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How do ecological vulnerability and disaster shocks affect livelihood resilience building of farmers and herdsmen: An empirical study based on CNMASS data

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Based on the survey data on animal husbandry from 1,689 households in semi-agricultural and semi-pastoral counties in Inner Mongolia, this paper applied the "buffer capacity–organizational capacity-learning capacity" framework to analyze the current livelihood resilience of farmers and herdsmen, as well as the impact of ecological vulnerability and disaster shocks on this resilience. The results show that, first, due to the vicious ecological environment and natural disasters, livelihood resilience among farmers and herdsmen is generally low in the region, but that of herdsmen is significantly higher than that of farmers. There are clear differences between the dimensions of livelihood resilience in different households. Second, natural disasters, of which drought is the most obvious, have a great impact on livelihood resilience. However, there is a significant positive correlation between ecological vulnerability and the livelihood resilience of farmers and herdsmen; thus, we should reflect on the past development model of the region. Third, In addition to the impact of ecological vulnerability and disaster shocks, per capita income, human capital, policy support, social networks, and information access are the main obstacles to livelihood resilience. Combined with these research findings, this paper seeks to improve livelihood resilience through the strategies of avoiding disaster risk, changing the development mode, reducing path dependence, and identifying obstacles.

KEYWORDS

livelihood resilience, ecological vulnerability, disaster shocks, household type, farmers and herdsmen

Introduction

The livelihoods of farmers and herdsmen in the Inner Mongolia Autonomous Region are quite vulnerable due to the poor natural conditions and socio-economic environment. Due to the low annual rainfall (normally under 400 mm), high elevation (sometimes above 4,000 m), thin topsoil (at times less than 10 mm), and large area of desertification (accounting for 23.3% of China's desertification land area), the region has an extremely vulnerable ecological environment and low land productivity (Tan and Tan, 2017). Living conditions are characterized by the region's remoteness (it can take more than 3 h by car to reach the closest city), poor infrastructure (in some areas, there is no access to public transport and electricity), and the lack of access to public services (such as education, healthcare, and credit). This has led to relatively backward social and economic development in this region. Farmers and herdsmen are also often affected by natural disasters or environmental pressures, such as drought, hail, strong winds, snowstorms, and animal diseases, which pose great challenges to the livelihoods of local farmers and herdsmen (Fan et al., 2014).

With the development of sustainable livelihoods, research on rural livelihood resilience has attracted increasing attention. Many scholars have focused on the response of farmers' livelihood resilience to climate change and natural disasters (Tanner et al., 2014) and taken the ways to improve the livelihood resilience as the coping strategy (Adger et al., 2011; Gupta et al., 2020). What are the main factors affecting the farmers'and herdsmen'livelihood resilience, which have not been well understood in China. Especially in the farming-pastoral region just like Inner Mongolia Autonomous Region, research using comprehensive evaluation indicators to demonstrate how natural disasters and climate change affect livelihood resilience is also relatively limited. This study therefore seeks to accomplish the following: first, to understand the general level of livelihood resilience in the region and compare the differences between households and regions; second, to examine how natural disasters and the ecological environment affect the livelihood resilience of farmers and herdsmen; and third, to explore effective ways to improve the response of farmers and herdsmen to shocks and pressures.

Literature review and analysis framework

Livelihood resilience: Concept and measurement

The concept of resilience was first used in physics and engineering to describe the ability of a system to return to a normal state (Doorn et al., 2018). It was first introduced in ecological science by Holling (1973) to measure the ability of a system to absorb changes and disturbances. In recent years, the concept of resilience has increasingly been used to explain dynamic changes in socio-economic status, but more emphasis has been placed on adaptability, transformability, social learning, and innovation (Folke, 2006). However, as livelihoods are increasingly being affected by changes in ecological, economic, and social systems, the concept of livelihood resilience is receiving increased attention (Quandt, 2018; Sina et al., 2019). The ability of residents to recover from external pressure events (Chambers and Conway, 1991), the adaptive strategies used to cope with the pressure and shocks (Liu et al., 2019), and the process of re-formulating livelihood strategies using livelihood capital and local resources (Sadik, 2009) are all regarded as elements of livelihood resilience. Although different scholars have put forward different concepts of livelihood resilience, they have reached a preliminary consensus that it refers to the ability of the livelihood system of a community or family to cope with environmental changes and to recover and transform in response to adverse impacts (Tanner et al., 2014; Li et al., 2019).

Measuring livelihood resilience is an arduous task. Because resilience is an evolving concept, a set of unified systems and methods for measuring it has not yet been developed. At present, the most comprehensive measurement is the household livelihood resilience model (HLRA) proposed by Quandt, (2018), which uses sustainable livelihoods and five kinds of capital to measure resilience. It not only provides a theoretical framework, measurement methods, and applicable tools for measuring resilience, but also includes subjective evaluation of resilience, emphasizing the heterogeneity of households and individuals. The other most widely used method is the three-dimensional measurement framework, which, represented by the work of Speranza et al. (2014), is an empirical application–oriented analysis and research method applicable to livelihood resilience. The framework contains buffer, self-organization, and learning capacities, and emphasizes the interaction between actors and social structure while laying a foundation for the empirical analysis of resilience from the perspective of groups and livelihoods.

Climate change, disaster shocks, and livelihood resilience

For farmers, when their livelihoods are directly or indirectly exposed to climate change, especially sudden disasters, it can have an adverse impact on family capacity, capital, or activities. Scholars have therefore explored the relationship between farmers' livelihood resilience and climate change or natural disasters (Adger et al., 2005; Forsyth, 2018). The impact of climate change on livelihoods mainly appears in the long-term change of climate elements and sudden meteorological disasters, and it has a large impact on the resources, livelihood activities, and capacity of farmers (Wu and Li, 2009). Agriculture and animal husbandry are directly dependent on natural factors such as light, temperature, precipitation, and soil; thus, the livelihoods of farmers and herdsmen are very sensitive to climate change, which can prolong the growth cycle of crops. Crops have also been affected by late frosts, resulting in reduced production (Zhu et al., 2013). Grassland climate warming and drying have reduced the quantity of grass production, which has an impact on animal husbandry (Zhang et al., 2007). Climate change has also led to meteorological disasters such as drought, flood, freezing, and hail, directly resulting in the decline of production and income (Zhang et al., 2018).

Numerous studies have assessed the impact of climate change and disasters on the vulnerability and sustainability of livelihoods. Hurricanes and storm surges have caused serious damage to the livelihoods and assets of coastal residents in Bangladesh, and even the careers of local residents will be changed due to the disasters (Msua et al., 2021). Long term drought, sudden rainstorms, high temperatures and frequent floods have brought long-term damage to agricultural production in northern Ghana, seriously reducing the livelihood resilience of local residents (Asante et al., 2021). In Wenchuan and Lushan earthquake-stricken areas, China, landslides and mudslides adversely affect on the livelihood of rural households (Yang et al., 2021). Severe climate change, including crop pests, disease outbreaks, droughts and floods, is the main reason for the vulnerability of families in South African (Mthethwa and Wale, 2022).

To mitigate the adverse impacts of climate change and disasters, the government and individual households have adopted different policies or measures to enhance livelihood resilience. The case of extreme drought events in rural Vietnam shows that livelihood resilience can be effectively improved by strengthening social participation, borrowing, saving, and choosing new economic activities (Arouri et al., 2015). Based on the research findings of Wenchuan and Lushan earthquake disaster areas, China, strengthening the communities' disaster prevention capacity and improving the residents' disaster preparedness capacity are gradually becoming an effective ways to cope with disaster risks and improve the well-being of residents (Ma et al., 2021). The vulnerability of climate change to food insecurity and poverty can be reduced through non-agricultural diversification, crop diversification, farm location changes and the application of agrochemicals (Asante et al., 2021). In addition, farmers can effectively improve their resilience to agricultural drought by participating in social networks and cooperatives more often. Diversification in on-farm enterprises, like livestock units, and off-farm income sources, play significant roles in increasing smallholder households' resilience to climatic risk (Kumar et al., 2020). At the same time, based on a survey of rural floods in Australia, it can be seen that livelihood resilience can be effectively improved by obtaining loans and the help of local partnerships and relief organizationss (Boon and Helen, 2014). There are also measures to cope with earthquake disasters, such as relocating settlements, improving social capital, and keeping away from dangerous environments (Despotaki et al., 2018). The impact of disasters such as sandstorms can be dealt with by using windbreak forests and planting disease-resistant plants (Licht et al., 2016).

Analysis framework

Before proposing the analysis framework, the key concepts of livelihood resilience, natural disaster risk, and ecological vulnerability must be clarified. In this study, livelihood resilience is measured according to the three-dimensional framework of buffer, organizational, and learning capacities proposed by Speranza et al. (2014).

Natural disaster risk refers to the probability of natural disasters occurring in a region. This indicator is a comprehensive evaluation of the level of risk of natural disasters, in combination with the various natural disasters occurring in a specific region (Yu et al., 2012). In the selection of evaluation indicators, disasters such as earthquakes, landslides, debris flows, floods, and droughts are considered, and a multi-index comprehensive evaluation model is designed (Liu et al., 2014). The specific evaluation method uses GIS technology and grid data to calculate the index weight and obtain a comprehensive value with a value ranging from 0 to 1.

Ecological vulnerability refers to the sensitive response and self-recovery ability of ecosystems relative to external disturbances at a specific scale of time and space. Related research looks at exposure, sensitivity, and adaptability (Wu and Zhang, 2014). Although ecological vulnerability is much talked about, it is not clearly defined vulnerability; it can, however, be measured (Jacquleen, 2013). Evaluation of the current situation is the most widely studied content in the measurement of ecological vulnerability, and the most commonly used method is index evaluation (Zhao et al., 2007).

According to the ecological landscape and production mode, the 54 counties in the Inner Mongolia Autonomous Region are divided into animal husbandry counties and semi-agricultural and semi-pastoral counties. Strictly speaking, there are no agricultural counties, but the actual situation is that in many semi-agricultural and semi-pastoral counties, farmers do not have grassland but are fully engaged in planting. Combined with the actual situation and research needs of the survey area, three types of households are defined: farmers refer to families who have no grassland but only cultivated land and are completely engaged in planting; herdsmen are families that only have grassland and no arable land and are completely engaged in animal husbandry; and agro-pastoralists to families that have both grassland and cultivated land and engage in both planting and animal husbandry.

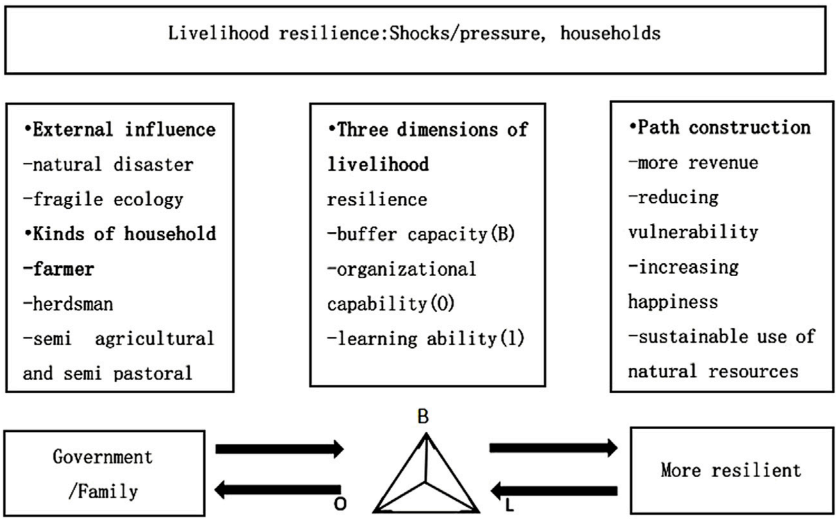

FIGURE 1
Organization of the article.

In this study, we first build an index evaluation system to measure the livelihood resilience of farmers and herdsmen in the study area. Second, we compare and analyze the livelihood resilience of farmers, herdsmen, and agro-pastoralists, as well as the differences in livelihood resilience between different households. Third, we build a hierarchical linear regression model and introduce two indicators of natural disaster risk and ecological vulnerability to study the impact of environmental differences and disaster shocks on household livelihood resilience. Finally, based on the research conclusions, this paper explores ways to improve the livelihood resilience of farmers in response to climate change and disasters. The organization of the article is shown in Figure 1.

Materials and methods

Study area

The study area is the Inner Mongolia Autonomous Region of China, which is located in the north of China, between 37° 24′–53° 23′ N and 97° 12′–126° 04′ E. The area spans more than 2,400 km from east to west and 1,700 km from north to south. Topographically, the Mongolian Plateau is the main feature, which has complex and diverse forms. Except for the southeast, the plateau accounts for about 50% of the total land area. The region primarily has a temperate continental monsoon climate. Precipitation is low and uneven, the wind is strong, and the variation between cold and heat are severe. From east to west, the region is composed of semi-humid, semi-arid, and arid areas, with, again from east to west, a vegetation landscape of forest, grassland, desert grassland, and desert. Except for the eastern part of the region, the annual average precipitation in most areas is less than 400 mm, and the precipitation decreases from east to west. The overall climatic condition of the whole region is poor, and the vegetation coverage is low. The region is often affected by natural disasters or environmental pressure, such as drought, hail, strong winds, and snowstorms. In terms of industry, the whole region is dominated by agriculture and animal husbandry, with agriculture in the plains and hilly areas (e.g., the plains of Hetao and Tumechuan) and animal husbandry mainly distributed in the grassland areas of Hulunbuir, the Xing'an League, and the Xilin Gol League.

Data collection

In the summer of 2018, the Inner Mongolia University carried out a comprehensive social survey (CNMASS) of animal husbandry counties and semi-agricultural and semi-pastoral counties in Inner Mongolia. This survey investigated the livelihood mode, agricultural and animal husbandry production, infrastructure, population change, and relation between nationalities in the region. Specifically, questionnaires and semi-structured interviews were used to collect data covering the levels of counties, townships, villages, households, and individuals. The survey was conducted by multi-stage stratified sampling. In the first stage, 10 of the 54 counties in the region were randomly selected, taking into account the geographical distribution. In the second stage, from the above 10 counties, three townships were randomly selected for sampling, and from each township, four villages were then

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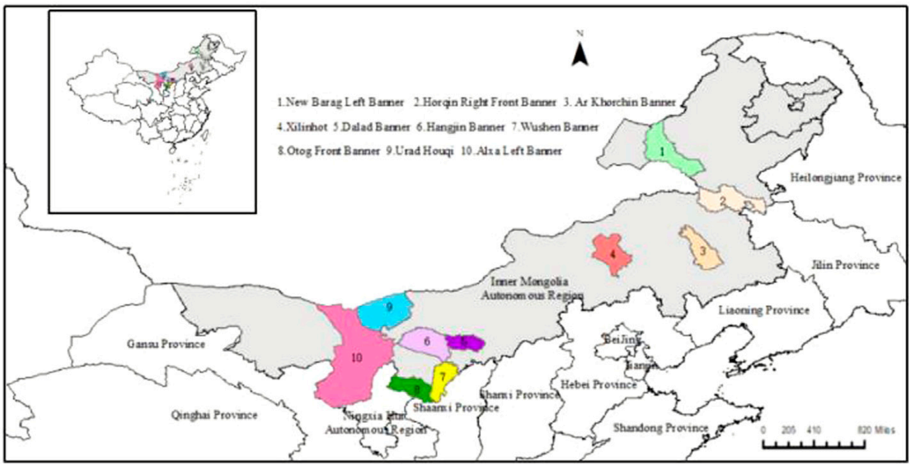

FIGURE 2
Survey area distribution[1].

selected for investigation based on convenience sampling (to ensure that there were at least 20 households in each village). In the third stage, among the selected villages, the respondents were selected according to indoor random sampling. The three-stage sampling yielded a total sample of 2,400 households and 120 villages. During the implementation of the project, roads in many villages were blocked due to heavy rain, and the random principle was not fully followed. We therefore selected the neighboring villages for investigation and finally investigated 2,412 households. The sampling distribution in the investigated area is shown in Figure 2.

Evaluation of ecological vulnerability and natural disaster risk

In June 2011, China officially released the "National Main Functional Area Planning." This document requires the country to divide the land space into four categories according to the resource and environment carrying capacity, existing development density, and development potential: optimized development, key development[1],

Restricted development, and prohibited development.[2] The Inner Mongolia Autonomous Region undertook the planning task of the "Inner Mongolia Main Functional Area Planning," studied the division of the main functional areas, and comprehensively evaluated the natural disaster risk and ecological vulnerability of the whole region. Finally, according to the level of natural disaster risk, all counties in the region are divided into five levels from low to high;[3] all counties in the region are also divided into five levels from low to high according to level of ecological vulnerability.[4] The results of the two indicators in the "Inner Mongolia Main Functional Area Planning" document are used in this paper as the macro variables reflecting the ecological environment and natural disaster risk at the county level in the analysis model.

Measurement of livelihood resilience

The selection of indicators to measure the livelihood resilience of farmers and herdsmen is based on an intensive review of the relevant literature and the data obtained from the field surveys. Table 1 shows the three components (buffer, organization, and learning) and composite indicators (Speranza et al., 2014).

Buffer capacity is a measure of the disturbance and change absorbed by a system while maintaining its structure, function, characteristics, and feedback unchanged. From the perspective of livelihood, buffer capacity refers to the ability of farmers to use their own resources and rights to resist livelihood risks (Kelly and Adger, 1999).

1 Banner is one of the administrative divisions at the same level as the county in China.

2 http://www.gov.cn/zhengce/content/2011-06/08/content_1441.htm.

3 The five assessment grades of natural disaster risk are areas of low risk, slight risk, medium risk, high risk, and extremely high risk.

4 The five assessment grades of ecological vulnerability are areas of low vulnerability, slight vulnerability, medium vulnerability, severe vulnerability, and extreme vulnerability.

TABLE 1 Indicator system to assess livelihood resilience.

Dimension	Indicator	Definition and description of indicators	Unit	Weight
Buffer capacity 0.540	Family labor (A1)	Total number of household labor force	Person	0.086
	Per capita education level (A2)	Ratio of total years of education to total population	Year/ person	0.245
	House quality (A3)	Thatched cottage = 0.25, Adobe house = 0.5, Brick-concrete bungalow = 0.75, Building = 1	4 levels	0.040
	Per capita income of housholds (A4)	#0000FF; Ratio of annual total household income to total household population	%	0.385
	Cultivated land area (A5)	Land area actually cultivated by the family	Mu	0.122
	Grassland area (A6)	Grassland area actually grazed by the family	Mu	0.122
Organizational capability 0.297	Policy support (B1)	Government aid financially and subsidies obtained	Yuan	0.555
	Social network (B2)	Number of friends and relatives that can help	Household	0.235
	Trust between neighbors (B3)	The level of trust between neighbors	5 levels	0.068
	Traffic convenience (B4)	Where the main road leads: Townships = 1, Counties = 2, Prefecture level city = 3, Other prefecture level cities = 4, Other provinces = 5	5 levels	0.143
Learning capability 0.163	Education level of household head (C1)	Expressed by the length of schooling of the household head	Year	0.285
	Non-agricultural work experience (C2)	Ratio of the number of families with non-agricultural work experience to the total number of people	%	0.084
	Information acquisition capability (C3)	Ways and channels for families to obtain market, disaster, and employment information	5 levels	0.403
	Education investment (C4)	Amount of annual family education investment	Yuan	0.229

Mu is a measure of land in China. Per mu = 666.67 m^2.

The buffer capacity of a system or individual can be improved by improving the resource endowment, as reflected in livelihood capital and stability (Chen et al., 2016). The labor force and per capita education level represent the human capital of farming and herding families. The higher the population quantity and quality, the stronger the buffer capacity in the face of risk interference (Wen et al., 2018). The actual cultivated and grassland area represent the natural capital. Whether they have sufficient cultivated land and property is very important in resisting the shock of natural disasters (Liu et al., 2019). Housing quality represents the material capital of farming families. When farmers' livelihoods are hit, they can realize the material capital to improve their financial capital (per capita income) and enhance buffer capacity. The amount of financial capital directly affects whether farmers can maintain the function, structure, and feedback of their original basic livelihood when encountering shocks and also creates a certain potential resilience (Zheng et al., 2020). This dimension is represented by the A1 to A6 indicators.

Organizational capacity reflects how the family's self-management, institutional policies, and social connectivity shape resilience (Fuchs, 2014). Milestad and Darnhofer (2003) define the self-organization of the agricultural system as the ability of farmers or agricultural groups to establish flexible communication and mutual assistance networks, as well as to integrate into the local social, economic, and institutional environment. Organizational capacity can be characterized by policy support, social network, neighborhood trust, and other indicators. Policy support represents the ability of farmers to obtain development opportunities and integrate their own resource advantages (Wen et al., 2018). Policy support is a powerful external force for families, and it is the main driving force for the improvement of family's organizational capacity when a disaster occurs. A social network indicates the degree of information sharing and mutual support among individual farmers. Lack of trust and communication isolates farmers and reduces their ability to self-organize (Wang et al., 2021). Social networks are the main source of informal loans and assistance. Accessibility reflects the ease with which an area in connected to the outside world, and reflects the efficiency of obtaining external assistance in an emergency (Wu et al., 2021). This dimension is represented by the B1 to B4 indicators.

Learning ability is the ability of individuals or organizations to create, acquire, transmit, and memorize knowledge and is of great significance to their rapid response and recovery after a shock (Kim, 1998). Four indicators, namely the education level of the household head, the ability to obtain information, the proportion of the population with non-agricultural experience, and the investment in family education, are selected. The education level of the household head directly affects a family's vision and planning for the future (Wen,2018). The ability to obtain information reflects the ways and opportunities

TABLE 2 Variable descriptive statistics.

Variable name		Frequency	Ratio (%)	Maximum	Minimum
Livelihood resilience	Continuous variable	1689	100	0.016	0.357
	Herdsman	834	49.38		
Kinds of household	(References group)			0	2
	Farmer	437	25.87		
	Agro-pastoralists	418	24.75		
Drought	Not affected (References group)	392	23.21	0	1
	Affected	1297	76.79		
Freeze	Not affected (References group)	1310	77.56	0	1
	Affected	397	22.44		
	Medium risk area	4	35.29		
Natural disaster risk	High risk area	3	32.92	3	5
	Extremely high risk area	3	31.79		
	Low vulnerable area (References group)	1	6.45		
Ecological vulnerability	(References group)				
	Slightly vulnerable area	1	9.59	1	4
	Moderately vulnerable area	4	44.76		
	Severe vulnerable area	4	39.19		

TABLE 3 t-test for mean differences in household livelihood resilience types.

	Kinds of household		Buffer capacity		Organizational capability		Learning capacity	
	Mean	T Value	Mean	T Value	Mean	T Value	Mean	T Value
Herdsman	0.116		0.091		0.092		0.250	
Farmer	0.109	4.028***	0.075	8.702***	0.127	−9.345***	0.191	10.209***
Agro-pastoralists	0.122	−3.451***	0.090	−0.393	0.126	−9.975***	0.221	4.817***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

for farmers to obtain information, which can help them grasp market information and adjust their strategies in a timely way to cope with the impact of adverse changes (Wu et al., 2021). The proportion of the population with non-agricultural experience represents the vision and diverse production experience ofdifferent members of the family. Households may adopt diversified agriculture and off-farm employment as adaptive strategies to combine and transform their livelihood assets to be resilient to the disturbance (Li et al., 2016). The education level of household head will directly affect a family's vision and future livelihood planning, as well as the education investment of the whole family and the education of their children (Wen et al., 2018). It is in line with the concept of resilience that emphasizes the future and dynamics (Li et al., 2019). This is characterized by the C1 to C4 indicators.

As mentioned above, family livelihood resilience is measured by three dimensions: buffer, organization, and learning capacity. Each dimension is represented by several indicators, and all indicators are integrated to form a comprehensive index (Table 1). Because each indicator is measured on a different scale, we adopt (Eq. 1) to standardize each indicator as an index (Wang et al., 2021):

$$index_{ij} = \frac{S_{ij} - S_{j,min}}{S_{j,max} - S_{j,min}}, \quad (1)$$

where S_{ij} and $index_{ij}$ are the original value and standardized value of index j of family i, respectively. $S_{j,\ min}$ and $S_{j,\ max}$ are the minimum and maximum values of index j, respectively. We use (Eq. 1) to adjust all indexes to 0–1. After each indicator is standardized, the analytic hierarchy process is used to determine the weights of specific indicators and dimension layers (Table 1). The livelihood resilience of different households can be obtained using standardized values for different indicator and dimension layer weights.

TABLE 4 Hierarchical linear regression of factors influencing livelihood resilience.

Variables		Null model (model 1)	Random-intercept model (model 2)	random-intercept model (including explanatory variables) (model 3)
		coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)
Level 1		Fixed effect		
Intercept (β_{0j})		0.116***(0.003)	0.113***(0.003)	0.105***(0.006)
Household (β_{1j})	Farmer		−0.006***(0.002)	−0.005**(0.002)
	Agro-pastoralists		0.001 (0.002)	0.001 (0.001)
Drought (β_{2j})			0.005**(0.002)	0.005**(0.002)
Freeze (β_{3j})			0.001 (0.002)	0.002 (0.002)
Level 2: Random-intercept model	Variance components			
Intercept (γ_{00})		0.008***(0.002)	0.007***(0.001)	0.004***(0.001)
Level 2: Explanatory variables				
Ndi (γ_{01})	High risk			−0.015***(0.005)
	Extremely high risk			−0.008*(0.001)
Ev (γ_{02})	Slight vulnerable			0.018**(0.009)
	Moderately vulnerable			0.015**(0.006)
	Highly vulnerable			0.017**(0.007)
Residual		0.029	0.028	0.028
ICC		0.071	0.065	0.027
AIC		−7153.195	−7164.528	−7162.495
BIC		−7136.899	−7126.505	−7097.312
Log likelihood		3579.5974	3589.264	3593.247
Individual observations		1689	1689	1689
Group observations		10	10	10

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; the values in brackets are standard errors.

Hierarchical linear regression model

A hierarchical linear regression model (HLM) is used to study the difference level and influencing factors of livelihood resilience among farmers, herdsmen, and agro-pastoralists. Different household types are thus taken as the main explanatory variables of livelihood resilience, and different types of disasters faced by households are introduced into the micro level of the model (Level 1) as individual factors affecting livelihood, similar to the ordinary OLS regression equation (Eq. 1). Natural disaster risk and ecological vulnerability are also included in the model (Level 2) as macro factors to explore the impact of ecological vulnerability and natural disasters on livelihood resilience. This level analyzes the variation of the intercept of the Level 1 (β_0, representing the average livelihood resilience level of households) in different counties. The intercept of level 1 (random intercept) is divided into two parts in level 2, the intercept (γ_{00}) and the random component (u_{01}), through which the random intercept model is constructed. At level 2, two indicators of natural disaster risk ($N\ id$) and ecological vulnerability ($E\ v$) are introduced to explain the variation of the random intercept. A random-intercept model with explanatory variables, is thus formed. It is worth noting that the slopes in level 1 does not change in level 2.

Level 1 (Eq. 1): $ln(y_{ij}) = \beta_0 + \beta_1 \cdot Household_{ij} + \beta_2 \cdot Drought_{ij} + \beta_3 \cdot Freeze_{ij} + \varepsilon_{ij}$

Level 2 (Eq. 2): Adding two explanatory variables *nid* and *ev*, we obtain

$$\beta_0 = \gamma_{00} + \gamma_{01} \cdot Ndi_j + \gamma_{02} \cdot Ev_j + u_{0j}$$

In (Eq 1), the β_0 represents the intercept, and β_1 to β_3 represents the regression coefficient related to the three explanatory variables of level 1. The subscript i represents the units in level 1—that is, each household—and j represents the units in level 2—that is, the county. In, β_0 is the intercept of level 1 related to the unit of level 2. γ_{00} is the intercept of level 2 and γ_{01} and γ_{02} are the regression coefficient corresponding to each explanatory variable of level 2. u_{0j} is the error term for level 2.

TABLE 5 Main obstacles of livelihood resilience indicators.

All households	Buffer capacity		Organizational capability		Learning ability	
Obstacle factor	A2	A4	B1	B2	C3	C4
Contribution (%)	8.71	14.71	21.23	8.54	15.40	7.68

Results

Descriptive analysis

Table 2 shows the family livelihood resilience and descriptive data for the main variables. A total of 1,689 effective samples were used after selection and processing. The maximum and minimum values of livelihood resilience are 0.357 and 0.016, respectively. The difference in livelihood resilience of different families is obvious. Drought and freezing are the main natural disasters affecting the agricultural and pastoral production in the region, and they have a great impact on livelihood resilience. According to the survey data, 76.79% of residents suffered from drought and 23.51% from freezing temperatures. For natural disaster risk, in the 10 counties in this survey, four are medium-risk areas, three are high-risk areas, and three are extremely high-risk areas.[5] The overall natural disaster risk level of the surveyed areas is high. In terms of ecological vulnerability, eight of the 10 counties have medium or severe vulnerability.[6] The overall ecological environment of the investigated area is very fragile.

Heterogeneity of livelihood resilience

From the results shown in Table 3, the resilience index of the surveyed residents' livelihood is not high as a whole, with an average of only 0.117. The resilience of farmers is the lowest, with an average of 0.109, followed by that of herdsmen (0.116) and then that of agro-pastoralists (0.122). The difference is quite clear. Although there is no significant difference in buffer capacity between herdsmen and agro-pastoralists, different dimensions of livelihood resilience differ significantly between household types.

The buffer and learning capacities of farmers are the lowest, with an average of 0.075 and 0.191, respectively, while the organizational capacity of herdsmen is the lowest, with an average of 0.092. To a large extent, this is related to the special geographical location of the region and the tradition of agriculture and animal husbandry. Since ancient times, the region has been dominated by nomadism, and agriculture is limited by natural conditions. Except in a few plain areas (such as Hetao), the development of agriculture is relatively backward. The livelihood resilience of herdsmen is thus relatively high, and the buffer capacity of farmers is relatively low. Agro-pastoralists have relatively strong resistance to external shocks such as climate change and disasters due to their diversified production modes. Their buffer capacity is thus also relatively higher than that of farmers. Moreover, farmers' learning ability is relatively low. Farmers' income is far below that of herdsmen; so, their investment in education is relatively low. The organization capacity of herdsmen is relatively low, which may be related to their mode of production and living. The residential areas in the pastoral areas are relatively scattered, not concentrated, and pastoral areas are also relatively backward in transportation and other infrastructure. When herdsmen encounter external shocks, obtaining external assistance is inconvenient and the ability to organize self-recovery is relatively weak.

Factors influencing livelihood resilience

We use an HLM and consider natural disaster risk and ecological vulnerability as macro factors, incorporating them into level 2 of the model to explain the variation of livelihood resilience across counties (see Table 4).

According to the regression results, the variance (level 2) of the model1 is 0.008 ($p < 0.01$), From the variance results, the household belonging to different counties shows the differences in livelihood resilience due to different groups (different counties), indicating that the hierarchical linear model is applicable. Specifically, the total variance is 0.008 + 0.029 = 0.037. The variance partition coefficient (VPC) is 0.008/0.037 = 0.2162, which indicates that 21.62% of the variance in attainment can be attributed to differences between counties. the ICC value of model one is 0.071 and that of model two is 0.065. Compared with model 1, the decline of model two is not very obvious, but it still shows that there is indeed a variation in livelihood resilience at level 2, and the random effect has an impact. After introducing explanatory variables into level 2, the ICC value of model three is 0.027, which decreased significantly, indicating that the

5 Medium-risk areas: New Barag Left Banner, Wushen Banner, and Otog Front Banner, Xilinhot; High-risk areas: Ar Khorchin Banner, Hangjin Banner, and Horqin Right Front Banner; Extremely high-risk areas: Dalad Banner, Urad Houqi, and Alxa Left Banner.

6 Medium vulnerability areas: Ar Khorchin Banner, Ulat rear banner, Otog Front Banner, and Xilinhot; High vulnerability areas: Wushen Banner, Hangjin Banner, Dalat Banner, and Alxa Left Banner.

introduction of random effect item is reasonable. The random effect item has an explanatory force of 0.071–0.027 = 0.044 (4.4%) on the county level (level 2). When the two indicators of natural disaster risk and ecological vulnerability are introduced, they can explain 42.85% of the variance in the average value of livelihood resilience across counties.

From the results of model 3, the fixed effect of the level 1 reflects the individual differences in livelihood resilience in different household types. Taking herdsmen as the reference group, the livelihood resilience of farmers is 0.005 units lower ($p < 0.05$), which indicates that, for the 10 counties in the survey area, the livelihood resilience of herdsmen is generally higher than that of farmers. However, the differences between herdsmen and agro-pastoralists did not reach the level of significance, which is in line with previous findings. In the Inner Mongolia Autonomous Region, herding is traditionally the main industry, and agriculture is restricted by the natural environment; so, its development is relatively weak. Drought is the main natural disaster affecting agriculture and animal husbandry. Compared with households affected by drought, the livelihood resilience of households not affected by drought was generally 0.005 units higher ($p < 0.01$). Drought not only reduces the yield of crops but also degrades the quality of grassland and harms animal husbandry. The impact of a freezing disaster is not obvious, but this may be related to the season during which we collected data. Before the period when the grassland is prone to frost in autumn and winter, the possibility of a frost disaster in the region is small.

Considering random effects, the intercept of level 1 (the average value of livelihood resilience of different household types) is significantly different from that of level 2 (between counties), and the variance component is 0.004 ($p < 0.01$). In terms of macro factors, the impact of natural disaster risk on livelihood resilience is negative and significant. The higher the level of natural disaster risk, the lower the overall level of livelihood resilience. Compared with medium-risk counties, the average livelihood resilience of farmers and herdsmen in counties with a high risk and an extremely high risk decreased by 0.015 ($p < 0.001$) and 0.008 ($p < 0.01$) units, respectively. The higher the level of risk of natural disasters, the greater the impact of disasters on livelihood resilience. Due to poor natural conditions, the living conditions of farmers and herdsmen are unstable, and the ability to cope with the pressure and shocks from natural disasters is significantly reduced (Tan and Tan, 2017). At this time, establishing a long-term risk early warning and risk management and control mechanism, promoting the diversification of livelihoods, and implementing active ecological policies have become effective ways to deal with livelihood vulnerability and improve livelihood resilience (Zhao, 2022). The government can improve access to land and water rights, thereby strengthening land governance to cope with drought (Bahta and Myeki, 2021). Residents and communities can increase awareness of disaster risks and reduce the loss of livelihoods from disasters (Ma et al., 2022).

The higher the level of ecological vulnerability, the higher the livelihood resilience of farmers and herdsmen. This may appear counterintuitive, but after careful analysis of the study area, it became apparent that the counties with lower ecological vulnerability are often nature reserves and restricted development areas focused on ecological protection. There is no large-scale development of agriculture and animal husbandry in these counties. The overall livelihood resilience of the region is thus poor. For example, the livelihood resilience of New Barag Left Banner, Ar Khorchin Banner, and Horqin Right Front Banner is 0.110, 0.111, and 0.113, respectively. The higher the ecological vulnerability, the higher the livelihood resilience of farmers and herdsmen. This phenomenon is related to the development mode of treatment after pollution. For example, Ordos (0.122), which has the highest average livelihood elasticity, has suffered irreversible damage to the ecological environment, such as water resources, air, and grassland, due to extensive coal mining. Despite rapid economic and social development, ecological vulnerability is becoming increasingly serious (Wang and Zhang, 2015). Another example is Xilin Gol (0.014); from the 1990s to the beginning of the 21st century, overgrazing led to serious grassland degradation. The disordered mining of underground coal mines led to the exposure of a large area of grassland surface, which accelerated degradation and desertification (Wu et al., 2017). The previous extensive development led to the destruction of the ecological environment. With the rapid development of agriculture and animal husbandry, ecological damage has also become a new problem for the development of the region. It is thus clear that there is a significant positive correlation between ecological vulnerability and livelihood resilience. The best way to alleviate ecological vulnerability is to develop ecological agriculture and industrial diversification. How to achieve a "win-win" between ecological protection and sustainable livelihood development is the key to solve ecological problems in the future industrial development process (Qin et al., 2022). Eco agricultural projects can not only contribute to a significant increase in livelihood capital, but also increase the diversity of farmers' livelihoods (Zhao et al., 2013). Encouraging farmers and herdsmen to develop characteristic farming, broadening income channels and reducing dependence on natural resources are important ways to achieve industrial transformation and sustainable development (Zhao, 2022).

Barriers to livelihood resilience

We further introduce factor contribution W_i (the weight of a single factor), indicator deviation V_i (the difference between the standardized value of a single indicator and 1), and obstacle O_i (indicating the impact of a single indicator on livelihood resilience) to build an obstacle diagnosis model to identify the main obstacles affecting the livelihood resilience of farmers and herdsmen. Following Wen Tengfei et al. (2018)[33], the formula is as follows:

$$O_i = \frac{W_i \times V_i}{\sum_{i=1}^{n} (W_i \times V_i)} \times 100\% \quad (2)$$

In the identification of obstacles to the overall goal of livelihood resilience, the top six obstacles (the top two in each dimension) are selected. The evaluation of the livelihood resilience of farmers and herdsmen should not only judge the livelihood status in different research units but should also clarify the obstacles that affect the final results to put forward targeted policies and suggestions, which is of great significance to improve the adaptability and resilience of the study populations (see Table 5).

Once these barriers are alleviated, the livelihood resilience of farmers and herdsmen will rapidly improve. Among buffer capacity indicators, household per capita income (A4) is the most direct reflection of farmers' ability to buffer livelihood risks and adverse changes. During a crisis, this may be the last line of defense for households. Farmers can sell productive and non-productive assets to cushion the impact. The per capita education level (A2) is the main guarantee for the family labor force. The agricultural and pastoral production requires the input of labor from the start, and it also requires the labor force to have the ability and vision to organize future reconstruction. Family size and education attainment are key factors affecting farmers' livelihood resilience (Quandt, 2018). Human capital and financial capital have significant positive effects on livelihood strategies (Xu et al., 2019). Higher education per capita can significantly improve farmer livelihood resilience (Zhao et al., 2022). Among the organizational capacity indicators, policy support (B1), as the most direct external support system, can quickly and effectively help farmers and herdsmen improve their livelihood resilience after a shock. The social network (B2) represents power based on the relationship between blood and geography, which can organize a rescue force immediately after a shock, thus contributing to livelihood restoration. The ability of households to use their social capital through access to social networks and information has been shown to lead to better adaptive outcomes and enhance adaptive capacity (Bahta and Myeki 2021). At the same time, farmers are encouraged to become members of social networks and cooperatives to obtain agricultural credit, which can significantly improve the resilience and adaptability of families (Kumar et al., 2020). Among the learning capacity indicators, information acquisition (C3) reflects the timeliness of a family's access to relief information after a disaster, and it predicts future family development prospects. If families can obtain information about recovery and production on time, they can effectively restore the family livelihood. The level of investment in education (C4) exacerbates the shortage of financial capital in the short term, but this long-term investment in the future has promising returns.

Discussion

The core of this study is to find methods to improve the livelihood resilience of farmers and herdsmen. The impact of natural disasters on livelihood resilience is negative, but there is a positive correlation between ecological vulnerability and resilience. Moreover, the variable resilience of different household types is also very obvious. Through the analysis of obstacle factors, we find that breaking through the main obstacle factors plays an important role in improving livelihood resilience; thus, we can focus on the aspects discussed below.

Avoiding disaster risk and expanding livelihood modes

From the analysis results of factors influencing livelihood resilience, natural disasters risk is the main factor restricting livelihood resilience. To cope with various risk environments, farmers and herdsmen should adopt a set of strategies, and both groups should pay attention to prior risk management. The eastern region can try to actively build a diversified industrial system on the basis of traditional animal husbandry to form an industrial chain to deal with the impact of disaster risks. More specifically, they can build the downstream industrial chain (including the production, processing, and sales of animal husbandry products) and create a business model combining chain operation with leading enterprises and family farms. Residents in the central and western regions are greatly affected by drought and freezing; so, the government should be committed to promoting land remediation, strengthening the construction of water conservancy projects such as reservoirs and irrigation canals, and promoting sprinkler and drip irrigation technologies (Wu et al., 2021). Farmers can reduce the impact of drought by adjusting the planting period and by building irrigation channels (Nwafor et al., 2014). Herdsmen can mitigate the adverse effects of climate change through artificial grass planting and adjustment of the livestock structure (Gongbuzeren and Li, 2018).

Farmers and herdsmen also need to deal with shocks afterward. Ideally, households can use risk-sharing tools, such as credit, crop and livestock insurance, and agricultural products options and futures, to transfer risks to the macro economy and operate more effectively (Zuo et al., 2007). However, tools such as agricultural insurance need the active support of the government, and most farmers and herdsmen do not have the specific skills required to make use of tools such as futures and options. Currently, saving, clearing assets, and borrowing in the short term are the best methods for avoiding risk. The use of private lending based on social networks also plays a notable role.

Identifying resource advantages and changing the development mode

In addition to the negative impact of natural disaster risk, ecological vulnerability has a significant positive effect on the livelihood resilience. The conclusion reminds us that the relationship between ecological vulnerability and the livelihood resilience of farmers and herdsmen reveals that the development mode of treatment after pollution is not coordinated with resources and the environment. Identifying resource advantages and changing the development mode are the long-term pathways to enhance the future livelihood resilience of the region. We should seek to take the ecological industry as the leading factor and promote the combined development of traditional agriculture and animal husbandry and modern industrial transformation, as well as the coordination between industrial development and the existing resources and environment.

Eco-agriculture can help small-scale producers adapt to and mitigate climate change. There is growing evidence that this approach is beneficial to the environment, biodiversity, farmers' income, climate change adaptation, and resilience to multiple shocks and pressures (Mottet et al., 2020). Eco-agriculture is closely related to biological and economic diversity: the more developed the ecological farm is, the more diverse the crops, trees, animals, and economic activities are, and the greater the enhancement of economic and environmental resilience (FAO, 2019). With the increase in biodiversity, the soil is improved, which in turn helps to improve ecological resilience and strengthen the ecosystem (FAO, 2018).

Breaking path dependence and restructuring livelihoods

Restricted by the geographical environment, the livelihood resilience of farmers and herdsmen in the Inner Mongolia Autonomous Region has exhibited strong path dependence, which makes the family production mode too unitary, as the vast majority are focused on small-scale production and operation. Their ability to resist disasters and risks is very low. This path dependence must therefore be broken, which can be done in two ways: first, we should ensure the diversity of agricultural and animal husbandry development and break the original unitary production mode (Ingalls, 2020). For farmers and herdsmen, diversification includes the choice of agricultural and livestock products. In addition to traditional local crop varieties and livestock species, residents can try to grow economic or improved crops and introduce new livestock varieties.

Second, breaking path dependence can also advocate cooperation. Taking collective action to strengthen the network and cooperation between small-scale producers, producers' associations, cooperatives, and other participants is the cornerstone of building livelihood resilience (Li, 2018). In areas where conditions permit, with the help of cooperation and the industrial production chain, farmers and herdsmen can engage in large-scale production and improve their collective bargaining power and risk resistance.

Identifying obstacle factors and strengthening policy interventions

Obstacle analysis identifies the main obstacle factors of livelihood resilience. The conclusion reminds us that once these obstacles are alleviated, the livelihood elasticity of farmers and herdsmen will increase rapidly. Therefore, owning assets is the key to enabling families to recover from disasters. It is necessary to encourage families to consider their asset management and protection and to diversify their assets to avoid risk. Family members with a higher level of education are more valued in the labor market. When shocks have a negative impact on the family livelihood, if they can (temporarily or permanently) rely on another source of (non-agricultural or pastoral) income, they may be better able to adapt to those shocks. It is thus necessary for the government, families, and other different subjects to strengthen investment in education (including both infrastructure and financing), to expand educational opportunities, and to improve the overall level of human capital in the region (Wu et al., 2021).

The development of social protection policies (including public and private initiatives) can provide a certain degree of insurance and liquidity for production and help families seize economic opportunities to provide support and manage risks (Lowder et al., 2017). In the process of helping families recover their productivity, social protection policies can be adopted through social assistance (including cash or in kind subsidies), social insurance (including an insurance mechanism for disasters), labor market planning (to solve employment problems after a disaster), and other methods. Social networks are critical for the resilience of poor households and can provide access to opportunities, informal credit, and savings mechanisms to help cope with emergencies and shocks. We should encourage the normalization of social networks, and link them with productive enterprises and financial services to enhance their resilience.

Conclusion

Due to poor natural conditions and a fragile environment, the production and lifestyles of farmers and herdsmen in the

Inner Mongolia Autonomous Region are often affected by extreme weather and natural disasters, and their livelihood resilience is generally low. This threatens sustainability and social stability in the region. Improving the adaptability of farmers and herdsmen so that they can attain resilience in the face of external shocks would be the ideal condition for building a coordinated and sustainable society. For this, it is helpful to understand the main factors leading to low livelihood resilience and how these factors work. Among the many factors considered in this paper, we believe that ecological vulnerability and natural disaster risk are the most important external drivers affecting the livelihood resilience of farmers and herdsmen in the Inner Mongolia Autonomous Region.

Using CNMASS data from the survey conducted by the Inner Mongolia University in 2018, this paper studied the specific impact of the ecological environment and natural disasters on the livelihood resilience of farmers and herdsmen, focusing on the specific impact of drought and freezing. The main results show that natural disasters have a great impact on livelihood resilience. The higher the level of natural disaster risk, the lower the livelihood resilience of farmers and herdsmen, with drought being the most obvious disaster type. There is, however, a significant positive correlation between ecological vulnerability and the livelihood resilience of farmers and herdsmen, which indicates that there were great problems in the previous development mode of treatment after pollution. While various industries and the social economy are developing rapidly, the problems of the ecological environment cannot be avoided. It is thus necessary to adopt policies and measures to improve the sustainable livelihood of herdsmen. By clarifying the resource advantages and changing the development model, we can make development itself resilient. This can maintain and even improve the livelihood resilience of farmers and herdsmen in both the short term and long term.

In addition, this paper puts forward exploratory suggestions to improve the livelihood resilience of farmers and herdsmen, by identifying the obstacle factors of livelihood resilience. Strengthening policy support and guarantee, broadening social networks and improving social cooperation are the core contents of organizational capacity-building. Paying attention to education investment, improving the level of human capital, building an information network platform and enhancing the ability to obtain information are the long-term strategic choices for farmers and herdsmen in realizing livelihood restoration and transformation.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/Supplementary Material.

Author contributions

YD: data collection, investigation, methodology, software, and writing original draft. SW: investigation, methodology, and writing—review and editing. YX: writing—review and editing and investigation. All authors contributed to the article and approved the submitted versi.

Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.998527/full#supplementary-material

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