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Can Environmental Risk Management Improve the Adaptability of Farmer Households' Livelihood Strategies? ——Evidence From Hubei Province, China

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With the rising temperature, uneven precipitation and frequent occurrence of extreme weather caused by global climate change, agricultural production is facing more severe challenges. Based on the sustainable livelihoods framework, this paper measures the index of farmer households' livelihood strategy adaptability and analyzes the benefits of farmer households' environmental risk management on livelihood strategy adaptability by using microscopic research data of 970 farmer households' livelihoods in Hubei Province, China, in 2020. This paper found that the farmer households' environmental risk management variables have a significant impact on the adaptability of farmer households' livelihood strategies, with the stronger the farmer households' environmental risk management capacity, the more adaptable its livelihood strategy. The impact of farmer households' environmental risk management variables on livelihood strategies varies for farmer households with different income levels. Therefore, this paper proposes that we should improve farmers' perception of climate change, promote the diffusion of adaptive technologies, improve agricultural insurance policies, give full play to the collective role of village collectives, companies and cooperatives, and promote the transformation and upgrading of livelihood approaches to further improve the adaptability of livelihood strategies.

Keywords: climate change, environmental risk management, farmer households, livelihood strategy adaptation, sustainable livelihoods

1 INTRODUCATION

Climate change is the main environmental risk faced by farm households in their agricultural production activities and has serious and far-reaching impacts on agricultural production. The adoption of adaptive livelihood strategies has become an important means for farmers to cope with environmental risks such as climate change, which helps stabilize farmers' livelihoods and secure agricultural income (Barham et al., 2014; Jin et al., 2015; Feng et al., 2017; Dougherty et al., 2020). With the increasing problems of rising temperatures, uneven precipitation and frequent extreme disaster weather brought about by global climate change, agricultural production is facing more severe challenges and food security is further affected. Adaptive behaviors such as adjusting agricultural production practices, spreading production risks, and changing livelihood strategies have become the main ways of coping with climate change and managing environmental risks. China is one of the leading countries affected by climate change and is exposed to a variety of environmental risks. Farming households located in rural areas of China are often poorly capitalized, have a single livelihood strategy, and are less resilient to environmental risks (Liu et al., 2018a). Therefore, exploring how to adopt long-term mechanisms for climate-resilient technologies, enhance the environmental risk management capacity of farmers, improve the adaptability of farmers' livelihood strategies and promote their sustainable development has become a focus of attention for researchers and policy makers.

Studies have shown that strengthening risk management and improving the adaptability of farmers' livelihood strategies are effective ways to achieve sustainable development, and have an important impact on the quality of household income (Gao and Lu, 2021). Farming households need to optimize the allocation of asset elements, choose multiple livelihood activities suitable for household development, increase income sources and quality, and reduce livelihood vulnerability as a means to sustain and improve household living standards (Khatun and Rov, 2016; Sun, 2018). However, in the process of choosing livelihood strategies, the risk management measures adopted by farmers gradually show diverse and different characteristics due to the diversity of risks faced by households (Heltberg et al., 2015), farmers' risk management capacity is further affected, which ultimately acts on household livelihood strategy adaptation. For rational farmers, the process of adaptation of their livelihood strategies is a behavioral strategy based on a combination of resource allocation that ensures that the environmental risks faced by farmers are within tolerable limits. Can environmental risk management play an effective and positive role in the selection and adaptation of farmers' livelihood strategies? What are the mechanisms underlying this role? In view of this, this paper establishes a theoretical analysis framework to empirically analyze the benefits of farm households' environmental risk management on the adaptation of livelihood strategies using microscopic research data on farm households' livelihoods in Hubei Province, China in 2020. We also classify farm households according to the level of household income and explore the mechanism of the role of farm household income in the impact of environmental risk management on the adaptation of livelihood strategies. On this basis, putting forward policy suggestions is of great significance for farmers to better cope with environmental risks and establish a long-term mechanism for adaptability of livelihood strategies.

Compared with previous studies, this paper has three main marginal contributions: first, it analyzes the livelihood strategy adaptability of farm households from the perspective of environmental risk management, which helps to enrich the research in the fields related to farm household risk management and livelihood strategy adaptability. Second, we adopt an econometric approach to measure the livelihood strategy adaptability of farm households in Hubei Province, China, to explore the mechanism of the effect of farm household income on environmental risk management on livelihood strategy adaptability, and to provide an empirical basis for the study of the measurement and influencing factors of livelihood strategy adaptability. Thirdly, we develop effective risk management strategies for farmers with different income categories, and provide decision ideas for farmers to improve their livelihood strategy adaptability.

2 LITERATURE REVIEW AND THEORETICAL ANALYSIS

2.1 Review of Relevant Literature

Adaptation is an important topic of research for the International Human Dimensions Programme on Global Environmental Change (IHDP). With the enrichment and expansion of the connotation and extension of ecological adaptability, the study of adaptability (force) has become a Frontier issue in comprehensive disciplinary research (Jiang et al., 2020). Among them, studies on climate change adaptive behavior are more extensive. For example, Feng et al. (2018a) examined the effect of asset specificity on climate change adaptive production behavior of professional farmers using micro-survey data from apple farmers in eight counties in Shaanxi Province. Among them, studies on climate change adaptive behavior are more extensive. Li et al. (2021) constructed a framework for analyzing farmers' "climate change perception-adaptive behavior" decisions to explore the influence of farmers' climate change perception on their adaptive farming behavior. Mao Hui et al. (2022) used an experimental economics approach to measure farmers' risk aversion and systematically examined the effect of risk aversion on farmers' climate-adaptive technology adoption behavior and the mechanism of action. There have been many studies on the factors influencing adaptive behavior of farm households. Livelihood capital is the main consideration for the adoption of adaptive behavior by farm households (Zhao et al., 2020). Farmers with better financial capital endowment are more inclined to adopt climate-adaptive technologies (Xu et al., 2018). Social capital and income provide sufficient material basis for farmers to adopt climate-adaptive technologies (Li et al., 2018). In addition, stable social networks, educational level of household heads, and policy support such as technology training and technology demonstration all have positive effects on farmers' climate-adaptive technology adoption behavior (Barrett et al., 2003; Goyal and Netessine, 2007; Yang, 2018; Zhang et al., 2019).

Farmers' livelihood strategy adaptability refers to the ability and process of resisting risks in a vulnerable ecological environment by adopting measures such as changing production methods, ecological migration or diversifying livelihood strategies (Xu and Hu, 2018a). Adaptation of livelihood strategies is an important issue for sustainable development in ecologically fragile areas (Shi, 2015). Existing studies on the livelihood adaptability of farm households mainly focus on relocated farm households and farm households in rural tourism areas. For example, Lai (2016) constructed an analytical framework for livelihood adaptation of migrant relocated farm households from social-ecological system adaptation theory, and analyzed the livelihood adaptation strategies, perceived resilience and their influencing factors of migrant relocated farm households in Ankang, Shanxi. Liu et al. (2018b) explored the livelihood adaptive capacity of relocated farm households in the concentrated contiguous special hardship areas of the Qinba Mountains and its influence on livelihood adaptation strategies. Li et al. (2020) used the Socio-Ecological Systems (SES) analysis framework to analyze the livelihood adaptation strategies and livelihood adaptability of farm households in rural tourism areas. Wen et al. (2020) used three typical rural tourism sites in Yan'an city as examples, combined the sustainable livelihood analysis framework and adaptation theory, analyzed the adaptation strategies and adaptation patterns of farm households under rural tourism disturbance, and quantitatively measured the adaptation results of farmers with different adaptation patterns.

Risk refers to the uncertainty or loss of the outcome of the choice of future livelihood strategies (Crane, 1984; Yang et al., 2018), and environmental risk refers to the rise in temperature, uneven precipitation, and frequent occurrence of extreme disaster weather brought about by global climate change. Risk management is a series of measures taken to identify, select and prevent the occurrence of future risks to them (Chen and Ding, 2003). Academic research on risk management includes the following three main areas: first, research on the factors influencing the choice of farmers' risk management strategies. Many scholars have shown that farmers' livelihood capital and individual endowments, farmers' subjective risk perceptions and risk attitudes, and risk categories and degrees all have an impact on the choice of risk management strategies (Tai et al., 2009; Menapace et al., 2012; Kira, 2017; Chen and Wei, 2019). The second is the research on countermeasures and policies for risk management. For example, Cheng and Du (2017) based on the risk management theoretical framework, explored agricultural drought risk management from the perspective of environmental changes and food security, and proposed countermeasures for agricultural drought risk management in three dimensions: technical innovation, institutional construction, and mechanism innovation. Zhao et al. (2019) sorted out the construction, effectiveness, and problems encountered in the U.S. agricultural risk management policy system, and observed and analyzed the direction of the new U.S. Farm Bill in 2018. For example, Hu and Wen (2021) explored the mediating role of livelihood risk management based on the impact of livelihood capital on the sustainable livelihoods of poor farmers. Wei and Yang (2021) showed that agricultural insurance plays a "mediating effect" in the "farm-biased" impact of labor resource allocation.

To sum up, there are abundant related researches on risk management and farmers' livelihood adaptation, which provides a good theoretical basis for this study, but there are still the following shortcomings: First, the studies on livelihood adaptation mainly focus on relocated farmers and farmers in rural tourism areas, and few studies have been conducted on the livelihood adaptation of other farmers. Second, the existing literature on risk management mainly includes studies on the influencing factors of risk management strategy selection, countermeasures and policies of risk management, and the mediating and regulating roles of risk management, but lacks studies that use risk management as an explanatory variable to explore the benefits of risk management on the adaptation of farmers' livelihood strategies.

2.2 Theoretical Analysis

The Sustainable Livelihoods Analysis Framework (**Figure 1**) developed by the UK Department for International Development (DFID) states that people make their living in a vulnerable environment and livelihood risks are present throughout the whole process of achieving a sustainable livelihood, directly affect the livelihood capital they have and their choice of livelihood strategies, further affect livelihood consequences. Therefore, farmer households need to optimize the allocation of livelihood capital, choose multiple livelihood strategies suitable for household development, improve their risk management capacity and the adaptability of their livelihood strategies, and strive to output better livelihood outcomes.

Farmers diversify their choice of livelihood strategies as a means to adapt to climate change. Risk management is a series of adaptive strategies adopted by farmers to identify, select and prevent the occurrence of future risks. The adaptive strategies of farmers to adapt to environmental risks mainly include internal risk avoidance and external risk avoidance strategies (Gu and Lu, 2015). Internal risk aversion strategies are the ways in which farmers rely on their own strengths to manage risk. Based on their own risk perceptions and risk preferences, farmers adopt appropriate soil testing and fertilizer application techniques and appropriate application behaviors to achieve livelihood objectives such as risk reduction and profit increase, which influence agricultural production decisions and livelihood strategy adaptation (Feng et al., 2018b; Qi et al., 2020). External risk aversion strategies are the ways of relying on external forces for risk management. Farmers can diversify agricultural risks, cover losses and reduce income uncertainty by purchasing agricultural insurance (Liu et al., 2021). The government plays an indispensable role in mitigating risks and pressure on farmers' livelihoods. The government has implemented a series of support measures such as arable land protection policies and ecological subsidies to mitigate the risks of farmers' adoption of green production techniques, improve farmers' income and stabilize farmers' livelihoods to a certain extent (Huang et al., 2020). Farmers join collective actions in the form of cooperatives, village collectives and companies to share external risks, adapt and adjust their livelihood strategies (Kassie et al., 2013; Jia and Lu, 2018). The important role that farmers play in risk diversification and transfer by relying on informal mechanisms such as social ties and collective organizations to form risk management mechanisms is an important factor influencing the adaptability of their livelihood strategies. Relying on a single risk management strategy alone can hardly produce positive results, and only by adopting diversified and differentiated risk management and livelihood strategies based on one's capital endowment and external forces, improving farmers' risk management capacity and gradually adapting to livelihood

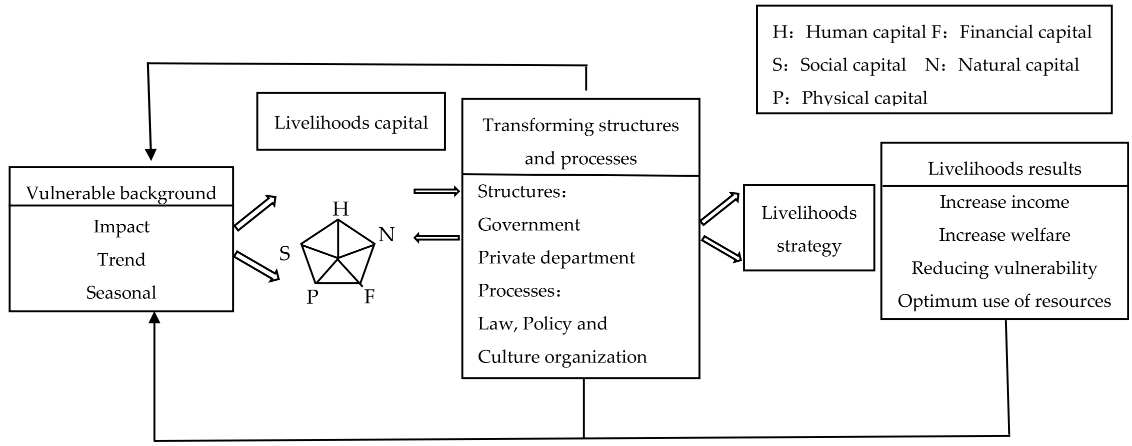

FIGURE 1 | Sustainable livelihoods framework.

risks, can more positive results be achieved. Therefore, in a given context, the choice and adaptation of adaptive livelihood strategies by farmers is determined by the status of their risk management capacity. The stronger the risk management capacity of farmers, the more options they have and the better they are able to use different types of livelihood strategies to improve the adaptability of livelihood strategies to stabilize household livelihoods.

Based on the above analysis, the following research hypothesis is proposed for this paper: the stronger the environmental risk management capacity of farmers, the more adaptable their livelihood strategies.

3 MATERIALS AND METHODS

3.1 Sample and Data Sources

The data used in this paper comes from a field survey conducted by the research team on the livelihoods of farming households in Hubei Province in 2020. The survey obtained basic information about farming households; household natural, social, financial and physical capital; production operations and farming households' rural perceptions. The survey was conducted in Honghu city and Qichun county in Hubei Province, China, which cover basically all the terrain in Hubei Province, including plains, hills and mountains, and are to some extent representative of the livelihoods situation in Hubei Province. The survey was conducted using a random sampling method, and the population surveyed involved 39 administrative villages in 12 townships, with 30–40 households selected from each village for the survey. A total of 1,100 questionnaires were distributed and 1,050 questionnaires were eventually returned. After excluding the missing samples, 970 valid samples were obtained. This paper also classifies farm households equal to income, drawing on existing literature on income grouping criteria to classify farm households into three categories: low income, middle income and high income (Cai et al., 2020; He and Zhou, 2020). Farmers with per capita household income less than RMB 8,000 were classified as low income, those with per capita household income between RMB 8,000 and RMB 30,000 were classified as middle income, and those with per capita household income greater than or equal to RMB 30,000 were classified as high income. The distribution of the sample is detailed in **Table 1**.

3.2 Definition of Variables

3.2.1 Farmers' Livelihood Strategy Adaptation Variables

In this paper, livelihood strategy adaptability is reflected by the fact that farmers engage in multiple types of livelihood activities. The diversity of livelihood strategies is an important component of farmers' livelihood strategies to improve the quality of life and increase farmers' income, and its index level directly affects the strength of farmers' livelihood adaptability (Xu and Hu, 2018b). This paper draws on the research method of scholars Gao and Lu (2021) and adopts the Simpson index to measure the adaptability of farmer households' livelihood strategies. Simpson's index is one of the composite indicators reflecting diversity and balance, and the value of this index is taken to increase gradually with the richness and balance of farmer households' livelihood strategies (Dong et al., 2019). The specific public indices are as follows.

$$\text{S.I.} = 1 - \sum_{i=1}^{N} P_i^2 \tag{1}$$

In **Eq 1**, N denotes the type of livelihood strategy, and this paper uses the income of each type of livelihood strategy for calculation, including agricultural business income, wage income, property income and transfer income; P_i denotes the proportion of the i livelihood type. the value of S.I. ranges from 0 to 1, and the larger the value, the higher the index, indicating the stronger the adaptive capacity of farmer households' livelihood strategies. When the value of S.I. is 0, farmers have a single livelihood type and the least adaptive capacity; when the value of S.I. is 1, it indicates that farmers adopt multiple livelihood strategies and have the highest adaptive capacity.

TABLE 1 | Sample distribution.

City (County)	Town	Administrative Villages	Effective Sample	Low Income	Middle Income	High Income
Honghu	4	20	547	108	299	140
Qichun	8	19	423	103	247	73
Total	12	39	970	211	546	213

TABLE 2 | Variable definition table.

Category		Variable Name	Variable Definitions
Explained variable		Livelihood Strategy Adaptability	Calculated Using Simpson's index
Explanatory variables	Risk management capability	Risk management capability	Calculated using the entropy weighting method
	Internal risk management	Soil testing and fertilizer application techniques	Adopted = 1, not adopted = 0
		Organic pesticide technology	Adopted = 1, not adopted = 0
	External risk management	Agricultural insurance	Whether to purchase agricultural insurance (Adopted = 1, not adopted = 0)
		Cooperatives	Participation in a cooperative or not (Adopted = 1, not adopted = 0)
		Enterprise's help	Whether agricultural production is assisted by village-run enterprises (yes = 1, no = 0)
		Agricultural subsidies	Income from agricultural subsidies (CNY, logarithm)
Control variables	Human capital	Average education level of household members	1 = illiterate, 2 = not graduated from primary school, 3 = primary school, 4 = junior high school, 5 = senior high school, 6 = tertiary and above
		Labor proportion	The proportion of household labor force in the total household population
		Proportion of the trained workforce	The proportion of the workforce trained in professional skills of the total workforce
	Natural capital	Land area	Family per capita land area (mu)
	Physical capital	Housing area	Per capita living area of a family (square meters)
	Social capital	Relationships with friends and relatives	Are there any relatives in the family who are village cadres or above (township cadres or above = 2, village cadres = 1, no = 0)
		Relationships with neighbors	The numbers of neighbours who visit each other
	Financial capital	Money lending	Whether to lend to others (yes = 1, no = 0)
		Financial products	Whether investing in financial products (Yes = 1, No = 0)

3.2.2 Farmers' Environmental Risk Management Variables

Environmental risk management is the core explanatory variable in this paper, and there is a large body of relevant literature on the selection and measurement of environmental risk management indicators. This paper draws on the research of scholars Gu and Lu (2015) and adopts a multi-indicator approach to classify farmer households' environmental risk management indicators into internal risk management and external risk management. Internal risk management mainly includes soil testing and fertilizer technology adoption behavior and organic pesticide technology adoption behavior. External risk management consisted of the following four variables: 1) Agricultural insurance. That is, whether farmers purchase agricultural insurance to obtain insurance payouts to diversify risks. 2) Cooperatives. That is, whether farmers participate in co-operatives to increase their organization and resilience to risk. 3) Enterprise's help. That is, whether farmers receive help from village-run enterprises for their production. 4) Whether farmers receive government help, which is measured in this paper by taking the agricultural subsidies received by farmers (see **Table 2** for details).

Drawing on the research of scholars such as Wang et al. (2021), the entropy weighting method is used to determine the weights of farmers' risk management capacity indicators system to measure the composite score. The higher the calculated composite score, the stronger the risk management capability of the farmer. The specific measurement steps are as follows:

First, dimensionless processing of the indexes is carried out:

$$X'_{ij} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)} \tag{2}$$

In **Formula (2)**, X'_{ij} represents the normalized value of index j of sample i. X_{ij} represents the variable value of index j of sample i. $\max(X_j)$ represents the maximum value of index j, and $\min(X_j)$ represents the minimum value of index j.

Second, the information entropy of each index is calculated:

$$E_j = -\frac{1}{\ln n}\sum_{i=1}^{N} P_{ij}\ln P_{ij} \tag{3}$$

Among them, $P_{ij} = \frac{X'_{ij}}{\sum_{i=1}^{N} X'_{ij}}$.

To determine the weight of each index, the entropy value of each index is calculated using **Formula (3)** (E1, E2, . . . , Em). To

TABLE 3 | Descriptive statistics of variables.

	Sample Size	Mean	Standard Deviation	Minimum value	Maximum value
Livelihood strategy adaptability	970	0.2054	0.1891	0	0.6650
Risk management capability	970	0.0069	0.0041	0	0.0223
Soil testing and fertilizer application techniques	970	0.0876	0.2829	0	1
Organic pesticide technology	970	0.2351	0.4242	0	1
Agricultural insurance	970	0.1701	0.3759	0	1
Cooperatives	970	0.0567	0.2314	0	1
Enterprise's help	970	0.0526	0.2233	0	1
Agricultural subsidies	970	4.4322	2.7669	0	12.6115
Average education level of household members	970	4.9746	2.5868	0	25
Labor proportion	970	0.6488	0.2632	0	2
Proportion of the trained workforce	970	0.6416	0.7842	0	5
Land area	970	1.8059	7.2566	0	200
Housing area	970	52.8377	35.3319	0	266.6667
Relationships with friends and relatives	970	0.2505	0.5280	0	6
Relationships with neighbors	970	7.3495	7.5197	0	80
Money lending	970	0.0402	0.1965	0	1
Financial products	970	0.0072	0.0847	0	1

calculate the weight of each index using the entropy value method, the following equation is used:

$$W_j = \frac{1 - E_j}{\sum E_j} \left(0 \le j \le m\right) \tag{4}$$

Finally, the risk management capability is calculated according to the weight of the index:

$$Z_i = \sum\nolimits_{i=1}^{14} X_{ij} {*} W_j \tag{5}$$

3.2.3 Control Variables

The control variables introduced in this paper are mainly the livelihood capital owned by farmer households, which consists of the following five components: 1) Human capital, including three measures of the average education level of the labor force, the proportion of labor force and the proportion of trained labor force. 2) Natural capital, which is measured by the average land area per capita owned by farmers. 3) Physical capital, which includes the average area of housing per farmer as an indicator. 4) Social capital, including two indicators of family and friend relations and neighborhood relations. 5) Financial capital, including two indicators of whether farmers borrow money from others and whether farmers buy financial products (see **Table 2** for details).

3.3 Model Construction

In order to test the research hypothesis of this paper, the Tobit regression model was constructed using the Livelihood Strategy Adaptation Index measured by the method described in the previous section as the explanatory variable, the soil testing and fertilizer application technology, organic pesticide technology, agricultural insurance, cooperatives, village enterprise assistance and agricultural subsidies selected in this paper as explanatory variables, and five livelihood capital as control variables as follows.

$$\mathrm{Y} = \mathrm{a} + bX_i + cControl_i + \varepsilon_i \tag{6}$$

In the above equation, Y denotes the adaptability index of farmers' livelihood strategies, X denotes farmers' risk management, i is the type of risk management, including soil testing and fertilizer technology, organic pesticide technology, agricultural insurance, cooperatives, village enterprise help and agricultural subsidies, control is a set of control variables, and a and ε_i denote the constant and random disturbance terms.

4 ANALYSIS OF EMPIRICAL RESULTS

4.1 Descriptive Statistical Analysis

Table 3 shows the descriptive statistical characteristics of the variables. The maximum value of the Livelihood Strategy Adaptation Index is 0.6650, the minimum value is 0, and the mean value is 0.2554, indicating that there is a large gap in the adaptability of farmers' livelihood strategies, and most farmers' livelihood strategy adaptability is at a low level. The core explanatory variable risk management capability has a maximum value of 0.0223, a minimum value of 0 and a mean value of 0.0069. the mean values of the core explanatory variables soil testing and fertilizer application technology, organic pesticide technology, agricultural insurance, cooperatives and village enterprise assistance are 0.0876, 0.2351, 0.1701, 0.0567 and 0.0526 respectively, which shows that most of the farmers have not adopted soil formula fertilizer technology and organic pesticide technology, and very few of them have joined cooperatives and received assistance from village enterprises. The mean value of the average education level of the labor force was 4.9746, indicating that the average education level of farming households was above junior high school in both Honghu city and Qichun county, Hubei Province. The mean value of the labor force share was 0.6488, indicating that more than half of the members of the household were capable of working. The mean value of the proportion of trained labor

TABLE 4 | Full sample regression results.

	Livelihood Strategy Adaptability (Full Sample)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Risk management capability	7.5614*** (5.11)	—	—	—	—	—	—
Soil testing and fertilizer application techniques	—	−0.0210 (-0.98)	—	—	—	—	—
Organic pesticide technology	—	—	0.0285** (2.00)	—	—	—	—
Agricultural insurance	—	—	—	0.0490*** (3.04)	—	—	—
Cooperatives	—	—	—	—	0.0605** (2.27)	—	—
Enterprise's help	—	—	—	—	—	0.0571** (2.11)	—
Agricultural subsidies	—	—	—	—	—	—	0.0099*** (4.52)
Average education level of household members	0.0070*** (2.75)	0.0077*** (3.02)	0.0079*** (3.07)	0.0075*** (2.92)	0.0076*** (2.95)	0.0078*** (3.06)	0.0070*** (2.75)
Labor proportion	0.0395** (1.68)	0.0535** (2.26)	0.0527** (2.23)	0.0491** (2.08)	0.0511** (2.16)	0.0523** (2.21)	0.0417* (1.77)
Proportion of the trained workforce	−0.0115 (-1.48)	−0.0097 (-1.23)	−0.0119 (-1.51)	−0.0108 (-1.38)	−0.0105 (-1.34)	−0.0114 (-1.46)	−0.0105 (-1.35)
Land area	0.0015** (1.76)	0.0024*** (2.80)	0.00217** (2.56)	0.0019** (2.23)	0.0021** (2.40)	0.0023*** (2.74)	0.0017** (2.03)
Housing area	0.0004** (2.52)	0.0004** (2.28)	0.0004** (2.45)	0.0004** (2.43)	0.0004** (2.33)	0.0004** (2.37)	0.0004** (2.43)
Relationships with friends and relatives	−0.0003 (-0.03)	0.0011 (0.09)	0.0007 (0.06)	0.0006 (0.05)	0.0007 (0.06)	0.0004 (0.04)	0.0001 (0.01)
Relationships with neighbors	−0.0013 (-1.59)	−0.0012 (-1.42)	−0.0013 (-1.56)	−0.0011 (-1.33)	−0.0012 (-1.45)	−0.0012 (-1.41)	−0.0013 (-1.54)
Money lending	0.0016 (0.05)	0.01215 (0.40)	0.0098 (0.32)	0.0069 (0.23)	0.0074 (0.24)	0.0100 (0.32)	0 0.0047 (0.15)
Financial products	0.0429 (0.61)	0.0594 (0.83)	0.0631 (0.89)	0.0472 (0.66)	0.0285 (0.39)	0.0382 (0.53)	0.0514 (0.73)
Sample size	970	970	970	970	970	970	970

*Note: ***, **, and * denote statistical significance at the 1, 5, and 10% levels, respectively. The values in parentheses are the t values.*

force is 0.6416, indicating that more than the average household labor force has received skills training.

4.2 Analysis of Model Regression Results

Table 4 shows the results of the full-sample regression of the effect of environmental risk management on the adaptation of farmers' livelihood strategies. The core explanatory variable farm household risk management capacity has a significant positive effect on farm household livelihood strategy adaptability at the 1% level, indicating that the higher the risk management capacity of farm households, the more adaptable their livelihood strategies are. The core explanatory variable, soil testing and fertilizer application technology, had a negative impact on the adaptation of farmers' livelihood strategies, but was not found to be significant. The reason for this may be that soil testing and fertilizer application technology has not yet been widely used in the study area, traditional fertilizer application patterns and blind fertilizer application still exist, and farmers' acceptance of soil testing and fertilizer application technology is low due to fertilizer application perceptions. The core explanatory variable, organic pesticide technology, was significantly positive at the 5% level, indicating that farmers' adoption of organic pesticide technology can significantly improve their livelihood strategy adaptability. The core explanatory variable agricultural insurance was significantly positively associated with the variable livelihood strategy adaptability at the 1% level, and the purchase of agricultural insurance by farmers can effectively diversify environmental risks and improve their ability to adapt their livelihood strategies. The core explanatory variables co-operatives and enterprise help are both significantly positive at the 5% level, indicating that farmers joining co-operatives and receiving help from village-level enterprises can improve their livelihood strategy adaptive capacity. The core explanatory variable, agricultural subsidies, was significantly positive at the 1% level, indicating that government-granted agricultural subsidies had a significant positive impact on the livelihood strategy adaptability of farm households.

The paper also divides the sample into three categories of low, middle and high income according to the income of the farming households, and regresses the sample in groups. **Table 5** shows the regression results for the low-income farming sample. The core explanatory variables soil testing and fertilizer application technology, organic pesticide technology, agricultural insurance and enterprise assistance all had a positive effect on the adaptation of farmers' livelihood strategies, but none of them passed the significance test. The reasons for this are as follows: for low-income farmers, the adoption of soil-formulation fertilizer technology and organic pesticide technology is more costly and relatively more technically difficult, and most farmers prefer traditional fertilizer and pesticide application techniques to reduce production costs. Low-income farmers have relatively low demand for agricultural insurance purchases and less chance of seeking help from enterprises due to the small scale of agricultural production. The core explanatory variable co-

TABLE 5 | Regression results for the low-income sample.

	Livelihood Strategy Adaptation (Low-Income Sample)				
Soil testing and fertilizer application techniques	0.0164 (0.32)	—	—	—	—
Organic pesticide technology	0.0030 (0.08)	—	—	—	—
Agricultural insurance	—	0.0583 (1.43)	—	—	—
Cooperatives	—	—	0.1113* (1.86)	—	—
Enterprise's help	—	—	—	0.0837 (1.45)	—
Agricultural subsidies	—	—	—	—	0.0121** (2.16)
Average education level of household members	0.0122** (2.42)	0.0113** (2.25)	0.0112** (2.23)	0.0118** (2.36)	0.0104** (2.06)
Labor proportion	0.1353*** (2.83)	0.1382*** (2.91)	0.1362*** (2.87)	0.1333*** (2.80)	0.1254*** (2.64)
Proportion of the trained workforce	−0.0203 (-1.13)	−0.0193 (-1.08)	−0.0213 (-1.20)	−0.0202 (-1.13)	−0.0201 (-1.14)
Land area	0.0329*** (3.47)	0.0310*** (3.27)	0.0345*** (3.70)	0.0336*** (3.57)	0.0254** (2.55)
Housing area	−0.0004 (-0.94)	−0.0003 (-0.78)	-0.0004 (−1.04)	−0.0003 (-0.82)	−0.0003 (−0.70)
Relationships with friends and relatives	0.0158 (0.65)	0 0.0118 (0.49)	0.0157 (0.65)	0.0140 (0.58)	0.0189 (0.79)
Relationships with neighbors	−0.0031 (-1.26)	−0.0029 (-1.21)	-0.0026 (−1.06)	−0.0029 (−1.20)	-0.0034 (−1.40)
Money lending	0.0712 (0.46)	0.0838 (0.55)	0.0696 (0.46)	0.0707 (0.46)	0.0696 (0.46)
Financial products	0.1267 (0.60)	0.1230 (0.59)	0.1337 (0.64)	0.1261 (0.60)	0.0863 (0.41)
Sample size	211	211	211	211	211

*Note: ***, **, and * denote statistical significance at the 1, 5, and 10% levels, respectively. The values in parentheses are the t values.*

TABLE 6 | Regression results for the middle-income sample.

	Livelihood Strategy Adaptation (Middle-Income Sample)				
Soil testing and fertilizer application techniques	0.0045 (0.17)	—	—	—	—
Organic pesticide technology	0.0146 (0.89)	—	—	—	—
Agricultural insurance	—	0.0184 (0.97)	—	—	—
Cooperatives	—	—	0.0458 (1.41)	—	—
Enterprise's help	—	—	—	0.0669** (2.11)	—
Agricultural subsidies	—	—	—	—	0.0011 (0.43)
Average education level of household members	0.0037 (1.14)	0.0037 (1.12)	0.0036 (1.10)	0.0042 (1.28)	0.0036 (1.10)
Labor proportion	0.0040 (0.14)	0.0031 (0.10)	0.0006 (0.02)	0.0030 (0.10)	0.0037 (0.12)
Proportion of the trained workforce	−0.0076 (−0.81)	−0.0066 (−0.71)	−0.0057 (−0.62)	-0.0075 (−0.81)	−0.0064 (−0.69)
Land area	0.0366*** (7.69)	0.0366*** (7.72)	0.0371*** (7.88)	0.0373*** (7.95)	0.0365*** (7.36)
Housing area	0.0001 (0.50)	0.0001 (0.44)	0.0001 (0.38)	0.0001 (0.43)	0.0001 (0.47)
Relationships with friends and relatives	0.0014 (0.09)	0.0011 (0.08)	0.0004 (0.03)	0.0012 (0.08)	0.0005 (0.03)
Relationships with neighbors	−0.0006 (-0.65)	−0.0004 (−0.47)	−0.0005 (−0.53)	−0.0005 (−0.52)	−0.0005 (−0.56)
Money lending	−0.0001 (−0.00)	−0.0042 (−0.11)	−0.0055 (−0.15)	−0.0004 (−0.01)	−0.0003 (−0.01)
Financial products	−0.1687 (−1.05)	−0.1689 (−1.05)	−0.1683 (−1.05)	−0.2353 (−1.44)	−0.1731 (−1.07)
Sample size	546	546	546	546	546

*Note: ***, **, and * denote statistical significance at the 1, 5, and 10% levels, respectively. The values in parentheses are the t values.*

operatives is significantly positive at the 10% level, with low-income farmers' membership of co-operatives improving their ability to adapt their livelihood strategies. The core explanatory variable agricultural subsidies is significantly positive at the 5% level, showing that government-granted agricultural subsidies also have a significant positive impact on the adaptability of livelihood strategies of low-income farmers.

Table 6 shows the regression results for the middle-income farm household sample. The core explanatory variables soil testing and fertilizer technology, organic pesticide technology, agricultural insurance, cooperatives and agricultural subsidies all positively affected the adaptation of farmers' livelihood strategies, but none of them passed the significance test. For middle-income farmers, the scale of their agricultural production is high relative to that of low-income farmers, but not yet at the scale of production of high-income farmers, and therefore the adoption of soil-formulation fertilizer technology and organic pesticide technology is low, and the marginal benefits of purchasing agricultural insurance are low. The core explanatory variable enterprise help was significantly and positively correlated with the explanatory variable livelihood strategy adaptation at the 5% level, indicating that middle-income farmers' access to enterprise help can significantly improve their ability to adapt their livelihood strategies. Since middle-income farmers do not have a complete production and marketing process, seeking help from enterprises to share and transfer risks can effectively improve their productivity and livelihood strategy adaptability.

Table 7 shows the regression results for the sample of high-income farmers. The core explanatory variable soil testing and

TABLE 7 | Regression results for the high-income sample.

	Livelihood Strategy Adaptation (High -Income Sample)				
Soil testing and fertilizer application techniques	–0.1007** (-2.44)	—	—	—	—
Organic pesticide technology	0.0387 (1.19)	—	—	—	—
Agricultural insurance	—	0.0692** (2.23)	—	—	—
Cooperatives	—	—	0.0556 (1.04)	—	—
Enterprise's help	—	—	—	-0.0481 (-0.74)	—
Agricultural subsidies	—	—	—	—	0.0138*** (3.12)
Average education level of household members	0.0216*** (3.08)	0.0190*** (2.76)	0.0197*** (2.83)	0.01867*** (2.68)	0.0206*** (3.02)
Labor proportion	0.1643** (2.23)	0.1240* (1.70)	0.1494** (2.05)	0.1449** (1.98)	0.1371* (1.92)
Proportion of the trained workforce	-0.0135 (-0.86)	-0.0189 (-1.20)	-0.01875 (-1.18)	-0.0161 (-1.00)	-0.0144 (-0.92)
Land area	0.0015* (1.71)	0.0005 (0.58)	0.0007 (0.82)	0.0010 (1.11)	0.0005 (0.63)
Housing area	0.0006 (1.60)	0.0008** (2.23)	0.0007** (2.12)	0.0008** (2.16)	0.0007** (2.06)
Relationships with friends and relatives	–0.0150 (–0.71)	–0.0123 (-0.58)	–0.0135 (–0.63)	–0.0122 (–0.57)	–0.0158 (–0.75)
Relationships with neighbors	–0.0007 (–0.39)	-0.0005 (-0.30)	-0.0006 (-0.33)	-0.0001 (-0.06)	-0.0002 (-0.11)
Money lending	0.0179 (0.40)	0.0238 (0.53)	0.0164 (0.36)	0.0223 (0.48)	0.0034 (0.08)
Financial products	0.1506* (1.83)	0.1135 (1.36)	0.1042 (1.14)	0.1580* (1.85)	0.1408* (1.73)
Sample size	213	213	213	213	213

*Note: ***, **, and * denote statistical significance at the 1, 5, and 10% levels, respectively. The values in parentheses are the t values.*

fertilizer application technology is significantly negatively related to the explanatory variable livelihood strategy adaptation at the 5% level, probably because high-income farmers tend to emphasize the application of inorganic fertilizers in soil testing and neglect the use of organic fertilizers, which to a certain extent tends to lead to a decrease in crop yield and quality, which is not conducive to livelihood strategy adaptation. The core explanatory variables agricultural insurance and agricultural subsidies are significantly positive at the 5 and 1% levels respectively, indicating that both the purchase of agricultural insurance and the receipt of agricultural subsidies by high-income farmers increase their ability to adapt their livelihood strategies. For high-income farmers, the larger scale of agricultural production and the generally higher losses caused in the event of environmental risks, the higher demand for agricultural insurance by farmers and the higher marginal benefits of purchasing agricultural insurance. In addition, the government grants more agricultural subsidies, etc. to high-income farmers with larger agricultural production, which plays an important role in the long-term stability of their agricultural production. The variables organic pesticide technology, cooperatives and enterprise help did not pass the significance test. The reason for this is that high-income farmers are mostly equipped with complete production materials due to the requirements of the development of their production scale, have better production and marketing processes, and have a lower need to participate in collective actions such as cooperatives and to obtain help from enterprises.

5 CONCLUSION AND DISCUSSION

With the increasing problems of rising temperatures, uneven precipitation and the frequency of extreme disaster weather brought about by global climate change, agricultural production is facing more severe challenges. Unlike the existing literature, this paper is based on a sustainable livelihoods framework, using micro research data on the livelihoods of farm households in Hubei Province, China in 2020, and using the Simpson Index to measure the adaptability index of farm households' livelihood strategies and analyze the benefits of different environmental risk management approaches of farm households on the adaptability of livelihood strategies. Heterogeneity analysis was also conducted by classifying farm households according to their household income. The results showed that 1) the higher the risk management capacity of farmers, the more adaptable their livelihood strategies. (2)The core explanatory variables organic pesticide technology, agricultural insurance, cooperatives, enterprise help and agricultural subsidies all had significant positive effects on the livelihood strategy adaptability of farm households in both Honghu city and Qichun county in Hubei province. This is consistent with the findings of previous studies that risk management has a positive effect on farmers' livelihood adaptation. 3) Soil testing and fertilizer application technology did not pass the significance test on livelihood strategy adaptation because soil testing and fertilizer application technology has not been widely used in both Honghu city and Qichun county in Hubei Province, and farmers' acceptance of soil testing and fertilizer application technology is low due to fertilizer application perceptions. 4) For low-income farmers, soil-formula fertilizer technology, organic pesticide technology, agricultural insurance and enterprise assistance all have insignificant effects on the adaptability of farmers' livelihood strategies. Joining cooperatives and receiving agricultural subsidies had a significant positive effect on the adaptation of livelihood strategies of low-income farmers. 5) For middle-income farmers, the effects of soil testing and fertilizer technology, organic pesticide technology, agricultural insurance, cooperatives and agricultural subsidies were not significant on the adaptation of farmers' livelihood strategies. The positive effect of enterprise assistance on livelihood strategy adaptation was significant, so middle-income farmers can effectively improve their productivity and livelihood strategy adaptation by seeking the help of enterprises for risk sharing and transfer. 6) For high-income farmers, soil testing and fertilizer application technology was significantly and negatively related to the explanatory variable of livelihood strategy adaptation, which is inconsistent with the findings of some existing studies. For example, Zhang et al. (2021) showed that the adoption of soil testing and fertilizer application technology can significantly improve the productivity of apple growers and also contribute to the improvement of planting profit. This paper suggests that the reason for this may be that high-income farmers tend to emphasize the application of inorganic fertilizers in soil testing and fertilizer application, neglecting the use of organic fertilizers, which to a certain extent tends to lead to a decline in crop yield and quality and is not conducive to the adaptation of livelihood strategies. In contrast, the purchase of agricultural insurance and access to agricultural subsidies can have a significant positive effect on the adaptation of livelihood strategies of high-income farming households with larger agricultural production. The marginal benefits of purchasing agricultural insurance are higher for high-income farmers, and the agricultural subsidies granted by the government play an important role in the long-term stability of their agricultural production.

6 POLICY IMPLICATIONS

Based on the above findings, the following recommendations are made with the objective of improving the adaptive capacity of farmers' livelihood strategies and achieving optimal livelihood outcomes: 1) Publicity on the risks posed by climate change to agricultural production should be strengthened to enhance farmers' perception of climate change, and farmers themselves need to strengthen their risk perception and prevent risk uncertainty caused by environmental disasters in advance, so as to increase the adoption of adaptive livelihood strategies by farmers This will increase the adoption of adaptive livelihood strategies and enhance the adaptive capacity of farmers' livelihood strategies. 2) The government should increase its policy support, strengthen the promotion of ecological technologies such as soil testing and fertilizer application, provide more technical training opportunities for farmers, improve their technical awareness, and improve the continuous technical formulation for farmers through technical training to facilitate the promotion of adaptive technologies. Improve agricultural insurance policies and strengthen the promotion of agricultural insurance policies to increase the demand for purchase by farmers. 3) Give full play to the collective role of village collectives, companies and co-operatives to create a good organizational climate for farmers, improve their ability to cope with risk and play an important role in improving the adaptability of livelihood strategies. 4) Farmers should adjust their livelihood strategies in a timely manner according to the way they allocate their capital and the proportion of their structure to enhance the sustainability of their livelihood outcomes. 5) To improve the adaptability of diversified livelihood strategies for farmers with a single livelihood activity, actively create more livelihood options, increase the proportion of farmers' wage, property and transfer income, promote the transformation and upgrading of livelihood options, raise farmers' income, improve the quality of life and further improve the adaptability of livelihood strategies (Barham et al., 2014; Xu and Hu, 2018a; Xu and Hu, 2018b; Yang et al., 2018; Zhang et al., 2021).

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 authors.

AUTHOR CONTRIBUTIONS

Conceptualization, WW and CZ; methodology, CZ, XL, and JS; software, ZF and ZH; validation, WW and CZ; formal analysis, CZ; resources, XL; data curation, JS and WW; writing—original draft preparation, ZF; writing—review and editing, ZH; visualization, CZ; supervision, WW and JS; funding acquisition, WW. All authors have read and agreed to the published version of the manuscript.

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