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The impact of livelihood resilience and climate change perception on farmers' climate change adaptation behavior decision

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Abstract

Purpose – Adopting adaptive behavior has become a basic measure for farmers because the increasingly severe climate change is affecting agricultural production. Perception is a critical first step in adopting adaptive behaviors. Livelihood resilience represents a farmer's ability to adapt to climate change. Therefore, this article aims to explore the impact of livelihood resilience and climate change perception on the climate change adaptation behavior of farmers in the Qinling Mountains region of China.

Design/methodology/approach – In this study, 443 micro-survey data of farmers are obtained through one-on-one interviews with farmers. The Logit model and Poisson regression model are used to empirically examine the impact of farmers' livelihood resilience and climate change perception on their climate change adaptation behaviors.

Findings – It was found that 86.68% of farmers adopt adaptive behaviors to reduce the risks of facing climate change. Farmers' perception of extreme weather has a significant positive impact on their adaptive behavior under climate change. The resilience of farmers' livelihoods and their perception of rainfall have a significant positive impact on the intensity of their adaptive behavior under climate change. Climate change adaptation behaviors are also different for farmers with different levels of livelihood resilience.

Originality/value – Based on the results, policy recommendations are proposed to improve farmers' perception of climate change, enhance the sustainability of farmers' adaptive behavior to climate change, strengthen emergency management and infrastructure construction and adjust and upgrade farmers' livelihood models.

Keywords Livelihood resilience, Climate change perception, Adaptive behavior, Qinling region

Paper type Research paper

1. Introduction

Currently, global climate and environmental change are unprecedentedly affecting natural resources, ecosystems, and human society. In the sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC), researchers points out that the impact of frequent heatwaves, droughts and floods has exceeded the tolerance limits of some animals and plants, which could result in loss of biodiversity and adverse effect on the ability of ecosystems, societies, regions, and populations to adapt to climate change, with poor and vulnerable populations particularly affected. According to FAO's Climate Change Strategy

2022–2031, the number of people facing hunger will rise to 7.2–811 million in 2020 [1], and climate change and extreme weather events are already having a tangible impact on food security, nutrition and poverty. Therefore, the urgency to address climate change has increased significantly.

In this context, mitigation and adaptation of climate change have become fundamental measures. Climate change mitigation focuses on reducing greenhouse gas emissions or increasing carbon sinks. Adaptation to climate change focuses on the adjustments, based on actual or expected climate scenarios and their impacts. In contrast, the inertia of mitigation actions may persist in the impact of climate change for centuries, even over a millennium, and adaptation aims to reduce the vulnerability and adverse effects of climate change through a series of policies and actions (Bryan *et al.*, 2013). Therefore, adapting to climate change and taking corresponding adaptation measures have become crucial (Reser and Swim, 2011).

Agriculture is one of the most vulnerable industries directly affected by climate change. The increasingly severe climate change is not only detrimental to agricultural production, but also has wide-ranging impacts on food security and farmers' livelihoods (Vogel *et al.*, 2019). The Blue Book on Climate Change in China (2022) shows that China is a sensitive area to global climate change, with a warming rate higher than the global average during the same period, and extreme weather and climate events such as high temperature and heavy precipitation are becoming more frequent and stronger. In 2021, 11.718 million hectares of crops were affected by meteorological disasters in China, with direct economic losses of 321.42 billion yuan [2]. As the main body of agricultural production and the most direct bearers of climate change, accurately understanding the adaptive behavior of farmers to climate change, exploring the influencing factors of farmers' adaptive behavior, is of great significance for the government to formulate climate change adaptation policies, improve the ability of the agricultural system to respond to climate change, reduce the vulnerability of farmers to climate change, and achieve sustainable development goals.

At present, a large number of studies on climate change adaptation behavior and its influencing factors are being carried out. Existing research has shown that farmers' adaptive behavior is influenced by factors such as individual characteristics, family endowment, social capital, farmers' awareness of climate change, risk appetite, and policy support. Although the existing studies have drawn rich conclusions, most of them are based on a single dimension. The livelihood resilience of rural households reflects their sensitivity, resistance, and adaptability in the face of risk shocks (Zhou and Yang, 2023). The more resilient the livelihoods, the more aware and resilient they are in the face of risks. Introducing the concept of livelihood resilience into research on climate change adaptation behavior can lead to a better understanding of livelihood dynamics. Understand how farmers can use existing resources and knowledge to create new livelihood opportunities in the face of risks, and adopt adaptive livelihood strategies to overcome threats. However, the current research on livelihood resilience usually focuses on the quantitative assessment of livelihood resilience and its influencing factors, the conceptual framework (Figure 1) of livelihood resilience, and livelihood recovery strategies, and few people have explored the impact of livelihood

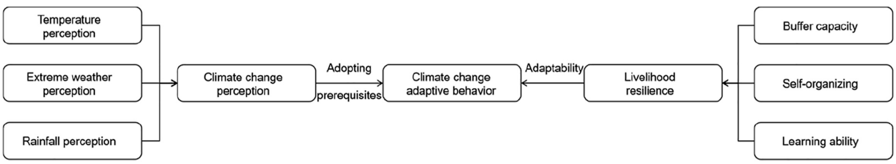

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Figure 1.
Research framework

resilience on farmers' livelihood decisions. As one of the important parts of farmers' livelihood decision-making, farmers' climate change adaptation behaviors have different risk resistance and adaptability even under the same climate change perception, and further produce different climate change adaptation behaviors of farmers.

Therefore, this paper takes farmers in the Qinling Mountains region of China as the research object to construct an evaluation system for livelihood resilience and measure the livelihood resilience of rural households. To explore the impact of climate change perception and livelihood resilience on farmers' climate change adaptation behavior. Village-level means of livelihood resilience are used to address possible endogeneity issues in estimating the impact of livelihood resilience on climate change adaptation behavior. In order to improve the ability of farmers to adapt to climate change, and to provide a basis for the Chinese government and relevant departments to formulate climate change adaptation policies, this paper also explores the differences in climate change adaptation behaviors of farmers with different livelihood resilience capabilities.

2. Theoretical analysis and research hypotheses

2.1 The impact of farmers' perception of climate change on their adaptive behavior to climate change

In psychology, adaptation refers to the subjective process by which an individual takes a series of measures to cope with challenging environments through situational assessment, emotional response, cognitive analysis, and reconstruction in a certain social context. In other words, individuals who are directly or indirectly threatened and affected by climate change must first perceive the existence of such threats and impacts, evaluate the threats and impacts, and then take corresponding response measures based on perception and assessment (Reser and Swim, 2011).

The perception of climate change by farmers is a prerequisite for them to adopt adaptive behavior towards climate change. Only when farmers perceive that climate change is occurring will they take corresponding adaptive behavior (Bryan *et al.*, 2009; Mertz *et al.*, 2009; Tambo and Abdoulaye, 2013). Integrating farmers' perception into the relevant research on adaptive behavior can make up for the shortcomings of previous studies that only focused on socio-economic, technological and institutional determinants (Grothmann and Patt, 2005; Jellason *et al.*, 2019). At present, a large number of scholars have also demonstrated this view. Mase *et al.* found through a survey of nearly 5,000 corn growers in 22 watersheds in the Midwest of the United States that perception is the key first step in adopting adaptive behavior, and the most important influencing factor in adaptive behavior is the degree of attention of farmers to risks such as drought, extreme rainfall, diseases and pests (Mase *et al.*, 2017). Linder *et al.* conducted a survey of Michigan fruit farmers and found that they have keenly perceived the huge impact of climate change on their production and operation. However, due to the great uncertainty of future climate change, local farmers are more inclined to adopt passive adaptive behavior to cope with short-term climate impacts and have not yet taken proactive adaptation measures (Linder and Campbell-Arvai, 2021). Jin *et al.* found that farmers' perception of the severity and probability of climate change has a positive impact on climate change adaptation decisions (Jin *et al.*, 2021). Demski *et al.* argue that changes in individuals' perception of climate change not only increase their tendency to take climate change mitigation actions, but also make them more supportive of relevant mitigation policies (Demski *et al.*, 2017). From this, it can be seen that the adaptive behavior of farmers to climate change depends more on their perception of climate change and climate risks, rather than the actual changes in climate patterns measured through scientific methods (Mertz *et al.*, 2009). Based on this, the hypothesis is proposed:

H1. Whether farmers adopt adaptive behavior is highly correlated with their perception of climate change, and it is believed that farmers with intensified climate change are more likely to adopt adaptive behavior.

2.2 The impact of farmers' livelihood resilience on climate change adaptation behavior

The term "resilience" was first proposed by Holling, referring to the ability of an ecosystem to absorb changes and maintain its normal function after being subjected to external pressure (Holling, 1973). Chambers *et al.* first combined the concept of resilience with livelihood research, considering livelihood resilience as an important component of sustainable livelihood analysis frameworks. They believed that individuals with stronger livelihood resilience were less affected by risk shocks (Chambers and Conway, 1992). Speranza *et al.* defined livelihood resilience as the ability of individuals to respond to risk shocks using their own resource endowments, and proposed a framework for analyzing livelihood resilience, which includes three dimensions: buffering ability, self-organizing ability, and learning ability (Ifejika Speranza *et al.*, 2014). Although the concept of "resilience" was initially developed from the field of ecology, with the deepening of research by scholars, it has been widely applied in various disciplines and has become one of the important concepts in climate change and sustainable development related research (Fang *et al.*, 2018; Gautam, 2017; Zhao *et al.*, 2022).

At present, a large number of studies have shown that the resource constraints faced by farmers are an important factor affecting farmers' climate change adaptation behavior. On the one hand, when farmers adjust their production patterns, they rely on the endowments they have. When farmers are constrained by economic resources, they do not have the ability or capital to respond to the challenges and threats caused by climate change, so they do not take any climate change adaptation behavior. On the other hand, different from other agricultural production information, climate change information, as a highly professional scientific and technological information, usually exceeds the learning ability of farmers themselves, and relies more on the transmission and guidance of external information (Wang *et al.*, 2023). When farmers are in a relatively closed social network, their ability to obtain information and accept new things are at a low level, which is not conducive to the adoption of climate change adaptation behaviors. Therefore, farmers with a high level of livelihood resilience have good risk coping ability, which can effectively alleviate the resource constraints on their families. Specifically, farmers with strong buffer capacity can freely dispose of household livelihood capital to cope with the harm caused by climate change under the condition of favorable resource endowment. Farmers with greater self-organization have wider access to climate change information and are able to share information through close social networks (Yang, 2018), thus increasing the likelihood that farmers will adopt adaptive behaviors. Farmers with strong learning ability are more receptive to new technologies, have a deeper understanding of adaptive behaviors, and are more willing to adopt climate change adaptive behaviors.

At present, a large number of scholars have also discussed the impact of farmers' livelihood capital, socio-economic and institutional environment, and their own learning ability on farmers' climate change adaptation behavior. For example, Wheeler *et al.* found that human capital and physical capital have a significant impact on farmers' choice of adaptive behavior through their research on Australian farmers (Wheeler *et al.*, 2013). In studies on farmers in Bangladesh (Ahmed *et al.*, 2021) and Pakistan (Khan *et al.*, 2020), it was also found that household size and farm size have a significant impact on the selection of adaptation strategies. In addition, some scholars have found that social capital and credit services are crucial in the process of adaptation (Jin *et al.*, 2021; Engler *et al.*, 2021; Bryan *et al.*, 2013; Below *et al.*, 2012). Others have found that training on climate change and adaptation behavior can increase the likelihood of farmers adopting adaptive behavior (Arunrat *et al.*, 2017). The more accessible information about climate change impacts and adaptation strategies is, the more likely farmers are to adopt climate change adaptation behaviors (Arunrat *et al.*, 2017; Asrat and Simane, 2018). Based on this, the hypothesis is proposed:

H2. Livelihood resilience represents the resilience of farmers to climate change, and the higher the resilience of livelihoods, the more likely they are to adopt climate-resilient behaviors.

3. Data sources and model construction

3.1 Research area

Climate change will have different impacts on agriculture in different regions of the world (Glantz *et al.*, 2009), and adaptive behavior is based on specific ecological, economic, and social environments (Alam *et al.*, 2017). Therefore, analyzing the adaptive behavior and influencing factors of farmers in different regions is crucial for developing more effective and supportive adaptation strategies (Kurupu and Liverman, 2011; Nguyen *et al.*, 2016). Qinling is located at 102°54′10″~112°48′41″E, 32°15′22″~34°58′52″N, which is an important climate and north-south geographical dividing line in China, the most important ecological barrier in central China, one of the richest areas in global biodiversity, and one of the sensitive areas for global climate change. In recent years, the temperature in the Qinling Mountains has risen significantly, the intensity of extreme precipitation has increased, and extreme weather and climate events have occurred frequently, causing great damage to local agricultural production. Therefore, studying the climate change adaptation behavior of farmers in Qinling area is of great significance to improve the adaptive ability of local farmers.

3.2 Data source

The data of this study comes from the field survey of farmers in Shaanxi Province conducted by the research group in June–July 2021, involving 25 administrative villages in 9 townships and towns in 3 counties and cities of Zhouzhi County, Yang County and Ningshan County. Located in the western part of central Guan, Zhouzhi County has a warm temperate climate, high temperatures in summer, rainfall in the form of heavy rainfall, prone to floods or droughts, and hailstorms in between. Yang County and Ningshan County are located in the southwest of Shaanxi Province, with a northern subtropical climate, high temperature and rainy summer, and occasional drought. Agriculture in the three regions is highly susceptible to climate disasters such as drought, flood and high temperature, and it is more scientific and representative to study the climate change adaptation behavior of farmers in this region. The survey uses a combination of stratified sampling and random sampling, with 2–5 townships or subdistricts randomly selected from the selected three sample counties, and 2–5 administrative villages randomly selected from the selected townships or subdistricts, which are selected with the help of local staff. The sample farmers were selected using a combination of random sampling and typical sampling, and the research group members conducted a one-on-one interview survey with the farmers, including the characteristics of individual heads of households, household characteristics, production and operation characteristics, farmers' climate change perception, and farmers' adaptive behaviors. A total of 468 questionnaires were obtained in this survey, invalid questionnaires were eliminated, and 443 valid sample data were finally obtained, with an effective rate of 94.66%.

3.3 Measurement of livelihood resilience

Based on the practices of Ifejika Speranza *et al.* (2014), Fachrista and Suryantini (2019), Chen *et al.* (2016) and Wen *et al.* (2018), this paper constructs an evaluation index system of livelihood resilience from three dimensions: buffering capacity, self-organization and learning ability, and quantifies the livelihood resilience of rural households.

Buffering capacity refers to the degree of change or interference that a system can withstand and maintain its original functional and structural properties (Carpenter *et al.*, 2001). From the perspective of farmers' livelihoods, buffer capacity refers to the ability of farmers to use their own livelihood capital or resource endowment to resist external risks and maintain livelihood stability. It generally includes human capital, natural capital, physical capital, etc. Specifically, households with a large number of labor and members with good health have higher labor force participation rates (Zhou and Yang, 2023), and can achieve sustainable livelihoods by optimizing labor allocation when they are at risk. Land is the most basic means of production for rural households, which can provide them with a stable source of livelihood and is the foundation of rural social security (Wang *et al.*, 2023). The higher the per capita income, the larger the house area, the better the quality of the house, and the more means of production and subsistence, the better the economic strength of the peasant family. Abundant natural capital and physical capital give farmers more options to deal with shocks.

Self-organization reflects the ability of farmers to get out of the real situation by obtaining and integrating external resources. It is generally expressed by policy support, social network, neighborhood trust, etc. Policy support represents an opportunity for farmers to access development (Wen *et al.*, 2018). Household funding opportunities, participation in social organizations, and neighborhood trust reflect the degree of connection between farmers and society and the possibility of villagers supporting each other, which is an insurance mechanism for farmers to use social networks to maintain their livelihoods (Wang *et al.*, 2023). Transportation accessibility represents how easily rural households are connected to the outside world (Chen *et al.*, 2016).

The ability to learn is key to improving livelihood resilience (Ifejika Speranza *et al.*, 2014). Farmers build their coping capacity by learning new knowledge, renovating production skills, and adapting their livelihood strategies (Cooper and Wheeler, 2015). Learning ability includes the education level of the head of household, the time spent working outside the home, the opportunity to participate in skills training, the investment in family education, and the exchange of information and skills.

Firstly, the range standardization method is used to standardize the original data to eliminate the influence of differences in dimensions, orders of magnitude and nature of indicators between evaluation indicators. Second, measure livelihood resilience.

$$B_j = W_{kb} \cdot \sum_{i=1}^{9} W_i Y_{ij}$$

$$S_j = W_{kS} \cdot \sum_{i=10}^{14} W_i Y_{ij}$$

$$L_j = W_{kl} \cdot \sum_{i=15}^{20} W_i Y_{ij}$$

$$R_j = B_j + S_j + L_j$$

Among them, B_j, S_j, and L_j respectively represent the buffering ability index, self-organizing ability index, and learning ability index of j research units; R_j represents the resilience index of farmers' livelihoods; Y_{ij} represents the normalized value of the *i-th* indicator in the *j-th* research unit; W_i represents the weight of the *i-th* indicator layer; W_k represents the weight of the dimension layer. The indicator weights of each dimension layer and target layer were obtained using the entropy method (Table 1).

3.4 Variable selection

Climate change adaptation refers to decision-making processes or actions taken in response to current or projected climate change (Nelson *et al.*, 2010). In the actual agricultural production process, it is manifested as the adjustment of agricultural production factors. In the context of climate change, the complete climate change adaptation behavior of farmers is determined by two stages: decision-making choice and use intensity, that is, whether farmers adopt adaptive behaviors and the degree of use of adaptive behaviors by farmers. Therefore, the explanatory variables in this paper are “whether to adopt climate change adaptation behavior” and “intensity of use”.

At present, there is no unified standard for the classification of climate change adaptive behaviors, and different scholars have divided adaptive behaviors and measures based on different perspectives. Burton divides adaptation strategies into long-term adaptation strategies and short-term adaptation strategies according to the duration of the strategy, and believes that short-term adaptation behavior to natural disasters is a necessary condition for adapting to long-term climate change (Burton, 1997). Engler *et al.* divided farmers’ climate change adaptation behaviors into two categories: active adaptive behaviors and passive adaptive behaviors according to the dynamic mechanism of adaptation (Engler *et al.*, 2021). Ahmed *et al.* divides adaptive behaviors into individual-level adaptation and planned adaptation based on the subjects who adopt adaptive behaviors (Ahmed *et al.*, 2021). In addition, some scholars divide farmers’ adaptive behavior into expected adaptation, autonomous adaptation, and planned adaptation (Arunrat *et al.*, 2017); Expansion, adjustment, and contraction (Wheeler *et al.*, 2013), and Below *et al.* divide adaptive behaviors into agricultural water management, farm and crop management adjustment, and off-farm diversification (Below *et al.*, 2012). Since scholars have not formed a unified classification standard for climate change adaptation behavior, this paper integrates existing research and local field research to divide farmers’ adaptive behavior into 12 categories: “diversity of planting varieties”, “switching to crops with short growth cycles”, “changing to drought-resistant crops”, “developing non-timber forest-based economy”, “increasing river irrigation”, “increasing chemical fertilizers and pesticides”, “non-agricultural employment transfer”, “covering crops”, “agroforestry management”, “fallowing”, “migration”, and “increasing grain and money storage”. If a farmer adopts any one, the intensity of use of its adaptive behavior is recorded as “1”, if it adopts two, it is recorded as “2”, and so on.

Climate change mainly affects the production and operation of farmers through the rise of temperature, changes in precipitation and frequent disasters, and when farmers perceive changes in temperature, precipitation and extreme weather, they will adopt different adaptive behaviors to mitigate the losses caused by climate change. Therefore, the explanatory variables in this paper are farmers’ perception of temperature, perception of extreme weather, and perception of rainfall. Objective adaptive capacity determines whether farmers have the ability to cope with climate change and whether to take adaptive actions when faced with climate change risks, and livelihood resilience, as a symptom of farmers’ adaptive ability, can help understand farmers’ climate change adaptation behaviors. Therefore, another core explanatory variable in this paper is livelihood resilience, which is calculated.

In addition, the gender of the head of household, the age of the head of the household, whether the head of the household is a village cadre, the maximum number of years of education of the household, and the number of cultivated plots may affect the differentiation of the climate change adaptation behavior of farmers, so the above variables are included in the model as control variables, which is conducive to comprehensively reflecting the impact

Target layer (A)	Dimension layer (K)	Indicator layer (Z)	Indicator description and definition	Indicator weight	Reference source
Livelihood resilience	Buffer capacity (0.37895)	Per capita income (Z1)	Ratio of annual total household income to total household population/yuan	0.04464	Zhao and Ren (2022), Liu *et al.* (2023), Guan and Yu (2021)
		Financial savings (Z2)	Annual household income balance/yuan	0.00034	
		Human capital (Z3)	Number of household labor force/person	0.01512	
		Residential type (Z4)	Civil = 1, brick and wood = 2, brick and concrete = 3, others = 4	0.05379	
		Total housing area (Z5)	Total housing area/square meter	0.02789	
		Health status (Z6)	The proportion of sick people in the total number of households	0.00037	
		Production and living materials (Z7)	Total number of production tools and durable goods owned	0.02414	
		Cultivated land area (Z8)	Total arable land area/mu	0.05412	
		Forest area (Z9)	Total forest area/mu	0.15856	
	Self-organization (0.21686)	Financial capital (Z10)	Whether bank loans can be obtained; Yes = 1, No = 0	0.06272	Wen *et al.* (2018)
		Family assistance opportunities (Z11)	Number of households/households that will provide financial assistance when families urgently need assistance	0.10620	
		Social organization participation (Z12)	Degree of participation in village collective activities; Not participated = 1, less than 5 times a year = 2, 5–10 times a year = 3, 10–20 times a year = 4, more than 20 times a year = 5	0.04037	
		Neighborhood trust (Z13)	The level of trust in the villagers of this village; Very untrustworthy = 1, untrustworthy = 2, average = 3, relatively untrustworthy = 4, very untrustworthy = 5	0.00536	
		Traffic reachability (Z14)	Distance from residence to town market/meter	0.00221	
	Learning ability (0.40419)	Skills training opportunities (Z15)	Number of times/time of participating in government organized agricultural and forestry production or employment technical training	0.12294	Chen *et al.* (2016)
		Education level of household head (Z16)	Head of household education years/year	0.01928	
		Outgoing working hours (Z17)	Per capita time spent working outside/month	0.05423	
		Number of migrant workers (Z18)	Number of migrant workers/person	0.05862	
		Family education investment (Z19)	Amount/yuan of education investment by households in 2020	0.12490	
		Information skills exchange (Z20)	Number/person of households using the internet	0.02422	

Source(s): Table created by authors

Table 1. Index system for evaluating the resilience of farmers' livelihoods

of climate change perception and livelihood resilience on climate change adaptation behavior of farmers. The descriptive statistics of variables are shown in Table 2.

In the face of climate change, 86.68% of farmers have adopted adaptive behaviors to reduce the risks caused by climate change, and only 13.32% have not taken any measures. Among the types of adaptive behaviors adopted by farmers, 40.41% of the farmers adopted 1 adaptive behavior to cope with climate change, 30.70% adopted 2 adaptive behaviors to cope with climate change, 10.16% adopted 3 adaptive behaviors to cope with climate change, and 3.16%, 1.81 and 0.45% adopted 4 adaptive behaviors, 5 adaptive behaviors and 6 adaptive behaviors, respectively. (See Figure 2)

Among the 12 types of climate change adaptation behaviors, the largest number of people adopted was "planting variety diversity", followed by "non-farm employment transfer", "increasing the use of chemical fertilizers and pesticides" ranked third, and the least number of people adopted was "covering crops" (See Figure 3).

The level of livelihood resilience of the surveyed households was low overall, with an average of only 0.07258. Yang County had the highest livelihood resilience index of 0.07773, followed by Ningshan County with 0.07502, and Zhouzhi County with the lowest index of 0.06692. Among the 25 administrative villages, the highest livelihood resilience index was Taishi Tomb Village, Qishi Subdistrict, Yang County, with 0.08819, and the lowest was Houbizi Village, Houbizi Town, Zhouzhi County, with 0.05637.

Table 2. Variable description and descriptive statistics

	Variable name	Definition and assignment	Mean value	Standard deviation
Dependent variable	Whether to adopt climate change adaptation behavior	1 Yes, 0 No	0.87	0.34
	Usage intensity	Take any one of the 12 climate change adaptation behaviors, denote the intensity as "1", take 2 behaviors, denote "2", and so on	1.57	1.10
Explanatory variable	Perception of temperature	1 significantly decreased, 2 slightly decreased, 3 remained unchanged, 4 slightly increased, and 5 significantly increased	3.73	0.93
	Perception of extreme weather	1 significantly decreased, 2 slightly decreased, 3 remained unchanged, 4 slightly increased, and 5 significantly increased	3.65	0.84
	Perception of rainfall	1 significantly decreased, 2 slightly decreased, 3 remained unchanged, 4 slightly increased, and 5 significantly increased	3.74	0.92
	Livelihood resilience	Calculated	0.07	0.02
Control variable	Gender of head of household	1 male, 0 female	0.91	0.29
	Age of household head	Actual age/year of household head	55.31	11.00
	Is the household head a village cadre	1 Yes, 0 No	0.11	0.31
	Family's highest level of education	Family's maximum education years/year	10.89	3.74
	Number of cultivated land blocks	Total number of household arable land/piece	2.73	2.35

Source(s): Table created by authors

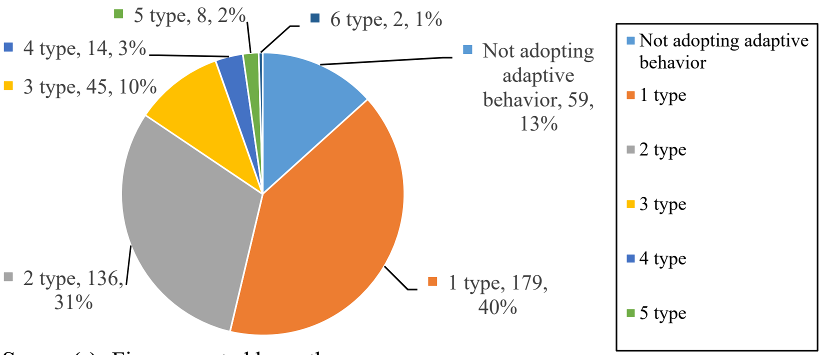

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Figure 2. Distribution of farmers' adoption of climate change adaptation behaviors

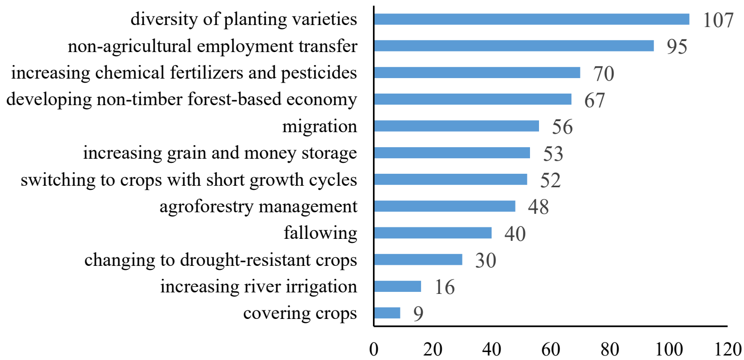

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Figure 3. Adoption of various adaptive behaviors by farmers

3.5 Model settings

Whether farmers adopt climate change adaptive behavior is a binary variable (1 yes, 0 no), so a Logit model is used to estimate whether they adopt climate change adaptive behavior. The use intensity of farmers' adaptive behavior to climate change is a counting variable. For the model whose explanatory variable is a counting variable, the conventional regression analysis usually has bias, and the corresponding statistical test results are also invalid. Poisson regression can effectively avoid such problems. However, the premise for the use of Poisson regression is that the expectation and variance of the Poisson distribution are equal. The sample data used in this paper is 443 households' adaptation to climate change and other relevant indicators. The variance (1.21) and expectation (1.57) of the explained variable "use intensity" are not equal, so there is excessive dispersion, so negative binomial regression is considered. After negative binomial regression, the over dispersion parameter "alpha" is infinitely close to 0, that is, the original assumption "alpha = 0" is true, and Poisson regression should still be used at this time. Even if there is excessive dispersion in the sample data, in the process of Poisson regression, using "Poisson regression + robust standard error" can still achieve consistent estimator of parameters and standard error. In addition, since 13.32% of farmers still do not take any adaptive behavior, it is also necessary to consider whether the "zero inflation Poisson regression" is applicable. With the help of Vuong statistics (−0.00), it is found that the standard Poisson regression should be selected.

Based on the above analysis, the following model is constructed:

$$CType_i = \beta_0 + \beta_1 LHresilience + \beta_2 TCPerception + \beta_3 EWPerception + \beta_4 RCPerception + \sum_{K=1} \beta_{5k} C_i + \varepsilon_i \quad (1)$$

Among them, $CType_i$ representing the intensity of climate change adaptation behavior usage by the *i-th* farmer, *LHresilience* representing the resilience of farmers' livelihoods, *TCPerception* representing farmers' perception of temperature, *EWPerception* representing farmers' perception of extreme weather, *RCPerception* representing farmers' perception of rainfall, C_i represents a control variable. β_0 is a constant term, β_1, β_2, β_3, β_4, β_{5k} to estimate the coefficient, ε_i is a random perturbation term. Should only apply to the Poisson model:

$$P(CType_i = n) = exp(-\lambda_i)\lambda_i^n / n! \quad (2)$$

Accordingly, the Poisson regression model is:

$$E(CType_i | LHresilience_i, TCPerception, EWPerception, RCPerception, C_i) = exp\left(\alpha_1 LHresilience + \alpha_2 TCPerception + \alpha_3 EWPerception + \alpha_4 RCPerception + \sum_i^k \alpha_{5i} C_I\right) \quad (3)$$

The variable meaning of equation (3) is consistent with equations (1) and (2).

4. Empirical results and analysis

4.1 Influencing factors of decision-making choices of farmers' climate change adaptive behavior

Using STATA software, the Logit model was used to analyze whether farmers adopt climate change adaptation behaviors. Model 1 is the regression result without each control variable, and Model 2 is the regression result with each control variable. From Table 3, it can be seen that farmers' perception of extreme weather has a significant positive impact on whether farmers adopt climate change adaptation behaviors, and has passed the significance test of 1% statistical level, that is, when farmers perceive an increase in the frequency of extreme weather, the more they will reduce the impact of extreme weather on production and life by adopting climate change adaptation behaviors, and the hypothesis H1 has been verified. Farmers' perception of temperature and perception of rainfall has no significant impact on whether farmers adopt climate change adaptation behaviors, the reason may be that the growth of crops requires suitable temperature and water, and different crops have different needs for temperature and water, so when the temperature and rainfall change, it will not seriously affect the growth of crops, and farmers are not sensitive to their perception of changes, so they will not respond to changes in temperature and precipitation by adopting a series of climate change adaptation behaviors. When extreme weather such as drought and hail occur, it will have a great impact on the production and life of farmers, and farmers will adopt different climate change adaptation behaviors to minimize their losses. The reason why farmers' livelihood resilience has no significant impact on whether farmers adopt climate change adaptation behaviors may be that regardless of whether farmers' ability to cope with risk shocks is high or low, that is, the level of farmers' livelihood resilience, they will take corresponding response behaviors to a certain extent according to their own livelihood

Variable	Whether to adopt climate change adaptation behavior Model 1	Model 2
Livelihood resilience	8.107	7.878
	(1.35)	(1.15)
Perception of temperature	0.019	0.015
	(0.12)	(0.09)
Perception of extreme weather	0.637***	0.591***
	(3.74)	(3.40)
Perception of rainfall	−0.069	−0.057
	(−0.42)	(−0.33)
Gender of head of household		−0.031
		(−0.06)
Age of household head		−0.018
		(−1.31)
Is the household head a village cadre		−0.706*
		(−1.70)
Family's highest level of education		−0.023
		(−0.54)
Number of cultivated land blocks		0.115
		(1.60)
Constant term	−0.746	0.501
	(−0.78)	(0.36)
Sample size	443	443

Note(s): All the results obtained by using the multicollinearity diagnostic method show that the variance expansion factor (VIF) is less than 3, and there is no multicollinearity between the respective variables; The *t*-value is enclosed in parentheses; *** is significant at 1%, ** is significant at 5%, * is significant at 10%
Source(s): Table created by authors

Table 3. Regression results of livelihood resilience and climate change perception on whether to adopt climate change adaptive behavior

conditions, so when farmers face climate change, regardless of the level of their livelihood resilience, they will adopt at least one climate change adaptation behavior to reduce the losses of climate change, rather than choosing to "sit and await one's fate". After adding control variables such as the gender of the head of the household, the age of the head of the household, whether the head of the household is a village cadre, the maximum number of years of education of the household, and the number of cultivated plots, the regression results and significance did not change significantly. Among the control variables, whether the head of the household is a village cadre has a significant negative impact on whether the farmer household adopts climate change adaptation behavior, and passed the significance test of 10% statistical level, which may be because when the head of the household is a village cadre, he can participate in more training on climate change, master more climate change information, and respond to climate change by adopting new technologies and developing smart agriculture in the daily production process, rather than adopting some traditional climate change adaptation behaviors.

4.2 Factors influencing the intensity of farmers' adaptive behavior to climate change

Poisson regression is used to analyze the adaptive behavior of farmers to climate change. Model 3 is the regression result without adding each control variable, and model 4 is the regression result with adding each control variable. From Table 4, it can be seen that the resilience of farmers' livelihoods and their perception of rainfall have a significant positive impact on the intensity of their use of climate change adaptive behavior, both of which have passed the significance test at the 1% statistical level. That is, the higher the resilience of

Variable	Usage intensity Model 3	Model 4
Livelihood resilience	4.329***	3.513**
	(3.28)	(2.45)
Perception of temperature	0.019	0.014
	(0.52)	(0.38)
Perception of extreme weather	0.009	0.005
	(0.20)	(0.12)
Perception of rainfall	0.094***	0.086**
	(2.74)	(2.48)
Gender of head of household		−0.107
		(−0.89)
Age of household head		−0.005*
		(−1.65)
Is the household head a village cadre		−0.137
		(−1.16)
Family's highest level of education		0.004
		(0.38)
Number of cultivated land blocks		0.028**
		(2.12)
Constant term	−0.331	−0.140
	(−1.30)	(−0.44)
Sample size	443	443

Note(s): The *t*-value is enclosed in parentheses; *** is significant at 1%, ** is significant at 5%, * is significant at 10%
Source(s): Table created by authors

Table 4. Regression results of livelihood resilience and climate change perception on use intensity

farmers' livelihoods, the stronger their perception of rainfall, and the more inclined they are to adopt various types of climate change adaptive behavior to cope with the damage caused by climate change. Hypothesis H1 and Hypothesis H2 have been verified. The resilience of farmers' livelihoods refers to the ability of farmers to respond, recover, and learn from certain changes or risks in different situations, and to adapt to changes or reduce risks by changing their livelihood patterns. When dealing with climate change, the higher the resilience of farmers' livelihoods, the richer the accumulation of their own livelihood capital. External driving factors such as markets, credit, and community organizations from top to bottom can provide more help. Farmers can also use their own learning, new knowledge, new technologies, and other means to change the adverse situation caused by climate change. This also indicates that the higher the resilience of farmers' livelihoods, the more capable they are to continuously adjust by adopting different types of climate change adaptive behaviors, namely changing the intensity of use, in order to seek the best livelihood strategies and reduce the adverse effects of climate change on production and life. With regard to the impact of farmers' perception of climate change on the use intensity of climate change adaptive behavior, farmers' perception of rainfall has a significant impact on the use intensity, but their perception of temperature and extreme weather has no significant impact. The reason may be that in recent years, the survey area has been dominated by climate disasters such as rainstorm, with strong precipitation extremes, strong rain, many rainstorm processes and long duration, which has had a great impact on farmers' production, The frequency of extreme weather events such as high temperatures, cold waves, and droughts is relatively low, so farmers have a stronger perception of rainfall. To reduce losses, farmers will choose to adopt various climate change adaptive behaviors to cope with disasters. After adding various control variables, there was no significant change in the regression results and significance.

Among the control variables, the age of the head of household had a significant negative impact on the intensity of farmers' adaptive behavior to climate change, passing the significance test at the 10% statistical level. The older the head of household, the more inclined they are to avoid risks in the production process, and adaptive behaviors such as "diversity of planting varieties" and "developing non-timber forest-based economy" all have certain risks. Moreover, as they age, their ability to accept new things, new technologies, and obtain information related to climate change becomes weaker, thereby affecting the intensity of their adaptive behavior. The impact of the number of farmland plots cultivated by farmers on whether to adopt climate change adaptive behavior is significant at the 5% statistical level, and the regression coefficient is positive, indicating that the more farmland plots cultivated by farmers, the more likely they are to adopt multiple climate change adaptive behaviors. The number of farmlands cultivated by farmers in the survey sample is positively correlated with the area of farmland. That is, the more farmland cultivated by farmers, the larger the area of farmland cultivated by farmers, and their production is more susceptible to the impact of climate change. To reduce losses, farmers are more willing to adopt various climate change adaptive behaviors.

4.3 Endogeneity and robustness test

This article has confirmed the important role of livelihood resilience in the intensity of farmers' adaptive behavior to climate change. However, it should be noted that there may be endogeneity between livelihood resilience and the intensity of farmers' adaptive behavior to climate change. On the one hand, the high or low level of farmers' livelihood resilience will affect the types and intensity of farmers' adaptive behavior to climate change, On the other hand, adaptive behavior refers to actual adjustments or changes in the decision-making process that ultimately enhance resilience or reduce sensitivity to observed or expected climate change (Akhtar *et al.*, 2018). Different types and intensities of use can have different impacts on farmers' livelihoods, thereby changing their resilience to livelihood, and the two are mutually causal. To avoid endogeneity affecting the conclusions of this article, the village level mean of livelihood resilience is used to address this issue. The classic group effect theory suggests that a certain characteristic of an individual is closely related to that of other individuals in the same region, but not to their other characteristics (Pan *et al.*, 2013). Therefore, the mean of endogenous variables in the region can be calculated and data from the family itself can be excluded to handle endogeneity (Eriksson *et al.*, 2014). Model 5 and Model 6 in Table 5 show the regression results after endogeneity treatment using village level means. Model 5 shows the regression results without the addition of each control variable, while Model 6 shows the regression results with the addition of each control variable. It can be seen that after adopting the village level mean of livelihood resilience, the regression results and significance did not show significant changes. Farmers' livelihood resilience and perception of rainfall still have a significant positive impact on the intensity of their adaptive behavior to climate change, indicating that endogeneity issues did not affect the conclusion of this article.

In this article, the robustness of the model is tested by substituting variables. According to the weights of the indicators of livelihood resilience above, the weights of "financial savings" and "health status" are only 0.00034 and 0.00037. Therefore, it is eliminated and the livelihood resilience index system is reconstructed and measured. Model 7 is the regression result without the addition of control variables, and model 8 is the regression result of adding each control variable. According to the regression results in Table 5, the regression results and their significance did not change significantly when the livelihood resilience was replaced, which was basically consistent with the previous results, indicating that the results of this paper are relatively robust.

			Usage intensity			
Variable	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Livelihood resilience	4.329***	3.513**	9.227**	9.372**	4.322***	3.506**
	(3.28)	(2.45)	(2.10)	(2.09)	(3.28)	(2.44)
Perception of temperature	0.019	0.014	0.020	0.011	0.019	0.014
	(0.52)	(0.38)	(0.53)	(0.29)	(0.53)	(0.38)
Perception of extreme weather	0.009	0.005	0.020	0.022	0.009	0.005
	(0.20)	(0.12)	(0.42)	(0.48)	(0.20)	(0.12)
Perception of rainfall	0.094***	0.086**	0.119***	0.108***	0.094***	0.086**
	(2.74)	(2.48)	(3.21)	(2.87)	(2.74)	(2.48)
Control variable		Controlled		Controlled		Controlled
Constant term	−0.331	−0.140	−0.781*	−0.617	−0.329	−0.074
	(−1.30)	(−0.44)	(−1.88)	(−1.46)	(−1.29)	(0.20)
Sample size	443	443	443	443	443	443

Note(s): The *t*-value is enclosed in parentheses; *** is significant at 1%, ** is significant at 5%, * is significant at 10%
Source(s): Table created by authors

Table 5.
Endogeneity and robustness test

4.4 Heterogeneity analysis

Will the climate change adaptation behavior of rural households with different levels of livelihood resilience be different? Therefore, with reference to the research of Cao and Shi (2021), this paper divides farmers' climate change adaptation behaviors into economic adaptation behaviors, technological adaptation behaviors, and migration adaptation behaviors. Among them, the economic adaptation behavior is a strategy to respond to climate risks by increasing capital reserves, including non-farm employment, increasing monetary reserves, and achieving compound operations. Technological adaptation behaviors improve farmers' coping capacity by adjusting production management measures, including variety improvement, increased irrigation, increased chemical fertilizers and pesticides, and crop covering. Migration and adaptation behaviors include fallow, migration, etc.

In addition, according to the average value of farmers' livelihood resilience, this paper divided farmers into high livelihood resilience level and low livelihood resilience level, so as to explore the differences in the impact of different livelihood resilience on farmers' adaptive behavior. The regression results are shown in Table 6. On the whole, the level of farmers' livelihood resilience has a significant positive impact on economic and technological adaptation behaviors, because the higher the level of farmers' livelihood resilience, the better their family resource endowment, the more developed their social networks, and the more abundant the channels for obtaining information. When they face climate risks, they can obtain timely information, adjust household assets, and change production management strategies to maintain livelihood stability. The level of livelihood resilience of farmers has no significant impact on migration adaptation behavior, because land can provide a stable source of livelihood for farmers and is the basis of rural social security. Due to the love of the soil and the fear of risk, farmers do not choose migration adaptation behaviors such as migration. Compared with farmers with high and low livelihood resilience, farmers with high livelihood resilience are more willing to adopt economic adaptation behaviors, and farmers with low livelihood resilience are more willing to adopt technological adaptation behaviors. The reason for this is that farmers with high livelihood resilience are more receptive to new things and have sufficient economic strength to support them to achieve compound management. In addition, farmers with high livelihood resilience are more educated and have more opportunities for non-farm employment, so farmers with high livelihood resilience are

Variable		Livelihood resilience	Climate change perception	Control variables	Constant terms	Sample size
Low livelihood resilience	Migration adaptation behavior	−4.518 (−0.30)	Significant	Controlled	−5.431*** (−2.75)	214
	Technological adaptation behavior	33.128*** (2.91)	Not significant		−1.471 (−0.99)	
	Economic adaptation behavior	−9.413 (−0.91)	Not significant		0.194 (0.13)	
High livelihood resilience	Migration adaptation behavior	−23.171* (−1.79)	Significant	Controlled	−1.683 (−0.90)	229
	Technological adaptation behavior	−8.407 (−0.79)	Not significant		1.950 (1.17)	
	Economic adaptation behavior	22.067** (2.04)	Not significant		0.432 (0.27)	
Full sample of farmers	Migration adaptation behavior	3.847 (0.67)	Significant	Controlled	−4.658*** (−3.92)	443
	Technological adaptation behavior	12.197** (2.52)	Significant		−0.018 (−0.02)	
	Economic adaptation behavior	8.952* (1.90)	Significant		0.118 (0.12)	

Source(s): Table created by authors

Table 6.
Heterogeneity analysis

more willing to adopt economic adaptation behaviors. Farmers with low livelihood resilience are constrained by their family endowments, social networks, and their own capabilities, and often choose to increase irrigation, fertilizers, and pesticides to cope with the risks of climate change. In addition, both high and low livelihood resilient farmers are reluctant to adapt to migration.

5. Conclusion and inspiration

The adaptive behavior of farmers towards climate change is the key to ensuring agricultural production and stabilizing income, and also is the core to formulating the relative policy of climate change for governments in the future. Based on 443 micro-survey data of farmers in Shaanxi Province, this paper empirically examines the impact of livelihood resilience and climate change perception on farmers' climate change adaptation behavior. It also explores how farmers with different levels of livelihood resilience differ in their climate change adaptation behaviors. The study found that perception is a critical first step in adopting adaptive behaviors. It is only when farmers perceive climate change that they adapt accordingly to their own capabilities. The resilience of farmers represents their buffering ability, self-organizing ability, and learning ability when facing risks. When farmers have a high level of livelihood resilience, they will adjust their household livelihood capital, leverage the advantages of social networks, and continuously learn and adopt adaptive behaviors to cope with the risks brought about by climate change. In addition, this article also found that farmers with different livelihood resilience have different preferences for adopting climate change adaptation behaviors. Farmers with high livelihood resilience are more willing to adopt economic adaptation behaviors, while farmers with low livelihood resilience are more willing to adopt technological adaptation behaviors.

To actively respond to climate change, improve the adaptability of farmers to climate change, and ensure their livelihoods, the following suggestions are proposed. (1) To enhance farmers' perception of climate change and improve the sustainability of their adaptive behavior to climate change. Farmers' perception of climate change can be improved by strengthening knowledge and information support on climate change. For example, regularly releasing relevant information on climate change and agricultural response guidance, establishing a weather warning system, strengthening education and training on farmers' awareness and adaptation to climate change, for helping farmers timely and correctly grasp the relevant situation of climate change and improving the accuracy of farmers' perception of climate change. Recently farmers are mostly adopting traditional and inefficient climate change adaptation behaviors, resulting those farmers exposed a higher risk environment. The government should increase the role of public policies, explore support methods for the mixed development of multiple adaptation behaviors, guide and help farmers adopt sustainable climate change adaptation behaviors, and promote green, low-carbon, and sustainable agricultural development.

To strengthen emergency management and infrastructure construction, firstly, emergency management measures are strengthen, relevant emergency plans in advance are developed, disaster prevention and reduction capabilities are enhanced, to reduce or even avoid losses to farmers' production and life caused by extreme weather. Secondly, the construction of high standard farmland and infrastructure for flood prevention and drought relief are strengthen to prevent risks such as mountain floods, and enhance the ability of agricultural production to respond to climate change.

To adjust and upgrade the livelihood model of farmers for focusing on the accumulation of their livelihood resilience, government should immediately follow up on services such as social employment security, healthcare, and inclusive finance in rural areas to improve farmers' ability responding to climate change and thus enhance enthusiasm adopting climate change adaptive behavior.

Notes

1. Source: https://www.fao.org/family-farming/detail/en/c/1618544/
2. Source: China Meteorological Administration's Blue Book on Climate Change (2022).

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