Research on the Issues and Countermeasures of Abandoned Farmland in Rural Areas Based on Mathematical Statistics and WSR System Methodology

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Keywords: Rural Revitalization, Farmland Abandonment, SPSS, WSR System Methodology

Abstract: Rural revitalization is a key strategy for addressing China's "three rural issues" (agriculture, rural areas, and farmers). This strategy is essential for ensuring the harmonious stability of rural society and improving the well-being of rural households. However, the abandonment of farmland is one of the main obstacles to its successful implementation. To promote the development of rural revitalization and support the resolution of the "three rural issues," this paper employs tools such as EXCEL and SPSS 27.0, utilizing mathematical statistics, WSR system methodology, and other relevant approaches. The study is structured around three key areas: the research background, an analysis of the factors influencing farmland abandonment in rural areas, and problem-solving recommendations based on the WSR methodology. The primary focus is on exploring effective measures to address the issue of abandoned farmland, with the aim of contributing to the governance of abandoned land in China's rural regions.

1. Research Background

Rural revitalization is a key component of China's modernization and one of the most important strategies for driving social and economic development. Its primary goal is to improve the happiness and well-being of the people, build beautiful villages, reduce the urban-rural gap, and ultimately promote common prosperity. Land, as one of the most important natural resources in rural China, is a critical foundation for accelerating high-quality development and ensuring the sustainable growth of rural areas. The efficient and scientific use of land resources is a fundamental prerequisite for the successful implementation of the rural revitalization strategy.

However, with the development of urbanization and industrialization, significant changes have occurred in the ecological environment, population structure, and economic system of rural China. A large portion of the rural population has migrated to urban areas, while those who remain have altered their production methods. Many farmers have reduced their investment in labor, capital, and other costs related to land cultivation or have abandoned farming altogether. As a result, a large amount of land in rural areas has been left idle or abandoned. The underutilization of these land resources severely hinders the implementation of the rural revitalization strategy, impacts economic development in rural areas, and exacerbates the livelihoods of rural households, ultimately undermining the social harmony and stability of these regions.

Guanli Town, located in the southwestern part of Yantai City, Shandong Province, is under the jurisdiction of Qixia City. It borders Yangchu Town to the east, Tangezhuang Town of Laiyang City to the south, Guandao Town to the west, and Xicheng Town to the north. The town covers an area of 97.25 square kilometers. In 2011, Guanli Town had a cultivated land area of 54,000 mu (approximately 36,000 hectares). By the end of 2011, the town had a total population of 34,157, with 3,938 residing in urban areas, representing an urbanization rate of 11.5%. With the development of society and advancements in technology, the issue of farmland abandonment in the town has become increasingly severe.

Qixia City, which governs 14 towns and 841 villages, has a total population of 174,000 agricultural households (with 152,800 households engaged in family contracting), and an agricultural population

  DOI: 10.25236/icssem.2025.067

of 449,000. The city's total cultivated land area is 835,000 mu, of which 733,600 mu is under family contract management. According to statistics from February 2021, the area of abandoned farmland in Qixia City reached 7,443 mu, accounting for 0.8% of the total cultivated land area.

This issue of farmland abandonment is a pressing challenge that needs to be addressed to ensure the sustainable development of rural areas and the success of the rural revitalization strategy in China.

2. Analysis of Factors Influencing Farmland Abandonment in Rural Areas

This study employs a survey questionnaire and participatory assessment methods to collect sample data and explore the factors influencing farmland abandonment in rural areas. The questionnaire is designed around the theme of "land abandonment," with principles of scientific rigor, clarity, and simplicity to ensure farmers' active participation in the survey. The questionnaire consists of two main sections: "Basic Information of the Farmers" and "Farmers' Views and Expectations Regarding Land Abandonment." The survey includes questions on farmers' gender, age, education level, household size, labor force, resident population, annual agricultural income, and awareness of land-related policies or laws.

The collected sample data were organized using EXCEL software. To facilitate subsequent statistical analysis, the following steps were taken with respect to the data:

(1) Gender was coded as a categorical variable: 1 for female, 2 for male.

(2) Education level was coded as: 1 for primary school or below, 2 for middle school, 3 for high school or technical school, and 4 for college or above.

(3) Awareness of land policies was coded as: 1 for unaware, 2 for somewhat aware, and 3 for basically aware.

(4) For the grouped data on age and annual agricultural income, the median value for each group was used to represent the sample data.

(5) Land abandonment level was calculated as: abandoned land area / total cultivated land area.

(6) The term labor force in this study refers to individuals aged 16 to 59 who are engaged in farming labor locally [1].

After organizing the sample data, SPSS 27.0 software was used for analysis, including variance analysis, correlation analysis, and regression analysis. In variance analysis, one-way ANOVA was used to compare the means, yielding the corresponding ANOVA results. For correlation analysis, bivariate correlation analysis and Pearson's correlation coefficient were employed, with a one-tailed significance test to obtain correlation coefficients and significance test results between variables. In regression analysis, a linear regression model was used, with the significance level for tests standardized at 0.05. The results included descriptive statistics, ANOVA, estimated regression coefficients, and the determination coefficient of the estimated regression equation.

Based on the analysis results, the main factors influencing farmland abandonment in rural areas are identified as follows:

2.1. Imbalanced Age Structure of the Rural Population

2.1.1. Data Analysis

Table 1 Linear correlation coefficient and significance test results between age and degree of farmland abandonment

		Farmland abandonment	Age
Pearson Correlation	Farmland abandonment	1.000	0.480
	Age	0.480	1.000
Significance (One-tailed)	Farmland abandonment	—	<0.001
	Age	0.001	—
N (Number of Cases)	Farmland abandonment	40	40
	Age	40	40

In Table 1, the Pearson correlation coefficient $r = 0.48$ indicates a positive linear correlation between age and the degree of farmland abandonment, with a moderate correlation between the two

variables. Additionally, since the significance test for r yields $P < 0.001 < 0.05$, this further suggests that the conclusion drawn from the sample data can be generalized to the population data. In Table 2, the significance level for ANOVA is set at 0.05. Based on the numerator degrees of freedom $df_1 = 1$ and denominator degrees of freedom $df_2 = 38$, the critical value from the F-distribution table is $F_\alpha = 4.098$. Since $F = 11.402 > F_a = 4.098$, this further confirms that the linear relationship between age and the degree of farmland abandonment is statistically significant.

Table 2 Test of the linear relationship between age and degree of farmland abandonment

Model	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance
Regression	0.012	1	0.012	11.402	0.002[b]
Residual	0.039	38	0.001	—	—
Total	0.051	39	—	—	—

[b] Predictors: (Constant), Age

2.1.2. Data Interpretation

This statistical evidence aligns with the broader trends observed in rural areas, where urbanization has led to the migration of young laborers to cities, leaving behind a predominantly middle-aged and elderly workforce. The resulting imbalance in the rural labor force significantly weakens agricultural productivity, making it increasingly difficult for the remaining laborers to sustain essential farming activities. Consequently, the likelihood of farmland abandonment has grown, as the remaining workforce is unable to manage the agricultural tasks effectively.

2.2. Prominent Issue of Rural Depopulation

2.2.1. Data Analysis

Table 3 shows that the Pearson correlation coefficient between the degree of farmland abandonment and total population is $r_1 = -0.687$, between the degree of abandonment and labor force is $r_2 = -0.611$,, and between the degree of abandonment and resident population is $r_3 = -0.709$. These results indicate significant negative linear correlations between the degree of farmland abandonment and total population, labor force, and resident population, respectively. Furthermore, the significance tests yield $P_1 < 0.01 < 0.05$, $P_2 < 0.01 < 0.05$ and $P_3 < 0.01 < 0.05$, suggesting that the findings based on the sample data can be generalized to the overall population.

Table 4 shows the ANOVA significance level, set at 0.05. Based on the numerator degrees of freedom $df_1 = 3$ and denominator degrees of freedom $df_2 = 37$, the critical value from the F-distribution table is $F_\alpha = 2.866$. Since $F = 14.059 > F_a = 2.866$, this further confirms that there is a significant linear relationship between total population, labor force, resident population, and the degree of farmland abandonment.

Table 3 Linear correlation coefficients and significance test results between total population, labor force, resident population, and degree of farmland abandonment

		Farmland abandonment	Total population	Labor force	Resident population
Pearson Correlation	Farmland abandonment	1.000	-0.687	-0.677	-0.709
	Total population	-0.687	1.000	0.784	0.920
	Labor force	-0.611	0.784	1.000	0.660
	Resident population	-0.709	0.920	0.660	1.000
Significance (One-tailed)	Farmland abandonment	—	<0.001	<0.001	<0.001
	Total population	0.000	—	0.000	0.000
	Labor force	0.000	0.000	—	0.000
	Resident population	0.000	0.000	0.000	—
N (Number of Cases)	Farmland abandonment	40	40	40	40
	Total population	40	40	40	40
	Labor force	40	40	40	40
	Resident population	40	40	40	40

Table 4 Test of the linear relationship between total population, labor force, resident population, and degree of farmland abandonment

Model	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance
Regression	0.027	3	0.009	14.059	<0.001[b]
Residual	0.023	36	0.001	—	—
Total	0.051	39	—	—	—

[b] Predictors: (Constant), Resident population, Labor force, Total population

2.2.2. Data Interpretation

In the process of urbanization, young rural laborers migrate to cities in search of higher material rewards. As they improve their living standards in urban areas, these workers often bring rural left-behind children and elderly relatives to live with them in the cities. Over time, this leads to the phenomenon of rural hollowing, where agricultural land is left uncultivated, ultimately resulting in farmland abandonment.

2.3. Low Agricultural Production Income

2.3.1. Data Analysis

In Table 5, the Pearson correlation coefficient $r = -0.851$ indicates a strong negative linear correlation between farmers' total annual farming income and the degree of farmland abandonment. The significance result $P < 0.001 < 0.05$ further suggests that the conclusions drawn from the sample data can be generalized to the overall population.

In Table 6, the ANOVA significance level is set at 0.05. Based on the numerator degrees of freedom $df_1 = 1$ and denominator degrees of freedom $df_2 = 38$, the critical value from the F-distribution table is $F_\alpha = 4.098$. Since $F = 100.004 > F_\alpha = 4.098$, this further confirms that there is a significant linear relationship between farmers' total annual farming income and the degree of farmland abandonment.

Table 5 Linear correlation coefficient and significance test results between the total annual income of farmers from farming and the degree of land abandonment

		Farmland abandonment	Total annual income
Pearson Correlation	Farmland abandonment	1.000	-0.851
	Total annual income	-0.851	1.000
Significance (One-tailed)	Farmland abandonment	—	<0.001
	Total annual income	0.000	—
N (Number of Cases)	Farmland abandonment	40	40
	Total annual income	40	40

Table 6 Test of the linear relationship between the total annual income of farmers from farming and the degree of land abandonment

Model	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance
Regression	0.037	1	0.037	100.004	<0.001[b]
Residual	0.014	38	0.000	—	—
Total	0.051	39	—	—	—

[b] Predictors: (Constant), Total annual income from farming (RMB).

2.3.2. Data Interpretation

The rising costs of agricultural inputs and labor, coupled with declining crop yields, have led to a frequent occurrence of the phenomenon known as "low crop prices hurting farmers." As a result,

farmers are increasingly opting to idle their land and shift to alternative forms of production to maximize their own economic benefits. This has contributed to the widespread issue of land abandonment in rural areas.

2.4. Insufficient Government Promotion Efforts

2.4.1. Data Analysis

The Pearson correlation coefficient in Table 7 is $r = -0.345$, indicating a negative linear relationship between farmers' understanding of land policies and the degree of land abandonment. The significance test yields a p-value of $P < 0.001$, which is less than 0.05, suggesting that the results from the sample data are statistically significant and can be generalized to the population.

In Table 8, the significance level for ANOVA is set at 0.05. With a numerator degree of freedom $df_1 = 1$ and a denominator degree of freedom $df_2 = 38$, the critical value from the F-distribution table is Fα = 4.098. Since the calculated F-value ($F = 4.098$) exceeds the critical value (Fα = 4.098), it further supports the conclusion that there is a significant linear correlation between farmers' understanding of land policies and the degree of land abandonment.

Table 7 Linear correlation coefficient and significance test results between farmers' understanding of land policies and the degree of land abandonment

		Farmland abandonment	Farmers' understanding
Pearson Correlation	Farmland abandonment	1.000	-0.345
	Farmers' understanding	-0.345	1.000
Significance (One-tailed)	Farmland abandonment	—	0.015
	Farmers' understanding	0.015	—
N (Number of Cases)	Farmland abandonment	40	40
	Farmers' understanding	40	40

Table 8 Test of the linear relationship between farmers' understanding of land policies and the degree of land abandonment

Model	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance
Regression	0.037	1	0.037	100.004	<0.001b
Residual	0.014	38	0.000	—	—
Total	0.051	39	—	—	—

[b] Predictors: (Constant), Degree of Understanding of Land Policies

2.4.2. Data Interpretation

The government has insufficiently promoted laws and regulations such as *the Land Administration Law of the People's Republic of China* and *the Rural Land Contracting Law of the People's Republic of China*. There is also a lack of necessary oversight and guidance for farmers, which has led to some farmers lacking an accurate understanding of relevant policies as well as their rights and obligations. As a result, they are unable to use their land rationally, contributing to the occurrence of land abandonment in rural areas.

3. Policy Recommendations Based on WSR

The WSR (Weaknesses, Strengths, and Recommendations) methodology was initially applied in the field of systems science. With the increasing depth and specialization of research, some scholars have introduced it into the management field. In this context, physical factors refer to elements related to the inherent properties of things, including both natural and social attributes. These factors primarily reflect the objective boundaries, characteristics, and laws of phenomena. The basic content of physical factors is scientific knowledge proven to be correct through quantitative analysis, rigorous logical reasoning, or precise scientific experiments, such as theorems in mathematics or laws in

physics. Rational factors focus on operations and planning, mainly referring to methods derived from real-world environments and laws that guide human practical activities, such as the rational arrangement of equipment, materials, and personnel. Human factors emphasize human agency, with research primarily drawing on knowledge from psychology, sociology, and behavioral sciences to analyze human psychology, behavior, and value orientations [2, 3].

Rural land abandonment is a complex, multifaceted issue that involves ecological, economic, technological, and cultural dimensions. The solutions to this issue are closely linked to people, things, and processes. To simplify and organize the proposed solutions in a more systematic manner, this paper utilizes the WSR methodology to provide a comprehensive set of recommendations for addressing the issue of land abandonment based on the relevant data calculated above.

3.1. Physical Factors

(1) Strengthen Rural Infrastructure Construction. Due to the combined effects of monsoon climate and hilly or mountainous terrain in China, natural disasters such as floods, soil erosion, and mudslides frequently occur in rural areas. Therefore, significant investments should be made in water conservation infrastructure, including the renovation of irrigation systems and the improvement of water management facilities in these regions.

(2) Enhance the Dissemination of Disaster Information. Villages should designate personnel to use methods such as radio broadcasts, offline lectures, and social media to disseminate disaster-related information. This would allow farmers to take preventive measures in advance, thereby reducing the costs and losses caused by disasters.

(3) Promote Knowledge and Techniques for Natural Disaster Management. Regular training sessions should be organized at the village or township level, where relevant experts lead farmers in learning about the latest knowledge on natural disasters and protective farming techniques. For example, techniques for pest control include no-till or minimum tillage, deep loosening, integrated pest management, and straw return [4]. By mastering these techniques, farmers will be better equipped to apply them in farming practices, reducing the negative impact of natural disasters on crop production.

(4) Explore Improvements to Agricultural Market Price Mechanisms. The government should actively explore mechanisms to improve the formation of agricultural market prices, linking subsidies to peak sales seasons and detaching them from off-season periods. During peak seasons, market self-regulation typically increases supply more than demand, lowering market equilibrium prices. However, due to the inelastic demand for agricultural products, the "low prices hurt farmers" phenomenon often arises. To encourage production and protect farmers' interests, the government should intervene by providing subsidies through mechanisms such as support prices during peak seasons. Conversely, the government should take countermeasures in the off-season to stabilize the market.

3.2. Rational Factors

(1) Cultivate New Professional Farmers: Rural leaders should leverage the role of technology by utilizing "Internet+" training models to offer practical training on planting techniques, equipment use, e-commerce, and online sales. This will equip farmers with necessary skills, enabling them to become professional farmers.

(2) Enhance Farmers' Market Forecasting Ability: Authorities should promptly share market trends with farmers to help them predict market conditions. Regular training on agricultural market knowledge will improve their forecasting abilities. Additionally, encouraging farmers to access multimedia resources will enable them to better understand market dynamics and make more informed decisions.

(3) Promote the "One Village, One Product" Model: Rural areas should develop products based on local resources and market demand. By building regional brands, areas like Songgezhuang Village can promote signature products such as apples, increasing farmers' income and reducing rural outflow [5].

(4) Extend the Industrial Chain: Local governments should integrate agriculture with other sectors

like cosmetics and pharmaceuticals to create value-added products. In terms of sales, exploring models like "company + farmers" and "cooperative + farmers" will enhance collaboration, reduce costs, and benefit farmers [6].

(5) Develop the "Agriculture Express" Online Platform: Governments should collaborate with agencies to create a platform offering services like agricultural supplies, risk prediction, pest control, and product sales. This will reduce costs, improve efficiency, and integrate the agricultural value chain, increasing farmers' incomes.

(6) Broaden Sales Channels: Governments and farmer organizations should expand sales channels through e-commerce, influencer partnerships, and supermarket contracts. This will reduce transportation costs, boost farmer incomes, and enhance logistics [7].

(7) Invest in Rural Cultural Development: Governments should invest in cultural infrastructure and create local markets for unique cultural products. Integrating agriculture with tourism and eco-industries will boost the local economy, improve land use, and increase farmers' income [8]. For example, Songgezhuang Village can attract tourists by combining agriculture with local tourism.

3.3. Human Factors

(1) Preserve and Promote Rural Traditional Culture: Village leaders should actively protect local cultural heritage, including landmarks and intangible traditions, to enhance farmers' sense of belonging and identity. This helps reduce rural depopulation and encourages the return of migrant workers, motivating them to actively engage in land cultivation and reduce land abandonment. For instance, Songgezhuang Village in Shandong has rich cultural heritage, including ancient ancestral halls and inscriptions, which reflect traditional virtues such as respect for ancestors, loyalty, and filial piety. The village also preserves unique folk customs and traditional crafts like flower bread, paper cutting, and clay sculptures. These cultural elements embody the resilient and innovative spirit of the local community. By safeguarding these traditions and promoting them through activities, the village can strengthen cultural confidence, foster greater attachment to the land, and reduce land abandonment.

(2) Use Multimedia to Promote Local Culture: Village leaders should leverage modern media, such as WeChat, Kuaishou, Douyin, and Weibo, to promote local culture alongside the core socialist values. This "Internet + Culture" approach can invoke a sense of responsibility and mission in farmers towards land stewardship, thereby reducing land abandonment.

(3) Promote Legal Awareness: Government departments and village leaders should regularly organize educational campaigns on laws like the Land Management Law and Basic Farmland Protection Regulations. These efforts should emphasize the importance of land protection and sustainable use, promptly address illegal land abandonment, and enforce penalties to minimize land neglect.

4. Conclusion

This study focuses on Songgezhuang Village in Guanli Town, Qixia City, Yantai, Shandong Province, as the research site. First, data was collected through surveys, offline interviews, and field measurements conducted with local farmers. Next, the data was integrated and analyzed using software such as Excel and SPSS 27.0. Both qualitative and quantitative dimensions were considered to examine the causes of rural land abandonment. The results indicate that factors such as the age structure of the rural population, population size (including total population, labor force, and local resident population), farmers' income from farming, and the government's promotion of land-related policies significantly influence the issue. Among these, only the age structure of the rural population showed a positive correlation with land abandonment, while the other three factors exhibited negative correlations.

Finally, based on the data analysis, this paper employs the WSR (Weaknesses, Strengths, and Recommendations) methodology to propose measures for addressing rural land abandonment (Figure 1). These recommendations include strengthening rural infrastructure, developing a "one village, one product" sales model, establishing an online service platform like "Agricultural Express," and

increasing economic investment in rural cultural development. The aim is to support the implementation of the rural revitalization strategy and contribute to the resolution of the "three rural issues" (agriculture, rural areas, and farmers) in China.

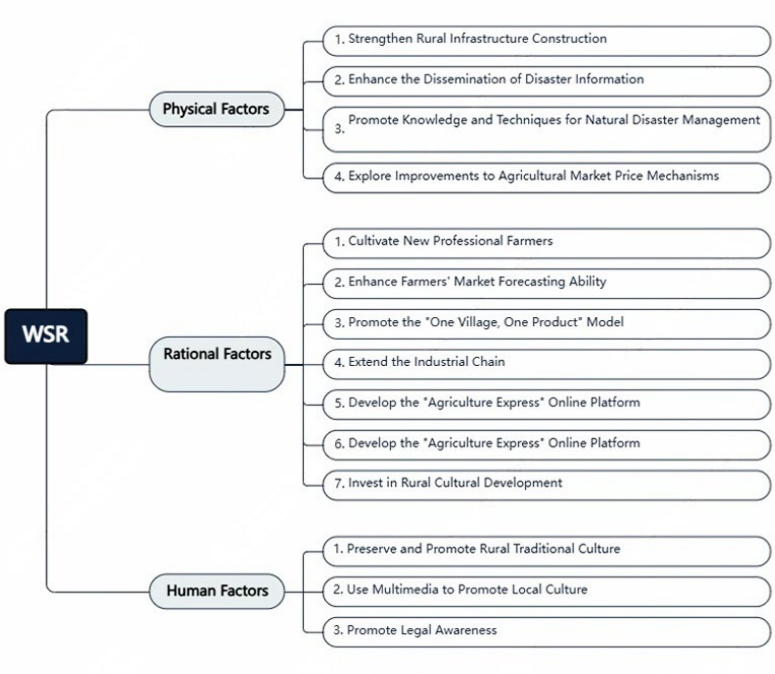

Figure 1 WSR system methodology flowchart

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