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EDITED BY
A. Amarender Reddy,
National Institute of Biotic Stress Management, India

REVIEWED BY
Weijun He,
China Three Gorges University, China
Kankanige Karunathilake,
University of Kelaniya, Sri Lanka

*CORRESPONDENCE
Chaolun Sun,
suncl@hpu.edu.cn
Yu Hao,
haoyu_he@163.com

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Evaluation of sustainable livelihood of reservoir resettlement based on the fuzzy matter-element model

Yu Hao[1,2]*, Fan Zhang[1,2] and Chaolun Sun[2,3]*

[1]Safety and Emergency Management Research Center, Henan Polytechnic University, Jiaozuo, China, [2]Emergency Management School, Henan Polytechnic University, Jiaozuo, China, [3]State Key Laboratory Cultivation Base for Gas Geology and Gas Control, Henan Polytechnic University, Jiaozuo, China

Introduction: The study of sustainable livelihoods for reservoir resettlers is of great significance for consolidating the poverty alleviation achievements of China and promoting the realization of the major strategy of China's rural revitalization.

Methods: On the basis of the Sustainable Livelihood Analysis Framework of the UK Agency for International Development and the general requirements of the rural revitalization strategy on industry, ecology, rural ethos, governance and life, this paper selects the material basis, living environment and Social Adaptability which are more close to China's national conditions and can more accurately measure the resettlers' livelihood. These three factors have established a Comprehensive Evaluation Index System for the sustainable livelihood of the reservoir resettlers. A mathematical model based on complex fuzzy matter-element and analytic hierarchy process (AHP) is established to assess the sustainable livelihood of reservoir resettlers. Furthermore, it conducts an empirical study on the resettlement of the Danjiangkou Henan Reservoir area of the South-to-North Water Diversion Project, which takes the whole of immigration in Henan Province as the research object.

Results: The results show that the current survey value of the overall livelihood of the resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project is 0.0085 lower than the maintaining livelihood target and 0.1725 lower than the sustainable livelihood target. Such a result indicates that the livelihood of Henan resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project has reached a sustainable level overall, but its gap with the sustainable livelihood goal remains obvious, which is primarily demonstrated by economic foundation and social adaptability.

Discussion: Therefore, immigration management agencies should make efforts to adjust the industrial structure, increase the income of resettlers, help resettlers integrate into the local society sooner, and promote the sustainable development of resettlers' livelihoods.

KEYWORDS

reservoir resettlement, sustainable livelihoods, analytic hierarchy process, fuzzy matter-element model, policy suggestions

1 Introduction

In the world, there are still a certain number of people living in poverty, and how to join hands to fight against poverty has become a global problem. Getting out of poverty is not simply about increasing income, or it will lead to a vicious circle from relative poverty to return to poverty. On the issue of Poverty Governance, general secretary XI has repeated ly stressed that eliminating poverty, improving people's livelihood and gradually realizing common prosperity are the essential requirements of socialism and an important mission of the Communist Party of China. By the end of 2020, with concerted efforts from all over the country, China had achieved the great victory of the poverty alleviation, eliminated the problem of absolute poverty, and thus opened a new stage in the country's development path, that is, to realize the new goal of revitalizing rural areas with prosperous industries, ecological amenity, rural civilization, effective governance and well-to-do life. The development of China's rural revitalization strategy has long-term characteristics, and its development results benefit the whole people. China is a country with frequent floods and droughts, as well as a country with energy shortage. As we all know, the relationship between industrial development and the application of water resources is closely related, and with the development of economy and society, the role of water resources in agriculture and service industry, including industry (Kong, 2023; Yuan, 2023), is increasingly prominent, providing strong support for high-quality economic and social development. Hydropower and water conservation initiatives can bring about significant, positive, economic and social benefits. In the past 70 years of large-scale economic development in China, more than 90,000 reservoirs and hydropower stations have been built, resulting in a total of more than 25.02 million reservoir resettlers (Ministry of Water Resources of the People' s Republic of China, 2022). The issue of the follow-up development of the relocated masses arising from the economic development has been widely concerned. It is undeniable that, in the current stage of the implementation of the work of land acquisition and resettlement, there are still problems in the implementation of resettlement measures. These water conservancy project resettlement families, who are impacted by forced relocation and resettlement, typically struggle with issues like low production capital, low production efficiency, lack of livelihood ability, and low sense of gain because of the alteration of geographical space and the breakdown of social relationship structures. These problems are in stark contrast to the hydraulic engineering economic and social benefits. China's sustainable growth is confronted with formidable obstacles (Sun and Zhao, 2017). Therefore, the success of reservoir resettlement is the key to measure the success of Water Conservancy and hydropower projects. From the point of view of welfare economics, Wang and Ke defined the objective of reservoir resettlers as that which can balance the absolute welfare and the relative welfare, that is, the living standard of the resettlers could reach or exceed the original level, and catch up with the living standards of the original residents of the resettlement area (Wang and Ke, 2009). The Chinese government has always committed to explore better ways to resettle migrants. In 2006, our country promulgated "Regulations on land expropriation compensation and resettlement for large and medium-sized water conservancy and hydropower projects" and "Opinions of the State Council on improving the policy for supporting the resettlement of large and medium-sized reservoirs in the later stage", and in 2017, the regulations were amended to better protect resettlers. In 2021, Document No. 1 of the Central Committee once again stressed through policy measures that follow-up support for relocation should be done firmly and that support should be strengthened to effectively enhance the capacity of community governance. The massive South-to-North Water Diversion Project in China has garnered interest from all over the world. The middle route project's water diversion line starts from the Danjiangkou reservoir area, with a long water diversion distance, a huge submerged land area, and a wide influence range. Currently, more than 160,000 residents of the reservoir in Xichuan County, Henan Province, have moved away from their original homes. The reservoir resettlement has the characteristics of large population and difficult personnel placement. The resettlement effect is related to the stability and development of the region and society, and the sustainable livelihood of the resettlers is the core issue that affects the living standard of the resettlers. Therefore, ensuring that the resettlers' life meets the goal of sustainable development is not only a practical problem that needs to be solved urgently, but also a typical case to explore the resettlement path of reservoir resettlements.

2 Literature review

Livelihood is defined as a means or method of maintaining life in the English language. The research on Sustainable Livelihood (SL) originated from Sen's investigation into the methods of solving poverty problems. In addition to examining income poverty in the traditional sense, they also focused on the poverty of development ability (Sen, 1983). In 1992, SL was added to the action agenda of the United Nations Conference on Environment and Development, highlighting the need of supporting and promoting stable livelihoods as a means of eradicating poverty. At the end of the 20th century, the United Nations Development Program held the view that resilience, economic benefits, ecological balance, and intergenerational equity are the four key components of SL. The definition of a livelihood that is more widely accepted is that it is a means of making a living based on capabilities, assets and activities (Chambers and Conway, 1992). The concept of livelihood is understood differently in academic circles, and the viewpoints of research and analysis into SL also vary. As a result, numerous frameworks for analyzing SL have been developed. Among them, the most popular one is the Sustainable Livelihoods Approach (SLA) put forth by the UK Department for International Development (Sen, 1983). In recent years, international research on SL has primarily concentrated on four areas, i.e., SL from the perspective of poverty alleviation (DFID, 2000; Ellis, 2000; Knutsson and Ostwald, 2006), SL of farmers from the perspective of livelihood risks (Gaillard et al., 2009; Oumer and Neergaard, 2011), SL of farmers from the perspective

of livelihood capital (Amos et al., 2015; Bilgin, 2012), and ways to explore the SL from various perspectives (Oumer et al., 2013; Ngugi and Nyariki, 2005). Young and Jacobsen (2013) conducted a study of the lifestyles of people who had moved to towns in conflict zones, and found that when people moved to towns, in the source of life, lifestyle, food supply, there are problems. (Fred., 2015) explores the livelihood of rural residents in a region of southern Africa and discusses factors such as the living environment of farmers, their level of education and price differences in daily necessities. Cernea (1988) found that farmers who lose their land may create new poverty that makes sustainable livelihoods impossible, this is consistent with Michael Cernea's assessment of the main risks of forced displacement and the starting point of the process of impoverishment (Cernea, 1997). In addition, meteorological disasters, price fluctuations are also important factors affecting the livelihood of farmers, and farmers are not responsive to external challenges and pressures (Sok and Yu, 2015). Kennedy, through the analysis of Kenya's ecological environment system, points out that it is necessary to adopt a suitable way of life in order to enable resettlers to achieve a sustainable life (Kimiti, 2018). In Mhongera's view, since underage girls are further impoverished because of the low level of government services and funding, the government should allocate sufficient funds to provide them with a full range of services and support measures, to help them earn sustainable livelihoods (Mhongera, 2016). As for the research on the resettlement of hydropower projects, the research of foreign scholars mainly focuses on the severe challenges to the economic and social sustainability of the reservoir basin after the relocation of reservoir resettlement (Downing, 2002; Singh and Hiremath, 2010; Zhang et al., 2013; Babu and Datta, 2016), as well as the considerable impacts of the relocation of the reservoir on various aspects such as the environment (Tan and Yao, 2006; Singer and Watanabe, 2014). However, the reservoir resettlement livelihood research is relatively small. Jing analyzes the changes of China's resettlement policy after the 1950s and the corresponding changes in the characteristics of resettlement. Examples such as Xin'anjiang Dam show the importance of focusing on resettlement planning and the basic welfare of migrants. The avoidance of livelihood difficulties and psychological trauma for large numbers of migrants and the assurance of a higher quality of life for migrants than in their areas of origin must be regarded as important indicators of the success of resettlement efforts. In addition, he compared resettlement measures from "Money placement" to "Blood production assistance," what we can learn is that, in order to improve the survival of immigrants, improve the employment environment, the individual's ability should be taken into account livelihood measures, which can better ease the resettlement of migrants contradictions (Jing, 2000). Academics (Reddy et al. 2022) used data from a representative sample of 576 across India in 2017 to assess the impact of organic agriculture at the farmer level (micro) using a double-difference method, the economic surplus model was used to assess the impact of socio-organic agriculture on the entire social (macro) level in India, based on the theory of change, this paper expounds how the activities under the organic agriculture (PKVY) program are supposed to produce a series of results that will help to achieve the final expected impact. It then suggests that the government needs to develop a tailored strategy based on national circumstances, and that for the Indian government it needs to carefully develop a strategy that prioritizes areas that can be transformed into organic agriculture, certification and marketing, to increase the area under organic farming to ensure that there is no loss to food security at the national level, while increasing farmers' profits. The development strategy of organic agriculture can provide reference for the improvement of immigrant livelihood in agricultural production. Reddy also uses the IRR model, taking the displaced families affected by the Tehri hydropower project as an example to measure the development of persons who have been involuntarily resettled in terms of shelter, employment, food security, medical conditions, community assets and social integration (Reddy, 2018). The survey found that people who are involuntarily resettled in urban areas are more likely to need help with job skills, job opportunities and market development, which is where local resettlements are most eager to improve. In addition, he notes the use of local resources to increase employment opportunities, expands the scope of employment training and the content of training to improve the living conditions of those who have been involuntarily resettled.

Numerous reservoir construction projects are underway in China, and the SL of reservoir resettlement is related to resettlers' living and working in peace and stability in society. Therefore, the necessity of SL of reservoir resettlement has been widely recognized by the academic circles in China. At present, the researches of Chinese scholars on the SL of reservoir resettlement mainly focus on the analysis of the vulnerability of resettlement livelihoods (Guo et al., 2003; Zhao and Yang, 2009), factors affecting livelihoods (Shang Guan et al., 2019; Sui and Chen, 2012; Zhao et al., 2019), livelihood risks (Hu et al., 2018) and livelihood strategies (Shi and Yang, 2011; Wang, 2013; Yan, 2013).

The perspective of vulnerability was first applied to the study of natural disasters, and then gradually expanded to include financial vulnerability, disaster vulnerability, climate change vulnerability, resource vulnerability and ecosystem vulnerability. The vulnerability of livelihoods is studied from the following perspectives. First, the study of livelihood vulnerability, such as through the assessment of environmental conditions (Feng et al., 2022), livelihood capital (Zhang and Chen, 2022), policy impact (Chen et al., 2022) to assess the livelihood vulnerability of residents. Second, the study of resilience of livelihood vulnerability, such as poverty risk measurement (Huang et al., 2021), poverty early-warning mechanism construction (Chen et al., 2023) and so on. The third is to construct vulnerability assessment methods, such as constructing vulnerability index to study vulnerability trends (Shiyu et al., 2017), constructing DEA to express vulnerability and disaster situation through the concept basis of "Input-output" (Liu et al., 2010). These studies generally agree that the three elements of livelihood capital, capacity and rights together build the link between poverty and vulnerability (He and Lan, 2022), and that vulnerability governance plays a key role in the governance of poverty return.

TABLE 1 Evaluation index system for SL of resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project.

	First-grade index	Second-grade index	Literature reference
Resettlers' SL evaluation	Economic foundation (M)	Per capita disposable income M_1	(Huang et al., 2015; Li et al., 2015; Sun and Zhao, 2017; Xia, 2019; Wang, 2020; Xie, 2020; Li et al., 2021; Wang et al., 2022; Wu et al., 2022)
		Engel coefficient M_2	
		Pension insurance coverage M_3	
		Medical insurance coverage M_4	
		Moderate scale of land operation M_5	
		Labor employment rate M_6	
	Environmental assurance ability (E)	Per capita housing area E_1	(Huang et al., 2015; Li et al., 2015; Sun and Zhao, 2017; Xia, 2019; Wang, 2020; Xie, 2020; Li et al., 2021; Wang et al., 2022)
		Tap water penetration rate E_2	
		Hardening rate of primary and secondary streets E_3	
		Street lighting rate of main roads and public places E_4	
		TV, radio, broadband coverage E_5	
		Village green coverage E_6	
	Social adaptability (S)	Education rate of residents in high school (technical secondary school) and above S_1	(Huang et al., 2015; Li et al., 2015; Sun and Zhao, 2017; Xia, 2019; Xie, 2020; Li et al., 2021; Wang et al., 2022)
		Operation status of "Two Committees and Three Commissions" organization S_2	
		Proportion of new-type professional farmers in employees in the primary industry S_3	
		Social relationship integration S_4	

Note: "Two committees and three commissions" organization refers to the village party branch committee, village committee, democratic commission, democratic supervisory commission and civil mediation commission.

The livelihoods of resettlers are affected by many factors. The development of ecological environment has a profound impact on the quality and level of economic and social development, and then on the quality of people's lives. Therefore, environmental indicators are important content of sustainable livelihood evaluation system (Yuan et al., 2022). Hu and Wen found a significant positive correlation between social networks, risk identification and sustainable livelihoods for rural resettlers. They believe that the government should actively create conditions, expand the scale and density of social networks for rural resettlers and improve their ability to identify risks (Hu et al., 2018). Yang Kun and so on selected the landless peasant household as the research object, constructed the index frame with the per-capita income, the livelihood diversity, the welfare coverage rate, the labor force employment rate as the main content, combined with the entropy value method and the path analysis method, in-depth analysis of the sustainable development of landless farmers and the impact of factors affecting the mechanism (Yang et al., 2021). According to Wang Gang, the policy guarantee, the life guarantee and the economic foundation of resettlers are the important aspects that affect the survival and sustainability of resettlers (Wang, 2020). On the basis of the difference of influencing factors, the index system of sustainable livelihood is also varied. Wu Jie and others used Natural capital, human capital, social capital, material capital and financial capital as primary indicators to construct a livelihood evaluation system for resettlers from Tibetan-related areas, and the cultivated land area, quality of life, social network, infrastructure as important secondary indicators (Wu et al., 2022). Huang Xing and his colleagues used living space *per capita*, water coverage, road satisfaction, and electricity coverage as environmental indicators for their survey of sustainable livelihoods for reservoir resettlers (Huang et al., 2015). Li Dan incorporated cultural heritage into the capital measurement system, taking into account the actual situation of ethnic minority reservoir resettlers (Li et al., 2015). Based on the sustainable livelihoods analysis framework (SLA) proposed by the UK Agency for International Development (DFID) and the above studies, and combined with the actual situation in China, we have established the evaluation index system of this study, as shown in Table 1.

How to better achieve the goal of sustainable livelihoods, scholars have also carried out relevant research. Liang and his colleagues found that after the migration, Natural capital, financial and physical capital suffered greater losses, human capital and social capital also suffered losses to varying degrees (Liang et al., 2016). The lack of Natural capital will make human capital invalid and ability impaired, and ultimately affect the income level of immigrants (Sun L, 2016). As a spiritual force, culture is also an important factor affecting the livelihood of immigrants, through positive guidance to better eliminate social contradictions (Duval, 2019). Yang and Yang explored

the distribution of farmers' livelihood capital by constructing a two-column model. The results showed that there was an imbalance in the level and structure of farmers' livelihood capital, they pointed out that the amount of livelihood capital should be increased and the structure of capital should be optimized in order to enhance the willingness of farmers to participate in environmental governance (Yang and Yang, 2022). The research of Wang Wenxiong, Lan Qingqin and others found that the financial level of farmers could directly affect the transformation and development of farmland, and then affect the economic status of farmers, the government should actively encourage and support the participation of social capital in farmland transformation and development in order to improve farmers' economic conditions (Wang et al., 2020). According to Zhou Li and Li Hongmei, human capital investment has provided important support for the relocation of farmers, enabling them to change from a traditional agricultural business model to a more flexible non-agricultural business model, therefore, it is necessary to strengthen the relevant education and training, improve the quality of the population, achieve effective use of resources, better development of local industries (Zhou et al., 2021). Jilin Wu and others found that farmers' sustainable livelihoods respond strongly to eco-cultural capital factors, and put forward livelihood transformation, strategic choice and improvement strategies and suggestions (Wu et al., 2023). In addition, late-stage support is a special policy to improve the livelihood of migrants, and the key to guarantee the rights of migrants is to adjust the policy appropriately (Zhao et al., 2019).

Through combing and analyzing the relevant literature at home and abroad, we find that the research on sustainable livelihood has been a hot topic in recent years. Scholars at home and abroad have conducted in-depth research on it, constantly enriching and expanding the field of sustainable research. Previous research serves as a significant point of reference for this paper, but it also contains the following deficiencies: (1) From the perspective of research content, previous research has paid more attention to changes in the status, capital, and vulnerability of reservoir resettlement livelihoods, but no quantifiable standard has been formed for the sustainability of reservoir resettlement livelihoods;(2) From the perspective of objects, most of the existing research objects are mainly based on a community, county or reservoir area, and few studies are carried out with the reservoir area as a whole. In this paper, taking Henan reservoir area resettlers as a whole as the research object can grasp the current.In addition, under the Sustainable Livelihoods Framework, Based on the system concept, the sustainable livelihood of the resettlers in the Danjiangkou Henan Reservoir Area in the South-to-North Water Diversion Project was evaluated and analyzed by using the model of material element extension. Analyze the problem based on the evaluation results and propose countermeasures, Some objectives, for the government departments to optimize the sustainable livelihood strategy development to provide reference, conducive to the overall promotion of rural revitalization strategy implementation.

For resettlers, it is of great importance to quantify the sustainability of their livelihoods as accurately as possible, find out the weakness of sustainable livelihood development, and provide them with accurate policy support for their future development. In addition, the accurate quantification of capacity and the implementation of accurate policy support are also important means to achieve a comprehensive rural revitalization strategy in the resettlement area. From the perspective of ensuring the SL of reservoir resettlement, this paper constructs a SL evaluation index system for reservoir resettlement by combining Maslow's hierarchy of needs theory. Then, the quantitative weights are determined with the AHP. Furthermore, the sustainability of livelihoods of resettlers in the Danjiangkou Henan reservoir area of the South-to-North Water Diversion Project is systematically evaluated based on empirical research data and the fuzzy matter-element model. The research results are expected to provide a foundation and reference for effectively addressing resettlers' subsequent livelihood problem and fostering their steady development.

3 Data source and evaluation index system construction

3.1 Data source and processing

3.1.1 Data source

Danjiangkou Reservoir, known as the "Asian Heavenly Lake", is the core water source area of the Middle Route of the South-to-North Water Diversion Project. The Danjiangkou Dam Heightening Project is a key control project in the Middle Route. The villagers who now reside in the original reservoir area will be inside the submerged area of the reservoir following the completion of the Danjiangkou Reservoir due to the scale of the South-to-North Water Diversion Project. In the case of reservoir project problem and water leakage, everything in the submerged area of the reservoir, including farming crops, woodland vegetation, residential buildings, etc., will suffer catastrophic destruction. Considering this fact, a number of resettlement measures must be taken. Henan Province is the main submerged area after the dam of the Danjiangkou Reservoir of the South-to-North Water Diversion Project is raised and impounded. In Xichuan County, the inundation affects 11 townships, 184 villages, and 1,276 villager groups. The inundated area affects 217,000 mu of land and 107,200 people of all kinds. Over 166,000 people were relocated and resettled in Henan Province in the period 2009–2011, and they were distributed among 27 counties (cities, districts) in 6 provincial cities including Zhengzhou, Pingdingshan, Xinxiang, Xuchang, Luohe and Nanyang and Dengzhou, a city directly under the provincial administration (Chow, 2017).

This paper conducted concentrated research on the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project, resettlement areas and resettlement management departments, and obtained data through questionnaires, semi-structured interviews and field observations. The empirical research covered all resettlement sites in the Henan reservoir area of the Danjiangkou Reservoir of the South-to-North Water Diversion Project, including Zhengzhou, Pingdingshan, Xinxiang, Xuchang, Luohe, Nanyang and other prefecture-level cities, involving 8 counties (cities) and 30 resettlement villages, a total

of 6180 households and 25,663 people. The questionnaire survey was carried out by random sampling from the resettlement households in relevant cities and counties. With reference to the national statistical survey system, the effective sample households of resettlers were controlled to be no less than 1% of the total, that is, more than 385 households were required. A total of more than 550 questionnaires were distributed for the survey, and 515 valid questionnaires were returned, the proportion of valid questionnaires reaching 93.6%.

On the basis of empirical research and questionnaire survey, this paper also collected relevant data from the Henan Provincial Immigration Office, provincial municipalities, and resettlement management departments through structured and semi-structured interviews. Since the latest data were updated at the end of 2019, the actual data from 2019 served as the source of all pertinent evaluation information in this paper.

3.1.2 Data processing

The data were standardized by adopting the method of extreme standardization because the survey data had varied dimensions, orders of magnitude, and ranges of change.

3.2 Construction of fuzzy matter-element evaluation model for sustainable livelihood of reservoir resettlements

3.2.1 The construction of evaluation index system

Scholars have different views on the construction of the sustainable livelihood system of resettlers, and the research angle also has its own emphasis Based on the DFID sustainable livelihoods analysis framework. Li and his colleagues set up an evaluation system from five dimensions: human capital, Natural capital, physical capital, financial capital and social capital, to compare regional, inter-domain differences in sustainable livelihoods, to find ways to improve (Li et al., 2021). Qin Q.H and Zhou D studied the mediating effect of direct subsidy fund and project support by analyzing the influence of material capital, human capital and social capital on sustainable livelihood strategy (Qin and Zhou, 2021). Huang Xing et al. evaluated the Base, living environment and policy support of the sustainable livelihoods of resettlers from the Ili Kazakh Autonomous Prefecture Valley Reservoir in Xinjiang (Huang et al., 2015). In the course of our actual investigation, we found that after the relocation of the reservoir resettlers, the original means of production and living had been destroyed, and the living environment and social interaction of the resettlers had undergone tremendous changes, based on the Sustainable Livelihoods Analysis Framework published by the UK Agency for International Development (DFID, 2000), drawing on existing research and consulting relevant experts, for example, the scholar (Reddy et al. , 2022) explored strategies for the development of organic agriculture using a problem-path approach and theories of change, emphasizing strategic arrangements and policies tailored to regional contexts, the indicators in the theory of change are divided into input, activity, output, result and influence, which can be used for reference to optimize the evaluation of the effectiveness of resettlement. According to the principles of systematicness, science, dynamics and combination with the national strategy of rural revitalization, the sustainable livelihood level of reservoir resettlers is measured from three dimensions: material base, living environment and social adaptability. From a hierarchical point of view, the three dimensions are highly consistent with Maslow's hierarchy of needs theory. After relocation, the resettlers lose their original houses and the land on which they lived, and need a certain economic foundation to maintain their basic survival needs; after a certain degree of adaptation, the resettlers need to pursue a higher level of livelihoods without destroying their basic life, which also reflects the sustainability of their living environment; most importantly, after adapting to the new environment, they need to pursue a higher standard of living and realize self-worth, which is the need for self-realization. From the economic foundation to the realization of self-worth, the aforementioned three elements are largely present in the SL of reservoir resettlement. Therefore, combined with the connotation of SL, 16 second-grade indexes are selected from the three dimensions of economic foundation, environmental assurance ability and social adaptability. These 16 indexes constitute an evaluation index system for SL of resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Transfer Project (Table 1).

3.2.1.1 Economic foundation

Since economic conditions are of great significance to individual survival and the normal functioning of families, economic foundation is taken as the fundamental index of sustainable livelihoods. Under normal conditions, changes in the environment and the state of the land under cultivation can have an impact on *per capita* income, which in turn affects *per capita* disposable income (Wang, 2020). The Engel's coefficient reflects the income and standard of living in the resettlement area. The coverage of old-age insurance and health insurance for immigrants has an important impact on the security of their lives. The higher the coverage rate and the degree of security, the higher the coverage rate and the degree of security, the better off the resettlers are (Huang et al., 2015). The moderate scale of land management and the employment rate of labor force can reflect the income of migrant families to a certain extent. Based on the existing literature and the actual situation of Danjiangkou Dam resettlement areas, eventually, it will include disposable income *per capita*, Engel's coefficient, pension coverage, health insurance coverage, land management on an appropriate scale, and employment as the concrete performance of the Base index, all indicators except the Engel's coefficient are positive indicators.

3.2.1.2 Environmental assurance ability

Environmental assurance ability, which refers to the support degree of the specific living environment obtained by the resettlers in the relocated area, is an important component of examining the livelihood level. Living infrastructure conditions and the natural environment are important indicators of the ability to ensure the environment, which to a large extent affects the degree of satisfaction of immigrants with living conditions. Li believes that housing area, housing structure, living facilities, infrastructure, public services, transport facilities are important factors to measure the material capital of migrants (Li et al., 2021). Wang believes that the household housing area, household large electrical equipment

ownership should also be included in the livelihood evaluation indicators (Wang et al., 2022). And Sun and Zhao believe that besides housing area, housing structure and housing environment are also important indicators of housing conditions (Sun and Zhao, 2017). This study chooses six indexes to evaluate the external support for the livelihoods of reservoir resettlement, i.e., *per capita* housing area, tap water penetration rate, hardening rate of primary and secondary streets, street lighting rate of main roads and public places, TV, radio, broadband coverage and village green coverage, and all the secondary indicators are positive indicators.

3.2.1.3 Social adaptability

Social adaptability refers to how resettlers adapt to their new homes when they move away from their original location and when their social relations change. The higher the adaptability, the better their quality of life. When resettlers have good social adaptability, they have better performance in interpersonal communication, life adaptation, physical and mental health (Sun and Zhao, 2017; Li et al., 2021) brings village-level grassroots organizations, immigrant cognition, Social Security and social integration into the field of social capital of immigrants. Incorporating the relationship with the original villagers into the evaluation criteria of social capital also reflects the degree of social integration of immigrants (Xia Y, 2019). Here, it is mainly evaluated from four aspects, i.e., education rate of residents in high school (technical secondary school) and above, operation status of "two committees and three commissions" organization, proportion of new-type professional farmers in employees in the primary industry and integration of social relations. And all the indicators are positive indicators, the higher the proportion, the better the expression results.

3.2.2 Determination of evaluation index weight and target value

In this paper, the evaluation indexes and corresponding weight ratios are determined by combining the AHP with scoring by immigration experts and immigration staff. China's immigration resettlement regulations implement a developmental resettlement policy to ensure that the production and living standards of the resettlers are not lower than those before the relocation. The "Opinions of the State Council on Improving the Later Support Policies for Large and Medium-Sized reservoir resettlement" makes it equally apparent that the solutions to the issues of food and clothing and long-term development must go hand in hand. Therefore, this evaluation incorporates the objectives of maintenaning livelihood (LM) and SL into the evaluation system. The former indicates that resettlers' current level of living has not dropped, and the latter demonstrates that resettlers' future lives can be guaranteed. Among them, the target value setting of livelihood maintenance mainly refers to the national economic statistics of Henan province in the survey year, and the target value setting of sustainable livelihood mainly refers to the "Rural Revitalization Strategic Plan of Henan Province (2018–2022)" and the main indicators in the system of good resettlement village construction published by the Leading Group on Immigration Work of the People's Government of Henan Province This article selects the highest standard to determine the target value of sustainable livelihood of resettlers (Table 2).

3.2.3 Model construction

The fuzzy matter-element evaluation method can solve the problem of incompatibility of evaluation results between single indexes. Thanks to its advantages of being easy to use, producing accurate findings and being very practicable, it is widely used to solve the problems of multiple incompatible, fuzzy and uncertain factors (Codification Commission, 2020). The evaluation process of SL of reservoir resettlement involves multiple indexes that interact with each other, which is a typical fuzzy concept. Therefore, this paper uses the fuzzy composite meta-analysis model to evaluate the SL of reservoir resettlement.

3.2.3.1 Composite fuzzy matter-element model

The goal of the matter-element theory is to encourage the transformation of objects and find solutions to compatibility issues. The main idea is to use "objects, properties, and values" to describe samples (Cai et al., 1984). Assuming that an object N whose property and value are c and v, respectively, constitutes a matter element R= (N, c, v). Substituting N into the evaluation system constructed in this paper, then N refers to the actual livelihood level, LM level and SL development level of resettlers. The 16 indexes of LM and SL are represented by c, and their corresponding values are represented by v. If the index value (V value) of the matter-element evaluation model contains fuzzy features, then the matter-element is fuzzy, which is called a fuzzy matter-element model. In the same way, for objects with "n" features (such as c1, c2 . . . cn) and fuzzy values (such as v1, v2 . . . vn), if all the n values are fuzzy, then R is said to be an n-dimensional fuzzy matter-element. The composite fuzzy matter-element R_{mn} for evaluating the SL of resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project is an n-dimensional fuzzy matter-element composed of m individuals to be evaluated, that is, m livelihood evaluation indexes.

$$\mathrm{Rmn} = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ C_1 & x_{11} & x_{21} & \cdots & x_{m1} \\ C_2 & x_{12} & x_{22} & \cdots & x_{m2} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ C_n & x_{1n} & x_{2n} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

where Rmn is the n-dimensional composite fuzzy matter-element of m objects; Mi is the i-th object (i = 1, 2, . . ., m); Cj is the j-th feature (j = 1, 2, . . ., n); xij is the fuzzy value corresponding to the j-th feature of the i-th object.

3.2.3.2 Optimal membership degree

In the optimization scheme, the fuzzy value corresponding to each single index obeys the membership degree of each corresponding fuzzy value, which is called the optimal membership degree (Deng et al., 2015). In the process of standardization, there are two types of optimal membership: the bigger the better and the smaller the better:

The bigger the better: μij = Xij/maxXij

The smaller the better: μij = min Xij/Xij

Where μij is the optimal membership degree; maxXij is the maximum value of the fuzzy value corresponding to the feature vector of the object; and minXij is the minimum value of the fuzzy value corresponding to the feature vector of the object. In the evaluation system for the SL of resettlers in the reservoir area, all

TABLE 2 Evaluation index system, weight and target value of SL of resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project.

Index classification	Index	Attribute for the indicator	Weight	LM target	SL target
Economic foundation	Per capita disposable income (yuan)	+	0.152	≥15,000	≥20,000
	Engel coefficient (%)	—	0.055	≤30.5	≤28.5
	Pension insurance coverage (%)	+	0.041	≥90	≥95
	Medical insurance coverage (%)	+	0.041	≥90	≥95
	The moderate scale of land operation (%)	+	0.034	≥37	≥42
	Labor employment rate (%)	+	0.100	≥90	≥95
Environmental assurance ability	Per capita housing area (m^2)	+	0.105	≥40	≥45
	Tap water penetration rate (%)	+	0.092	≥90	100
	Hardening rate of primary and secondary streets	+	0.039	≥80	100
	Street lighting rate of main roads and public places (%)	+	0.037	≥75	≥90
	TV, radio, broadband coverage	+	0.036	≥99	100
	Village green coverage	+	0.033	≥25	≥35
Social adaptability	Education rate of residents in high school (technical secondary school) and above	+	0.103	≥49.3	≥65
	Operation status of "Two Committees and Three Commissions" organization(general/good/excellent)	+	0.013	Excellent	Excellent
	Proportion of new-type professional farmers in employees in the primary industry (%)	+	0.034	≥10	≥14
	Social relationship integration (point)	+	0.085	4	5

indexes are positive indexes except the Engel coefficient, that is, the larger the index value, the better the livelihood situation. In view of this fact, Formula (2) is used to standardize the value. Through the above calculation, the fuzzy matter-element R'mn of the preferred membership degree can be obtained.

$$R'_{mn} = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ C_1 & \mu_{11} & \mu_{21} & \cdots & \mu_{m1} \\ C_2 & \mu_{12} & \mu_{22} & \cdots & \mu_{m2} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ C_n & \mu_{1n} & \mu_{2n} & \cdots & \mu_{mn} \end{bmatrix} \quad (2)$$

3.2.3.3 Standard fuzzy element and difference square composite fuzzy element

Usually, the standard fuzzy matter element R0n is determined by the maximum or minimum value of the fuzzy matter element R'mn of the priority degree of membership. In this paper, the maximum value of the priority degree of each livelihood index is taken as the optimal result, that is, the priority degree of each index is 1, which is recorded as:

$$R_{0n} = \begin{bmatrix} & M_0 \\ C_1 & \mu_{01} \\ C_2 & \mu_{02} \\ \cdots & \cdots \\ C_n & \mu_{0n} \end{bmatrix} \quad (3)$$

Then, the difference square composite fuzzy matter element RΔ is constructed, which can be composed of the square of the difference between the standard fuzzy matter element R0n and the fuzzy matter element R'mn of the optimal membership degree, that is, $\Delta ij=(X0j-\mu ij)^2$.

$$R_\Delta = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ C_1 & \Delta_{11} & \Delta_{21} & \cdots & \Delta_{m1} \\ C_2 & \Delta_{12} & \Delta_{22} & \cdots & \Delta_{m2} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ C_n & \Delta_{1n} & \Delta_{2n} & \cdots & \Delta_{m3} \end{bmatrix} \quad (4)$$

3.2.3.4 Euclid nearness degree selection and evaluation results

Euclid nearness is a measure of how close an object is to the optimal object, and the greater the value is, the closer the object is to the optimal object (Han et al., 2019). This paper uses the value of the Euclid nearness to measure the SL level of reservoir resettlement. According to the index weight ωj established by the AHP above, the nearness of the investigation base value, the maintenance target value and the sustainability target value of economic foundation, environmental assurance ability and social adaptability are calculated. The livelihood of the resettlers in the Danjiangkou Reservoir area of the South-to-North Water Diversion Project is deemed to be at a sustainable level if the Euclid gap between the survey present value and the SL target value is the least. On the contrary, it is believed that the livelihood of the resettlers cannot be sustained. The Euclid nearness Kj is calculated in this case using the multiply-add procedure, and the Euclid nearness composite fuzzy

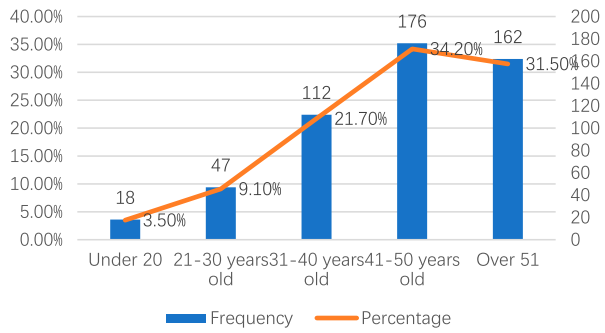

FIGURE 1
The age distribution of the immigrant population.

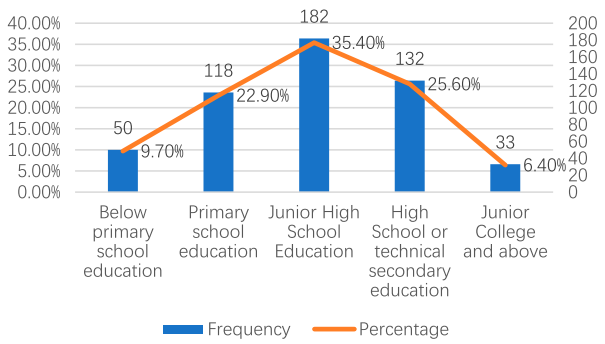

FIGURE 2
Education level of respondents.

matter-element Rkis subsequently built. The calculation formula of Euclid nearness K_j is as follows:

$$K_j = 1 - \sqrt{\sum_{j=1}^{n} \omega_j \Delta_{ij}} \quad (5)$$

where ω_j is the comprehensive weight of the index j, and Δ_{ij} is the square of each difference between the standard fuzzy matter-element R0n and the optimal membership degree fuzzy matter-element R'mn.

$$R_k = \begin{bmatrix} & M_1 & M_1 & \cdots & M_m \\ K_j & K_1 & K_2 & \cdots & K_m \end{bmatrix} \quad (6)$$

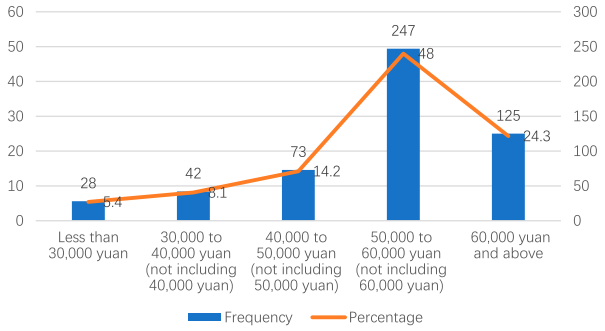

FIGURE 3
The household income of immigrants.

4 Results and analysis

Based on the field survey data of the Danjiangkou Reservoir of the South-to-North Water Diversion Project in Henan Province, this paper adopts the constructed fuzzy matter-element model to evaluate the SL of resettlers in the reservoir area. First, the resettlement livelihood is descriptively analyzed and evaluated by calculating the completion rates of maintaining the original livelihood and achieving the target value of sustainable development. Afterwards, the fuzzy matter-elements of classification and comprehensive indexes are calculated through the evaluation model constructed. Finally, whether it meets the requirements of livelihood sustainability is judged by the Euclidean distance.

4.1 The basic information table of the questionnaire

According to the survey results, 54.37% of the immigrants are male and 45.63% are female. The analysis of the age-stage characteristics of migrant households in the study area is shown in Figure 1. The proportion of resettled households under the age of 20 in the study area is 3.5 per cent; the proportion between the ages of 21 and 30 is 9.1 per cent; 21.7 per cent are between the ages of 31 and 40,34.2 per cent between the ages of 41 and 50 and 31.5 per cent between the ages of 50 and over, the distribution within the survey area mainly represents the intention of the resettled group aged 41 to 50 and over 51.

The analysis of the characteristics of the educational level of the immigrant households in the survey area is shown in Figure 2. Among the immigrants who participated in the questionnaire, 9.7% have less than a primary education and 22.9% have a primary education, the proportion of junior high school education is 35.4%, the proportion of senior high school or technical secondary school education is 25.6%, and the proportion of junior college education and above is 6.4%. It can be seen that the educational level results of this survey basically accord with the distribution of educational level of rural residents, at the same time, the distribution of age is consistent with the results.

The analysis of the characteristics of the annual income of migrant households in the survey area is shown in Figure 3. The number of households with an annual income of less than 30,000 among the surveyed migrant households in the study area is 5.4 per cent, 8.1% of the households have an income of 30,000 to 40,000 yuan, and 14.2% have an income of 40,000 to 50,000 yuan (not including 50,000 yuan), 48% of the households have an annual income of 50,000 to 60,000 yuan (excluding 60,000 yuan), and 24.3% have an annual income of more than 60,000 yuan.

TABLE 3 Economic foundation of resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project.

Index	Survey present value	Maintenance target completion rate (%)	Sustainability target completion rate (%)
Per capital disposable income (yuan)	13,957	93.04	69.79
Engel coefficient (%)	41	76.25	69.51
Pension insurance coverage (%)	92.8	103.11	97.68
Medical insurance coverage (%)	93.4	103.78	98.32
Moderate scale of land operation (%)	24	64.86	57.14
Labor employment rate (%)	89	98.89	93.68

4.2 Classified evaluation of SL of reservoir resettlement

$$R_{kj} = \begin{bmatrix} & \text{Survey present value} & \text{LM} & \text{SL} \\ K_j & 0.8633 & 0.9575 & 1 \end{bmatrix} \quad (7)$$

4.2.1 Economic foundation

According to Table 3, the *per capita* disposable income of resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project in 2019 was 13,957 yuan, the maintenance target completion rate being 93.04% and the sustainable target completion rate being 69.79%. The *per capita* disposable income is still far from the target of sustainable development. Resettlers will inevitably face challenges in their quest to raise their income due to changes in the cultivated land and ecological requirements of special areas. After calculation, the Engel coefficient in the resettlement area is 41%, which is only 76.25% of the maintenance target. The consumption of resettlers is still dominated by food, and the quality of life needs to be improved. In addition, according to survey findings, the completion rate of the moderate scale of land operation is 24%, which is more than 35% lower than the completion rates of the maintenance target and the sustainable target. On the other hand, the coverage rates of endowment insurance and medical insurance are both over 90%, exceeding the task of maintaining the target and basically reaching a sustainable state. With regard to labor employment, the employment rate reaches 89%, which is at a relatively high level.

Then, the current value and weight of each project survey are substituted into the fuzzy matter-element evaluation model constructed above for calculation, analysis and evaluation. The Euclid nearness of economic foundation, LM indexes and SL indexes of Danjiangkou reservoir resettlement is calculated step by step:

After calculation, the gap between the actual economic foundation of the resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project and the LM target is 0.0942 and the gas between it and the SL target is 0.1367. Such a result indicates that the resettlers have essentially reached the goal of maintaining their livelihoods in terms of economic foundation, and more work is required to ensure its sustainable development.

4.2.2 Environmental assurance ability

During the survey period, the *per capita* housing area reached 43 m^2, and 100% of households had access to tap water, TV, radio, and broadband. The hardening rate of primary and secondary streets, the green coverage rate of villages, and the street lighting rate of main roads and public places all complied with the LM target. It demonstrates that the government departments have built resettlement housing, infrastructure and public service facilities with high standards, creating a good living environment for residents of the resettlers. A slight gap exists between village greening, street lighting of main roads and public places, and *per capita* housing area and the SL target. The primary reason is as follows: after relocation, the population surges while the construction area is limited, resulting in a gradual decline of *per capita* housing area; meanwhile, the lighting equipment is damaged due to insufficient maintenance as shown in Table 4.

TABLE 4 Environmental assurance ability of resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project.

Index	Survey present value	Maintenance target completion rate (%)	Sustainability target completion rate (%)
Per capita housing area (m^2)	43	100	95.56
Tap water penetration rate (%)	100	100	100
Hardening rate of primary and secondary streets	89.1	100	89.1
Street lighting rate of main roads and public places (%)	75.5	100	83.89
TV, radio, broadband coverage	100	100	100
Village green coverage	29	100	82.86

Bringing the data into the fuzzy meta-model calculation, the Euclid nearness of the actual environmental assurance ability, LM target and SL target enjoyed by the resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project is obtained:

$$R_{kj} = \begin{bmatrix} & \text{Survey present value} & \text{LM} & \text{SL} \\ K_j & 0.8657 & 0.8462 & 0.8874 \end{bmatrix} \quad (8)$$

Calculated by Rkj, the gap between the current situation of resettlers' environmental assurance ability in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project and the LM target is −0.0195, and the gap between it and the SL target is 0.0217, indicating that the resettlers' environmental assurance ability has surpassed the LM goal and is close to the SL goal.

4.2.3 Social adaptability

According to the survey, the resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project have achieved 100% of the LM and SL targets in terms of "two committees and three commissions", showing that the villagers' autonomous organizations were successfully run after the resettlers were relocated. However, immigration management institutions in various places tend to be weakened and the long-term balance between resettlers and immigration management institutions will no longer exist as a result of the reform of the next round of institutions. The resettlers worry that the aid for them would be scaled back. In terms of social relationship integration, the completion rate of the LM target is 97.5%, and that of the SL target is 78%. It suggests that after 10 years of development following the immigration, the resettlers have largely assimilated into the local community in terms of production methods and way of life, although a certain gap remains. The education rate of residents in high school (technical secondary school) and above is 32%, accounting for just 64.91% of the LM target and 49.23% of the SL target, indicating that most resettlers' children join the workforce after completing their compulsory education due to a variety of causes. The proportion of new-type professional farmers in employees in the primary industry is only 20% of the LM target, and the SL target completion rate is as low as 14.29%, revealing that most of them are still self-cultivated and the proportion of large-scale operations remains low after immigration as shown in Table 5.

By substituting various survey data and weights into the fuzzy matter-element evaluation model, the current social adaptability, LM indexes and SL indexes of the resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project are calculated step by step:

$$R_{kj} = \begin{bmatrix} & \text{Survey present value} & \text{LM} & \text{SL} \\ K_j & 0.5549 & 0.6057 & 1 \end{bmatrix} \quad (9)$$

After calculation, the gap between the survey present value of social adaptation of the resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project and the LM target is 0.0508, and the gap between it and the SL target is 0.4451. The LM standard has not been attained, and there is still a long way to reach the SL state.

4.3 Overall evaluation of SL of reservoir resettlement

On the basis of analyzing the evaluation of economic foundation, environmental assurance ability and social adaptability, the overall Euclid nearness of resettlers from the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project is calculated:

$$R_{kj} = \begin{bmatrix} & \text{Survey present value} & \text{LM} & \text{SL} \\ K_j & 0.7480 & 0.7565 & 0.9205 \end{bmatrix} \quad (10)$$

It is clear that the current value of the survey of the overall livelihood of the resettlers in the Danjiangkou Henan Reservoir Area is 0.0085 lower than the LM target and 0.1725 lower than the SL target. According to the principles of Euclid nearness, the livelihood level of resettlers in the Danjiangkou Henan Reservoir Area is basically to maintain the original water conservancy and there are still some gap with the SL target. The gap is most manifested in two aspects: economic foundation and social adaptability. Immigration management agencies in Henan at all levels should strive to adjust the industrial structure, increase immigration income, improve the level of education, and cultivate new types of farmers. Especially, at the policy level, they should assist resettlers in fully integrating into the community and promote the development of SL of resettlers in the Danjiangkou Henan Reservoir Area.

5 Conclusion

As a form of involuntary resettlement, the lives of reservoir resettlers have undergone significant changes due to relocation, restitution and reconstruction of resettler livelihoods which is a

TABLE 5 Social adaptability of resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project.

Index	Survey present value	Maintenance target completion rate (%)	Sustainability target completion rate (%)
Education rate of residents in high school (technical secondary school) and above	32	64.91	49.23
The operation status of "Two Committees and Three Commissions" organization (general/good/excellent)	Excellent	100	100
Proportion of new-type professional farmers in employees in the primary industry (%)	2	20	14.29
Social relationship integration (point)	3.9	97.5	78

long process. It is possible to comprehensively and systematically understand the current situation of resettlers' livelihoods by considering the entire storage and resettlement area as the focus of research, in addition, more assured, more scientific solutions to the problem of the subsequent livelihood of resettlers. Based on the study of sustainable livelihood by domestic and foreign scholars, this paper focuses on Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project as the research area. The study examines the 25,663 resettlers from eight cities in the Reservoir District (County) as research subjects, taking into account the local situation, the paper aims to construct a sustainable livelihood assessment system for resettlers in the reservoir area, from the perspective of livelihood sustainability. The current situation of sustainable livelihood for resettlers in the reservoir area is evaluated and analyzed using data obtained through field research and questionnaires. According to the current situation, this paper summarizes the challenges that resettlers in the Danjiangkou Henan Reservoir Area face in achieving sustainable livelihood development. It also analyzes the underlying causes of these problems. Finally, the author presents several countermeasures and suggestions to enhance the sustainable livelihood of resettlers in the reservoir area. The main conclusions of this paper are as follows:

(1) The evaluation results indicate that the survey status of the overall livelihood of resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project is by 0.0085 from the target of livelihood maintenance and is by 0.1725 from the set goal of sustainable livelihood.
(2) In the second-level evaluation indicators, the difference between the economic base and the livelihood maintenance target is 0.0942, while the difference between the economic base and the sustainable livelihood goal is 0.1367. It shows that the economic ability of the resettlers in Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project has basically achieved subsistence, however, sustained efforts are still needed to ensure that sustainable development goals are met. The current distance between environmental assurance ability and livelihood maintenance target is −0.0195, and the distance between environmental assurance ability and sustainable livelihood targets is 0.0217. This indicates that resettlement environmental assurance ability has now exceeded livelihood objectives and is approaching sustainable livelihood standards. The existing survey value for social adaptation is 0.0508 from the livelihood maintenance target and 0.4451 from the sustainable livelihood target. This indicates that resettlers are currently not meeting the livelihood maintenance status standard in terms of social resilience, they are still a long way from achieving sustainable livelihood goals, and it will take time to integrate and adapt.
(3) The framework of sustainable livelihood assessment for reservoir resettlers engineering is more effective. It provides a quantitative assessment of the current status and level of sustainability of resettlers' livelihoods, and offers supporting evidence for accurate national poverty alleviation management results testing.

In conducting impact assessments, the theory of change helps to identify the data that needs to be collected by the study and how the data should be analysed. Change theory often divides the indicators of evaluation system into input, output, result, influence, etc. (Rogers, 2008; Rogers, 2014). Based on the theory of Change, Reddy discusses a series of processes of activities under the organic agriculture (PKVY) program, which are helpful to achieve the final expected results, and puts forward some pertinent suggestions. This paper holds that the theory of change is also applicable to the study of the sustainability of the livelihood of reservoir migrants, drawing on the research ideas of the theory of change, this paper constructs a flow chart for the improvement of the sustainability of the livelihood of reservoir migrants, as shown below Figure 4:

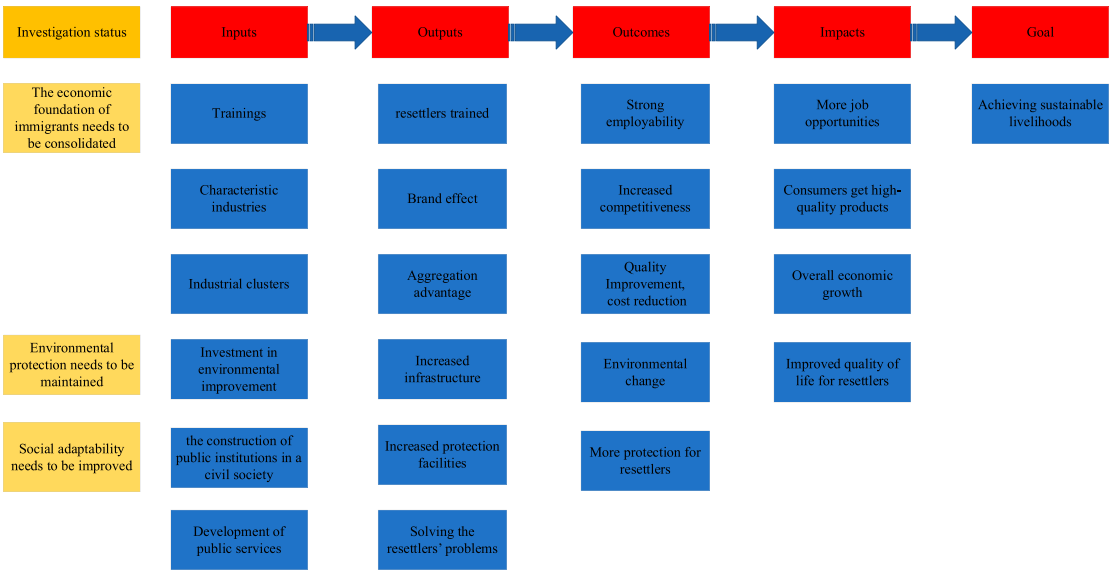

FIGURE 4
The application of the theory of change to sustainable livelihoods.

Based on the analysis of the above results, the research status of related fields and the research ideas of change theory (See Figure 4 above), some suggestions are put forward as follows:

(1) To strengthen resettlers' economic foundations, we will continue to strengthen economic policies, promote internal growth of resettlers' economic capacity, improve vocational education and skills training, improve resettlers' employability, and expand opportunities for resettlers to find new employment through environmentally friendly means. Furthermore, we will concentrate on integrating resettlers' capital, extending the industrial chain in resettlement villages, establishing local industrial projects based on local conditions, and enhancing overall income and wealth development in communities, villages, and towns. We will provide economic aid to help the long-term development of future resettlerment areas.
(2) In order to sustain resettlers' ability to live in a stable environment, the ecological conditions of resettlerment areas should be continuously maintained, infrastructure building should be enhanced, and resettlers' quality of life should be improved. Simultaneously, it is essencial to improve the development of public institutions such as schools, hospitals, libraries, and other security facilities to fulfill the demands of resettlers, in order to thoroughly improve resettlerment residents' ecological and social environmental protection capacity.
(3) In terms of improving resettlers' society's resilience, we should improve the public cultural service system of resettlerment towns and villages, improve the publicity work of immigration services, and encourage resettlers to come into active contact to explore the living environment; at the same time, we will improve the relevant social support systems, effectively respond to resettlers' concerns, and help them adapt to the local environment and life as soon as possible.

The sustainable livelihood of resettlers, in the context of the major water conservancy project studied in this paper, addresses the significant concerns regarding people's livelihood in the country. The sustainable livelihood evaluation index system, based on the fuzzy material element model, provides a theoretical basis for government decision-making to enhance the wellbeing of resettlers. Of course, there are some limitations in this paper. The sustainable livelihood of reservoir resettlers is a dynamic process, changes in social and environmental conditions, and government policy adjustments affect the sustainable livelihood development of resettlers. This paper only evaluates the current state of sustainable livelihoods among resettlers in the Danjiangkou Henan Reservoir Area of the South-to-North Water Diversion Project, it does not analyze the variations in sustainable livelihoods between different provinces and reservoir areas. In the construction of the index system, we find that with the deepening of the study, on the basis of the index system already built, some factors such as the psychological security of migrants(Jing, 2000), food security (Reddy et al., 2022) and human rights protection (Chang, 2014; Dai, 2015) can also reflect the social adaptation level of migrants in the livelihood capital to some extent. In the following research, the index system can be further expanded and deepened on the existing basis, such as the increase of psychological security, human rights protection indicators, etc. , In addition, the research object selected in this paper is the issue of resettlers' livelihood in the Henan Reservoir Area, within the context of the South-to-North Water Diversion Project, this scope is not sufficient to fully describe the sustainable livelihood mechanism of resettlers within the entire the South-to-North Water Diversion Project. Therefore, a long-term follow-up study will be conducted in the subsequent research projects to further investigate the dynamic evolution process and mechanism of sustainable livelihood response among resettlers affected by major water engineering projects.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

YH: conceptualization; methodology; validation; writing–original draft. FZ: data curation, supervision, editing. CS: supervision, resources. 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.

Publisher's note

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