https://doi.org/10.17221/49/2024-AGRICECON

How does single- or double-cropped rice policy influence spatially irrigated land value in China?

Yuqun Dong, Yaming Zhuang*

School of Economic and Management, Southeast University, Nanjing, P. R. China

**Corresponding author: 230228714@seu.edu.cn*

Citation: Dong Y., Zhuang Y. (2024): How does single- or double-cropped rice policy influence spatially irrigated land value in China? Agric. Econ. – Czech, 70: 279–290.

Abstract: Rice cropped policy has been constantly changing, affecting the value of irrigated land. This study aims to examine distribution patterns of irrigated land value from a new perspective of uncertainties in single- and double--cropped rice policies in China. The real options approach was employed to calculate irrigated land value under policy uncertainty, and Moran's index was applied to identify the spatial distribution characteristics of irrigated land value at the provincial level. The empirical results were as follows: significantly positive spatial correlations existed between the land value under two cropped rice policies. The northeast region of China had a low-value clustering effect based on geographical characteristics. In contrast, the southern provinces of China had a high-value clustering effect based on the criteria of administrative regions. This study considered policy uncertainty when evaluating the economic effect on irrigated land when revealing spatial correlation in land value. We provide a theoretical and empirical basis for the formulation of cropped rice policies.

Keywords: cropped rice policy; land economic value; real options approach; spatial correlation

National food security is the foundation of governance, especially in the current complex international situation. The access and stability dimension of food security is measured at a regional level by evaluating different elasticities in developed countries (Forero-Cantor et al. 2020). Also, the impact of macroeconomic policies on national food security in developing countries has been analysed under simulation (Akbar et al. 2017; Mulyo et al. 2023). China, as the most populous country in the world, is responsible for ensuring that 1.4 billion Chinese people have a self-sufficient rice supply (Deng et al. 2019). Therefore, developing rice production and increasing the multiple cropping index of rice to increase rice yield have been the long-term goals pursued by China (Wang et al. 2015). Since the outbreak of the pandemic in 2020, the country has attached increasingly more importance to food security. Governments in cropped rice areas have quickly responded and introduced policy measures to encourage farmers to switch from single rice to double rice mode.

Regions are gradually showing certain tendencies in food consumption patterns these days. Selected EU

Supported by the Emergency Management Project of China Natural Science Foundation 'Research on Policy Innovation of Financial Support for Rural Revitalization'(72141019), and General Programs of Humanities and Social Sciences of the Ministry of Education 'Modeling and simulation of systemic risk contagion between banks and enterprises under multiple correlation networks' (21YJA630128).

https://doi.org/10.17221/49/2024-AGRICECON

countries are becoming increasingly similar in consumption patterns, and the opposite situation has occurred in food production (Bajan et al. 2020). As the main rice-producing area, south China has traditionally planted double-cropped rice for many years. However, for more than 20 years (since the end of the 20th century), double to single mode has been developing in an irreversible trend (Wang et al. 2021). Considering labour shortages, low comparative benefits, and the impact of natural disasters, farmers tend to shift more labour time and production resources to part-time or non-agricultural production activities (Xu et al. 2023). It can be seen that the rice planting system is a market-oriented choice for farmers.

Farmers in various parts of China adapt to local conditions and make reasonable changes to the cropped rice policies, which is a rational market choice for farmers with low grain production efficiency. Although China has introduced various subsidy policies to encourage farmers to cultivate double-cropped rice (Agriculture and Rural Bureau 2023; The Central People Government 2020), due to the autonomy of farmers, there is still uncertainty in cropping policies across the country, making it difficult to carry out unified management. As cropped rice mode is a market-oriented choice for farmers, the value of irrigated fields has substantial guiding significance in selecting cropped rice policies (Zhang et al. 2017).

Motivated by the need to select appropriate rice cropped policy at the regional level in China, this study aims to evaluate irrigated lands after considering single- and double-cropped rice policies and to reveal food production patterns at the regional level. The novelties of this study are considering policy uncertainty and conducting a spatial correlation study of the value of irrigated lands at a provincial level in China. In this way, the real options approach wsa employed to calculate irrigated land value under policy uncertainty. Moran's index was applied to identify the spatial distribution characteristics of irrigated land value at the provincial level. After simulating 38 cities from 2017 to 2023 in China, this study provides corresponding references for cropped rice policies for certain provinces.

MATERIAL AND METHODS

Research methodology. This study aimed to choose an appropriate cropped-rice policy based on the irrigated land value at the regional level in China. In this way, this study achieves the expectations through the following steps in the entire process:

Step 1: Describe policy uncertainty of single- or double-cropped rice policy through a stochastic process.

Step 2: Calculate the irrigated land value under the real options approach.

Step 3: Reveal the spatial correlation among the value of irrigated lands in China under single- and double-cropped rice policies, applying univariate and bivariate Moran's index.

Step 4: Establish a rice price database from agricultural product industry data and connect data from fixed observation points in rural areas nationwide from 2009 to 2017 in China.

Step 5: Simulate and conduct empirical research based on the data from Step 4 to reveal the spatial correlations in administrative or geographical regions.

To sum up, this study calculates the economic value of irrigated land by considering the uncertainty of rice-cropped policies and provides a theoretical and empirical basis for formulating cropped rice policies. The specific model design is shown below.

Real options approach. To characterise cropped-rice policy uncertainty, this study followed a switching option model (Zervos et al. 2018) to demonstrate the shift between double-cropped and single-cropped rice policies.

Operation in irrigated land yielded a payoff rate that was a function of the market price for local rice (P_t). Thus, P_t satisfied the geometric Brownian motion (GBM).

$$\mathrm{d}P_t = bP_t dt + \sigma P_t dW_t \tag{1}$$

where: b – shift rate of GBM; σ – volatility rate of GBM; W – a standard Brownian motion.

China encourages the conversion of single-cropped rice to double-cropped rice, but the reform is not mandatory, and the timing is uncertain. Thus, it was assumed that operation on irrigated land had two optional policies: single-cropped and double-cropped. A process X with values in {0,1} was applied to simulate the shift between policies. In particular, $X_t = 1$ or $X_t = 0$ was denoted if the irrigated land was under a double-cropped rice policy or single-cropped rice policy, respectively. The stopping times at which the jumps of X occurred were the intervention times the cropped rice policies change.

Besides, under the land contract management system in China, the terms of use rights of irrigated land is generally 30 years. Irrigated land was assumed to be permanently abandoned at a stopping time τ with

https://doi.org/10.17221/49/2024-AGRICECON

abandoned cost C. With the strategy (X, τ), the performance criterion was:

$$G_{x,p}(X,\tau) = E\left[\begin{array}{l}\int_0^\tau e^{-rs} h(P_s) X_s ds - \sum_{j=1}^{\infty} e^{-rT_j^1} C_1 1_{\{T_j^1 \le \tau\}} - \\ - \sum_{j=1}^{\infty} e^{-rT_j^0} C_0 1_{\{T_j^0 \le \tau\}} - e^{-r\tau} C\end{array}\right] \quad (2)$$

where: T_j^1 – the sequence of times at which X jumps from 0 to 1; C_1 – cost switching from single-cropped rice policy to double-cropped rice policy; C_0 – cost switching from double-cropped rice policy and single-cropped rice policy.

Moreover, one irrigated land user can choose to plant rice or rice substitutes, such as wheat, corn, soybeans, and potatoes. Thus, the economic value function υ was defined as:

$$\upsilon(x,p) = \sup_{(X,\tau)\in\pi_x} G_{x,p}(X,\tau) \quad (3)$$

In addition, $h(P)$ was the monetary income model related to price (P_t) and supply (S) for local rice, using the choice $(a \in R)$.

$$h(P_t) = a + (SP_t)^\theta \quad (4)$$

Under the Hamilton-Jacobi-Bellman (HJB) equation and the assumption that if $P > \alpha$, the single-cropped rice policy will turn to a double-cropped rice policy to benefit more, and if $P < \beta$ ($\le \alpha$), the double-cropped rice policy will turn to a single-cropped rice policy.

Thus, we achieved the real option value of irrigated lands calculated as follows:

$$\upsilon(1,\mathrm{P}) = \begin{cases} \lambda P^n - C_0, & \text{if } P \le \beta \\ \xi P^m + R(P), & \text{if } P > \beta \end{cases} \quad (5)$$

$$\upsilon(0,P) = \begin{cases} \lambda P^n, & \text{if } P \le \alpha \\ \xi P^m + R(P) - C_1, & \text{if } P > \alpha \end{cases} \quad (6)$$

Where: $R(P) = -\frac{P^\theta}{\sigma^2\theta^2 + (b-\sigma^2)\theta - r} + \frac{a}{r}$,

$$m,n = \frac{1}{2\sigma^2}\left[\sigma^2 - b \mp \sqrt{(b-\sigma^2)^2 + 4\sigma^2 r}\right],$$

$$\xi = \frac{\beta^{-m}}{\sigma^2(n-m)}\left(\frac{rC_0 + a}{m} - \frac{\beta^\theta}{\theta - m}\right),$$

$$\lambda = \frac{\alpha^{-n}}{\sigma^2(n-m)}\left(\frac{\alpha^\theta}{n-\theta} - \frac{rC_1 - a}{n}\right).$$

For price thresholds α and β satisfy the following equations,

$$(rC_1 - a)\alpha^{-m} + (rC_0 + c)\beta^{-m} + \\ + \frac{m}{\theta - m}\left(\alpha^{\theta-m} - \beta^{\theta-m}\right) = 0 \quad (7)$$

$$(rC_1 - a)\alpha^{-n} + (rC_0 + c)\beta^{-n} + \\ + \frac{m}{n-\theta}\left(\alpha^{-(n-\theta)} - \beta^{-(n-\theta)}\right) = 0 \quad (8)$$

Moran's index method. This paper aimed to reveal the spatial correlation among the values of irrigated lands in China under single- and double-cropped rice policies, applying univariate Moran's index. Global Moran's index tests the spatial correlation over an entire region, indicating a match between attribute similarities in land value and spatial attributions. The global univariate Moran's index is calculated as follows (Ripley 1984):

$$I = \frac{n}{\sum_{i=1}^n \sum_{j=1}^n w_{ij}} \times \frac{\sum_{i=1}^n \sum_{j=1}^n w_{ij}(\upsilon_i - \bar{\upsilon})(\upsilon_j - \bar{\upsilon})}{\sum_{i=1}^n (\upsilon_i - \bar{\upsilon})^2}, \quad i \ne j \quad (9)$$

where: n – the number of values for irrigated lands of the whole region at a provincial level; $\bar{\upsilon}$ – the average of the real option value; υ_i, υ_j – observations at different provinces in the whole region; w_{ij} – the spatial weights matrix among provinces with different weighted methods.

Corresponding to the global Moran's index, local Moran's index is a specific test statistic in each province allover the region to verify attributions in spatial correlation and reveal the distribution of spatial clusters. Local univariate Moran's index was computed as the following formula:

$$I' = \frac{n(\upsilon_i - \bar{\upsilon})\sum_{j=1}^n w_{ij}(\upsilon_j - \bar{\upsilon})}{\sum_{i=1}^n (\upsilon_i - \bar{\upsilon})^2} \quad (10)$$

However, different regions might experience different cropped rice policies in real-world applications, indicating that the real option values of irrigated lands under single- and double-cropped rice policies are affected by mutual spatial correlation. Bivariate Moran's index compares similarities and correlations between the value of irrigated lands under single- and double-cropped rice policies. Bivariate Moran's index was calculated between υ_1 and υ_2 as following formula derived from bivariate Moran's index calculation:

https://doi.org/10.17221/49/2024-AGRICECON

$$I_{1,2} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(\upsilon_{1,i} - \overline{\upsilon}_2\right)\left(\upsilon_{1,j} - \overline{\upsilon}_2\right)}{\sum_{i=1}^{n}\left(\upsilon_i - \overline{\upsilon}\right)^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \quad (11)$$

Similarly, local bivariate Moran's index follows:

$$I'_{1,2} = \frac{\upsilon_{1,i} - \overline{\upsilon}_1}{\left(\upsilon_{1,i} - \overline{\upsilon}_1\right)^2} \sum_{j=1}^{n} w_{ij} \frac{\upsilon_{2,j} - \overline{\upsilon}_2}{\left(\upsilon_{2,j} - \overline{\upsilon}_2\right)^2} \quad (12)$$

The selection of the weight matrix was the priority for calculating spatial correlation among irrigated land with single- and double-cropped rice policies. Generally, there are two main types of spatial weight matrices. One is the contiguity matrix based on adjacency attributes, and the other is the distance matrix based on geographical distance. This paper selected four classic weight matrices (shown in Table 1) to compare the spatial correlation in values of irrigated lands at the provincial level all over China. According to the definitions, the contiguity matrix depicts the spatial correlation between provincial administrative units under the influence of single- and double-cropped rice policies. The distance matrix describes the spatial correlation of geographical or natural locations under the influence of sowing policies.

In the local Moran's index analysis, categories with five different cluster attributes can be distinguished in an area. High-high (low-low) category possesses a spatial cluster where high (low) values are surrounded by high (low) values. Low-high (high-low) category contains spatial outliers where low (high) values are surrounded by high (low) values. Furthermore, the last cluster attribute is spatial randomness without significant spatial correlation.

Table 1. Different types of weighted methods in spatial correlation analysis

Categories	Types	Description
Contiguity matrix	queen contiguity	A spatial matrix with a virtual variable of two regions with common boundaries or nodes is 1; otherwise, it is 0.
	rook contiguity	A spatial matrix with a virtual variable of two regions with a common boundary is 1; otherwise, it is 0.
Distance matrix	*k*-nearest neighbours	Assuming the object has *k* nearest objects, when the region belongs to the nearest objects, the weight between two regions is 1; otherwise, it is 0.
	distance band	A spatial matrix with a virtual variable within the specified critical distance is 1; otherwise, it is 0.

Source: Spatial correlation methods described in Geoda software from http://geodacenter.github.io/

Table 2. Statistic description of relevant variables in this study

Parameter	Symbol	Unit	Source	Average value	SD	Median
Market price of local rice in South area	P_S	USD/kg	average retail price of indica rice in 38 cities (2017–2023) from Wind database	0.88	0.027	0.89
Market price of local rice in North area	P_N	USD/kg	average retail price of japonica rice in 38 cities (2017–2023) from Wind database	0.95	0.013	0.95
Supply of local rice	S	kg/ha	micro data of fixed observation points in rural areas in China (2009–2017)	1 134.90	2 787.50	650.00
Yield from one season of rice substitutes	C_0	USD/ha		2 513.10	2 113.50	2 000.00
Yield from one season of rice	C_1	USD/ha		2 867.80	8 143.30	1 522.50
Abandoned cost for irrigated land	C	USD/ha		314.25	622.07	180.00

The yield from one season of rice substitutes is measured as the maximum revenue from wheat, corn, soybeans, potatoes and others sources.

Source: Data from average retail price of rice in 38 cities (2017–2023) from Wind database and micro data of fixed observation points in rural areas in China (2009–2017) (Ministry of Agriculture and Rural Affairs of the People's Republic of China 2009–2017; Wind Database 2017–2023)

https://doi.org/10.17221/49/2024-AGRICECON

Data description. To depict the trend in the market price of local rice all over China, this paper established a rice price database of agricultural product industry data in the Wind database, compiled from the National Development and Reform Commission. The average retail prices of indica and japonica rice in 38 cities from 2017 to 2022 were selected for price matching for China's northern and southern regions. It is worth noting that the division of China's northern and southern regions was based on the Qinling and Huaihe Rivers.

The second source wass data from fixed observation points in rural areas nationwide from 2009 to 2017. This database provides comprehensive research data that is timely updated and improved through long-term tracking and investigation of various economic units in rural areas and dynamic information at the grassroots level. This data system covers 31 provinces (districts, cities) and 368 counties in China, with a survey target of 375 villages, 23 000 accounting farmers (livestock) households, and over 1 600 new business entities. The survey content included 1 250 indicators from 8 major categories of the household survey indicator system and over 700 indicators from 11 major categories of the rural survey indicator system. A statistical description of the relevant variables is shown in Table 2.

RESULTS

Parameter estimation. To estimate the geometric Brownian motion in the local price of rice [Equation (1)], we applied Matlab 2022b to calculate the drift rate and fluctuation rate for the local price of rice in the southern and northern areas. The drift rate describes the trend of local price, and the fluctuation rate values the uncertainty of local price. As shown in Table 3, the local price of rice in the northern area increased more rapidly as the drift rate was 0.0157 but had smaller fluctuations as the fluctuation rate was only 0.0131, revealing the stability of local prices in the northern area.

We also fitted the constant and exponential coefficients in the monetary income model (Equation 4) using Matlab 2022b. As shown in Table 3, the constant term and exponential term in the monetary income model were –108.6809 and 1.0151, respectively. Related fitted curves are drawn in Figure 1, and most of the data falls on the fitted curve in Shanxi Province. The phenomenon was more apparent in data from all over China.

Real option value. After getting the parameters in geometric Brownian motion and monetary income model, this paper calculated real option values in irrigated lands under single- and double-cropped rice policies for 3 885 cases all over the country, averaging the real option value of land cases in the same province to represent the land value in the province. Thus, Figure 2 reflects the heat map of land value in provinces under single-cropped rice policy (value 0) and double-cropped rice policy (value 1) calculated from Equation (5) and Equation (6). The heat map under the double-cropped rice policy revealed that southeast China has the highest value of irrigated lands. The heat map under the single-cropped rice policy shows the highest value of irrigated lands in the middle of China.

While calculating the real option value of 3 885 irrigated fields, this paper obtained the price thresholds for the conversion between double- and single-cropped rice policies [Equations (7–8)]. As shown in Figure 3, most thresholds range around three units. Separately, the minimum, maximum and average threshold α were 0, 5.9806, and 2.5258. Those of threshold β were 0, 5.5921, and 2.1636. If the local price of rice was larger than the threshold α for each irrigated land, then the policy switched to double-cropped, which brought more economic benefits. However, if the local price of rice was smaller than the threshold β, the local policy transferred to a single-cropped rice policy, which led to higher returns. If the local price of rice was between α and β, policies did not need to be changed.

Univariate Moran's index. After calculating the economic value of irrigated land and identifying policy

Table 3. Fitting results of geometric Brownian motion and monetary income model methods

Models	Geometric Brownian motion				Monetary income model	
	southern area		northern area			
Parameters	drift rate	fluctuation rate	drift rate	fluctuation rate	constant term	exponential term
Symbol	b_S	σ_S	b_N	σ_N	α	θ
Estimated value	0.0121	0.0301	0.0157	0.0131	–108.6809	1.0151

Source: Own calculations from Matlab 2022b, based on average retail price of rice in 38 cities (2017–2023) from Wind database and micro data of fixed observation points in rural areas in China (2009–2017) (Ministry of Agriculture and Rural Affairs of the People's Republic of China 2009–2017; Wind Database 2017–2023)

https://doi.org/10.17221/49/2024-AGRICECON

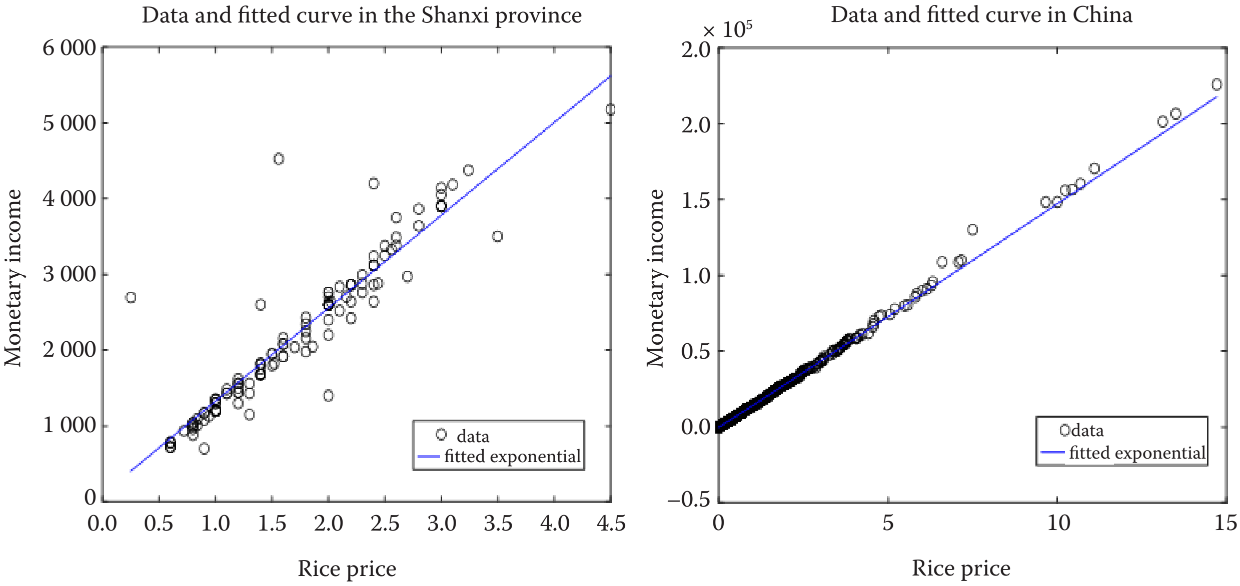

Figure 1. Data and fitted curves in Shanxi province and China in monetary income model.

Source: Own calculations based on average retail price of rice in 38 cities (2017–2023) from Wind database and micro data of fixed observation points in rural areas in China (2009–2017)

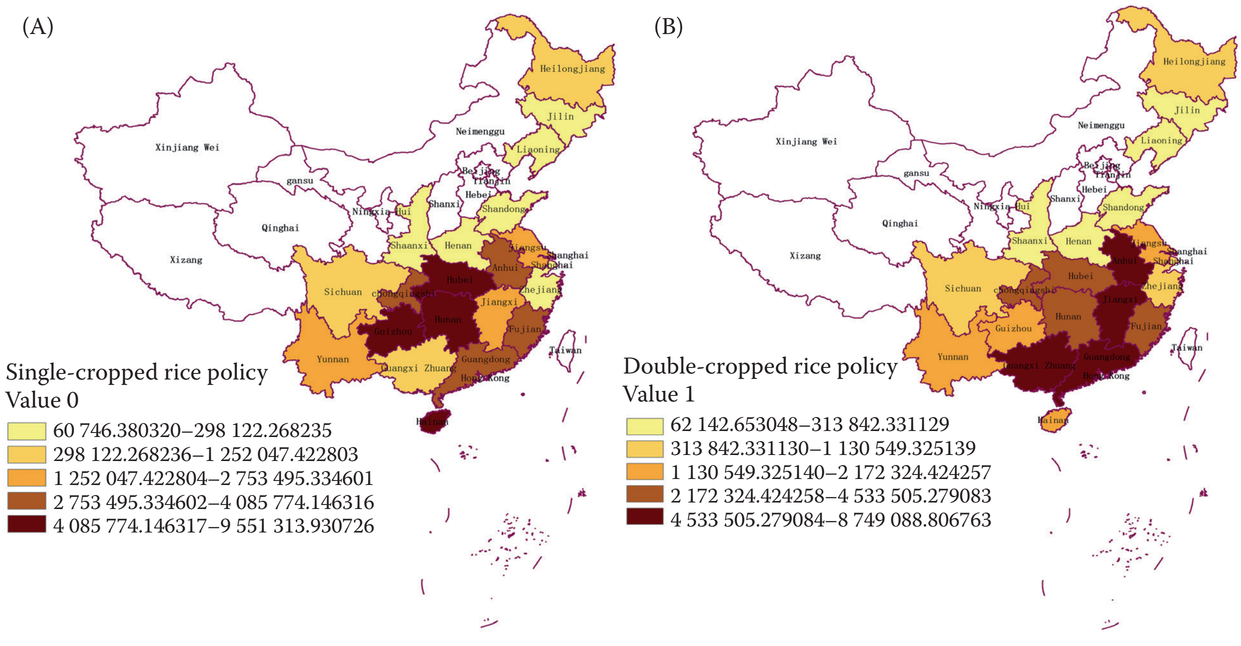

Figure 2. Heat maps of real option value of irrigated lands in provinces under (A) single-cropped and (B) double-cropped rice policies; the darker the color, the higher the value of the land

Source: Own calculations based on average retail price of rice in 38 cities (2017–2023) from Wind database and micro data of fixed observation points in rural areas in China (2009–2017) (Ministry of Agriculture and Rural Affairs of the People's Republic of China 2009–2017; Wind Database 2017–2023)

shifting triggers for 3 885 irrigated fields in China, this study applied Geoda software to set weights matrices of contiguity and distance weight, assuming that contiguity weights can be queen contiguity or rook contiguity, whose order of contiguity is 1. On the other hand, the number of neighbours in *k*-nearest neighbours under distance weight is up to 4. The specified bandwidth was assumed to be 587 200 units calculated by Euclide-

https://doi.org/10.17221/49/2024-AGRICECON

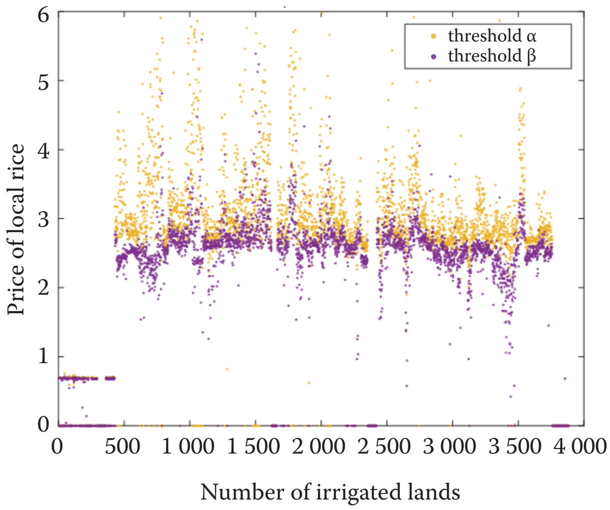

Figure 3. Scatter plot of thresholds of alpha and beta for real option values in irrigated lands

Source: Own calculations based on average retail price of rice in 38 cities (2017–2023) from Wind database and micro data of fixed observation points in rural areas in China (2009–2017) (Ministry of Agriculture and Rural Affairs of the People's Republic of China 2009–2017; Wind Database 2017–2023)

an distance. Simply put, a contiguity weighted model indicates spatial relationships according to administrative regions. However, the distance weighted model reveals spatial relationships based on geographical regions.

The global univariate Moran's index for double- and single-cropped rice policies are shown in Table 4, calculated from Equations (9) and (10), where Moran's index indices were significant at a 95% confidence interval as contiguity weight matrices were introduced. However, Moran's index for double-cropped rice policy was only significant under the distance band. Moran's index was significant for single-cropped rice policy under *k*-nearest neighbours.

Bivariate Moran's index. The statistical results of bivariate Moran's indices are displayed in Table 5, calculated from Equations (11) and (12), where bivariate Moran's indices were statistically significant at a 95% confidence interval under different weighted matrices. This paper selected real option values under double- and single-cropped rice policies as the input variables. When the first input variable was real option value under double-cropped rice policies, the bivariate Moran's indices were 0.2815, 0.1979 and 0.2020 under contiguity, *k*-nearest neighbours and distance band matrices, respectively. The positive bivariate Moran's index indicates a positive correlation between real option values under double- and single-cropped rice policies in the geographical space surrounding areas where double-cropped rice policies are implemented.

Local Moran's index. According to the spatial correlation theory, global optimality generally does not represent local optimality. In order to reveal more detailed spatial correlation attributes in each province, this paper conducted local Moran's index analysis (LISA), calculating observations and spatial adjacency through local relationships, as shown in Figure 4.

For the univariate LISA map under the single-cropped rice policy in the contiguity method, Jiangsu province was in the low-low category, which means that the real option values of irrigated lands in Jiangsu were low and

Table 4. Statistic value of univariate Moran's index

Statistic value	Double-cropped rice policy				Single-cropped rice policy			
	contiguity weight		distance weight		contiguity weight		distance weight	
Weighted method	queen contiguity	rook contiguity	KNN	distance band	queen contiguity	rook contiguity	KNN	distance band
Moran's index	0.2176**	0.2176**	0.0782	0.1807**	0.1728**	0.1728**	0.1827**	0.0602
P-value	0.0480	0.0500	0.1600	0.0500	0.0200	0.0300	0.0480	0.1800
Z-value	1.8045	1.7448	0.9249	1.6856	2.0128	2.1056	1.7699	0.8737
Mean	–0.0580	–0.0569	–0.0590	–0.0725	–0.0707	–0.0916	–0.5910	–0.0610
SD	0.1527	0.1573	0.1483	0.1502	0.1204	0.1256	0.1366	0.1387
Permutations	999	999	499	499	999	999	499	499

KNN – *k*-nearest neighbor; under the KNN distance weighted model, the object has $k = 4$ nearest objects; when the region belongs to the nearest objects, the weight between the two regions is 1, otherwise, it is 0.

Source: Own calculations based on average retail price of rice in 38 cities (2017–2023) from Wind database and micro data of fixed observation points in rural areas in China (2009–2017) (Ministry of Agriculture and Rural Affairs of the People's Republic of China 2009–2017; Wind Database 2017–2023)

https://doi.org/10.17221/49/2024-AGRICECON

Table 5. Statistic value of bivariate Moran's index

Statistic value	Double-cropped rice policy				Single-cropped rice policy			
	contiguity weight		distance weight		contiguity weight		distance weight	
Weighted method	queen contiguity	rook contiguity	KNN	distance band	queen contiguity	rook contiguity	KNN	distance band
Moran's *I*	0.2815**	0.2815**	0.1979**	0.2020**	0.2695**	0.2695**	0.2681**	0.2911**
P-value	0.0150	0.0180	0.0400	0.0200	0.0280	0.0190	0.0220	0.0160
Z-value	2.3636	2.2848	1.9071	1.9728	2.1446	2.2640	2.2712	2.2890
Mean	–0.0147	–0.0189	–0.0145	–0.0192	–0.0130	–0.0132	–0.0045	–0.0035
SD	0.1253	0.1315	0.1114	0.1121	0.1317	0.1249	0.1200	0.1287
Permutations	999	999	499	499	999	999	499	499

KNN – *k*-nearest neighbor; under the KNN distance weighted model, the object has $k = 4$ nearest objects; when the region belongs to the nearest objects, the weight between the two regions is 1, otherwise, it is 0.

Source: Own calculations based on average retail price of rice in 38 cities (2017–2023) from Wind database and micro data of fixed observation points in rural areas in China (2009–2017) (Ministry of Agriculture and Rural Affairs of the People's Republic of China 2009–2017; Wind Database 2017–2023)

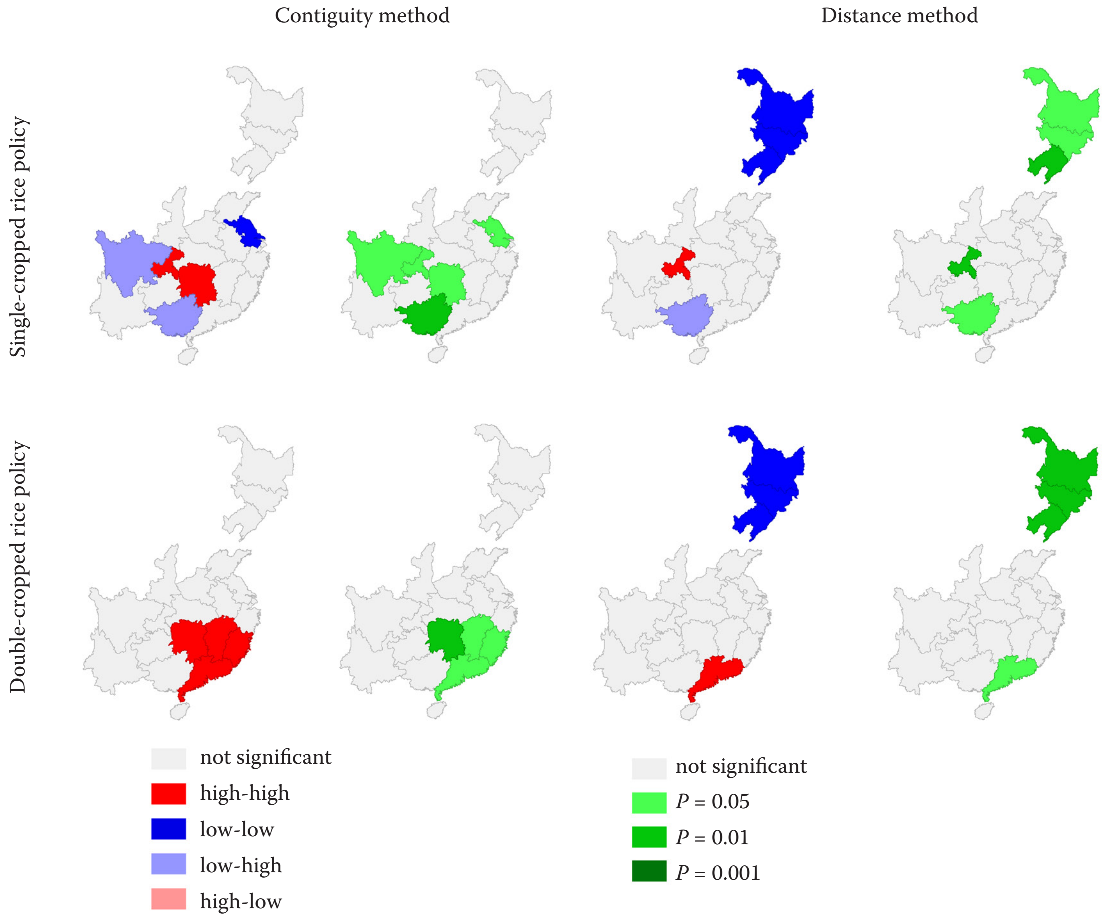

Figure 4. Univariate local Moran's index analysis (LISA) under double- and single-cropped rice policies with contiguity and distance weighted matrices

Source: Own calculations based on average retail price of rice in 38 cities (2017–2023) from Wind database and micro data of fixed observation points in rural areas in China (2009–2017) (Ministry of Agriculture and Rural Affairs of the People's Republic of China 2009–2017; Wind Database 2017–2023)

https://doi.org/10.17221/49/2024-AGRICECON

surrounded by low values. Sichuan and Guangxi provinces were in the low-high category, indicating that the real option values were low but surrounding provinces had high values of irrigated lands. Chongqing and Hunan provinces with high values belonged to the high-high category surrounded by provinces with high values.

For the univariate LISA map under the double-cropped rice policy in the contiguity method, the southeastern region composed of Hunan, Jiangxi, Fujian, and Guangdong provinces, exhibited a high degree of clustering, which means that the real option values in these four provinces were not only high but also were surrounded by high-value provinces. Nevertheless, the low degree of clustering was significant in the northeast region of China, as Heilongjiang, Jilin and Liaoning provinces all fit into the low-low category. Thus, the low clustering was apparent under geographical criteria, ignoring the concept of administrative regions.

Next, the bivariate local Moran's index was calculated by selecting real option values of irrigated lands under single- and double-cropped rice policies as two main input variables. The bivariate LISA maps (Figure 5) demonstrated spatial correlation and mutual influence between two input variables.

For the bivariate LISA map under the single-cropped rice policy in the contiguity method, Sichuan and Yunnan provinces lay in the low-high category, indicating that the values of irrigated lands with single-cropped rice policy in these two provinces were low but were surrounded by high values with double-cropped rice policy. However, Chongqing, Guangxi, and Hunan provinces belonged to the high-high category, where

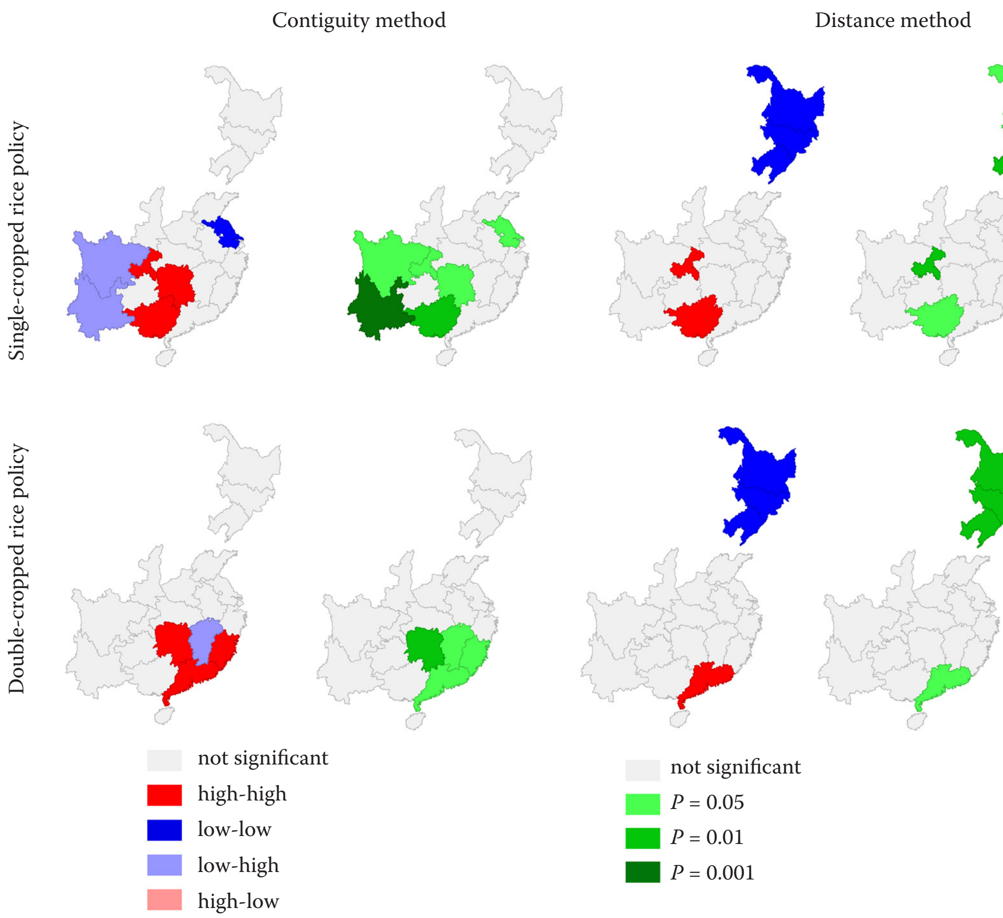

Figure 5. Bivariate local Moran's index analysis (LISA) under double- and singled-cropped rice policies with contiguity and distance weighted matrices

Source: Own calculations based on average retail price of rice in 38 cities (2017–2023) from Wind database and micro data of fixed observation points in rural areas in China (2009–2017) (Ministry of Agriculture and Rural Affairs of the People's Republic of China 2009–2017; Wind Database 2017–2023)

https://doi.org/10.17221/49/2024-AGRICECON

high values under a single-cropped rice policy were generally surrounded by high values under a double-cropped rice policy.

For a bivariate LISA map under the double-cropped rice policy in the contiguity method, the southeastern area of China sustained significant spatial correlation. Hunan, Fujian, and Guangdong provinces showed high values under the double-cropped rice policy, surrounded by a high value under the single-cropped rice policy. However, Jiangxi province lay in the low-high category, which differed from the univariate LISA map. The different spatial significance presented by specific provinces enables governments or local farmers to explore the formulation and development of better rice-cropped policies, which is conducive to mutual learning and reference between provinces and regions.

DISCUSSION

Based on the real options approach proposed in the previous methodology (Zervos et al. 2018) and Moran's index method for spatial relationships (Ripley 1984), the empirical results in Hunan province indicated that there were high-high clusters regardless of the planting policy. This phenomenon suggests that irrigated land users in Hunan province were not devoted to paying more attention to the cropping policies and lost the incentive to switch cropped policies, as the proportion adopting double-cropped rice in Hunan province is low, only 55% of households (Liu et al. 2012). For Guangdong Province, a major rice growing area under a double-cropped rice policy, both the adjacent weights matrices and the distance weights matrices exhibit a phenomenon of high-value aggregation. The high value clustered in irrigated fields has led to a stable double-cropped rice index since the reform and opening-up. From 1978 to 2011, except for a few years with slight fluctuations, the proportion of double-cropped rice planting in Guangdong was more than 95% (Yang and Wang 2013).

As Jiangxi province was in the low-high category under the double-cropped rice policy, it showed low value under the double-cropped rice policy and was surrounded by high value under the single-cropped rice policy. In this way, Jiangxi province tended to shift from a double-cropped to a single-cropped rice policy. This phenomenon is similar to the conclusions obtained in the literature (Huang et al. 2022). Moreover, a reduced rural labour supply and rising labour wages due to urbanisation and economic growth are the crucial driving forces for the phenomenon (Jiang et al. 2019).

The northeastern area of China showed significant statistical results in clustered low values under single- and double-cropped rice policies, especially under the geographic criteria. This phenomenon aligns with the established practice of treating the three northeastern provinces as a whole in China (Dong et al. 2023). The essential reason for the low land value aggregation in northeast China may be the adverse impacts of the intensification of rice production (Xin et al. 2019). Moreover, after calculating the spatiotemporal distribution characteristics of primary climate resources, such as total sunshine hours, total effective accumulated temperature, daily range of average temperature, total precipitation, total precipitation days, and average precipitation intensity, scholars found that the northeast region of China has relatively unified regional characteristics (Jiang et al. 2011). Therefore, the local Moran's index divided by geographical distance was more significant than when divided by administrative units.

This study innovatively proposed guiding suggestions for local rice-cropped policies by comparing the economic value of irrigated land under administrative and geographical boundaries. Besides, even though some scholars have considered policy uncertainty in policy decisions through policy content uncertainty and policy enforcement uncertainty extracted from an existing database (Hu et al. 2023), this study estimated policy uncertainty quantitatively for the first time and developed the economic land values in China. In other words, this study constructed a new irrigated land value database for 3 885 irrigated lands in China.

CONCLUSION

Based on the empirical research in this study, there was a significant positive spatial correlation between the land value under single- and double-cropped rice policies. Different rice production patterns existed between regions defined by administrative boundaries and regions defined by natural geographical distances. For local spatial correlation with administrative boundaries, this study concluded that the economic value of irrigated lands under rice-cropped policies had significant spatial relationships in southwest China. On the other hand, rice production had a significant relationship with economic land value in the northeast of China under geographical boundaries. Those categories with high clusters can provide a reference for local changes in rice-cropped policies. In addition, this research methodology is conducive to estimating the economic values

https://doi.org/10.17221/49/2024-AGRICECON

of irrigated lands, considering policy uncertainty, and achieving appropriate triggers to transform between single- or double-cropped rice policy.

As international food consumption patterns tend to reveal regional convergence, this study provided a reference basis for cropped rice policies in China regarding food production patterns. Firstly, the cropped rice policy was tailored to local conditions while ensuring self-sufficiency in grain production by the local government. Secondly, land value can be treated as an economic criterion for local farmers to decide cropping policies based on land returns. Finally, as mentioned in the introduction, while market-oriented economic value was crucial for the choice, the choice of rice-cropped policies can be made according to the spatial correlation between land value and the policy-making of surrounding areas. The core content of this study not only verified the impact of rice-cropped policies on spatial irrigated land value but also provided feasible solutions to capture the uncertainty of policies. The decision triggers in the real options approach could be calculated in other agricultural contexts, such as subsidy policies and taxation of agricultural land.

REFERENCES

Agriculture and Rural Bureau (2023): Stable yield and supply guarantee promote spring plowing and early rice sowing. Available at http://www.moa.gov.cn/ztzl/2023cg/xmgl/202303/t20230303_6422096.htm (accessed May 02, 2023; in Chinese).

Akbar M., Jabbar A. (2017): Impact of macroeconomic policies on national food security in Pakistan: Simulation analyzes under a simultaneous equations framework. Agricultural Economics – Czech, 63: 471–488.

Bajan B., Genstwa N., Smutka L. (2020): The similarity of food consumption patterns in selected EU countries combined with the similarity of food production and imports. Agricultural Economics – Czech, 67: 316–326.

Deng N., Grassini P., Yang H., Huang J., Cassman K.G., Peng S. (2019): Closing yield gaps for rice self-sufficiency in China. Nature Communication, 10: 1725.

Dong X., Zhang T., Yang X., Li T., Li X. (2023): Rice yield benefits from historical climate warming to be negated by extreme heat in Northeast China. International Journal of Biometeorology, 67: 835–846.

Forero-Cantor G., Ribal J., Sanjuán N. (2020): Measuring regional differences in food security from access and stability dimensions: A methodological proposal based on elasticities. Agricultural Economics – Czech, 66: 112–119.

Hu Y., Bai W., Farrukh M., Koo C.K. (2023): How does environmental policy uncertainty influence corporate green investments? Technological Forecasting and Social Change, 189: 122330.

Huang M., Chen J., Cao F. (2022): Estimating the expected planting area of double- and single-season rice in the Hunan-Jiangxi region of China by 2030. Scientific Reports, 12: 6207.

Jiang X., Tang L., Liu X., Huang F., Cao W., Zhu Y. (2011): Spatial and temporal characteristics of rice production climatic resources in main growing regions of China. Transactions of the Chinese Society Agricultural Engineering, 27: 238–245.

Jiang M., Li X., Xin L., Tan M. (2019): Paddy rice multiple cropping index changes in Southern China: Impacts on national grain production capacity and policy implications. Journal Geographical Sciences, 29: 1773–1787.

Liu Z., Liu L., Peng Q. (2012): Analysis of rice cropping decision-making in a double-cropping rice area of Southern China. Resources Science, 34: 2234–2241.

Ministry of Agriculture and Rural Affairs of the People's Republic of China (2009–2017): Micro data of fixed observation points in rural areas in China. [Dataset]. Available at http://zdscxx.moa.gov.cn:8080/nyb/pc/index.jsp (accessed Mar 20, 2023; in Chinese).

Mulyo J.H., Prasada I.Y., Nugroho A.D. (2023): Impact of political and security stability on food security in developing countries: Case of Africa, Asia, Latin America and the Caribbean. Agric. Econ. – Czech, 69: 375–384.

Ripley B.D. (1984): Review of Spatial Processes: Models and Applications., by A.D. Cliff & J.K. Ord. Journal of the American Statistical Association, 79: 238–238.

The Central People's Government (2020): Make efforts to change from single to double cropped rice. Available at https://www.gov.cn/xinwen/2020-04/22/content_5505217.htm (accessed May 02, 2023; in Chinese).

Wang Q., Chen H., Zhuang Q., Zhou H. (2015): Planting pattern switch from double-cropped to single-cropped rice and income increase: A study on the effects of social services in rural areas. China Population Resources and Environment, 25: 153–162.

Wang X., Zeng K., Liu J., Xie J., Zhang Y., Deng B. (2021): Variation characteristics of heat resources and temperature suitability for double cropping rice growing seasons in the middle and lower reaches of Yangtze River. Journal of Northwest A & F University, Natural Science Edition, 49: 27–37.

Wind Database (2017–2023): Average retail price of rice in 38 cities. [Dataset]. Wind database. Available at https://www.wind.com.cn/portal/en/WDS/database.html (accessed Mar 26, 2023).

https://doi.org/10.17221/49/2024-AGRICECON

Xin F., Xiao X., Dong J., Zhang G., Zhang Y., Wu X., Li X., Zou Z., Ma J., Du G., Doughty R.B., Zhao B., Li B. (2019): Large increases of paddy rice area, gross primary production, and grain production in Northeast China during 2000–2017. Science of the Total Environment, 711: 135183.

Xu L., Yuan S., Wang X., Yang G., Pan X., Yu X., Wang F., Huang J., Peng S. (2023): Productivity and global warming potential of direct seeding and transplanting in double-season rice of central China. Food and Energy Security, 12: e419.

Yang W., Wang Y. (2013): Analysis on the changes and influencing factors of multiple cropping in double cropping rice regions in China: An empirical study based on 10 major rice production provinces. Rural Economy, 11: 24–28.

Zervos M., Oliveira C., Duckworth K. (2018): An investment model with switching costs and the option to abandon. Mathematical Methods of Operations Research, 88: 417–443.

Zhang Y., Chen Y., Liu Y., Lu Z. (2017) The influence of farmers‘ land values on the cultivated land utilization efficiency. Journal of Arid Land Resources Environment, 31: 19–25.

Received: February 10, 2024
Accepted: May 14, 2024