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Livelihood resilience and livelihood construction path of China's rural reservoir resettled households in the energy transition

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The construction of reservoirs has led to difficult livelihood transitions of resettled households after relocation and resettlement, resulting in a series of socioeconomic problems. How to scientifically integrate regional resource advantages and improve the livelihood resilience of resettled households has become an important problem to be solved to prevent and resolve social equity and justice risks and sustainable livelihood development. Taking Xiangjiaba Hydropower Station (Yunnan Reservoir area) as an example, the evaluation index system was constructed from the three dimensions of buffer capacity, self-organization capacity and learning capacity, the gray correlation degree method was used to evaluate index system, and the clustering method was selected to screen the indices that have a great impact on livelihood resilience. On this basis, the comprehensive index method was used to calculate the livelihood resilience, and the contribution degree model was used to identify the main contribution factors of livelihood resilience and to explore the path of livelihood construction to improve the livelihood resilience of resettled households. The results showed that (1) the level of livelihood resilience of resettled households was not high as a whole, in which the self-organization capacity was the strongest, the buffer capacity was the second strongest, and the learning capacity was the weakest; (2) there were differences in the livelihood resilience of resettled households who choose different livelihood modes. Among them, buffer capacity, learning capacity and livelihood resilience were characterized by wage operation type > part-time balanced type > agricultural operation type > subsidy dependent type, while self-organization capacity was characterized by agricultural operation type > part-time balanced type > wage operation type > subsidy dependent type. (3) The main contribution factors of the livelihood resilience of resettled households who choose different livelihood modes are similar. The number of laborers, participation in social organizations, skills training opportunities and 11 other main indices promote the formation and development of livelihood resilience from different dimensions. (4) The livelihood of resettled households should follow the construction path of "identifying transition capacity, clarifying resource advantages, strengthening livelihood support, and promoting livelihood reorganization" to promote the comprehensive improvement of livelihood resilience, ultimately achieving sustainable livelihood and high-level welfare. The livelihood resilience of resettled households

is a continuous and dynamic development process, therefore, it is necessary to further improve the dynamic monitoring and evolution process of livelihood resilience, incorporate the impact of diverse data.This is also an important breakthrough in the study of livelihood resilience.

KEYWORDS

reservoir resettled households, just transition strategy, livelihood resilience, main contributing factors, livelihood construction path, Xiangjiaba Hydropower Station

1. Introduction

To assume the responsibility of building a community with a shared future for mankind, China has proposed a new goal of the "double carbon" strategy to promote sustainable development (Zhang Y. Z., 2021). In this context, the just transition strategy has become the guiding ideology and inevitable requirement of China's energy transition (Mazzochi, 1993; Hsiang et al., 2017; Fazey et al., 2018; Mayer, 2018; Shi, 2021; Soergel et al., 2021; Zhang Q., 2021; Ning and Yang, 2022; Wang, 2022). Clean energy such as hydropower has further improved its structural position in energy, and the reservoir, as the core facility of water projects, has also gained new opportunities and impetus for construction (Wang and Hu, 2011; Fan et al., 2020). The construction of the reservoir has effectively met the needs of people's livelihood, such as regional power generation, water supply, irrigation and flood control, but resettled households have made great sacrifices to leave their homes (Cernea and Mathur, 2007; Duan, 2007). Due to various reasons, such as the non-uniform support policies of local governments, the low actual support standards, and the lack of effective protection of direct rights and interests, the livelihood transition of resettled households after relocation and resettlement is difficult, resulting in a series of socioeconomic problems (Peng et al., 2016). Therefore, how to scientifically integrate regional resource advantages, reduce the negative impact of external disturbance on the livelihood development of resettled households, and improve the livelihood resilience of resettled households has become an important problem that urgently needs to be solved to prevent and resolve social equity and justice risks and sustainable livelihood development.

The term resilience originates from Latin and originally means the action of jumping back to the original state. Later, it was used to describe the capacity of the system to recover to the initial state when it was disturbed and stressed (Sun et al., 2007; Yan et al., 2012). Since Holling introduced the concept of resilience into the study of ecosystem stability in 1973 (Holling, 1973), the concept has been widely applied to many fields, such as social ecosystems (Huang et al., 2019), which also provides a new perspective for livelihood research. For the study of livelihood resilience, foreign countries have experienced the development process of research framework integration and empirical research. Among them, Speranza et al. built an analysis framework of livelihood restoration based on three dimensions, buffer capacity, self-organization capacity and learning capacity, which has been highly recognized by scholars at home and abroad (Speranza et al., 2014). This assessment framework has changed the past research that only focused on the livelihood capital of farmers but not on people's learning behavior and management capacity. Foreign research fields mainly focus on the concept, evaluation, influencing factors and adaptive management of livelihood resilience under specific interference, such as natural disasters, climate change, food security and policy changes (Marschke and Berkes, 2006; Gautam, 2017; Alam et al., 2018; Pu et al., 2020). In the early stage, the livelihood resilience focused on climate change in China (Yang et al., 2010). With the dramatic change in social policies, the research on livelihood resilience was gradually combined with national policies and guidelines, mainly focusing on ecosystems, disaster prevention and mitigation, targeted poverty alleviation and other fields (Chen et al., 2016; Hou et al., 2018; Li et al., 2019; Liu et al., 2019; Wu et al., 2021; Ye et al., 2021; He et al., 2022). In general, although research at home and abroad has achieved rapid development, the research objects are mainly concentrated on villagers, such as relocation, coastal fishermen, and post-disaster reconstruction. With reservoir resettlement as the research object, almost all of the literature has used the sustainable livelihood analysis framework (DFID) for reference. Exploring the livelihood level of resettlers from the five major livelihood capitals leads to the limitation that individuals rely too much on natural conditions to adjust their livelihood strategies while ignoring social relations in the face of external disturbances. Therefore, this study considered Xiangjiaba Hydropower Station (Yunnan Reservoir Area) as an example to evaluate and analyze the livelihood resilience of resettled households and their contribution factors and then designs a livelihood construction path to enhance livelihood resilience, with a view to providing a reference for the sustainable development of resettled households' livelihoods and the formulation of relevant policies and measures for later support.

2. Materials and methods

2.1. Case introduction

The Xiangjiaba hydropower station is located in Yibin city, Sichuan Province and Shuifu County, Yunnan Province. It is a cascade hydropower station at the end of the hydropower development in the lower reaches of the Jinsha River. It mainly generates electricity while taking into account flood control, irrigation and shipping functions. The construction of the project involves 3 counties, 9 towns and 42 administrative villages/communities in Suijiang County, Yongshan County and Shuifu County of Zhaotong City in Yunnan Province. The preparatory construction began in 2004, and the resettlement was completed in 2013. In December 2021, when the research group carried out the production and living standards evaluation of affected households in Xiangjiaba Hydropower Station (Yunnan Reservoir area), they found that the production and living standards of affected households in the Yunnan Reservoir area were relatively low, and there was a large gap with local indigenous households. The restoration of the livelihood level of resettled households became a major problem faced by the project. Therefore, it is of great significance for livelihood development to study livelihood resilience and explore the livelihood construction path of livelihood resilience.

2.2. Data source

To ensure the accuracy and representativeness of the data, the research group conducted a presurvey in Zhaotong city, Yunnan Province, in March 2022 and revised and improved the questionnaire. In June 2022, the research group went to Zhaotong city again to carry out a formal survey. As the project covers a wide range of areas, it is impossible to sample all the towns, villages and households involved in resettlement. According to the overall situation of resettlement of Xiangjiaba Hydropower Station (Yunnan Reservoir Area), the survey takes the stratified random sampling. A total of 700 questionnaires were distributed to resettled households in the twelve selected regions. After removing invalid questionnaires, the number of valid questionnaires was 643, with an effective rate of 91.86%.

The study used a questionnaire with quantitative measures to collect data from households at the study site, which consisted of five sections. The first section dealt with demographic information about the respondent and basic information about the resettler's household. The second part was on the household's land resource status from before and after the land acquisition. The third and fourth sections ask for information on household income and expenditures for the current year, to examine the economic conditions of the resettler's household in a comprehensive manner. The fifth part of the respondents scored their perceived livelihood resilience to identify important indices of livelihood resilience.

2.3. Method

2.3.1. Construction of the evaluation index system

Based on the livelihood resilience analysis framework constructed by Speranza et al., this study constructed the livelihood resilience evaluation index system from the three dimensions of buffer capacity, self-organization capacity and learning capacity. Referring to the existing research (Du et al., 2019; Shangguan et al., 2019; Jiang and Huang, 2020; Wang and Ma, 2020; Zheng et al., 2020; Zou et al., 2020), combined with the livelihood development environment and external disturbance in the study area, the evaluation alternative indicators are finally selected, and the results are shown in Table 1.

Buffer capacity refers to the capacity of resettled households to use their own capital to resist the interference of external changes. It is mainly measured by the five major livelihood capitals, specifically represented by indices such as per capita cultivated area to ecological environment. Self-organization capacity refers to the impact of social networks, social systems, information access and other aspects on the livelihood resilience of resettled households, which is specifically represented by indices such as policy awareness to traffic accessibility. Learning capacity refers to the capacity of resettled households to acquire knowledge and skills, as well as the capacity to transform learning capacity into the accumulation of livelihood capital, to enhance the resilience of livelihoods, which is specifically represented by indices such as education level to exchange of elite experience.

There are many alternative indices established in this study, and the impact of each index on the livelihood resilience of resettled households is different. Therefore, the gray correlation degree method is used to comprehensively evaluate all indices, and the clustering method is selected to screen the indices that have a great impact on livelihood resilience (Shangguan et al., 2019). See the following formula for the analysis process.

2.3.1.1. Establish a reference data column and calculate the absolute difference sequence

This study selected the livelihood resilience evaluation index options agreed upon by the questionnaire adjusters as the reference data column. The reference data are listed as x_0, and the reference value of the j livelihood resilience evaluation index is $x_0(j)$. The comparison data column is x_i. The value of the jth livelihood resilience evaluation index is $x_i(j) = (i = 1, 2, 3, \cdots, n)$.

TABLE 1 Alternative indices for livelihood resilience evaluation of resettled households.

Target layer	Dimension layer	Specific evaluation indices
Livelihood resilience	Buffer capacity	Per capita cultivated area, Housing situation, Means of production and living, Labor force quantity, Labor capacity, Health status, Per capita annual income, and Ecological environment
	Self- organization capacity	Policy awareness, Social network support, Social organization Participation, Neighborhood trust, Social status, Cultural Atmosphere, Social security, Management capacity, and Traffic accessibility
	Learning capacity	Education level, Employment opportunities, Income diversity, Family education input, Information acquisition capacity, Skills training opportunities, Willingness to start their own businesses, Number of migrant workers, and Exchange of elite experience

2.3.1.2. Calculate the minimum difference and maximum difference of the two stages

The column difference was obtained by calculating the absolute value of the difference between the reference data column and the comparison data column. The calculation method is shown in Equations 1 and 2.

Minimum difference between two stages:

$$\min\left({}_{i}\min\right) = \min_{i}\min_{j}\left|x_0\left(j\right) - x_i\left(j\right)\right| \tag{1}$$

Maximum difference between two stages:

$$\max\left({}_{i}\max\right) = \max_{i}\max_{j}\left|x_0\left(j\right) - x_i\left(j\right)\right| \tag{2}$$

2.3.1.3. Relevance calculation and ranking

Calculate the correlation coefficient based on Equation 3, wherein $\varepsilon_i\left(j\right)$ is the correlation coefficient between the reference data series and the comparison data series of the j livelihood resilience evaluation index, and β is the resolution coefficient, which was set in this study to β 0.5. The relevance of each index was obtained based on Equation 4, and the relevance was sorted.

$$\varepsilon_i\left(j\right) = \frac{\min_i \min_j \left|x_0\left(j\right) - x_i\left(j\right)\right| + \beta \max_i \max_j \left|x_0\left(j\right) - x_i\left(j\right)\right|}{\left|x_0\left(j\right) - x_i\left(j\right)\right| + \beta \max_i \max_j \left|x_0\left(j\right) - x_i\left(j\right)\right|} \tag{3}$$

$$\gamma_i = \sum_{i=1}^{n} \omega_i \times \varepsilon_i\left(j\right) \tag{4}$$

Where $\varepsilon_i\left(j\right)\left(i = 1, 2, 3, \cdots, n\right)$ is the correlation coefficient, $\gamma_i\left(i = 1, 2, 3, \cdots, n\right)$is the correlation degree of the *jth* livelihood resilience evaluation index, and ω_i is the weight.

2.3.2. Calculation of livelihood resilience index

In this study, the range standardization method was used to homogenize the indices, and the principal component analysis method was selected to calculate the weight of the indices. See references for the specific calculation process (Wu et al., 2021). The comprehensive inWex method was used to calculate the livelihood resilience index. The model calculation formula is as follows.

2.3.2.1. Define the analysis model of each principal component index

$$\begin{cases} F_1 = A_{11}X_1 + A_{21}F_2 + \ldots A_{i1}F_i \\ F_2 = A_{12}X_1 + A_{22}F_2 + \ldots A_{i2}F_i \\ \cdots \\ F_j = A_{1j}X_1 + A_{2j}F_2 + \ldots A_{ij}F_i \end{cases} \tag{5}$$

2.3.2.2. Calculate the coefficient of the index in the linear combination of principal components

$$a_{ij} = \frac{\mu_{ij}}{\sqrt{\lambda_j}}\left(i = 1, 2 \ldots p, j = 1, 2 \ldots k\right) \tag{6}$$

In Equation 6, a_{ij} is the coefficient of the *ith* index corresponding to the jth principal component, μ_{ij} is the initial factor of the *ith* index corresponding to the *jth* principal component, λ_j is the characteristic value corresponding to the jth principal component.

2.3.2.3. Calculate the coefficient of the index system

$$b_p = \left(a_{ij} \times \theta_j\right) / \sum_{j=1}^{k} \theta_j \tag{7}$$

In Equation 7, b_p is the index coefficient, θ_j is the principal component variance contribution rate.

2.3.2.4. Normalize the index weight

$$W_p = b_p / \sum_{p=1}^{k} b_p \tag{8}$$

In Equation 8, W_p is the weight value, b_p is the index coefficient.

2.3.2.5. Calculate the livelihood resilience

$$R_i = \sum_{p=1}^{k} W_p \times F_p \tag{9}$$

In Equation 9, where R_i is the livelihood resilience index, W_p is the weight, F_p is the standardized value.

2.3.3. Contribution model

In this study, the contribution model was used to analyze the impact of indices on livelihood resilience (Wu et al., 2021). The model calculation formula is as follows:

$$Z_j = P_{ij}G_j / \sum_{j=1}^{m} P_{ij} \times 100\% \quad (10)$$

In Equation 10, Z_j refers to the contribution of the j index to the target, G_j refers to the impact of the j index on the target, which is characterized by the weight of the corresponding index, and P_{ij} refers to the membership of the target.

3. Results

3.1. Index screening of livelihood resilience

The comprehensive evaluation of each index is conducted by the gray correlation degree method. The correlation degree and ranking results of indices are shown in Table 2.

According to the correlation degree and ranking results of livelihood resilience indices of resettled households, the cluster method is used to screen the indices that have a greater impact on livelihood resilience. According to the screening results, indices that have little impact on livelihood resilience include the ecological environment, cultural atmosphere, social status, income diversity, and employment opportunities. According to the field survey, most of the rural reservoir resettlement households of Xiangjiaba Hydropower Station (Yunnan Reservoir area) have moved from rural areas to county towns or market towns. The resettlement site was close to the urban circle, and the ecological environment is relatively stable, which has little impact on livelihood recovery. After moving to the new resettlement site, what the resettled households urgently need was the restoration and improvement of their living conditions and production and labor capacity, and they do not pay much attention to their social status. The new resettlement site and the original residence are both within the same county, with a relatively close distance and a relatively similar cultural atmosphere. As the social relations of resettlers change from simple family, relatives and neighborhood relations to complex social network relations, the richer the employment opportunities and income diversity provided, the less the impact on livelihood resilience. By excluding the indices with a small impact on livelihood resilience, 21 indices with a large impact on livelihood resilience were obtained, and the results are shown in Table 3.

3.2. Family type division

Before relocation, the affected households of Xiangjiaba Hydropower Station (Yunnan Reservoir area) will choose their own relocation and production resettlement methods according to their wishes and application conditions. Different choices will lead to different livelihood modes. Therefore, with reference to the existing studies on the classification of farmers' livelihood types and in combination with the situation in the study area (Du et al., 2019; Jiang and Huang, 2020; Wang and Ma, 2020; Zheng et al., 2020; Zou et al., 2020), five variables, including the proportion of labor, the proportion of agricultural income, the proportion of migrant and part-time income, the proportion of subsidies, and the proportion of other income, were selected as input indices for k-means cluster analysis. The results showed that the livelihood modes of resettled households can be quantitatively divided into four types: agricultural operation type, wage operation type, subsidy dependent type, and part-time balanced type.

There were differences in the characteristics of the family structure of households who choose different ways of livelihood. In terms of family size, the average population size of the four types of resettlers was between 4 and 6 people/household. Among them, the family size of the agricultural operation type and the part-time balanced type of resettlers was larger, and the family structure is more stable. This is because the structure of the agricultural operation type and the part-time balanced type of resettled households is mostly mature families composed of the elderly + adults + children. In terms of family dependency ratio, the subsidy-dependent family is the largest, and the wage-operated family is the smallest. In terms of average education, wage operation households are the highest, and subsidy-dependent households are the lowest. This is because most of the subsidy-dependent affected households are old couples or elderly people living alone.

3.3. Evaluation and analysis of livelihood resilience

3.3.1. Validity test

In this study, the validity of the samples was tested. Kmo and Bartlett's sphere tests in principal component analysis were used to test the validity of index variables. The results are shown in Table 4. The test results showed that KMO = 0.625, Bartlett's approximate chi square value = 897.617, P = 0, and the data variables meet the requirements of principal component analysis.

3.3.2. Evaluation results

According to the calculation results (Table 5), the livelihood resilience index of affected households in Xiangjiaba Hydropower Station (Yunnan Reservoir area) was 0.459, which is not high as a whole and needs to be further improved. From the perspective of all dimensions, the self-organization capacity index was 0.237, ranking the highest. The buffer capacity index

TABLE 2 Correlation and ranking results of livelihood resilience indices of resettled households.

Index	Relevance	Sort	Index	Relevance	Sort
Per capita cultivated area	0.702	15	Cultural Atmosphere	0.398	25
Housing situation	0.760	11	Social security	0.609	19
Means of production and living	0.787	6	Management capacity	0.674	17
Labor force quantity	0.934	1	Traffic accessibility	0.708	14
Labor capacity	0.836	4	Education level	0.672	18
Health status	0.859	3	Employment opportunities	0.425	22
Per capita annual income	0.902	2	Income diversity	0.417	23
Ecological environment	0.391	26	Family education input	0.732	13
Policy awareness	0.571	20	Information acquisition capacity	0.789	5
Social network support	0.770	10	Skills training opportunities	0.777	8
Social organization participation	0.686	16	Willingness to start their own businesses	0.736	12
Neighborhood trust	0.779	7	Number of migrant workers	0.774	9
Social status	0.407	24	Exchange of elite experience	0.543	21

was 0.120, ranking second, while the learning capacity index was 0.101, ranking the lowest. It can be seen that involuntary resettled households in the study area had the weakest learning capacity and the strongest self-organization capacity. To further analyze the difference in livelihood resilience of resettled households who choose different livelihood modes, this study provides statistics on the scores of various indices, such as buffer capacity, self-organization capacity and learning capacity (Figure 1), and uses the single factor analysis method (ANOVA) for analysis. The analysis was as follows.

Table 5 shows that the livelihood buffer capacity index of resettled households shows the characteristics of wage operation type (0.202) > part-time balanced type (0.147) > agricultural operation type (0.138) > subsidy dependent type (0.105). From the scores of each index of buffer capacity (as shown in Figure 1), the livelihood buffer capacity of different types of resettlers is significantly different ($P = 0.001$). Because of the differences in the characteristics of family structure, production mode and livelihood mode of different types of resettlers, the livelihood capital of affected households has advantages and disadvantages, which affects the buffer capacity. For example, subsidy-dependent type affected households mainly rely on state subsidies for their livelihood. The population with low household savings and a lack of labor force is obviously at a disadvantage compared with other types of affected households in terms of livelihood capital, resulting in the lowest buffer capacity.

Table 5 shows that the livelihood self-organization capacity index of resettled households shows the characteristics of agricultural operation type (0.243) > part-time balanced type (0.213) > wage operation type (0.163) > subsidy dependent type (0.144), and the self-organization capacity of livelihood of different types of resettlers were obviously different ($P = 0.015$). From the scores of each index of self-organization capacity (as shown in Figure 1), as the whole family of agricultural operation type resettlers lives in the village for a long time, they are mostly engaged in family business activities in the primary industry and have a high self-organizing capacity for their long-term living environment. The family structure of part-time balanced type resettlers is relatively stable, which belongs to the family structure in which adults go out to work and the elderly work at home. Their self-organization capacity was not different from that of the agricultural operation type. Wage operation-type resettlers who go out to work can generally not return to the village for a long time and only return home during the new year or festivals. The maintenance of family, relatives and neighborhood relations is relatively inactive, and participation in social organizations and neighborhood trust are low. Most of the subsidy-dependent type resettlers are elderly and non-working family members, and all indices of self-organization capacity were low.

Table 5 shows that the livelihood learning capacity index of resettled households shows the characteristics of wage operation type (0.216) > part-time balanced type (0.164) > agricultural operation type (0.103) > subsidy dependent type (0.098), and the livelihood learning capacity of different types of resettlers were obviously different ($P = 0.029$). From the scores of each index of learning capacity (as shown in Figure 1), the wage operation type and the part-time balanced type resettlers are mostly young people in the family structure. The heads of household and their family members have higher education, higher information acquisition capacity, diverse employment opportunities and skills, and higher income than the agricultural

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TABLE 3 Evaluation index system for livelihood resilience of resettled households.

Target layer	Dimension layer	Weight value	Index layer	Weight value	Explanation and assignment
Livelihood resilience	Buffer capacity	0.371	Per capita cultivated area	0.055	Farmland area owned by family (mu)/total family population (person)
			Housing situation	0.062	Considering the two factors of housing structure and per capita housing area, Housing structure * 0.5+per capita housing area * 0.5; housing structures are classified according to different materials: buildings = 1, brick concrete buildings = 0.75, stone brick buildings = 0.5, earth buildings = 0.25, dilapidated buildings = 0; According to the urban and rural per capita housing area of 40.8 m^2, it is classified as: more than 40.8 m^2 = 1, 34.16–40.8 m^2 = 0.75, 30–34.16 m^2 = 0.5, 25–30 m^2 = 0.25, <25 m^2 = 0
			Means of production and living	0.032	The number of production tools and durable goods owned by families, mainly including TV sets, washing machines, refrigerators, air conditioners, range hoods, motorcycles, agricultural vehicles, cars, etc.
			Labor force quantity	0.079	Number of adult labor force with family members aged 18–60
			Labor capacity	0.082	Overall labor capacity of family members, full labor = 1, semi labor = 2, non-labor = 3
			Health status	0.009	Annual medical expenditure of families (yuan)/annual total expenditure (yuan)
			Per capita annual income	0.051	Total annual household income (yuan)/total household population (person)
	Self-organization capacity	0.388	Policy awareness	0.117	Family members' awareness of social security, poverty alleviation, subsidies and other policies: very clear = 1, relatively clear = 0.75, general, vague = 0.25, little understanding = 0.25, almost no understanding = 0
			Social network support	0.028	When the family is faced with risks and difficulties, whether they can get support from their relatives and friends in terms of human, material and financial resources, yes = 1, no = 2
			Social organization participation	0.063	The degree of trust between families and the opportunity to support each other and resist risks. Very trust = 1, comparative trust = 0.75, general trust = 0.5, less trust = 0.25, and total distrust = 0
			Neighborhood trust	0.067	Family members' evaluation of rural social security system: very satisfied = 1, relatively satisfied = 0.75, generally = 0.5, dissatisfied = 0.25, very dissatisfied = 0
			Social security	0.047	The Likert scale is the representation of satisfaction with the rural social security policy, very satisfied = 1, relatively satisfied = 0.75, general = 0.5, dissatisfied = 0.25, very dissatisfied = 0
			Management capacity	0.053	The evaluation of family members on the management capacity and attitude of the village committee shows that strong capacity and timeliness = 1, strong capacity, but need to run several times = 0.75, good attitude, average capacity = 0.5, average capacity, few contacts = 0.25, poor attitude, poor capacity = 0
			Traffic accessibility	0.012	The distance between the family residence and the nearest market and road
	Learning capacity	0.242	Education level	0.013	The overall education level of family members: college degree or above = 1, high school or junior college = 0.75, junior high school or technical secondary school = 0.5, primary school = 0.25, illiterate = 0

(Continued)

TABLE 3 (Continued)

Target layer	Dimension layer	Weight value	Index layer	Weight value	Explanation and assignment
			Family education input	0.024	Annual education expenditure of families (yuan)/total annual expenditure (yuan)
			Information acquisition capacity	0.042	Sum of the number of channels for family members to obtain employment, market and other information every year
			Skills training opportunities	0.044	Sum of the times that family members take skill training courses every year
			Willingness to start their own businesses	0.033	Whether the family has the idea and plan to start a business, yes = 1, no = 2
			Number of migrant workers	0.052	Family members who work outside cannot go home often, and can only go home during busy farming or holidays, and the number of people who work outside for more than half a year or more
			Exchange of elite experience	0.035	The degree of experience exchange between family members and village elites: much exchange = 1, more exchange = 0.75, general exchange = 0.5, less exchange = 0.25, no exchange = 0

*, Stands for the multiplication sign.

TABLE 4 KMO and Bartlett sphere inspection.

KMO		0.625
Bartlett	Approximate chi square value	897.617
	df	153
	Sig.	0.000

operation type and subsidy dependent type resettlers. Diversity of livelihood capacity means stronger transition capacity and higher learning capacity. Most of the agricultural operation type and subsidy-dependent type resettlers live in the village for a long time. Most of the family members are middle-aged and old people. The heads of household and their family members have low education, low access to information, a single livelihood structure and low learning capacity. However, compared with the other two types, they have more opportunities to participate in agricultural skill training, which relatively increases their learning capacity. Compared with subsidy-dependent resettlers, they have higher self-organization capacity.

Table 5 shows that the livelihood resilience index of resettled households shows the characteristics of wage operation type (0.580) > part-time balanced type (0.523) > agricultural operation type (0.484) > subsidy dependent type (0.347), and the livelihood resilience of different types of resettlers are obviously different ($P = 0.008$). Livelihood resilience was the result of the combination of buffer capacity, self-organization capacity and capacity for learning. The quality of each dimension will have a great impact on the livelihood resilience of resettlers. Therefore, wage operation type resettlers have the highest buffer capacity, capacity for learning and livelihood recovery capacity. Subsidy-dependent type resettlers have relatively low dimensions and the lowest livelihood resilience. The agricultural operation type resettlers were in the middle of the three.

3.4. Analysis of the contributing factors of livelihood resilience

According to the contribution model in 2.2.3, the contribution degrees of livelihood resilience of resettled households with different livelihood modes under three dimensions were calculated, and then the main contribution factors were identified. As there were many indices, the indices with the top three contribution degrees in the three dimensions were selected as the main contribution factors, and the results are shown in Table 6.

3.4.1. Buffer capacity

Labor force quantity, labor capacity, per capita cultivated area and per capita annual income were the main contributing

TABLE 5 Livelihood resilience measurement and ANOVA results of resettled households.

Livelihood type	Buffer capacity			Self-organization capacity			Learning capacity			Livelihood resilience		
	Index value	*F*-value	*P*-value	Index value	*F*-value	*P*-value	Index value	*F*-value	*P*-value	Index value	*F*-value	*P*-value
Agricultural operation type	0.138	6.064	0.001	0.243	4.774	0.015	0.103	3.147	0.029	0.484	5.661	0.008
Wage operation type	0.202			0.163			0.216			0.580		
Subsidy dependent type	0.105			0.144			0.098			0.347		
Part-time balanced type	0.147			0.213			0.164			0.523		
Reservoir area as a whole	0.120			0.237			0.101			0.459		

factors, and there is a certain convergence. Among them, the contribution of the labor force ranks first among the four types of resettlers; labor capacity ranks second among the other three types of resettlers except for subsidy-dependent resettlers. In the study area, farming and going out to work were the main livelihood of resettlers. The number and capacity of the labor force represent the human capital of each resettled family. The higher the number and capacity of the labor force are, the stronger the buffer capacity of resettled households in the face of external environmental interference, and it is easier to obtain higher income at the present stage and in the future. It is extremely important to improve the buffer capacity of resettlers' livelihood. Natural capital ranks third in the contribution of agricultural operation-oriented and part-time balanced resettlers, mainly because arable land is the most basic natural capital possessed by resettlers and the basic source of livelihood guarantee for them. Reservoir construction expropriates most of its land, and the amount of land it owns was quite small. The area of arable land determines the agricultural output, which further affects the income and livelihood capital of the affected families. The contribution of per capita annual income ranks third among wage-operated and subsidy-dependent types, mainly because the income level represents the family's financial capacity. Financial capacity is the basis of buffer capacity, which directly reflects the family's economic situation. Financial capital directly represents the resistance and recovery capacity of resettlers when they encounter livelihood risks.

3.4.2. Self-organization capacity

Social organization participation, neighborhood trust, social network support and management capacity are the main contributing factors, and there is a certain convergence. Among them, social organization participation ranks first in the contribution of agricultural operation type and part-time balanced type. Social organization participation reflects the degree of resettler families' participation in collective affairs in the village. The higher the participation, the larger the scope of the social network, the stronger the decision-making power in village affairs, and the stronger the self-organization capacity of resettlers. At the same time, the more resettled families can understand the state's subsidy, support and poverty alleviation policies for resettlers, the greater they can apply for policies in time according to their own family conditions. Neighborhood trust ranks first in the contribution of wage-operated and subsidy-dependent types. The degree of trust between resettlers and the opportunity to resist risks affect their self-organization capacity. A lack of neighborhood trust will isolate resettlers and reduce their self-organization capacity.

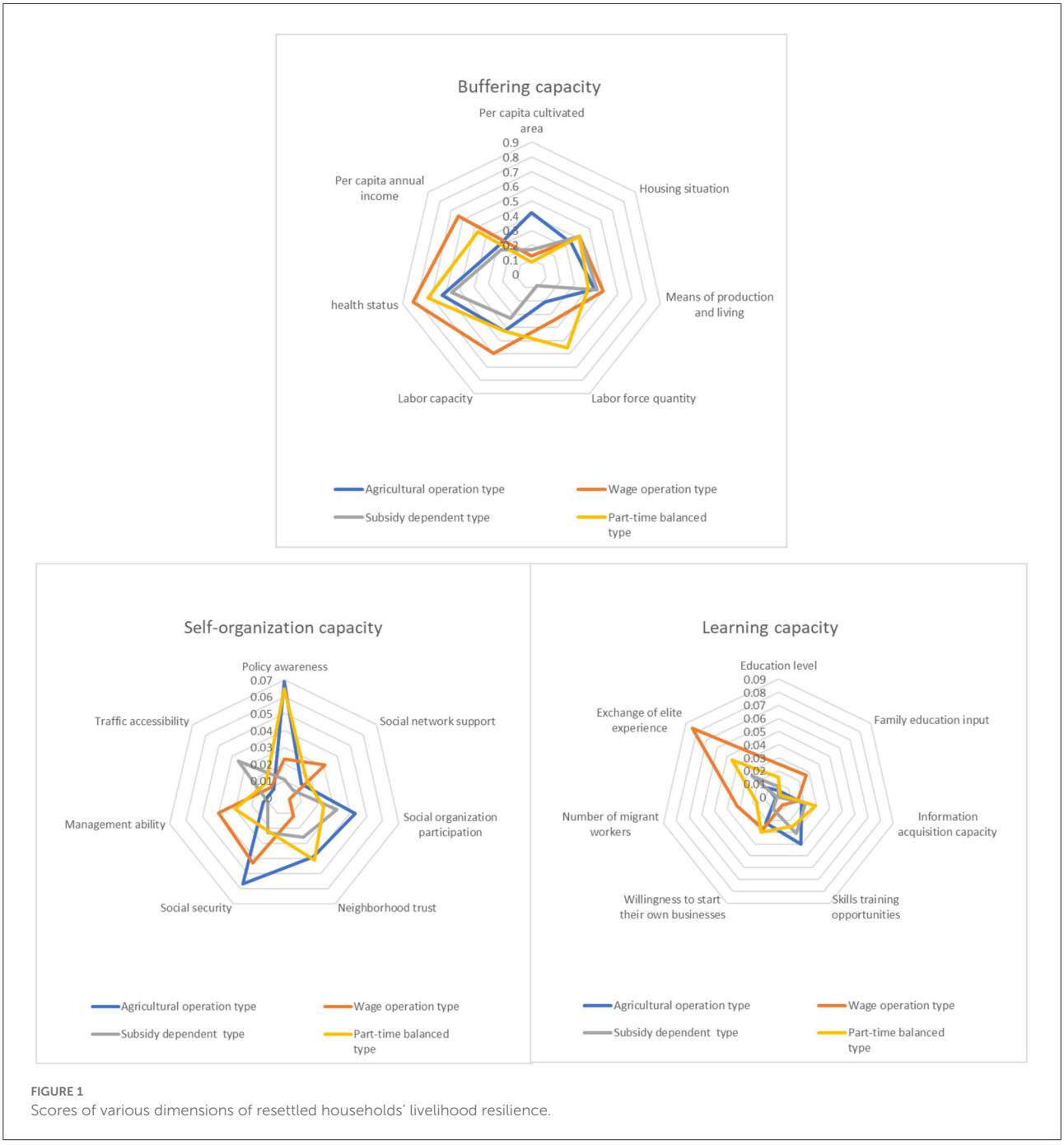

FIGURE 1
Scores of various dimensions of resettled households' livelihood resilience.

3.4.3. Learning capacity

Skill training opportunities, family education investment and the number of migrant workers are the main contributing factors, and there is a certain convergence. Among them, skill training opportunities rank first in the contributions of the four types of resettlers. Learning capacity is not only reflected in the acquisition of knowledge and skills but also emphasizes the capacity to transform into concrete livelihood. The more resettlers participate in skills training, the more skills they master, which is a performance of improving their learning capacity. In addition, after receiving skill training, resettlers have the capacity to use and obtain jobs matching their skills, which also reflects the strengthening of resettlers' learning capacity. Skill training opportunities, family education investment and number of migrant workers rank among the top three in terms of their contributions to wage operated and part-time balanced resettlers. Although in the short term, family education investment has increased the family's economic burden, in the long term, it will bear returns beyond expectations in the future. This is a

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TABLE 6 Main contributing factors to the livelihood resilience of resettled households.

Livelihood type	Ranking	Buffer capacity			Self-organization capacity			Learning capacity		
		1	2	3	1	2	3	1	2	3
Agricultural operation type	Contribution factor	Labor force quantity	Labor capacity	Natural capital	Social organization participation	Social network support	Neighborhood trust	Skills training opportunities	Number of migrant workers	Experience exchange of capable people
	Contribution (%)	21.689	18.394	18.342	32.907	18.422	13.733	20.032	19.160	15.237
Wage operation type	Contribution factor	Labor force quantity	Labor capacity	Per capita annual income	Neighborhood trust	Management capacity	Social network support	Skills training opportunities	Family education investment	Number of migrant workers
	Contribution (%)	32.932	29.811	14.806	35.240	19.416	17.169	34.361	24.915	20.333
Subsidy dependent type	Contribution factor	Labor force quantity	Natural capital	Per capita annual income	Neighborhood trust	Social organization participation	Management capacity	Skills training opportunities	Information acquisition capacity	Family education investment
	Contribution (%)	28.521	20.562	14.141	25.852	21.216	16.517	38.183	30.946	10.576
Part-time balanced type	Contribution factor	Labor force quantity	Labor capacity	Natural capital	Social organization participation	Management capacity	Neighborhood trust	Skills training opportunities	Number of migrant workers	Family education investment
	Contribution (%)	20.996	20.960	17.429	28.219	25.779	16.054	20.667	20.524	19.283

forward-looking investment, reflecting the future and dynamics of livelihood resilience. The number of migrant workers represents the possibility of livelihood transition of resettlers. Generally, migrant workers have more opportunities to contact new things, improve their horizons, easily understand the latest social development trends, are more likely to change their family livelihood strategies, have the possibility of different livelihood development modes and are more stable when facing external risks.

3.5. Construction path of livelihood resilience

According to the above analysis, the main contributing factors to livelihood resilience were similar. The number of laborers, participation in social organizations, skills training opportunities and 11 other main indices promote the formation and development of livelihood resilience from different dimensions. Combined with the actual situation of the study area, a large amount of agricultural land has been expropriated for the construction of the Xiangjiaba Hydropower Station (Yunnan Reservoir Area). For resettled households that rely on agricultural land, the possibility of relocating traditional agricultural production in the local area was low because of fewer land resources that can be allocated. Therefore, most resettled households were engaged in non-agricultural production after relocation. However, due to the low education level of the labor force and serious aging, it was difficult for resettled households to find new jobs. Even migrant workers are also engaged in simple manual labor, and their salary and safety cannot be guaranteed. Only a few people can take advantage of opportunities or have simple skills to find local jobs. At the same time, because the local government did not pay enough attention to the production resettlement of resettled households, it was difficult for resettlers to participate in employment skills training, resulting in a difficult situation of "no land for farming and no job for migrant workers." In addition, the original social networks of relatives and friends of migrants have been destroyed due to the loss of production and living materials. To meet the needs of emotion, production and life, resettlers must adjust their new social network relations after losing their land and homes. Therefore, a livelihood path of "identifying transition capacity, clarifying resource advantages, strengthening livelihood support, and promoting livelihood reorganization" should be built to promote the comprehensive improvement of livelihood resilience.

3.5.1. Identifying the transition capacity of resettled households and providing targeted support

Identify the vulnerable groups generated in the just transition. The first type of vulnerable group was the new vulnerable groups created by reservoir construction. This kind of vulnerable group involves land inundation, livelihood destruction, social network disruption and other adverse effects, with the characteristics of long time spans and wide and far-reaching impacts. Additionally, among the first category of vulnerable groups, there are also vulnerable groups due to unequal initial endowment, such as the economic poor, the disabled, and elderly individuals, which are the second category of vulnerable groups. For the above two categories of vulnerable groups, the state should take relevant measures such as financial compensation, technical support and system guarantees to effectively safeguard the substantive and procedural rights of vulnerable groups and strengthen the right relief and government intervention; However, targeted at the vulnerable groups divided by types, the state should provide targeted later support to enhance their transformation capacity, help them recover their livelihoods and exceed their original production and living standards, and achieve sustainable livelihoods.

3.5.2. Clarifying regional resource advantages and expanding new ways of livelihood

We should clarify the advantages of regional resources and explore new ways of livelihood development for resettled households by relying on superior resources. Focus on the comprehensive development of ecological resources around the reservoir area, innovate the integrated comprehensive resettlement mode of "reservoir resettlement + resettlement + ecological resource development," fully tap the value of ecological resources around the reservoir area, and improve the overall development efficiency of the project. However, local governments are encouraged to allocate operational resources for the project, explore joint development mechanisms such as "project + resources" and "project + tourism," fully tap the operational potential of the project, explore the mechanism of resettler resource shareholding, provide better resettlement methods for affected people, promote the non-agricultural transfer of labor to compensate for the lack of arable land resources on the livelihood buffer capacity, and further improve the livelihood buffer capacity of resettled households.

3.5.3. Promoting industrial innovation and development and strengthening the support foundation for livelihood development

First, the post-project evaluation mechanism is introduced to analyze the operation and benefits of the existing industries in the reservoir area and resettlement area, summarize experiences and lessons, and ensure that the funds invested in industrial development bear benefits. Second, we should build an interactive model of industrial integration, focus on characteristic resources and advantages, implement unified planning and layout of surrounding areas, promote the extension of the industrial chain in the reservoir area and

resettlement area, promote the integrated development of agriculture, ecotourism, cultural industry, and e-commerce, and cultivate leisure tourism agriculture, rural tourism and other characteristic industries. Finally, the construction of regional roads and other infrastructures should be strengthened, the regional transportation network should be improved, the degree of contact with outside the region should be enhanced, and the self-organization capacity of resettled households should be improved.

3.5.4. Breaking the original livelihood path dependence and realizing livelihood capital restructuring

Build a special network information collection and release platform, promote the diversification of information access channels for resettled households, improve their awareness of employment, market and national policy information, and further improve their learning and self-organization abilities. Improve the adult education and production skills training system, carry out employment reeducation and periodic production skills training, promote the knowledge-based transformation of the human capital structure of resettled households, and then improve their livelihood buffer capacity and learning capacity. In addition, while clarifying resource advantages and livelihood support industries, we should break the original path dependence and reorganize the livelihood capital of resettled households. First, promote the scale transfer of land resources, promote the specialization and scale of agricultural production, and break the path dependence on the small-scale agricultural production mode with industrial benefits. Second, we should keep pace with the times to optimize the livelihood capital structure, weaken the leading supporting role of arable land and the labor force for livelihood development, strengthen the supporting role of labor skills, knowledge and culture levels, and information networks for resettled households, realize livelihood capital restructuring, and then enhance the livelihood resilience of resettled households to achieve sustainable livelihoods and high levels of wellbeing.

4. Discussion and conclusion

Based on the logical thinking of "livelihood resilience evaluation-identification of main contributing factors-livelihood path construction," this study combined empirical research with path construction, forming a close combination of theoretical analysis and landing practice, with a view to providing a reference for the sustainable development of resettled households' livelihoods and the formulation of relevant policies and measures for later support. However, due to differences in research areas and research methods, the results of the research are slightly different from other researchers' findings in terms of resettled households' livelihoods. For example, Reddy, A. A. examined the resettlement of displaced families affected by Tehri Hydro Power Project by constructing an entirely new town "New Tehri Town" (NTT) by using impoverishment risks and reconstruction framework developed by Cernea (Reddy, 2018). The result shows that project-affected families are better off in NTT in terms of community amenities, income and employment opportunities and in terms of increase in value of houses, but traditional employment opportunities have been lost, they have to search for new jobs and livelihoods. The R&R policies in urban areas should focus on improving skill sets of the people along with increased income and employment opportunities through the development of market and business opportunities. According to this research, the level of livelihood resilience of resettled households was not high as a whole, in which the self-organization capacity was the strongest, the buffer capacity was the second, and the learning capacity was the weakest. There are differences in the livelihood resilience of resettled households that choose different livelihood modes. Among them, buffer capacity, capacity for learning and livelihood resilience are characterized by wage operation type > part-time equilibrium type > agricultural operation type > subsidy dependent type, while self-organization capacity is characterized by agricultural operation type > part-time equilibrium type > wage operation type > subsidy dependent type. The main contributing factors to livelihood resilience are similar. The number of laborers, participation in social organizations, skills training opportunities and 11 other main indices promote the formation and development of livelihood resilience from different dimensions. The lack of learning capacity limits the development of livelihood resilience of families in the study area. It can be seen that further improving learning capacity is an important breakthrough to enhance livelihood resilience. Therefore, in subsequent livelihood restoration, resettled households should make use of their higher self-organization capacity to drive the enhancement of learning capacity and transform learning capacity into buffer capacity that can be accumulated continuously to improve their livelihood resilience. Combined with the actual situation of the study area, this study believes that by identifying the transition capacity of resettled households, clarifying the regional resource advantages, and promoting industrial innovation and development, on the basis of efforts to break the original livelihood path dependence, livelihood capital restructuring can be achieved, thereby enhancing the buffer capacity, self-organization capacity, and learning capacity of livelihoods, which is an important way to improve the livelihood resilience of resettled households and achieve sustainable livelihoods and high levels of wellbeing.

However, due to multiple reasons, such as the availability of individual indices, the feasibility of quantifying government policies, the different stages and attributes of rural development under the background of rural revitalization, and the difference

in the local government support that resettled households can enjoy, the choice of alternative indices for evaluating the livelihood resilience of displaced families will be different. Additionally, due to different factors, such as the structural characteristics of resettled households and their education level, there are also differences in the self-development capacity of various types of households. Even with the same policy support, the improvement level of livelihood resilience is different. The government regulation mechanism lacks foresight, and it also often takes corresponding measures after problems occur, which generally leads to lagging issues. With the further implementation of the energy transformation strategy, the livelihood development and transformation of resettled families will face new disturbances, resulting in increasingly complex impacts on their livelihood resilience, and social equity and justice risks may still exist. In other words, the livelihood resilience of resettled households is a continuous and dynamic development process. Therefore, in follow-up research based on the just transformation strategy, it is necessary to further improve the dynamic monitoring and evolution process of livelihood resilience, incorporate the impact of diverse data, such as the public capital of different geomorphic regions, county towns and villages, on the livelihood resilience of resettled households, and carry out systematic research on their livelihood resilience at multiple scales. This is also an important breakthrough in the study of livelihood resilience.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Author contributions

JW was primarily responsible for writing the main body of the manuscript and provided the results of the empirical analysis for the research in this manuscript. RL provided the original data used in this manuscript. KZ provided all the tables used in this manuscript. SC made significant contributions to improve the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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