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A study of spatio-temporal changes in the functional efficiency of rural occupation and residence in Jilin Province based on the gray correlation model

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Abstract The accelerated pace of urban-rural integration and development has pushed the harmonization of occupation and residence functions in rural areas to gradually become an important factor affecting the sustainable development of the region. In this paper, Jilin Province, a classic agricultural province, is taken as the study area to explore the synergistic evolution law of occupation and residence functions. Based on the gray correlation analysis algorithm, the two-way gray correlation model based on slope difference is proposed from the similarity perspective, using the two-way gray correlation based on slope difference to represent the difference in the rate of change. At the same time, the existing rural vocational education supply and demand problems in Jilin Province are analyzed to reflect the structural causes of its rural vocational status quo. And from the three major perspectives of residence, production and ecology, the rural territory is divided into six major functional areas. A two-way gray correlation model based on slope difference is applied to analyze the changes in the structure of rural occupations in different functional zones in Jilin Province, in which the highest percentage of rural agricultural occupations in the urban functional expansion area and the new urban development area is only 38.36%. The advancement of urbanization development has subconsciously affected the adjustment and upgrading of rural occupational structure while diluting the rural residential function and promoting the functional diversification of rural areas.

Index Terms two-way gray correlation model, rural occupational structure, slope difference, urban-rural integrated development, residential function

I. Introduction

With the continuous advancement of urbanization, rural decline has become a global challenge [1]. In China, the problems of “urbanization and rural decline”, “hollowing out of the countryside” and “rural disease” have come to the fore [2]. Among them, the contradiction between the rapid decline of rural land resources and population and the continuous increase of rural settlement land is obvious, which seriously hinders the transformation and development of the countryside as well as urban-rural integration and coordination [3], [4]. How to effectively optimize the space of rural settlements and maximize the benefits is an important issue in the implementation of rural revitalization strategy.

As the strongest manifestation and presentation of the interaction of human-land relations in rural areas, rural settlements show diversity and flexibility to human needs, possess multifunctional attributes, and play an important role in living conditions, agricultural production and social interaction [5], [6]. As the functional form of rural settlements gradually shifted from homogeneous isomorphism to heterogeneous diversity, and its functional form also shifted from a single living function to multifunctional synthesis, the role of the relationship between the functions of rural settlements tends to be integrated and complex [7]-[9]. The complex interaction between the functions of rural settlements brings challenges to the development of rural settlement optimization strategies according to local conditions [10]. At the same time, the renovation mode of intensively utilizing rural settlements with the goal of quantity, while ignoring the internal land use types of rural settlements and their functional diversity, can no longer meet the realistic needs of rural development, let alone support the implementation of rural revitalization strategy [11]-[13]. Under the double driving force of policy orientation and realistic demand, focusing on the functional characteristics of rural settlements to carry out zoning research is of great significance to rural revitalization and urban-rural integrated development [14].

This paper firstly elaborates the principle of gray correlation analysis algorithm and the calculation steps as the theoretical basis of research and analysis. Considering the similarity difference between the sequences, a two-way gray correlation model is constructed by using the slope difference, and the definitions of slope, slope difference, correlation coefficient between different sequences, as well as the calculation process, are further explained. Then, the causes of supply and demand problems in rural vocational education in Jilin Province are analyzed briefly to reflect the changes in rural vocational development in the province. At the same time, it describes the six classifications of rural territorial functions and their focuses by combining the existing research and the actual situation. Finally, it calculates the degree of coordination between rural vocational education and economic development in Jilin Province, analyzes the driving factors of rural territorial development in Jilin Province, determines the evaluation criteria of the degree of economic coordination and transformation, and analyzes the changes in rural vocational structure under different functional areas.

II. Two-way gray correlation model

II. A. Principles of Gray Correlation Analysis

Gray correlation analysis is a method of determining the degree of correlation between two curves based on the degree of similarity between the curves composed of reference data and comparison data. This method is used to measure the correlation between two curves, complete the comparative analysis of the relevant data curves in the system, and find out the gray correlation between the reference data and the comparative data, so as to determine the correlation strength between them. The greater the correlation with the reference data, the closer the trend is to the reference data. The smaller the correlation with the reference data, the farther the trend is from the reference data. Gray correlation analysis requires less data and is less computationally intensive. The applicability of gray correlation analysis is not limited by data laws, avoiding inconsistencies between quantitative and qualitative analysis results. For the actual operation of PV arrays, the simulation calculation results under the standard operation state are used as the reference data, and the data under the fault state are used as the comparison data. The basic steps of gray correlation analysis are as follows:

(1) Determine the reference sequence and comparison sequence according to the purpose of PV array health leveling.

Where the reference sequence is set as equation (1):

$$X_0 = (x_{01}, x_{02}, \cdots x_{0j}, \cdots, x_{0n}) \tag{1}$$

The original evaluation matrix is set as equation (2):

$$X = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_i \\ \vdots \\ X_m \end{bmatrix} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1j} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2j} & \cdots & x_{2n} \\ \vdots & \vdots & & \vdots & & \vdots \\ x_{i1} & x_{i2} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \vdots & & \vdots & & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix} \tag{2}$$

where, m is the number of samples. n is the number of features, x_{ij} is the value of the j feature in the i sample moment.

(2) In order to deal with the differences in the magnitude of the values due to different data ranges, the data need to be normalized. This step adjusts data of different ranges and units to a common numerical interval, usually $[0,1]$, in order to reduce the direct influence of numerical size and ensure the accuracy of data comparison and analysis.

(3) The data that have been normalized are analyzed by first calculating the absolute error between each data point and the corresponding data point in the reference series, and identifying the maximum and minimum errors from these error values.

(4) The correlation coefficients corresponding to each reference and comparison data were calculated by equation (3):

$$\xi_{ij} = \frac{\min_i \min_j \left|x_{ij} - x_{0j}\right| + \rho \max_i \max_j \left|x_{ij} - x_{0j}\right|}{\left|x_{ij} - x_{0j}\right| + \rho \max_i \max_j \left|x_{ij} - x_{0j}\right|} \tag{3}$$

where, ξ_{ij} is the correlation coefficient, whose value is a positive number less than one. x_{0j} and x_{ij} are the reference and measured data. ρ is the resolution coefficient with the value interval of $[0,1]$, usually set to 0.5.

(5) The resulting correlation coefficients are averaged through equation (4), and the average obtained is the gray correlation.

$$r = \frac{1}{m}\sum_{j=1}^{m}\xi_{ij} \tag{4}$$

II. B.Two-way gray correlation model based on slope difference

The slope of the series has the dual characteristics of characterizing the growth rate and the direction of growth of the series, so this paper uses the slope difference to construct a two-way gray correlation model. This not only reflects the degree of similarity of the series, but also can characterize the direction of the association of the series. When the two series tend to change in the same increase and decrease, the two series change in the same direction, the correlation should be positive. When the two sequences tend to one increase and one decrease in change, the correlation between the two sequences should be negative.

Definition 1 Let there be sequences X_0'' and X_i'', the slopes of the first k and $k+1$ two items of the sequence can be expressed as equation (5)-(6):

$$l_0''(k+1) = \frac{x_0''(k+1) - x_0''(k)}{k+1-k} \quad k = 1, 2, \cdots, n-1 \tag{5}$$

$$l_i''(k+1) = \frac{x_i''(k+1) - x_i''(k)}{k+1-k} \quad k = 1, 2, \cdots, n-1 \tag{6}$$

The difference in slopes based on X_0'' and X_i'' is shown schematically in Figure 1.

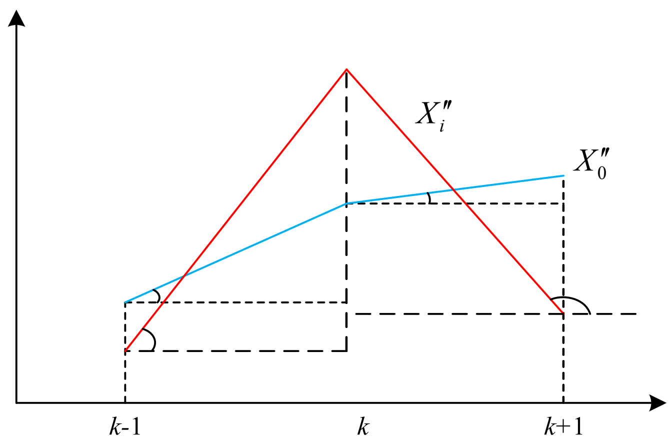

Figure 1: Based on the slope difference between X_0'' and X_i''

As can be seen from Figure 1, the slopes of the sequences X_0'' and X_i'' within a time period are both of the same sign, as shown in the interval $[k-1, k]$, and of different sign, as shown in the interval $[k, k+1]$. If the slopes of the sequences are of the same sign in a segment, the difference in their slopes is the absolute value of the difference in the slope values. And if the two sequences slope different sign, the sequence with the other sequence of the increase and decrease of change and reverse change, if still using the sequence of the same number when the calculation of the slope difference of the way, it can not accurately characterize the degree of correlation between this reverse change in the sequence, so this paper comprehensively consider the two cases defined the slope difference between the sequences, see Definition 2.

Definition 2 Let Eq. (7):

$$\Delta'(k+1) = \left\| l_0''(k+1) \right| - \left| l_i''(k+1) \right\|, k = 1, 2, \cdots, n-1 \tag{7}$$

Then $\Delta'(k+1)$ is called the slope difference between the sequences X_0'' and X_i'' on the interval $[k, k+1]$.

On the basis of determining the slope difference between the sequences, in order to effectively characterize the directionality of the sequence correlation, this paper introduces the sign function $\mathrm{sgn}(x)$ to define the bi-directional gray correlation coefficients based on the slope difference. When the sequences X_0'' and X_i'' are increasing and decreasing in the interval $[k, k+1]$, the correlation coefficient of the two sequences is positive. When the sequences X_0'' and X_i'' vary in opposite directions in the interval $[k,k+1]$, the correlation coefficient of the two sequences is negative.

Definition 3 Let the sequences X_0'' and X_i'' with slopes $l_0''(k+1)$ and $l_i''(k+1)$ on the interval $[k,k+1]$ be called equation (8):

$$\varsigma_{0i}(k+1)=\operatorname{sgn}\left(l_0''(k+1),l_i''(k+1)\right)\cdot\left(1-\frac{\left\|l_i''(k+1)\right|-\left|l_0''(k+1)\right\|}{\left|l_i''(k+1)\right|+\left|l_0''(k+1)\right|}\right) \quad (8)$$
$$k=1,2,\cdots,n-1$$

which has the formula (9):

$$\operatorname{sgn}\left(l_0''(k+1),l_i''(k+1)\right)=\begin{cases}1 & l_0''(k+1)\cdot l_i''(k+1)\geq 0\\ -1 & l_0''(k+1)\cdot l_i''(k+1)<0\end{cases} \quad (9)$$

is the coefficient of association on the interval $[k,k+1]$.

Definition 4 Given a sequence X_0'' and X_i'', the association coefficient in the interval $[k,k+1]$ is denoted as $\varsigma_{0i}(k)$, then Eq. (10) is said to be:

$$\varphi_{0i}=\frac{1}{n-1}\sum_{k=1}^{n-1}\varsigma_{0i}(k+1) \quad (10)$$

is the bi-directional gray correlation based on the difference in slopes. Where $|\varphi_{0i}|$ denotes the strength of association between the two sequences, and the positivity or negativity of φ_{0i} characterizes the direction of association of the sequences. When the bi-directional gray correlation based on the slope difference is positive, it indicates that the overall tendency of the two sequences is to change in the same direction, and the reference sequence increases or decreases with the increase or decrease of the comparison sequence. When the bi-directional gray correlation based on the slope difference is negative, it indicates that the whole of the two sequences tends to change in the opposite direction, and the reference sequence changes in the opposite direction with the change of the comparison sequence.

III. Rural Occupational Development and Changes in Residential Functions in Jilin Province

III. A. Analysis of the causes of supply and demand problems in rural vocational education

At present, the supply and demand of rural vocational education in Jilin Province is full of contradictions and there are many problems, the reasons for which are as follows:

(1) Insufficient government support

The government plays a very important role in the supply and resource allocation of rural vocational education, and rural vocational education will stagnate in the absence of government support, because the government can provide sufficient funds and good educational mechanisms in the supply of vocational education to guarantee the reasonable allocation and full utilization of vocational education resources.

(2) Vocational education schools themselves are lagging behind in development

Vocational education schools are the main places for farmers to learn vocational skills and have a direct impact on the scale and quality of vocational education. Vocational education schools in Jilin Province are currently lagging behind in development, without clear school positioning and clear goals, emphasizing theory over practice in curriculum, results over process in cultivation programs, and weak teachers.

(3) Farmers' insufficient understanding of agricultural vocational education

Influenced by Chinese traditional culture and the old concept of talent, most farmers lack the necessary understanding of agricultural vocational education, and unilaterally believe that engaging in agricultural production is undignified and has no future, which seriously affects the enrollment of agricultural majors and restricts the development of agricultural vocational education.

III. B. Functional classification of rural territories

(1) Living and dwelling function

As a gathering space for rural residents, the traditional manifestation of the spatial dependence of the rural area is its living and dwelling function. Whether it is the coercion of the natural environmental factors on the spatial scale and density of the settlement in the early days, or the drive of the humanistic factors such as economic policy and culture on the development of villages at present, the function of living and living has always been the basic component of the functional system of the rural areas. The multifunctional structure of rural areas is shown in Figure 2.

(2) Living security function

The guarantee function refers to the self-regulation ability of the living function system of the rural area when the supply capacity of life reaches a certain stage. The quality of life in the rural area is closely related to this function, and in addition to providing people with the values of leisure, aesthetics and education, it also undertakes the functions of maintaining the original way of life, protecting the diversity of cultural heritages, and inheriting and carrying forward the traditional history and culture. The function of livelihood security is aimed at providing support for people living in the regional space, and is an important guarantee for the functional system of rural areas.

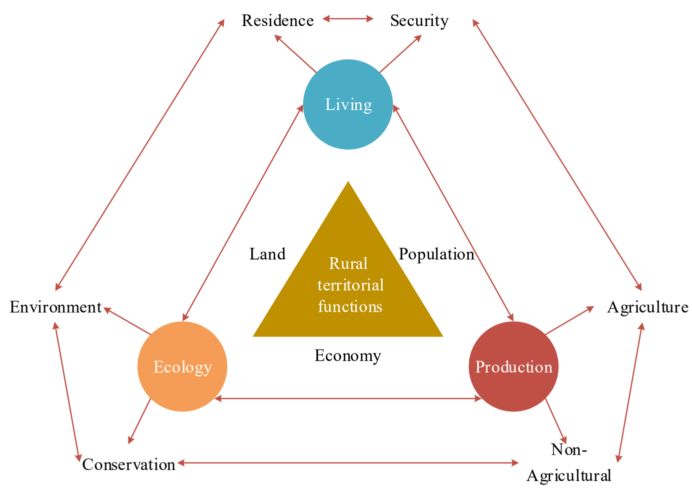

Figure 2: Rural regional multifunctional structure

(3) Agricultural production function

As a spatial carrier that provides sufficient agricultural products, the agricultural production function lays the original foundation for the development of rural areas. The output of agricultural production activities ensures national food security, provides employment for rural farmers, and provides sustainable development power for village development. Therefore, the agricultural production function is the traditional driving force of the functional system of rural areas.

(4) Non-agricultural production function

Non-agricultural production refers to the production capacity outside the agricultural production for the rural labor force to increase income, and non-agricultural production is mainly manifested in the correlation production far away from but not detached from agriculture, such as the deep processing of agricultural products or traditional mining and metallurgical industry and the current tourism industry relying on environmental resources. Non-agricultural production can bring higher income-generating efficiency to rural areas, promote the professional differentiation of farmers, and promote the diversification of rural production, which serves as the main support in the functional system of rural areas.

(5) Ecological environment function

The ecological environment is the base of the existence of rural areas, refers to the ecological landscape of the unity of the aggregate, the ecological environment function as a spatial carrier for rural life and production to provide natural elements. It can not only provide support for ecological protection and restoration, but also provide sustainable supply for multi-functional development of rural areas through ecological management. Therefore, the advantages and disadvantages of the ecological environment function reflect the sustainable development potential of the rural area, and this function is the potential of the rural area function system.

(6) Ecological security function

Ecological security refers to the ecological maintenance and natural adjustment function of the rural ecological environment as a carrier, on the one hand, it helps to repair and adjust the rural living and production system, and on the other hand, it receives the negative outputs of human beings, such as wastes, garbage, and chemical liquids and gases. The ecological security function provides the development tolerance and correct guidance for the rural area space, and is the public property of the rural area function system.

IV. Analysis of Changes in the Functional Efficiency of Occupation and Residence in Rural Jilin Province

IV. A. Linkage between rural vocational education and economic development

A total of 15 counties and districts (U1-U15) in U city of Jilin province were selected as the research object, and the collected comprehensive evaluation values of the 15 counties and municipalities in 2008 and 2020 were substituted into the two-way gray correlation model based on the slope difference, and the discrimination coefficient was taken to be 0.5, and the results of calculating the degree of coordination between the rural vocational education and the economic development of the 15 districts in 2008 and 2020 are shown in Table 1. where Coordination degree grades are categorized as (C1) very satisfactory, (C2) satisfactory, (C3) average, (C4) unsatisfactory, and (C5) very unsatisfactory.

Table 1: Coupling correlation degree

Region	Correlation coefficient		Amount of variation	Coordination degree grade
	2008	2020		
U1	0.9114	0.4812	0.4302	C2
U2	0.5612	0.2886	0.2726	C3
U3	0.7833	0.4096	0.3737	C3
U4	0.446	0.3357	0.1103	C4
U5	0.4906	0.4977	-0.0071	C5
U6	0.472	0.5933	-0.1213	C5
U7	0.7448	0.4316	0.3132	C3
U8	0.4336	0.4104	0.0232	C4
U9	0.8916	0.3956	0.496	C1
U10	0.914	0.5374	0.3766	C2
U11	0.7013	0.4951	0.2062	C3
U12	0.7197	0.5128	0.2069	C3
U13	0.954	0.1556	0.7984	C1
U14	0.9967	0.5575	0.4392	C2
U15	0.7283	0.3152	0.4131	C2

When the discrimination coefficient is 0.5, only four counties and districts in total, U4, U8, U5 and U6, have a coordination rating of (C4) unsatisfactory or (C5) very unsatisfactory, and most of the counties and districts have a coordination rating of (C3) average. It can be seen that there is no major problem in the overall harmonization of rural occupations and economic development in City U in 2008 and 2020, but the development of rural occupations in the city does not fully meet the development needs of the city's rural economy.

IV. B. Coordinated Transformation Degree Evaluation Model

IV. B. 1) Driver analysis

Further, the landscape pattern index of U city with demographic, economic, and natural location data for a total of 4 periods in 2008, 2012, 2016, and 2020 were inputted into a two-way gray correlation model based on slope difference. The results of the standardized regression coefficients (SC) computed from the 4-period correlation model are shown in Table 2 to explain the strength ranking, and the selected drivers are (X1) elevation, (X2) slope, (X3) road, (X4) water system, (X5) population, (X6) population urbanization rate, and (X7) financial revenue.

Table 2: Ranking of driving factors for the landscape evolution of rural homesteads

Factor	2008		2012		2016		2020	
	SC	Sort	SC	Sort	SC	Sort	SC	Sort
X1	0.744	2	0.775	2	0.893	2	0.861	2
X2	0.117	6	-0.219	7	-0.012	6	-0.245	7
X3	0.386	4	0.281	5	0.322	4	0.421	4
X4	-0.108	7	0.103	6	0.175	5	0.131	6
X5	0.833	1	0.855	1	0.955	1	0.915	1
X6	0.275	5	0.347	4	-0.139	7	0.22	5
X7	0.423	3	0.595	3	0.573	3	0.516	3

From 2008 to 2020, the top three rankings of explanatory power of drivers of landscape pattern evolution of rural homesteads were always (X5) population, (X1) elevation, and (X7) financial income, of which (X5) population had a standardized coefficient of 0.955 in 2016, indicating that talent was the most important influencing factor. While (X2) slope and (X3) roads ranked lower.

IV. B. 2) Evaluation criteria for harmonizing the degree of transformation

In order to facilitate a unified comparison of the values of the three indicators of functional transformation degree, comprehensive coordination degree and coordination transformation degree in different periods, the study adopts the quartile method to classify the indicators of 15 counties and districts in U city in four periods, and sets the values of 25% (1/4th quartile), 50% (median) and 75% (3/4th quartile) as the interval thresholds for the classification of the grades, which are divided into four grades of (F1) lower, (F2) lower, (F3) higher and (F4) higher, and the classification criteria are shown in Table 3. Functional transformation indicators are: (FI1) population bearing functional transformation, (FI2) asset functional transformation, (FI3) residential functional transformation, (FI4) functional transformation degree, (FI5) comprehensive coordination degree, and (FI6) coordinated transformation degree.

Table 3: Functional transformation measurement index grade

Level	F1	F2	F3	F4
FI1	(0.7944,0.2388]	(0.2388,0.2792]	(0.2792,0.2985]	(0.2985,0.3528]
FI2	(0.0335,0.0851]	(0.0851,0.1068]	(0.1068,0.1327]	(0.1327,0.2014]
FI3	(0.252,0.4002]	(0.4002,0.4281]	(0.4281,0.4531]	(0.4531,0.562]
FI4	(0.5339,0.6209]	(0.6209,0.6505]	(0.6505,0.6506]	(0.6507,0.6508]
FI5	(0.2551,0.5831]	(0.5831,0.7264]	(0.7264,0.9561]	(0.9561,1.1123]
FI6	(0.3261,0.6068]	(0.6068,0.7114]	(0.7114,0.7764]	(0.7764,0.9415]

IV. C. Changes in the structure of rural occupations in different functional areas

The trend of change in the occupational structure of villages located in different functional zones is basically the same. On the basis of the six rural territorial functions proposed above, and taking into account the actual situation of the urban-rural integration process, this section divides the functional zones into (E1) urban function expansion zones, (E2) new urban development zones, and (E3) ecological conservation and development zones, and compares the changes in the occupations practiced by the rural population of the 15 urban districts in different functional zones in 2008 and 2020 as shown in Table 4.

Table 4: The changing trends of rural occupations in different functional areas

Functional zone	Year	Total number of rural employees (in ten thousand)	Primary industry (%)	Secondary industry (%)	Tertiary industry (%)
E1	2008	101.5	4.43	24.97	70.6
	2020	230.69	2.61	17.34	80.05
E2	2008	62.1	24.63	32.19	43.18
	2020	72.88	24.63	32.19	43.18
E3	2008	155.97	38.36	20.05	41.59
	2020	103.83	11.09	27.27	61.64

Changes in the occupational structure of rural areas located in different functional zones also show a tendency towards non-agriculturalization. Non-farm occupations predominate in the rural areas of the (E1) Urban Function Expansion Zone and the (E2) New Urban Development Zone, where the share of agriculture is only 38.36% at the highest. The share of the population engaged in related occupations characterized by services increases significantly, especially in the rural areas of the new urban development zones. (E3) In the rural areas of the ecologically sheltered development zones, the proportion of the population engaged in agricultural occupations decreases, by 27.27% compared to 2008, and the occupational structure shows a tendency towards non-agriculturalization. In other words, the rural occupational structure has changed towards non-agriculturalization, both in areas close to the center and in peripheral areas.

V. Conclusion

For the rural areas of Jilin Province, which are facing multiple challenges of industrial structure transformation and upgrading, population outflow and residential environment improvement, this paper builds a two-way gray correlation model based on slope difference as an analytical method for the time-series changes in the efficiency of their rural occupational development and residential function.

The analysis of the correlation between vocational development and residential function of 15 counties and districts in U City, Jilin Province from 2008 to 2020 based on the two-way gray correlation model shows that the coordination between rural vocational and economic development in U City in 2008 and 2020 is general, and the rural vocational development is not fully adapted to its economic development. Based on the correlation between rural vocational education and economic development in Jilin Province, the evaluation model of the coordinated transformation degree of occupation and residence is established.

With the diversified development of Jilin Province's rural territorial functions oriented to residence, production and production, its agricultural occupation no longer occupies a dominant position, and more tertiary industries are dominant. In rural areas where ecological conservation and development is the main functional area, the proportion of the population engaged in agricultural occupations has decreased by 27.27% compared with 2002.

Data Availability Statement

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to the ongoing nature of the research.

Conflicts of Interest

The authors declare no conflicts of interest.

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