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Impact of Different Models of Relocating Coal Mining Villages on the Livelihood Resilience of Rural Households—A Case Study of Huaibei City, Anhui Province

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Abstract: Applying the livelihood resilience theory to the relocation of coal mining villages, the present study explored the levels and the factors hindering livelihood resilience among farmers under different relocation models. This has important implications for enhancing the livelihood resilience of farmers during coal mining relocation and promoting rural revitalization in coal mining areas. Based on the livelihood resilience framework and the actual conditions of mining areas, we formulated an evaluation index system, employed the stratified mean square deviation method to determine weights, used the comprehensive index method to assess the livelihood resilience level, and investigated the obstacles to livelihood resilience among farmers under different relocation models using the random forest model. The results indicate the following: first, the overall livelihood resilience level in the coal mining relocation area of Huaibei City is low and is not significantly different among the four types, with the ranking being as follows: central village agglomeration type > township-centered village construction type > mining-village combination type > suburban community type. Significant differences exist in the indicators and dispersion levels of the resilience dimensions of buffering capacity, self-organization ability, and learning ability among farmers under different relocation models. Second, factors such as household deposits, labor force quantity, social networks, and participation in village collective meetings significantly affect the livelihood resilience level of farmers. However, the degree of influence varies under different relocation models. Third, improvements such as increasing employment opportunities, investing in education resources, and building social networks are necessary to improve farmers' livelihoods under the four types of relocation models.

Keywords: livelihood resilience; relocation of coal mining villages; farmers; influencing factors; Huaibei City

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1. Introduction

Due to the abundance of natural resources in China, resource-based cities have contributed substantially to the country's socio-economic growth. Nevertheless, due to irrational resource planning and overexploitation, resource-based city depletion has emerged as a formidable global issue [1]. In regions depleted of natural resources, the ecological underpinnings of vegetation and land have been compromised, resulting in laborious and time-intensive undertakings including ecological restoration and environmental management. Furthermore, resource-based cities exhibit a significant reliance on external resources, which leads to inadequate endogenous dynamics and a diminished standard of living in the short term. Cities that have depleted their internal resources are confronted with the challenge of navigating the disruptions caused by the external environment. As a result, the socio-economic system becomes more visibly vulnerable [2]. The majority of extant research centers on government intervention in resource-depleted cities and the promotion of high-quality development in such areas from the standpoint of local governments. This includes examining the effects of government policies on resource-exhausted city programs [3], and industrial transformation in resource-depleted regions [4], energy efficiency [1], as well as regional innovation in China [5]. All of the findings suggest that government policies significantly contribute to the advancement of resource-depleted cities. However, there is a scarcity of research examining the micro-family livelihood status of farmers residing in resource-depleted urban areas, particularly in regions where coal mining villages have been relocated. The relocation of coal mining villages is distinctly different from regular relocations. When coal mining takes place, the land experiences phenomena such as ground cracks, subsidence, and water accumulation, making it impossible to restore some of the original village sites and arable land to their pre-mining state [6]. Relocated families undergo the dual effects of changes in local production and living environments and socio-economic transitions, resulting in the disruption or termination of their livelihood activities and formidable challenges to their livelihood systems [7].

Livelihood resilience refers to the ability of communities or households to cope with and absorb changes, thereby transforming their livelihood patterns to adapt to challenges and changes [8]. With the gradual impact of socio-ecological system changes on livelihood systems, the concept of livelihood resilience has gained increasing attention [9,10]. Although scholars have different interpretations of the concept [11], the preliminary consensuses are as follows: (1) livelihood resilience presupposes that the system has been subjected to external disturbances, including human and natural interferences and (2) the livelihood system can withstand external disturbances while maintaining or enhancing its attributes and functions to adapt to external changes. The integration of livelihood approaches with resilience thinking is important in understanding how rural households pursue and improve their livelihoods to effectively respond to changes and disturbances. In recent years, research on livelihood resilience has shown continuous growth both domestically and internationally, with expanding research areas focusing on livelihood resilience [12], evaluation of livelihood resilience [11,13], influencing factors [14,15], and adaptive strategies [16]. The determinants of farmers' livelihood resilience vary in accordance with the distinct categories and magnitudes of disturbances to which they are exposed. Fang et al. [17] reached the conclusion that the livelihood resilience of rural residents is primarily determined by food consumption, arable land, labor force, investment in rural public services, the number of health professionals, and the capacity of local financial supply. The study conducted by Li et al. [18] on relocation for poverty alleviation identified several key factors that significantly influence the livelihood resilience of farm households. These factors include household burden ratio, household size, education investment, government investment, and social network compactness and quality. In conclusion, the following factors exert influence: (1) economic and physical factors; (2) social factors; and (3) labor force factors. The complexity and diversity of disturbances, the variety of influencing factors on livelihood resilience, and the breadth of studies collectively contribute to the complexity and diversity of adaptive strategies for livelihood resilience. International studies on livelihood resilience predominantly concentrate on disruptions caused by natural disasters [19,20], climate change [21], food security [22], policy changes [23,24], and other related contexts. Domestically, scholars have primarily focused on the following three areas: (i) empirical research on livelihood resilience in regions characterized by poverty, ecological vulnerability, and tourism from the perspective of household livelihoods [25,26]; (ii) linking livelihood resilience with themes such as poverty alleviation, relocation, urbanization, or land consolidation; exploring their interrelationships; and using enhanced livelihood resilience to achieve poverty alleviation and reduction and sustainable migration outcomes [27,28]; (iii) analyzing the spatial dimension of livelihood resilience [29–31]. Despite considerable research on livelihood resilience, studies on the effects of long-term, high-intensity external disturbances remain limited, particularly in the context of relocation in coal mining villages. Different relocation models involve variations in the destination of relocation, compensation standards, housing construction methods, and agricultural household livelihood conditions. Understanding livelihood resilience, identifying the main obstacles to livelihood resilience, and developing strategies to enhance livelihood resilience for different relocation models are the main issues addressed in this study.

Huaibei City has significance as a prominent coal production base within China, characterized by the extensive presence of coal fields. However, in 2009, it was officially designated as a resource-depleted city, thereby indicating the depletion of its coal reserves. Consequently, the region is marked by the coexistence of numerous villages that have been affected by coal mining activities, leading to subsequent relocation. Coal-induced subsidence has been observed in varying degrees across over 300 villages. Throughout the years, Huaibei City has conducted extensive research on relocation models. The current study examines the relocating households in Huaibei City, which combines concerns regarding means of subsistence with resilience in regions relocating for coal mining. An evaluation index system was developed for livelihood resilience in areas designated for the relocation of coal mining villages, in accordance with the livelihood resilience framework. The current study examined the determinants that affect the level of livelihood resilience among households residing in mining communities in relation to various relocation models, expanding the research scale and application scope of resilience theory, providing a new approach and paradigm for sustainability studies of household livelihoods. In addition, it offers theoretical and policy support for improving the livelihoods of mining area households, enhancing the livelihood resilience level of relocated farmers, and achieving rural revitalization and sustainable development in coal mining relocation areas.

2. Materials and Methods

2.1. Research Area and Coal Mining-Village Relocation Models

2.1.1. Research Area

Huaibei City, located in the northwest part of Anhui Province, China, is among the most important coal production bases in the country. The location is shown in Figure 1. The coalfields in the region are extensive, spanning over 130 km, earning it the title of "Coal City of a Hundred Miles". However, coal mining has also resulted in a large number of subsidence areas and village relocations. As of the end of 2019, Huaibei City had more than 50 identified mineral exploration sites, with a coal reserve of approximately 4.88 billion tons. Since the establishment of the city, over 1.1 billion tons of coal have been produced and 416,000 acres of land have collapsed, affecting 553 villages and approximately 320,000 people. Since the 1970s, efforts have been made to remediate 206,000 acres of deep subsidence areas, with an investment of over 15 billion yuan, resulting in the establishment of 479 relocation and resettlement areas for nearly 300,000 people. Currently, four relocation models have become more mature. This study selects the four most typical villages in Huaibei City where coal mining villages have been relocated, namely: (1) Penglou Village in Liuqiao Town, which belongs to township-centered village construction type. Liuqiao Town, Suixi County, plans new villages according to the town construction plan and the needs of the relocated people, investing 850 million yuan to build 154 new multi-story residential buildings, resettling 18,000 people from five administrative villages, and the buildings in the resettlement area are constructed in the mode of five-story plus attic and basement construction, with supporting facilities such as commercial areas, warehouses, public toilets, and a leisure and fitness square; (2) Beihunan Village and Miaoqian Village, which belong to the mining-village combination type. The villages are located within the mining area of the Yuandian mine of Huaibei Mining Group. In accordance with the principle of "relocation first, mining later", the mining enterprise submitted the village relocation program three years in advance, and adopted the cooperation method between local government and mining enterprise to relocate 8 natural villages in Wugou and

Linhuan Towns to the vicinity of the mining area, and built the new Beihunan Village to resettle more than 3000 people. (3) Renhe community in Xiangshan District is of the suburban community type. They adopted the method of building farmers' apartments according to the standards of urban residential areas, bringing farmers into the management of urban residents, and including landless farmers into the social security coverage of urban residents. The new village settlement is located in the south of the main urban area, covering an area of 395.75 acres. A total of 108 new 6-story residential buildings have been built, and 4286 households and 11,926 people have been relocated. At the same time, the community has reserved commercial storefronts as collective assets, laying the foundation for the next step of community management and property management. (4) Renji Village in Nanping Town is of the central village agglomeration type. Nanping Town, Suixi County, merged seven subsided villages into Renji Village, with 3620 people moving into 860 new houses under centralized planning, with supporting facilities such as schools, supermarkets and health clinics.

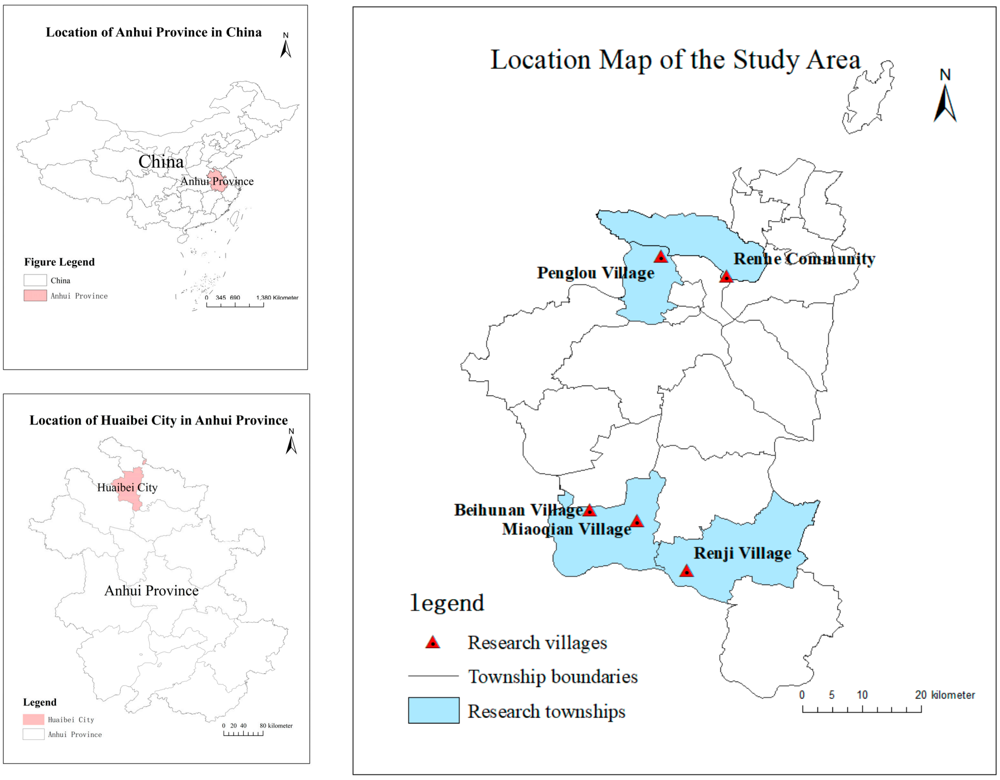

Figure 1. Geographic location of the research area.

The four relocation modes are now more mature. The specific location distribution and relocation situation is shown in Table 1.

Table 1. Basic situation in research area.

Sample Area	Belonging Type	Relocation Time	Geographical Location	Distance from the County Road	Construction Mode	Community Type	Relocation Compensation
Penglou Village	Township-centered village type	7–9 years	Near Liuqiao Town	0.2 km	Build according to the overall planning	Five-story plus attic and basement	30 m^2/person
Beihunan and Miaoqian Village	Mining-village combination type	11–13 years	Near the coal mining area	1.5–3.1 km	Build oneself	Rural community	15,000 yuan/person
Renhe community	Suburban community type	13–14 years	Close to the city	0.25 km	Build according to the overall planning	Six-story farmer new village	29.1 m^2/person
Renji Village	Central village agglomeration type	12–14 years	Independent lot	1.3 km	Build oneself	Rural community	16,000 yuan/person

2.1.2. Relocation Models for Coal Mining Villages

The relocation of coal mining villages is a special way of relocation. In practice, due to the fact that a certain place or village has rich mineral resources underneath the ground, with the mining of coal, it will make the lower land of the village appear hollow, and in serious cases, there will be a subsidence of the whole village surface, and the houses or courtyard walls will be cracked and collapsed, so that the houses of the villagers will become a "dangerous house", which will seriously affect the basic safety of the villagers' life, and so it is necessary to relocate the affected villages or the inhabitants in a holistic manner. According to statistics, the coal mining volume under "Three Downs" (buildings, railways, and water bodies) in China reaches a staggering 13.79 billion tons, with the coal mining volume under villages accounting for 60% of the total coal mining volume under buildings (approximately 5.221 billion tons). This particularly affects densely populated and village-concentrated plain areas in the central and eastern parts of China such as Jiangsu, Anhui, Henan, and Shandong, impacting 13.2164 million people. Relocation is considered the optimal solution for liberating coal resources in mining areas and protecting the lives and property of villagers. When formulating specific relocation plans for mining areas, the natural and geological conditions of the mining area location, farmers' economic resources, and other considerations like urban construction, the selection of relocation destinations and the origin and destination of relocation need to be considered.

Through years of practice and exploration, China has developed four relocation models for coal mining villages (Table 2). The township-centered village construction (TCV) model concentrates on subsiding villages into small towns, combining them with the public infrastructure resources of the towns, and implementing urbanization management for relocated farmers. This model is suitable for villages that are relatively close to townships and are somewhat dispersed. Centering around the townships involves moving villages, expanding the scale of the town, and enhancing the functions of the market town to accelerate the development of new rural areas. The mining-village combination (MVC) model utilizes cooperative efforts between the mining industry and the village for relocation and resettlement. The model relies on the basic infrastructure of the mining area such as electricity supply, water supply, road construction, and social resources like shops, hospitals, and schools. This model involves relocating coal mining villages to the vicinity of the mining area and is suitable for small-scale villages around remote mining areas. The suburban community (SC) model applies to coal mining villages near central cities, constructing new relocation settlements according to the standards of residential neighborhoods, and integrating relocated farmers into urban resident management. This model is suitable for coal mining villages that are relatively close to towns and whose residents primarily engage in non-agricultural occupations (or whose occupations can be easily transformed into non-agricultural ones). This aims to achieve urbanization management for households or workers in mining areas and expedite the process of urban–rural integration. The central village agglomeration (CVA) model breaks the existing administrative divisions and concentrates on the relocation of coal mining villages by merging small villages into larger ones and strengthening dominant villages. This model aims to optimize resource allocation and is suitable for villages with extensive agricultural production and chooses a distant village with a larger population and scale or a geographically superior village as the central village, gradually attracting surrounding villages to concentrate around this focal point.

Table 2. Basic information on different relocation models.

Relocation Mode	Relocation Scale (Person)	Distance from Town (km)	Land Use Type	Types of Livelihood Activities	Mine Distribution
Township-centered village	18,000	0–5	Cropland and construction land	Agricultural employees	More concentrated
Mining-village combination	3000	>15	Cropland and construction land	Agricultural employees and self-cultivated small farmers	More dispersed
Suburban community	12,000	0–10	Construction and commercial service land	Agricultural employees and businesses	More concentrated
Central village agglomeration	40,000	>10	Cropland and construction land	Agricultural employees and agricultural business entities	More dispersed

2.2. Data Source

2.2.1. Questionnaire Survey

The primary method used in this study was the questionnaire survey. Prior to this study, relevant basic information on the social, economic, and ecological aspects of the county and township where the resettlement village is located was collected from various government departments. This was performed to gain a general understanding of the area. The following two methods of survey were employed: key informant interviews and random household surveys. Key informant interviews were conducted with township officials, village chiefs, or village team leaders to obtain an overall understanding of the relocation process and changes in livelihoods. Random household surveys were conducted to gather information on the actual livelihood conditions of the households.

The survey was divided into the following three parts: (1) preliminary research: prior to the formal survey, a preliminary investigation was conducted in February 2022 and eight to 10 households were randomly selected from each township for an overall picture of their situation; (2) formal research: based on the preliminary research, the original questionnaire was improved and revised and the formal field survey was conducted in March and April 2023, with 15–20 sample households selected from each village for the survey; to cover households with different levels of education, face-to-face interviews were conducted for 20–30 min per household; and (3) supplementary research: in May 2023, supplementary research was conducted to fill in missing or incomplete data.

Moreover, due to the lengthy relocation period in the selected region, young individuals have a weaker perception of the relocation process. Therefore, interviews were conducted with adult male participants aged over 30 years and adult female participants aged over 35 years. A total of 514 questionnaires were distributed in this survey. After excluding invalid and abnormal questionnaires, 508 valid questionnaires were obtained, resulting in a response rate of 98.83%. The questionnaire mainly covers five aspects: (1) basic information of the household, including family population structure and health level of family members; (2) household livelihood capital, including natural capital (such as various types of agricultural and cash crop planting areas, and livestock breeding numbers); financial capital (including family income and saving status); material capital (including the number of fixed assets owned by the family, housing quality and area); social capital (sharing knowledge ability and social networks, etc.); (3) Policy sensitivity (understanding of resettlement policies, participation in village collective meetings, etc.); (4) Livelihood risk perception and adaptation strategies (degree of social integration, information acquisition ability, etc.); (5) Welfare perception (life confidence index, attitude towards coal mine development, etc.). Table 3 shows the basic characteristics of the survey sample.

Table 3. Basic characteristics of the sample.

Variable	Option	Frequency	Percentage	Variable	Option	Frequency	Percentage
Sex	Male	248	48.81%	Degree of education	Illiterate	60	11.81%
	Female	260	51.18%		Primary school	183	36.02%
Age	20–40 years	179	35.23%		Junior school	209	41.14%
	40–60 years	226	44.48%		Senior high school	45	8.86%
	>60 years	103	20.20%		University or above	11	2.17%
Relocation mode	Township-centered village construction model	136	26.77%	Health condition	Good	417	82.09%
	Mining-village combination type	132	25.98%		Common	56	11.02%
	Suburban community type	131	25.79%		Seriously ill and unable to work	25	4.92%
	Central village agglomeration type	109	21.46%		Physical disability	10	1.97%

The obtained data results were imported into SPSS (27.0) for analysis. Furthermore, the reliability and validity of the scale data were tested. Cronbach's α was $0.745 > 0.7$, indicating a high level of reliability of the questionnaire data. The Kaiser–Meyer–Olkin measure (0.729 > 0.7) and Bartlett's test of sphericity ($p = 0.000$) indicated that the questionnaire had good validity. The SPSS analysis demonstrated that the questionnaire data were meaningful and ensured the reliability and accuracy of the research findings based on these data.

2.2.2. Construction of an Indicator System

Numerous domestic and international studies have examined evaluation frameworks and theoretical research related to livelihood resilience. These include sustainable livelihood and livelihood resilience frameworks. However, currently, no unified evaluation framework is available. Speranza, through a review and integration of literature on livelihoods and resilience theories and experiences, proposed a framework for comprehensive empirical analysis of livelihood resilience. This framework holds significant importance for the quantification of livelihood resilience and has been widely applied [32,33]. This framework consists of the following three main components: buffering capacity, self-organizing capacity, and learning capacity. Buffering capacity refers to the ability of a system to withstand external shocks and simultaneously utilize new opportunities to achieve better livelihood outcomes [17]. Self-organizing capacity emphasizes the agency of groups [34]. Learning capacity implies adaptive management and encompasses the ability to acquire experience, knowledge, or skills and translate theoretical knowledge into practical action. In this study, based on the actual situation in mining area relocation, we constructed the livelihood resilience evaluation indicator system shown in Table 4.

Table 4. Livelihood resilience evaluation indicator system.

Dimension Layer	Index Layer	Index Definition and Assignment	Attribute	Weight
Buffering capacity (0.31)	Labor force (X_1)	Working ability of family members of farmers.	+	0.1680
	Cultivated land area (X_2)	Existing cultivated land area, including the area of cultivated land transferred out and planted by itself (acres).	+	0.1258
	Environmental quality status (X_3)	Environmental changes after relocation. Significantly better = 4; slightly better = 3; little change = 2; variation = 1	+	0.1534
	Health status of family members (X_4)	Annual investment in medical treatment (RMB).	-	0.0854
	Per capita income (X_5)	The ratio of the total annual income of farmers' families to the total family population.	+	0.1179
	Physical capital (X_6)	The main means of production and living in families.	+	0.1133
	Housing capital (X_7)	Expressed in terms of the housing area and housing structure.	+	0.0731
	Household deposit (X_8)	Total household deposits.	+	0.1631
Self-organization ability (0.37)	Social network (X_9)	It consists of two aspects: the relationship and trust of the neighbors. Bad = 1, poor = 2, general = 3, better = 4, very good = 5.	+	0.1658
	Leadership potential (X_{10})	Number of family members who are party members or village cadres.	+	0.1182
	Leadership of Community cadres (X_{11})	Very low = 1, low = 2, general = 3, high = 4, very high = 5.	+	0.1492
	Traffic accessibility (X_{12})	Distance from the nearest county road (km).	-	0.1844
	Family Life Confidence Index (X_{13})	Very low = 1, low = 2, general = 3, high = 4, very high = 5.	+	0.0983
	Attitude toward the development of coal mines (X_{14})	The development of coal mining areas meets the livelihood of farmers. Very dissatisfied = 1, less satisfied = 2, generally satisfied = 3, relatively satisfied = 4, very satisfied = 5.	+	0.1293
	Life improvement expectation index (X_{15})	Very low = 1, low = 2, general = 3, high = 4, very high = 5.	+	0.1547
Learning ability (0.32)	Investment in education (X_{16})	Annual investment in education (RMB).	+	0.0729
	Participation in village collective meetings (X_{17})	Whether to participate in the village meeting. Yes = 1, no = 0.	+	0.2340
	Information acquisition ability (X_{18})	Watching TV or browsing the Internet every day (h).	+	0.0969
	Sensitivity to relocation policy (X_{19})	Understanding of relocation policy. Know well = 1, know a little = 2, do not know = 3.	+	0.1569
	Degree of social integration (X_{20})	Better = 3, can be = 2, difficult = 1.	+	0.1460
	Risk perception (X_{21})	Relocation has obvious risks = 4, a small amount of risk = 3, no change = 2, risk reduction = 1.	-	0.1331
	Ability to share knowledge (X_{22})	Very low = 1, low = 2, general = 3, high = 4, very high = 5.	+	0.1602

2.3. Research Methodology

2.3.1. Measurement of Livelihood Resilience

Data Standardization and Determination of Indicator Weights

(1) Due to differences in scale and nature among the original data, the extreme value method was employed to standardize the indicator data to eliminate differences and enhance comparability. The formula is as follows:

$$\begin{aligned} X_{ij} &= \left[\frac{\left(x_{ij} - \min x_{ij}\right)}{\max x_{ij} - \min x_{ij}}\right] \\ X_{ij} &= \left[\frac{\left(\max x_{ij} - x_{ij}\right)}{\max x_{ij} - \min x_{ij}}\right] \end{aligned} \quad (1)$$

where x_{ij} is the original research data value and X_{ij} represents the value after normalization.

(2) The weights of each indicator were determined using the stratified mean-variance decision-making method. The specific formula can be found in [35].

The indicator layer weight calculation formulas are as follows:

$$u_{ij} = \frac{1}{m}\sum_{i=1}^{m} X_{ij} \quad (2)$$

$$s_{ij} = \sqrt{\sum_{i=1}^{m} \left(X_{ij} - u_{ij}\right)^2} \quad (3)$$

$$w_{ij} = s_{ij} / \sum_{i=1}^{m} s_{ij} \quad (4)$$

where m represents the farmers, n represents the indicators, u represents the average of the indicator layer, s is the variance of the indicator layer, and w is the weight of the indicator layer.

The formulas for calculating the criterion layer are as follows:

$$r_j = \sum_{i=1}^{m} w_{ij} X_{ij} \quad (5)$$

$$U_j = \frac{1}{n}\sum_{j=1}^{n} r_j \quad (6)$$

$$S_j = \sqrt{\sum_{j=1}^{n} \left(r_j - U_j\right)^2} \quad (7)$$

$$W_j = S_j / \sum_{j=1}^{3} S_j \quad (8)$$

where U is the average of the criterion layer, S is the variance of the criterion layer, and W represents the weight of the criterion layer. The weight calculation results are shown in Table 4.

Calculation of Livelihood Resilience

The livelihood resilience index was calculated using the composite index method, wherein livelihood resilience is the sum of buffering capacity, self-organizing capacity, and learning capacity. The formulas for the livelihood resilience index are as follows:

$$D_{ij} = W_j \times \sum_{j=1}^{n} w_{ij} X_{ij} \quad (9)$$

$$LR = D_{Bj} + D_{Sj} + D_{Lj} \tag{10}$$

where D represents the values of each dimension, LR represents the magnitude of livelihood resilience, B represents buffering capacity, S represents self-organizing capacity, and L represents learning capacity.

2.3.2. Analysis of Influencing Factors

Random forest is a machine-learning algorithm proposed by Breiman, a member of the National Academy of Sciences [36]. The algorithm is a Bagging algorithm with decision trees as estimators, combining multiple decision trees, each time the dataset is selected randomly and with put back, while randomly selecting some features as inputs. Due to its unique algorithm advantages, the model can be used for clustering discrimination analysis and regression analysis to study the importance of numerous influencing factors [37].

The specific algorithm steps are:

(1) Assuming the size of the training set T is N, the number of features is M, and the size of the random forest is K.
(2) There is a method of putting back sampling from training set T, sampling N times to form a new sub training set D.
(3) Randomly select m features, where m < M.
(4) Using the new training set D and m features, learn a complete decision tree to obtain a random forest.

This study uses R language to perform random forest model operations and measures the relative importance of each variable to the results, where 80% of the data is used as a training set to train the model and 20% is used as a test set to prevent model overfitting. By adjusting the parameters of ntree and mtry to obtain the optimal model (where ntree is the number of decision trees contained in the specified random forest; mtry is the number of variables used for binary trees in the specified node), the main parameters of the optimal model are: p = 0.8, ntree = 1000, mtry = 2. For the trained random forest model, the importance ranking of indicators is carried out.

In the actual use process, first rank the overall indicators of the livelihood resilience of the four relocation modes based on the degree of obstacles; There are three dimensions in each mode: buffering ability, self-organizing ability, and learning ability. To analyze the obstacle factors in each dimension in detail, a regression model is constructed between each indicator layer and dimension layer in buffering ability, self-organizing ability, and learning ability, and the relative importance of each variable to the results is accurately measured, while the fitting accuracy is judge.

3. Results

3.1. Evaluation of Livelihood Resilience

Using the formulas mentioned above, the evaluation results of livelihood resilience were calculated and imported into SPSS for statistical analysis. The K-means clustering method was employed to classify the indicators into the following five levels: low, relatively low, middle, relatively high, and high. Table 5 presents the classification results. Furthermore, a detailed explanation is provided for the dimensions of buffering capacity, self-organization capacity, learning capacity, and the livelihood resilience indicator.

Table 5. Classification of livelihood resilience by dimension.

Dimension	Low	Relatively Low	Middle	Relatively High	High
Buffer capacity	0.2766	0.3526	0.4338	0.5300	0.6632
Self-organizing ability	0.3603	0.4799	0.5872	0.6713	0.7667
Learning ability	0.2191	0.3351	0.4284	0.5734	0.7202
Livelihood resilience	0.3671	0.4371	0.4957	0.5654	0.6587

Considering the large and scattered nature of the dataset in this study, box plots were used to intuitively depict the values for each dimension of livelihood resilience (Figure 2). Additionally, box plots are resilient to the influence of outliers, enabling the visualization of data dispersion, overall distribution patterns, and skewness. As the overall distribution of this dataset is relatively uniform, the mean values in the box plots are a representative measure of the overall level of each dimension.

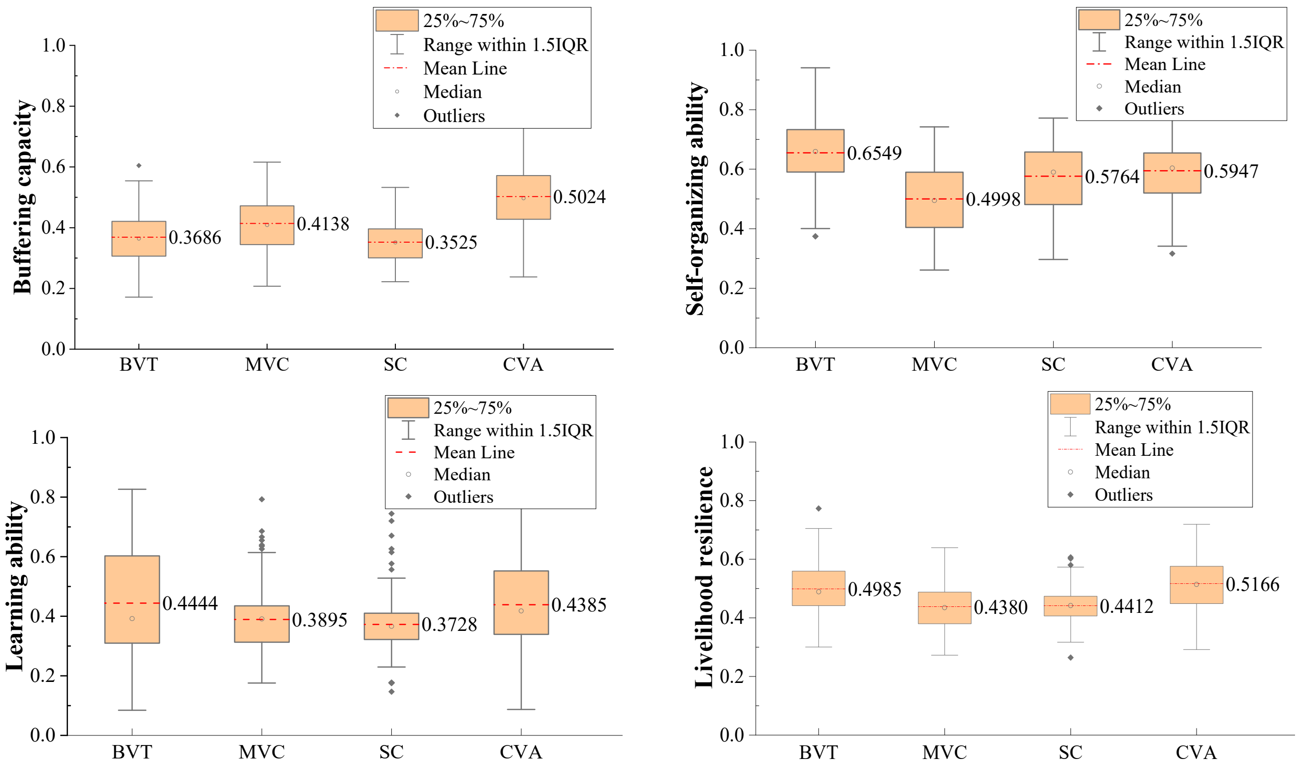

Figure 2. Evaluation indicators of livelihood resilience for different relocation modes.

3.1.1. Buffering Capacity

Figure 2 shows that the buffering capacity is not high in any of the four relocation modes. Among them, the suburban community type (0.3525) < township-centered village construction type (0.3686) < mining-village combination type (0.4138) < central village agglomeration type (0.5024). Referring to Table 5, the buffering capacity of the suburban community type is relatively low, whereas those of the township-centered village construction and mining-village combination types are moderate. The central village agglomeration type exhibits the highest buffering capacity among the four types, indicating a higher level. Moreover, the larger the "box" in the box plot, the greater the dispersion. Among the four relocation types, the central village agglomeration type demonstrates the greatest dispersion, resulting in the most scattered outcomes. Contrarily, the suburban community type displays the smallest dispersion, revealing minimal internal differences. The results of the township-centered village construction and suburban community types are similar and possess the smallest overall indicators.

3.1.2. Self-Organization Capacity

Figure 2 shows that the self-organization capacity of relocated coal village areas is generally high. Among them, the township-centered village construction type (0.6549) > central village agglomeration type (0.5947) > suburban community type (0.5764) > mining-village combination type (0.4998). Referring to Table 5, the township-centered village construction type and central village agglomeration type exhibit moderate self-organization capacity, whereas the suburban community type and mining-village combination type demonstrate lower self-organization capacity. The suburban community and mining-village combination types display higher dispersion, indicating substantial internal differences among households. Conversely, the township-centered village construction type and central village agglomeration type show lower dispersion, with similar internal differences. Additionally, both the suburban community and central village agglomeration types for self-organization capacity approach the upper quartile of the box plot, suggesting a concentration of internal self-organization capacity at a higher position.

3.1.3. Learning Capacity

Figure 2 shows that, among the four relocation types, the township-centered village construction type (0.4444) > central village agglomeration type (0.4387) > mining-village combination type (0.3895) > suburban community type (0.3728). Referring to Table 5, the average learning capacity of all four relocation types falls within the lower level. The box plot highlights significant variation in learning capacity among the four types, with the township-centered village construction type exhibiting the highest dispersion and the largest internal differences. This is followed by the central village agglomeration type, whereas the suburban community type displays the smallest internal differences. Furthermore, outliers are more prevalent in the mining-village combination and suburban community types. Upon individual case examination, these outliers were determined to belong to correctly recorded datasets.

3.1.4. Livelihood Resilience

Figure 2 shows that, among the four relocation types, the central village agglomeration type (0.5166) > township-centered village construction type (0.4985) > suburban community type (0.4412) > mining-village combination type (0.4380). Referring to Table 5 and the classification criteria, the livelihood resilience level of the central village agglomeration type is categorized as moderate, whereas the other three types fall within the lower level. The box plots demonstrate relatively small dispersion for all four types, indicating a balanced distribution of the overall livelihood resilience level.

3.2. Analysis of Factors Influencing Livelihood Resilience Capability

In the present study, the random forest algorithm was employed to quantitatively investigate the importance of various dimensions in different relocation modes. The importance of influencing factors within each dimension was ranked within the constructed livelihood resilience assessment framework. In the random forest model, incremental mean squared error (IncMSE) can be used to evaluate the explanatory power of each independent variable on the dependent variable. A higher IncMSE value indicates a greater contribution of the independent variable to the explanation of the dependent variable. In this study, the magnitude of this value was used to represent the relative importance of each factor. The Var explained value represents the overall explanatory power of the prediction variables on the response variable, with higher values indicating a more accurate model and higher explanatory power. To facilitate comparison, the results were subsequently normalized. The prediction accuracy ranged from 80.25% to 92.94%, indicating relatively high accuracy. The contributions of the identified influencing factors were plotted as a radar chart (Figure 3).

3.2.1. Influencing Factors of Livelihood Resilience

The results of the random forest model indicated that the barriers to livelihood resilience under different relocation models are broadly similar, but the differences in the specific degree of barriers are more obvious (Figure 3). The top 25% of indicators under each relocation type were selected for analysis. For the township-centered village type relocation model, whether or not to participate in village collective meetings, social network and household savings are the three most important impact indicators; the main factors affecting the mining-village combination model are whether or not to participate in village collective meetings, the ability to share knowledge and the leadership ability of community cadres; the main factors affecting the suburban community model are life improvement expectation index, number of labor force and leadership ability of community cadres; and the main obstacle factors of the central village agglomeration relocation model are participation in village collective meetings, household savings and per capita income. Although the influence factors and the degree of influence are different in the four relocation models, it is clear from the results that the indicator "whether to participate in village collective meetings" has a greater degree of influence on all relocation models, especially township-centered village model, where the degree of obstacle is as high as 21.41%.

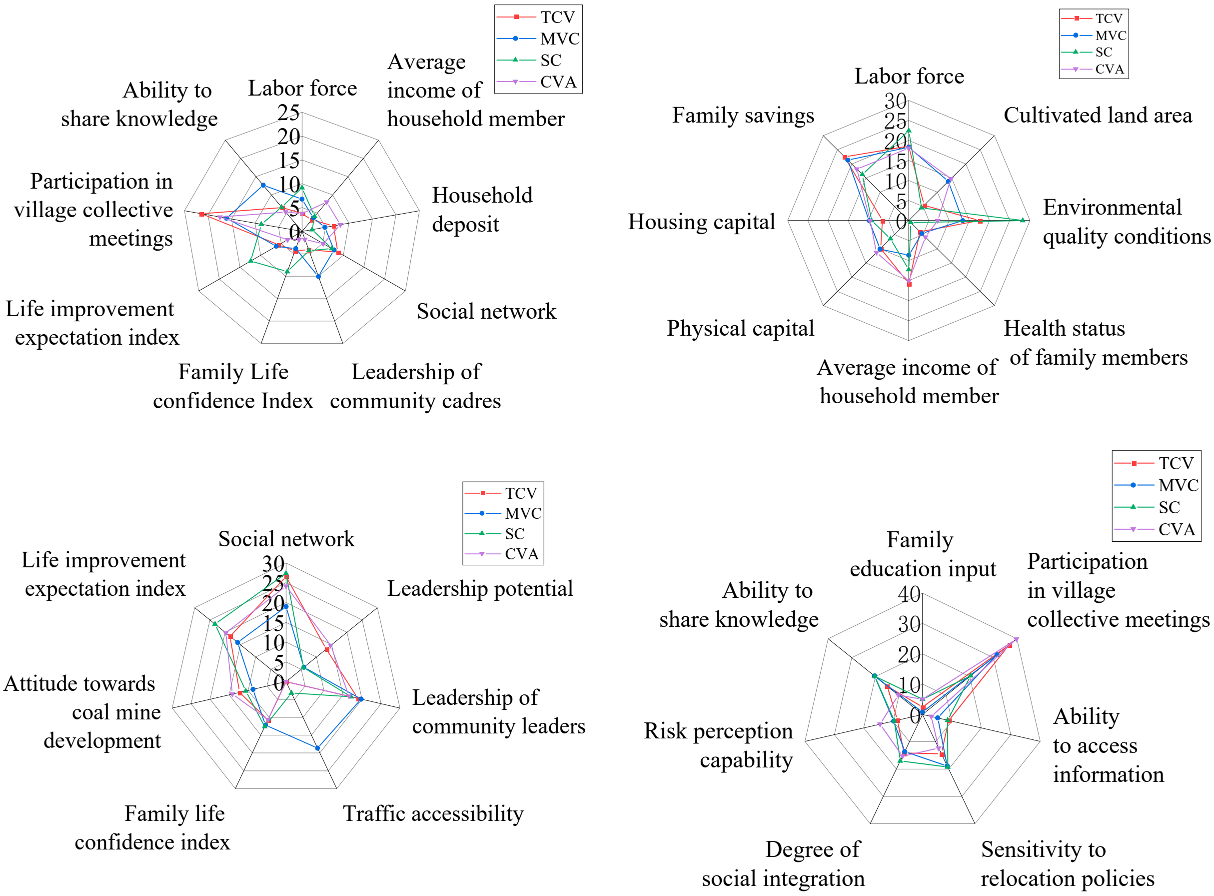

Figure 3. Influencing factors of livelihood resilience in different relocation modes.

3.2.2. Influencing Factors of Buffering Capability

Figure 3 shows that, among various factors influencing the villagers in different relocation modes, family savings, followed by labor force quantity, is the most important indicator for township-centered village construction type households. For the mining-village integrated type, the main influencing factors are also family savings and labor force quantity. The predominant factors for suburban community type are environmental quality and labor force quantity. The major barriers to buffering capability for central village cluster-type households are family savings, labor force quantity, and per capita income. The impact of these three indicators is similar and they are closely related to economic capital. In summary, among the four relocation types, economic and human capital are the main reasons that influence the family buffering capability. The more family savings and labor force, the stronger the ability to buffer against external risks.

3.2.3. Influencing Factors of Self-Organization Capability

Based on Figure 3, overall, the social network is the main factor influencing the self-organization capability of coal-pressure villages. For the township-centered village construction type, the most important factors influencing self-organization capability are social networks, the leadership ability of community cadres, and the index of expectations for improved living conditions. For the mining-village integrated type, the highest contributing factor is the leadership ability of community cadres, followed by social networks and transportation accessibility. For the suburban community type, the main influencing factors of self-organization capability are social networks, the index of expectations for improved living conditions, and the leadership ability of community cadres. For the central village cluster type, the most important factors are social networks and the index of expectations for improved living conditions.

3.2.4. Influencing Factors of Learning Capability

According to Figure 3, the main factor influencing the learning capability of relocated farmers is their participation in village collective meetings, which has a relatively high overall contribution. For township-centered village construction type, the most important factors are participation in village collective meetings and the ability to share knowledge regarding the sensitivity to relocation policies, particularly participation in village collective meetings, which has a contribution percentage as high as 36.67%. The contributions of the above three factors are similar for the mining-village integrated type. For the suburban community type, the most significant influencing factors are participation in village collective meetings, the ability to share knowledge, and sensitivity to relocation policies. For the central village cluster type, the most significant influencing factors are participation in collective meetings, social integration level, and risk perception.

4. Discussion

4.1. Impact of Different Relocation Models on Livelihood Resilience Indicators

Overall, the buffering capacity results for town relocation and suburban community models have relatively lower overall indicators. These two types of relocations have similar compensation standards, similar living environments, and relatively small living spaces. The Penglou Village community has better governance with a well-established community activity center and strong self-organizational capacity. The suburban community households are closer to the town, with a higher number of nearby job opportunities and fewer left-behind populations and children (26.71%). Education and healthcare facilities are relatively well developed, resulting in a stronger learning ability. However, due to better access to resources in the region, the households in this area aim for higher standards, leading to lower subjective satisfaction and ultimately lower overall livelihood resilience indicators.

The combined mining-village relocation model offers larger housing spaces for households—with an average size of 194.58 m^2—that can adequately meet the family's living standards. Additionally, they have cultivated land that can satisfy the household's basic food needs and have a larger labor force, resulting in a stronger buffering capacity. However, due to the remote locations of Beihunan Village and Wanglou Village from the town, the proportion of people working in nearby mines is less than 5%. The primary labor force in rural areas chooses to work outside the village throughout the year, leading to a higher proportion of older adults and left-behind children in the village (40.38%). Consequently, the self-organizational and learning abilities of the community are lower, resulting in the lowest level of livelihood resilience indicators among the four relocation models.

The central village agglomeration relocation model offers higher compensation standards that can provide resettlement with new homes based on the current price standards. Before and after relocation, housing types remain the same, with brick houses and relatively larger residential areas. Additionally, Renji Village in Nanping Town has abundant cultivated land resources, with an average of 12.4 mu per household, which can satisfy the basic food needs of the family. The centralized residential area covers an area of 500 mu and can accommodate 15,000 people, forming a relatively concentrated population. As the relocation area is located in rural areas, the education level of the main labor force in households is generally low, with 83.3% possessing only primary school or junior high school education or being illiterate, resulting in relatively poor information acquisition abilities.

4.2. Influences of Different Relocation Models on Livelihood Resilience Factors

Based on field research, for relocation areas dependent on the town, the amount of cultivated land is not the main indicator affecting buffering capacity. The main source of income is migrant work. Penglou Village has relatively good community governance and good overall satisfaction of villagers. The proportions of generally satisfied, moderately satisfied, and very satisfied households account for 79.13%. Therefore, neighbor relationships and the leadership capacity of community cadres are the main indicators that influence community resilience. Additionally, the party and mass cadres in the Penglou Village community demonstrate good leadership and play a leading role. Relatively frequent village collective meetings take place, making participation in these meetings the most important influencing factor.

In the combined mining-village relocation model, households are self-built and the relocation process is relatively long. With a compensation standard of 15,000 RMB/person at the time, it can generally meet the housing construction needs. After the new houses are built, the family's economic capital becomes the main constraint on buffering capacity. The distance from the county road is relatively far for households in the combined mining-village model. Beihunan Village is approximately 1.5 km away from the county road, whereas Wanglou Village is approximately 3.1 km away. Compared to the other three models, different transportation accessibility has the strongest impact on self-organizational capacity.

The main factors contributing to the suburban community's characteristics are the environmental quality and its location on the outskirts. The area has favorable hygiene and greenery conditions, resulting in a satisfaction rate of 91.59% among the residents regarding the environmental quality. This quality serves as an important indicator influencing the community's buffering ability. Furthermore, the farmland in this region has been requisitioned, and the primary source of household income comes from out-of-town work. The proximity to the city center provides abundant employment and learning opportunities. Additionally, the densely populated nature of the community fosters frequent interpersonal communication, enhancing the ability to share knowledge. The proximity of suburban residents to commercial areas results in a relatively high pursuit of lifestyle consumption levels, significantly impacting their expectations for improved living standards, which, in turn, influences self-organization.

In central village cluster areas, the living conditions in the villages are similar, with sufficient farmland to meet the food needs of farmers. The demand for housing construction can be met with the compensation standards of the time, which were 16,000 per person. In addition, the village has a larger population and is more concentrated, fostering closer communication among neighbors. The relocation process in Renji Village is longer, resulting in a relatively stable life. The houses are also self-built, eliminating issues such as difficulties in moving upstairs and enabling better overall integration.

4.3. Strategies to Enhance Livelihood Resilience under Different Relocation Models

The overall resilience level of relocated areas of coal mining villages is relatively low. Among them, the resilience of mining-village integrated types is the lowest, whereas the resilience of central village agglomeration types is the highest. Among the numerous influencing factors, the main obstacles for different types of relocated households vary. Therefore, corresponding strategies should be proposed according to the specific regional conditions.

For the township-built village relocation model, it is necessary to focus on the social network relationships in the area and utilize local activity centers and entertainment facilities to promote integration and communication among households. In the mining-village integrated regions, it is necessary to introduce employment opportunities and increase investment in education. Simultaneously, organizing learning and skills training programs will help absorb labor from the older adult population who have relatively weaker capacities. In the urban–suburban community relocation model, it is important to focus on self-organization ability. Efforts should be made to organize community activities, establish activity centers, and hold regular cultural events to bring households closer together. Village cadres and party members should conduct propaganda and organization.

4.4. Comparative Analysis

Fewer previous studies in the field of relocation of coal-suppressed villages have dealt with livelihoods. Most international coal mines are open-pit mines, and there is no acute conflict between people and land. The research on coal-suppressed villages in China mostly focuses on how to obtain construction land indicators [6], how to concentrate relocation [38], land policy research and relocation model research [39]. The relocation of coal-suppressed villages is different from general relocation in that after underground coal mining, land cracks, subsidence, and waterlogging will occur, and some of the original homesteads and arable land cannot be restored to their pre-mining appearance, and the level of resilience of the livelihoods of the farming households is generally low. Existing studies on the livelihoods of relocated farm households have mostly focused on disaster and poverty areas, in which Liu et al. [40] studied the status of livelihood resilience levels in resettlement areas due to disaster in China, and their results similarly showed that the livelihood resilience scores in relocated areas were lower, which is consistent with the findings of this study. However, the impact of relocation on livelihood resilience is not always the same, and there are also studies that prove that resettlement produces significant positive environmental effects and social impacts [41], which can increase incomes, expand employment opportunities, and improve life and livelihood conditions [42,43]. In addition, although relocation gives resettlement compensation, the huge resettlement cost is also a huge expense, which will bring new challenges to the relocated population [44,45], and agriculture can no longer satisfy the basic life of the relocated population, and they will choose to migrate to the city to seek for diversified livelihood strategies. At this time, the closer to the city, the more the opportunities for learning and employment for the farming households, which is in line with the results of this study. Li et al. [18] explored the impact of different relocation modes on the livelihood resilience of immigrants from impoverished areas. Although the reasons and results of relocation are different, the impact of different relocation modes on the resilience of farmers' livelihoods is similar to the results of this study.

Compared with the existing studies, the contribution of this study is to introduce the concept of livelihood resilience into the field of relocation of coal-suppressed villages, which expands the research field of livelihood resilience and is of great significance in measuring and improving the livelihood resilience of relocated farm households. In addition, through empirical analyses, this paper explores in detail the level of livelihood resilience and influencing factors of farm households under different relocation modes, which also provides guidance to the government in formulating relocation policies for coal-suppressed villages. However, there are some limitations in this study. First, this paper selects several typical areas in Huaibei City where coal-suppressed villages have been relocated, but the relocation time of these four areas is relatively long, most of them are even more than ten years, so this study lacks the impacts of different relocation times on the livelihood resilience of farm households in coal-suppressed villages. Secondly, during the field research, the middle-aged and elderly populations aged 45 years and above accounted for a large proportion of the population, and the young group did not live in the original village site due to going to the city to work, so the value of livelihood resilience may be lower than the real value. Thirdly, the indicators in this study are mostly from the perspective of the farm household, so the indicators may be insufficient. As such, this study should be considered factoring in the local socio-economic situation in the future, as well as taking a macroscopic perspective to study the situation in terms of livelihood resilience of the areas where coal-suppressed villages have been relocated more comprehensively.

5. Conclusions

Despite increasing empirical research on livelihood resilience in China, studies specifically on the relocation of coal mining villages are lacking. Introducing the concept of livelihood resilience into the coal mining-village relocation field is important in assessing the livelihood conditions of households and improving their livelihood resilience levels. The present study utilized 508 field survey data to examine the livelihood resilience status, including buffer capacity, self-organization ability, and learning ability, of four different types of relocated coal mining-village households. This study identified the limitations of each type and proposed targeted improvement strategies. The following conclusions were drawn:

1. Relocated coal mining areas have relatively low overall livelihood resilience level, with self-organization ability ranking higher than learning ability and buffer capacity. Among the different types, the greatest internal difference was observed in the central village agglomeration type, followed by the township-centered village construction type and the mining-village combination type, whereas the most concentrated type was the suburban community. In terms of each dimension, the buffer capacity ranked as follows: central village agglomeration type > mining-village combination type > township-centered village construction type > suburban community type; self-organization ability showed the following order: township-centered village construction type > central village agglomeration type > suburban community type > mining-village combination type; and learning ability exhibited the following order: township-centered village construction type > central village agglomeration type > mining-village combination type > suburban community type.
2. The barriers to livelihood resilience in different types of relocation models are relatively similar. Regarding buffer capacity, factors such as labor force size and family savings significantly impact human and economic capital. Regarding self-organization ability, factors such as social networks and the leadership abilities of community cadres are major obstacles. Regarding learning ability, active participation in meetings is the primary influencing factor and has a relatively high degree of impact.
3. Strategies to enhance livelihood resilience should vary according to the type of relocated households. For town-based settlement households, the focus should be on building social networks and enhancing self-organization ability. Mining-village integration households require strengthened training and improved learning ability the introduction of enterprises and increased employment opportunities in the area. Suburban community households should regularly organize community activities and leverage the leadership role of village cadres and party members. Central village agglomeration households should attract educational resources, increase investment in education, and enhance their learning ability.

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