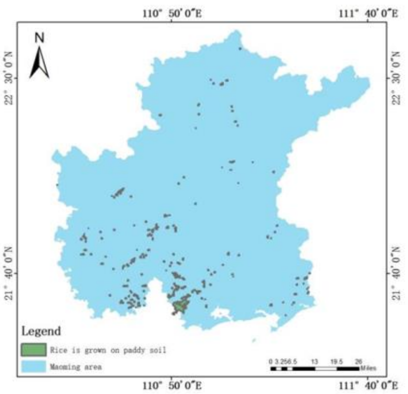

Figure 5 Rice planting distribution on paddy soil in 2005

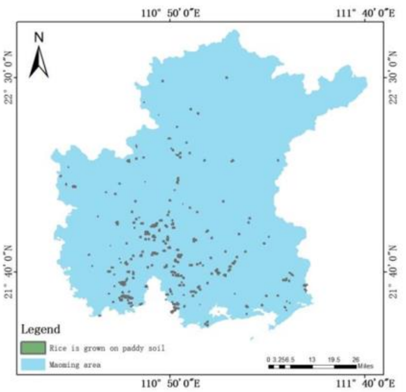

Figure 6 Rice planting distribution on paddy soil in 2011

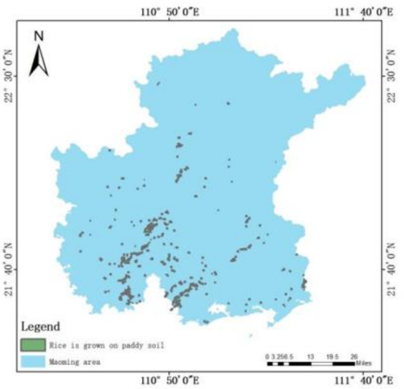

Figure 7 Rice planting distribution on paddy soil in 2016

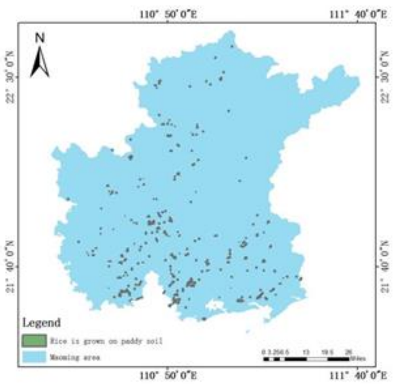

Figure 8 Rice planting distribution on paddy soil in 2021

From the perspective of spatial dimension, the paddy soil planting area is mainly distributed in the south, and is concentrated in the southern coastal area, and continues to expand to the north. From 2001 to 2021, the overall range of rice planting has improved. However, the paddy soil in the Maoming region gradually became sparse from 2001 to 2011 but became very dense in 2016, and gradually spread gently in 2021. Such rice planting law presents discontinuity in space.

The spatial distribution of Maoming was analyzed, namely, the five districts of Xinyi City, Maonan District, Gaozhou City, Dianbai District, and Huazhou City were analyzed separately (show as Figure 9). Because the planting space distribution of the recent years has less variation in a certain period of time, it can represent the planting space distribution of the inner region in a certain period of time. Therefore, the spatial distribution of rice planting in paddy soil in 2021 was selected to analyze the spatial distribution in Maoming City.

Huazhou is mainly characterized by a long and narrow terrain, which also makes the paddy soil of Huazhou extend in a north-south direction. In space, rice planting is distributed in the east and south, mostly concentrated in the southeast of Huazhou. The rice planting in the paddy soil of Maonan District is mainly in the middle of Maonan District, and the border source of the southeastern Maonan District is dense and distributed along the district. Rice planting in Gaozhou City is concentrated only in the southwest of the city, and in the north of the city shows sporadic distribution characteristics, and relatively sparse among each other. The paddy soil in Dianbai District has a wide range of rice plants, which is the most uniform planting area among the five districts in Maoming. In addition to the areas along the northeastern part of the region where there is no paddy soil rice planting, the rest of the areas along the region have rice planting, and there are some planting manifestations in the middle part of the region. In Xinyi City, rice planting tends to the west, and there is almost no paddy soil planting rice in the east

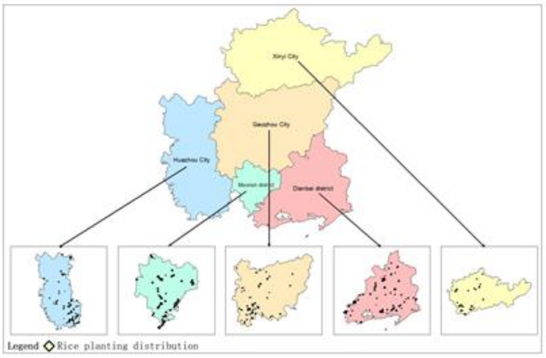

Figure 9 Rice planting on paddy soil in Maoming City

To sum up, the five regions divided into Maoming City have their own characteristics in the spatial distribution, forming a kind of paddy soil rice planting law. In particular, it can be seen that Dianbai District paddy soil is an important place for rice planting.

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In addition, when observing the spatial distribution of rice planting, this study compared the spatial proportion of rice areas. If the space ratio is greater than 50%, it indicates that more rice is planted in paddy soil. If the space ratio is less than 50%, it indicates that more rice is grown on soil other than paddy soil. The software ArcGIS was used to calculate the total area of rice planting in paddy soil and the total area of rice planting in Maoming area during the five years (show as Table 1). The space proportion of rice planting area in paddy soil was obtained.

Table 1 Area calculated of rice planting and planting in paddy soil in Maoming

Time	Total area of rice *planting* (mu)	Area of rice *planting* in paddy soil (mu)
2001	165240	94263
2005	209131	88784
2011	185396	71133
2016	202035	108661
2021	188434	82562

Through the space ratio formula such as follow(1) which can recognize the relation between rice planting area and planting on paddy soil.

$T_i = \frac{S_i}{Z_i} \times 100\%$ ....(1)

Where (1)： i=2001，2005，2011，2016，2021；

T---Space proportion of rice planting area on paddy soil；

S--Rice planting area on paddy soil；

Z---Total rice planting area in Maoming；

The calculation results are as follows (show as Table 2*):*

Table 2 Space ratio *of rice planting area on paddy soil*

i	2001	2005	2011	2016	2021
T_i	57.1%	42.5%	38.4%	53.8%	43.8%

According to the space ratio, it was more than 50% in 2001 and 2016. That is to say, rice planting was mainly carried out in paddy soil in these two years, while in the remaining three years, rice planting was mainly carried out on other soil. From this aspect, it can be seen that rice planting in paddy soil has discontinuity. However, the space proportion of paddy soil planting area can reach 38.4% at the lowest level, indicating that the overall planting proportion is still paddy soil as the main planting area.

Analysis of rice planting time distribution in paddy soil of Maoming

From the perspective of time dimension, rice planting has been carried out in paddy soil in these five years, and its planting area can be seen to be changeable. Figure 10 is made according to the rice planting area of Maoming paddy soil in Table 1.

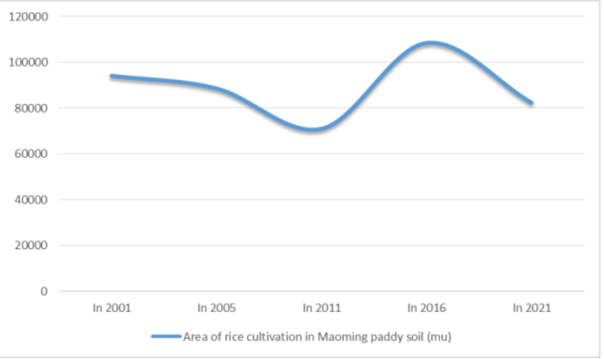

Figure 10 Time variation of rice planting area

In the past five years, the rice planting area of paddy soil has fluctuated between 70,000 mu and 110,000 mu. From 2001 to 2011, the overall planting area showed a decreasing trend, but it reached a relative peak in 2016 and gradually declined in 2021, indicating that the planting area has a certain volatility.

To explore the reasons, it is closely related to the wide suitability of rice planting in Maoming. Due to the unique geographical environment of Maoming, there are more choices of rice planting areas, and paddy soil is one of its main producing areas. Although various soil elements of paddy soil are very beneficial to the growth of rice, paddy soil still needs a recovery period. This makes the area of rice planted in paddy soil fluctuate to a certain extent.

In addition, Maoming paddy soil is very fertile, high plant ability, not only food crops planting, but also most of the cash crops planting. The social and economic conditions that affect crop planting structure are the first major component, including the level of local economic development, planting conditions, and transportation accessibility (Huang et al., 2021). The cultivation of crops is not only affected by natural conditions, but also by human conditions. Therefore, the fluctuation of rice planting areas on paddy soil is a normal phenomenon.

Spatial-temporal distribution of rice planting on paddy soil in Maoming

By analysis, indicated that the spatial distribution of rice planting in Maoming paddy soil showed discontinuity, while the temporal distribution showed fluctuation. It can be seen that the spatial-temporal distribution of rice planting in Maoming paddy soil is characterized by fluctuation and discontinuity.

From the horizontal perspective, the space proportion shows a trend of first decreasing, then increasing, and then decreasing, which is the same as the change trend of planting area from the time dimension (show as Figure 11). As shown in Figure 11, the spatial-temporal trends are generally very similar. It can be seen that the spatial-temporal relationship of rice planting area on paddy soil has a high consistency.

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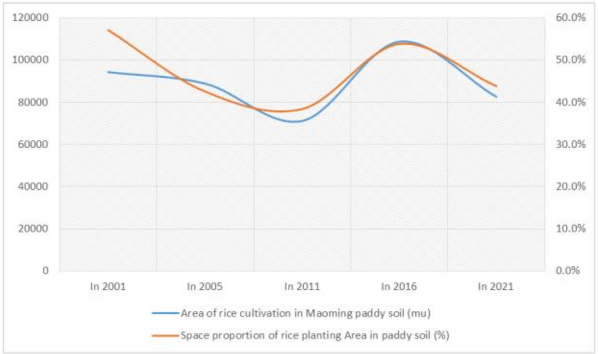

Figure 11 Spatial-temporal combination trend graph

Correlation analysis of rice area and rice yield in paddy soil of Maoming

The rice production level of a region is generally measured by its yield per unit area and sown area (Chen et al., 2021). Therefore, analyzing the correlation between rice planting area and rice yield in paddy soil in Maoming is helpful to measure the rice production level in Maoming region.

The data of rice yield per mu in 2001, 2005, 2011, 2016, and 2021 were obtained from Guangdong Statistical Yearbook of Guangdong Bureau of Statistics (2021). According to the statistics data, the approximate rice yield in this study was calculated by multiplying the rice planting area of paddy soil during the five-year period (show as Table 3).

Table 3 Rice yield estimation value list for paddy soils

Time (year)	Yield per mu (kg)	Paddy soil rice planting area (mu)	Corresponding rice yield (ton)
2001	445	94263	445×94263=41947
2005	443	88784	443×88784=39331
2011	411	71133	411×71133=29236
2016	409	108661	409×108661=44442
2021	425	82562	425×82562=35089

In Table 3, it is obvious that there is a positive correlation between the rice planting area of paddy soil and the corresponding rice yield. The larger the planting area, the more rice yield, but the degree of positive correlation between them is difficult to reflect in the results of Table 3. In this regard, this paper refers to the grain farming sensitivity model (Liu et al., 2009) and adjusts it into a grain farming sensitivity model suitable for this analysis, so as to quantitatively analyze the change relationship between rice yield and rice planting area. The formula is as follows:

$$\boldsymbol{\beta_u} = \frac{(P_{i+1}-P_i)/P_i}{(Q_{i+1}-Q_i)/Q_i} \quad ....(2)$$

In formula (2)： β_u is grain sensitivity；

P_{i+1} is the grain yield of the study area in the next year period；

P_i is the grain yield of the previous year in the study area；

Q_{i+1} is the planting area of the study area in the next year period；

Q_i is the planting area of the previous year in the study area；

Since the five years (2001, 2005, 2011, 2016, and 2021) are selected as the data in this paper, four interval periods results are calculated in chronological order and expressed as β_1、β_2、β_3 and β_4 respectively. The calculation results are as table 4:

Table 4 the grain sensitivity of five years (2001, 2005, 2011, 2016, and 2021)

β_1	β_2	β_3	β_4
1.073	1.291	0.986	0.876

note： β_1---Grain sensitivity from 2001 to 2005；

β_2---Grain sensitivity from 2005 to 2011；

β_3---Grain sensitivity from 2011 to 2016；

β_4---Grain sensitivity from 2016 to 2021；

When $\beta>0$， it indicates that the grain yield changes positively with the change of planting area and has a certain correlation. Small changes in planting areas can cause large changes in grain yield. That is, under normal circumstances, an increase in planted areas leads to a corresponding increase in grain yield and vice versa. And the larger the value, the higher the sensitivity of grain yield to the change of planting area.

Among them, When $0<\beta<1$， the change rate of grain yield is lower than that of planted area, that is, the increase or decrease of planted area affects the increase or decrease of grain yield, with a high impact rate.

When $\beta>1$， the change rate of grain yield is higher than that of planting area, that is, the increase or decrease of planting area has a very high impact on the increase or decrease of grain yield.

When $\beta<0$，it indicates that the change of grain yield and cultivated land amount is reversed, and grain yield is not sensitive to the change of cultivated land area, with low correlation (Qu et al., 2022).

It can be seen that the rice planting area of paddy soil is positively correlated with the corresponding rice yield. The values of β_1 and β_2 are both greater than 1, indicating that the change rate of rice yield in these two periods is higher than the change rate of rice planting area in paddy soil. However, the rice planting area on paddy soil decreased in 2001, 2005, and 2011, resulting in a corresponding decrease of rice output value on paddy soil. At the same time, the influence rate of planting area on grain yield was extremely high in these two periods, resulting in the rapid decline of rice output value in the soil when the rice planting area was relatively gentle.

Between β_1（2001 and 2005）and β_2（2005 and 2011）, the value of β_2 is greater than that of β_1， See the comparison between rice planting area and yield in Figure 12. It can be seen that from 2005 to 2011, compared with the previous period, the planting area decreased sharply, but the rice output value dropped in a cliff. It shows that the sensitivity of grain tillage was the highest between 2005 and 2011, which was also the period when the influence rate of rice planting area on rice yield was the highest.

However, in the time period of β_3 and β_4, the grain sensitivity of these two groups was less than 1, and the influence rate of rice planting area change on rice yield was lower, and the influence of planting area on rice yield was less than that in the period of β_1 and β_2. However, as the value of β_3 is very close to 1, the influence rate of planting area on yield is also relatively obvious.

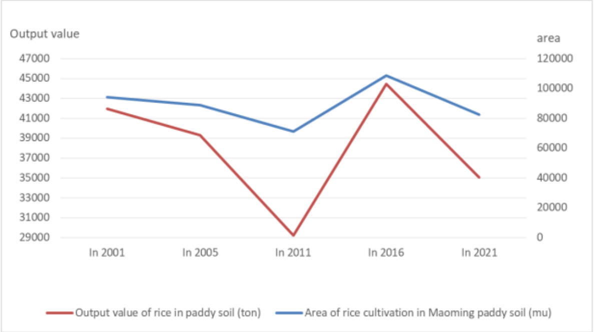

Figure 12 Comparison of rice planting area and yield from 2001 to 2021

Prediction model of rice yield in paddy soil of Maoming

The general prediction model takes time as an independent variable to predict. However, through the above correlation analysis of the rice planting area on the paddy soil of Maoming and the corresponding rice yield, it can be seen that the planting area of the paddy soil in the five years has a certain influence on the rice yield. According to this correlation, the rice planting area of the paddy soil of Maoming can be predicted on the rice yield on the paddy soil. Therefore, the mathematical model of rice yield prediction is established in this study according to the two variables of rice yield and planting area.

An X and Y two-dimensional axis was established, with rice planting area as the X-axis and rice yield as the Y-axis, to form a correlation graph between rice yield and planting area. Among them, the value of rice planting areas is sorted from small to large and from left to right (show as Figure 13).

By observing the correlation graph between rice yield and planting area, and according to the general shape of the change of mathematical function, the function expression form of exponential function, linear function, logarithmic function, and polynomial function with the best fitting effect was determined, that is, the estimated yield model.

Excel table was used to generate the convergence line of two-dimensional table of rice yield and planting area, and the four functions were numerically analyzed. The fitting rate of exponential function was 93.84%. The fitting rate of linear function is 96.37%. The fitting rate of logarithmic function was 99.76%. The fitting rate of polynomial function in three terms is 99.98%.

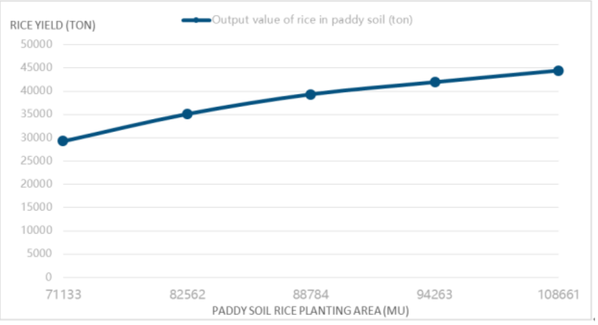

Figure 13 the trend relation map of planting area and rice yield

Obviously, the trinomial function has the highest fitting rate and is the most suitable model for Interpreting predicting yield.

Let the rice planting area on paddy soil be the independent variable x (unit: mu); the corresponding rice yield is the dependent variable y, and the unit is ton. Finally, the formula is obtained by the approach line and the actual two-dimensional axis. The formula is as follows:

$$y = 124.17x^3 - 1713.4x^2 + 10232x + 20571 \quad \text{.........} (3)$$

However, it should be noted that the yield prediction model in this paper is valuable only when there is a significant positive correlation between planted area and crop yield, and is suitable for short-term prediction.

5. CONCLUSIONS

Based on the importance of rice planting research from the perspective of agrogeography, this paper analyzes the spatial-temporal distribution of rice planting and its agricultural function in the paddy soil of Maoming and draws relevant conclusions.

In terms of time dimension, rice planting in Maoming paddy soil shows fluctuation, which is influenced by not only nature but also humanity. In the space dimension, there is discontinuity and no continuous distribution law. The relationship between time and space is consistent, showing a trend of first decreasing, then increasing, and then decreasing. The five regions divided into the inner space of Maoming city have their own characteristics in spatial distribution, forming a certain spatial-temporal distribution law.

Based on the correlation analysis between rice area and rice yield of paddy soil in Maoming, the concept of grain sensitivity was introduced, and the relationship between rice area and rice yield was quantitatively analyzed. Finally, the grain planting sensitivity of the preceding and following years of the five years period was obtained, the four years period of β_1、β_2、β_3 and β_4 were respectively. It was found that the rice area and rice yield showed a positive correlation in the investigated year period, and the grain planting sensitivity was the highest in the year period, and the rice planting area had the greatest influence on the rice yield.

In this study, based on the correlation between rice yield and planting area, this paper reflected the agricultural effect of paddy soil on rice and estimated the yield of rice planting area and yield. Furthermore, according to the positive correlation between rice area and grain tillage sensitivity of rice yield, four functional models were selected for fitting. Finally, it was found that the trinomial function had the best fitting effect, and thereby the formula for predicting rice yield was formed.

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