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When nature strikes: Unraveling the mental health consequences among herders in China's pastoral region

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ABSTRACT

Frequent natural disasters in ecological conservation regions threaten economic activities and human health. Using the first field survey dataset on herders' mental health collected in pastoral regions of China, we analyzed the impacts of natural disasters on their mental well-being. Empirical results indicate a significant rise in distress among herders, as assessed by the K6 score, attributable to the effects of natural disasters. This increase is especially pronounced in the context of severe and persistent common natural disasters such as droughts and snowstorms. Further analysis reveals that the adverse effects of natural disasters on herders' mental health are due to economic loss from increased fodder costs and, more importantly, a social multiplier effect that doubles the psychological impact on individual herders. In response to these negative impacts, disaster warning information, access to modern productive infrastructure facilities, and grassroots informal institutions prove beneficial. These findings underscore the necessity of giving increased attention to the mental health of residents in ecologically fragile regions, especially considering the growing adverse impacts of nature disasters resulting from climate change.

1. Introduction

Natural disasters are occurring more frequently and becoming more severe due to climate change (Masson-Delmotte et al., 2021), imposing serious challenges on the agricultural sector and rural regions. This trend poses significant threats not only to the livelihood of small farmers but also to their overall health. While existing literature extensively documents the socio-economic and environmental impacts of natural disasters (Cui and Tang, 2024; Grosset et al., 2023; Smith et al., 2024), the health repercussions, particularly on farmers' mental well-being, are profound and far-reaching. Mental disorders represent a substantial global health burden, with disproportionately severe effects on farmers in low-income and ecologically fragile regions (Vigo et al., 2016). Understanding whether farmers can maintain psychological balance under these nature strikes is crucial for designing targeted policy interventions to safeguard mental health and sustainable rural livelihoods.

While substantial research has focused on farmers' mental health in general, studies specifically examining the psychological impact of natural disasters on herders engaged in grassland farming remain scarce. Given that the grasslands, covering 40 % of the global land area, are particularly vulnerable to climate change (Herrero et al., 2016; Smith et al., 2024), the risks faced by herders may differ significantly from those of crop farmers due to their distinct cultural, economic, and environmental conditions. The extent of mental health impacts and the underlying mechanisms may also vary, necessitating a more nuanced analysis. Investigating the mental well-being of herders affected by natural disasters not only addresses a critical research gap but also enhances our understanding of the broader health challenges faced by small-scale pastoralists worldwide. Furthermore, most existing studies rely on quantitative methodologies to assess the mental health consequences of natural disasters, while qualitative insights into individual experiences remain limited. Although efforts have been made to establish causal relationships, well-identified causal evidence remains rare.

This paper aims to provide robust empirical estimates of the impact of natural disasters on herders' mental health by conducting a comprehensive analysis of identification strategies, heterogeneity effects, underlying mechanisms and potential mitigation measures. Our empirical work focuses on the pastoral regions in China, covering 30 %

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of China's land area, where millions of herders rely on natural grasslands for livestock production and their livelihoods (Hou et al., 2021; Li et al., 2021), and are increasingly affected by extreme natural events due to accelerating climate change. Mental health in existing studies is typically represented by anxiety, stress, distress, depression, hopelessness, solastalgia, and even suicide (Austin et al., 2020; Berry et al., 2011; Doherty et al., 2023). This study measures mental health using the widely-used Kessler Psychological Distress Scale (K6 score), where a higher K6 score indicates more distress (Wheeler et al., 2018). A natural disaster is defined comprehensively to include extreme climate events such as snowstorms, droughts, floods, windstorms, and other weather-related anomalies. This broad definition reflects that multiple types of disasters often co-occur in pastoral areas. Based on this definition, we primarily use village-level natural disasters reported by village leaders as our independent variables of interest. We conduct checks using LASSO-predicted natural disasters and weather shocks, both based on exogenous climate-related factors to ensure robustness.

By coupling field survey data on personal mental health with the occurrence of village-level natural disasters, our empirical analysis provides robust evidence that the strike of natural disasters significantly deteriorates mental health. The magnitude of this impact varies across various mental health indicators and intensifies with both the severity and duration of the disasters. Our analysis of individual natural disasters also reveals that frequent events, such as snowstorms and droughts, exert the most profound and sustained impact on mental health in pastoral regions. Additionally, herders in Inner Mongolia exhibit significantly higher levels of psychological distress compared to their counterparts in Xinjiang and Tibet.

Our findings further indicate that the deterioration in mental well-being caused by natural disasters is primarily attributed to economic losses and the social multiplier effect. Natural disasters result in an approximately 12 % decrease in grassland productivity, leading to a 70 % increase in fodder expenses. Consequently, herders experience nearly a 30 % reduction in net income from grazing livestock. In addition to the economic strain, herders in pastoral regions are deeply influenced by social networks (Herrero et al., 2016). The shared experience of hardship within the community results in a social multiplier effect, where the aggregate impact exceeds individual effects. Our comparison between household-level and village-level disaster measurements reveals that the latter's impact is nearly twice as severe, indicating that the social multiplier effect doubles the impact of natural disasters on mental health. Fortunately, this mental distress can be partially mitigated through measures such as disaster warnings, public investment, and grassroots governance with informal institutions.

This paper contributes to an increasingly active literature on the health impacts of natural disasters or climate change in two significant aspects. First, it provides the most comprehensive causal evidence on the effects of natural disasters on herders' mental health. To the best of our knowledge, this is the first study to use a field survey dataset on herders' mental health collected in China. Our results provide new evidence that the negative mental health repercussions of natural disasters are particularly severe for herders, highlighting their heightened vulnerability compared to other rural populations. Second, this paper advances the literature on social multiplier mechanisms by applying social capital theory to understand how community dynamics influence individual responses to disasters (Abunyewah et al., 2024; Herrero et al., 2016). Social capital, which encompasses the networks, norms, and trust within communities, plays a crucial role in moderating the harmful effects of disasters on mental health (Berry et al., 2011; Biddle et al., 2025). Our results underscore the connections between social capital and mental well-being, contributing to the ongoing dialogue on how social factors can mitigate mental distress in disaster-affected communities.

This paper is organized as follows. Section 2 reviews the literature and presents the theoretical framework. Section 3 introduces the data collection and description, and lays out the empirical methods employed in the analysis. Section 4 presents the results on the natural disaster impacts, exploring heterogeneity, mechanisms, and the effective of mitigations. The final section concludes with key findings and implications.

2. Theoretical framework

Climate change and its impact on farmers' mental health have been the focus of increasing scholarly attention worldwide. Adverse climate events—defined in this study as natural disasters—are now widely recognized as significant threats to farmers' psychological well-being across diverse agricultural settings (Atwoli et al., 2022; Austin et al., 2020; Freeman et al., 2024; Spencer and Thompson, 2024; Talukder et al., 2021). Climate change patterns "*have exacerbated farmers' worries about the weather, undermined notions of self-identity, and contributed to cumulative and chronic forms of place-based distress, culminating in heightened perceived risk of depression and suicide* (Ellis and Albrecht, 2017)."

Recent research identifies economic loss as a primary pathway through which natural disasters affect mental health. Disruptions to agricultural productivity and profitability caused by these events intensify financial pressures, contributing significantly to psychological distress among farming communities (King et al., 2015; Talukder et al., 2021). For herders, who depend almost entirely on grassland-based livestock production for their livelihoods, this link is especially pronounced. As one of the most climate-vulnerable groups globally, herders in pastoral regions face increasing exposure to climate-related hazards (Thornton et al., 2009). Droughts, snowstorms, and other extreme weather events have become more frequent and intense, directly threatening the ecological and economic underpinnings of livestock systems. These disasters reduce the availability of water and forage, destroy animal shelters, and damage essential infrastructure such as roads and veterinary stations (Talukder et al., 2021). The resulting declines in livestock productivity undermine the economic stability of herder households, potentially leading to long-term emotional and mental health consequences.

However, the mental health consequences of climate-induced disasters may extend beyond individual economic losses. Drawing on social capital theories, recent work highlights a second channel: the social multiplier effect, whereby emotional distress spreads within communities through informal social systems. Social capital—commonly conceptualized through the dimensions of trust, networks, and norms—crucial role in shaping how individuals and communities respond to external shocks (Aldrich and Meyer, 2015). Building on the theoretical insights of Glaeser et al. (2003), we argue that social multiplier effects may amplify the mental health consequences of natural disasters. In tightly knit pastoral villages, individuals are embedded in overlapping networks of kinship, friendship, and community ties (Abunyewah et al., 2024; Berry et al., 2011). When a natural disaster affects one household, the psychological distress experienced is often transmitted through these social connections. Neighbors witness each other's losses, exchange stories of hardship, and share collective anxieties. As a result, even individuals who may not be directly affected economically by a disaster can experience significant mental health burdens due to the relational and emotional spillovers generated by shared community experiences.

Based on the above discussion, this paper proposes a theoretical framework (Fig. 1) to conceptualize the relationship between climate-induced natural disasters and herders' mental health. The core hypothesis posits that natural disasters significantly deteriorate the mental health of herders. Building on this, the framework identifies two primary mechanisms through which such impacts may unfold. First, economic stress, triggered by losses in livestock productivity and household income, undermines financial security and increases psychological burden. Second, social multiplier effects stemming from the spread of emotional distress through dense social networks. These mechanisms, operating in tandem, are expected to contribute to elevated levels of

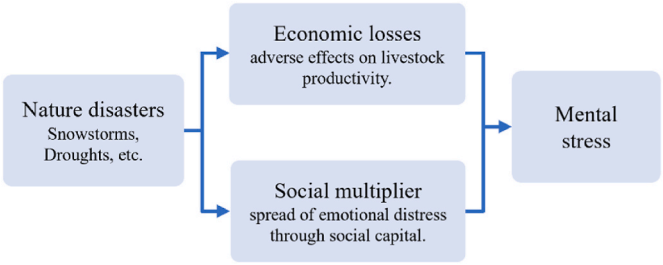

Fig. 1. Theoretical framework.

anxiety, depression, and overall psychological vulnerability among herders in climate-sensitive regions.

3. Methods

3.1. Data collection

Our analysis primarily relies on unique field survey data from three provinces in the pastoral regions of China: Inner Mongolia, Xinjiang, and Tibet. These provinces constitute three of China's five major pastoral regions and cover 70 % of the country's grassland area. The study area is remote, and the pastoral households are often hard to reach due to long distances and underdeveloped infrastructure. Hence, our extensive survey offers invaluable insights into the mental well-being of the herder population in China. The primary herding ethnic groups in these provinces are the Mongolian, Kazakh, and Tibetan populations, the main herding ethnic groups in China. Therefore, herders in the three provinces also represent the broader pastoral communities across the country.

The field survey was conducted sequentially in Inner Mongolia, Xinjiang, and Tibet in 2018. A stratified random sampling strategy was used to select samples from these provinces. Initially, 4-6 pastoral counties per province were chosen based on grassland type and annual income. Within each county, townships were divided into two or three quantiles based on their grassland area per capita, and one township was randomly selected from each quantile. Similarly, 2–3 villages were randomly chosen from each township, and ultimately, 6–8 households were randomly selected from each village. This process resulted in a sample of 664 households from 104 villages. The sample distribution for each province is detailed in Appendix Table A1. We used structured survey questionnaires to conduct face-to-face interviews with household members and village leaders, which allowed us to collect more accurate data about herders' mental well-being and other socio-economic factors.

Collection and construction of the primary outcome variable. Mental health in existing studies is typically represented by anxiety, depression, hopelessness, and solastalgia (Doherty et al., 2023). To assess herders' mental well-being, we used the K6 scale, a widely recognized and validated tool for measuring psychological distress, ensuring reliable and comparable results. During the field survey, respondents were asked to rate six items related to feelings over the past four weeks—such as depression, nervousness, fidgetiness, hopelessness, feeling that everything was an effort, and worthlessness—on a five-point Likert scale ranging from 1 ("None of the time") to 5 ("All of the time"). Based on the Likert scale responses for each dimension of the K6, we calculated the total score of these six questions to determine herders' distress level, reflecting their overall mental health.

Collection and construction of the key independent variable. We identified natural disasters as the primary independent variables of interest. Village leaders were asked if their village had experienced various disasters - such as snowstorms, droughts, floods, windstorms, and others not initially listed - during the previous livestock cycle year, 2018. Each type of natural disaster was recorded as a yes or no response. For villages that reported experiencing a disaster, we further inquired about the extent of the reduction in grassland yield and livestock production, as well as the duration of the event. Following these questions, we created a dummy variable named "village-level natural disaster" to measure whether any natural disasters occurred during 2018, alongside the average reductions in grassland yield and livestock production caused by these events. We also included five dummy variables to indicate the presence of snowstorms, droughts, floods, windstorms, and other natural disasters, respectively. Additionally, we tallied the number of natural disaster types and recorded the duration of natural disasters to represent how a village has been continuously affected. Similarly, we queried household members about the natural disasters they had experienced and constructed the variable "household-level natural disaster" for further robustness analysis.

We included various covariates commonly used in previous literature to control for potential confounding variables in the following empirical analysis. First, existing studies have found that the impacts of climate factors on farmers' mental health vary by individual or household characteristics (Daghagh Yazd et al., 2019; Wheeler et al., 2019). Therefore, we gathered person-level information about the respondents, including household head status, gender, ethnicity (Han or minority), marital status, hukou (a Chinese household registration system, which ties individuals to pastoral or non-pastoral), physical health status, proficiency in Chinese, employment in an off-pastoral job, smartphone ownership, age, and education level. Additionally, we collected household-level variables, including the number of people in the household, the number of young people (ages 1–15), the number of older adults (above 66 years old), operated grassland area in hectares, livestock number in sheep units, grassland ecological compensation policy (GECP) subsidy amount, loan amount, and total income.

Second, climate adaptations, such as public investment and land use policy, implemented in villages may help farmers respond to disasters (Grosset et al., 2023; Wang et al., 2024). Therefore, we collected village-level variables, including the number of households, whether the village is connected to a paved road or the national power grid, whether the village has any public investment in production facilities (e.g., livestock sheds), the presence of formal institutions that contract grassland to households, and informal institutions, often referred to as "*cun gui min yue*" in the Chinese context, which constrains the behavior of villagers.

Third, we collected remote sensing climate data to measure the natural and weather conditions of villages, including village-level annual average precipitation and temperature in 2018, the coefficient of variation (CV) of precipitation/temperature over the past 10 years, derived by merging the original climate data from the National Meteorological Information Center of China with the geographical coordinates of each village. We also utilized Normalized Difference Vegetation Index (NDVI) data at the village level in 2018 to account for grassland quality, consistent with the approach used by Hou et al. (2021). The original NDVI data comes from MOD13A3 product with 1 km by 1 km spatial resolution. We create village-level NDVI data by combining the original NDVI data and the geographical coordinates of each village.

3.2. Data descriptions

Table A2 in the appendix presents the descriptive statistics, revealing that most of the sample are male-headed and minority ethnic households. The statistics of K6 highlight the nuanced nature of psychological distress among herders, providing a detailed snapshot of their mental health status. The mean K6 score is 8.262 in the pastoral regions, according to our field survey. This score is lower than the mean score (9.619) reported by the China Family Panel Studies (CFPS) (Zhang and Li, 2022), indicating that the overall psychological distress among herders is relatively lower compared to the general Chinese population.

Breaking down the K6 score into its components, the average scores for each dimension reveal subtle variations in mental health experiences. Depression has the highest mean score of 1.492. The feelings of

everything being an effort, nervousness, and fidgetiness are similarly distributed, with mean scores of 1.476, 1.471, and 1.456, respectively. Hopelessness is slightly less prevalent, with an average score of 1.223. Worthlessness, the least commonly reported feeling, has the lowest mean score of 1.143. The variation in scores across different dimensions of the K6 scale underscores the complexity of mental health experiences, revealing areas where individuals might be more or less affected by distress.

Regarding the natural disaster challenges within these villages, about 44.2 % of the villages experienced natural disasters, with droughts affecting 37.5 % and snowstorms impacting 15.4 %. Windstorms (4.8 %), floods (7.75 %), and other natural disasters (11.5 %) were less common but still present. On average, each village faced nearly 0.8 type of disaster annually, leading to significant impacts on graze-farming, such as a 12.48 % reduction in grassland yield and a 5.17 % drop in livestock production. These disasters lasted, on average, just over a year, but among the affected villages, more than 40 % experienced continuous disasters for three or more years.

In terms of preparedness, 32.7 % of the villages provided disaster warning information to herders, which means that over a quarter of the affected villages did not have disaster warnings. Public investment in production facilities was relatively rare, occurring in only 18.3 % of villages. Informal institutions were prevalent in 65.4 % of the communities, highlighting the importance of community-based rules in managing both daily life and disaster responses.

3.3. Identification strategy

Basic empirical models. To identify the effects of natural disaster on herders' mental health measured by K6 score, we specify an empirical model as follows:

$$Y_{ijk} = \alpha_0 + \beta D_k + \delta \boldsymbol{P}_i + \gamma \boldsymbol{H}_j + \tau \boldsymbol{V}_k + u_{town} + \varepsilon_{ijk} \quad (1)$$

where Y_{ijk} is K6 score for herder i in household j and village k, indicating the distress level of herders. D_k is a dummy variable representing village-level natural disasters, indicating whether village k experienced natural disasters in 2018, the year of data collection. $\boldsymbol{P_i}$ is a vector of person-level control variables, including dummies for household head, male, minority ethnicity, married, pastoral hukou, physically healthy, proficient in Chinese, having an off-pastoral job, owning a smartphone, and the respondent's age and education level. $\boldsymbol{H_j}$ is a vector of household-level control variables, including household size, share of young, share of old, operated grassland area per capita in log form, livestock number per capita in log form, GECP subside per capita in log form, loan per capita in log form, and total income per capita in log form. $\boldsymbol{V_k}$ is a vector of village-level control variables, including: household number, dummy of connected to a paved road or the national power grid, contracted grassland allocated to households, public investment in production facilities, informal institutions, and environmental factors such as NDVI, average precipitation, and average temperature. u_{town} is town-level fixed effect, control some unobserved variables that beyond the village level (e.g. county level policy that related to natural disasters). Robust standard errors clustered at the village level.

Although the village-level disaster variable we use is expected to be exogenous to individual herders' mental health, the occurrence of disasters within villages is still endogenous to the long-term village-level mitigation measures such as infrastructure construction and migration. These measures could influence herders' distress levels, potentially causing endogeneity issues.

To address this above concern, we first apply the LASSO prediction of natural disaster as the key independent variable in Equation (1) for robustness checks. The procedure for LASSO prediction of natural disasters is as follows: Initially, we consider a series of climate-related factors associated with natural disasters generation, including the mean precipitation for the current year, the CV of precipitation over the past 10 years, the mean temperature for the current year, and the CV of temperature over the past 10 years. We generate all possible interactions among these variables. Subsequently, a LASSO procedure is implemented during the pre-period to forecast natural disaster based on the identified climate characteristics that are exogenous. Second, we use weather shocks for further robustness checks. The weather shock, which can be seen as a good exogenous indicator of natural disaster (Nath et al., 2023), is defined as the residual from the regression of the 2018 village average temperature/precipitation on the 2018 provincial average temperature, the past 10-year village average temperature/precipitation, and the past 20-year village average temperature/precipitation. Third, we employ an instrumental variables (IVs) approach, using the aforementioned three variables as instruments for a robustness check.

Heterogenous analysis strategies. In addition to the above baseline results, we focus on the heterogeneity of the impact of natural disasters across three levels. First, we examine potential variations across different dimensions of the K6 indicators. To investigate these variations, we substitute the Y variable in Equation (1) with the K6 subquestions: depression, nervousness, fidgetiness, hopelessness, feeling that everything was an effort, and worthlessness, respectively. Second, we address the heterogeneous impacts of the types, intensity, and persistence of natural disasters. For different disaster types, we sequentially replace the D_k in Equation (1) with dummy variables indicating the presence of snowstorms, droughts, floods, windstorms, and other natural disasters. To analyze disaster intensity, we use three village-level indicators: the number of disasters in the past year, the proportion of grassland yield reduction due to disasters, and the proportion of livestock production reduction due to disasters. These indicators are successively substituted as D_k variables in Equation (1). To examine the impact of the persistence, we substitute the D_k variable in Equation (1) with the duration of natural disasters. Third, we explore the heterogeneous effects of natural disasters based on different socio-economic characteristics by introducing interaction terms between D_k and person-, or household-level variables indicating specific situations in Equation (1). This results in the following equation:

$$Y_{ijk} = \alpha_0 + \beta_0 D_k + \beta_1 D_k \cdot X + \delta P_i + \gamma H_j + \tau V_k + u_{town} + \varepsilon_{ijk} \quad (2)$$

where X represents the person-, or household-level variables from P_i and H_j. β_1 is our coefficient of interest. A positive and significant β_1 would imply that X intensifies the effects of natural disasters, whereas a negative β_1 would suggest that an increase in X reduces the effects of natural disasters. All other variables are defined as in Equation (1).

Mechanism and extensions. We further conduct mechanism analysis from two pathways: economic loss and social multiplier. For the former, we replace the outcome variable in Equation (1) with two household-level economic variables: fodder costs and grazed net income per capita. For the latter, we substitute the village-level natural disaster variable with the household-level natural disaster variable. Referring to Glaeser et al. (2003), if the new estimate of $\widehat{\beta}_{household}$ is significantly less than $\widehat{\beta}_{village}$, a social multiplier exists and can be calculated as $\widehat{\beta}_{village}/\widehat{\beta}_{household}$.

Finally, we extend the analysis to assess potential mitigation measures for mental health. Drawing on existing studies on natural disasters (Botzen et al., 2019; Dell et al., 2014), and acknowledging the potential social multiplier effects, we focus on three village-level measures: disaster warnings, public investment in production facilities, and informal institutions. These measures are incorporated as dummy variables interacting with village-level natural disasters in the estimation of β_1 in Equation (2).

4. Empirical results

4.1. Basic results

Table 1 presents the basic estimates of β in Equation (1) regarding

Table 1
Regression of herders' distress level on natural disaster.

Variables	OLS		NBR	
	(1)	(2)	(3)	(4)
Village-level natural disaster	0.665*	1.763***	0.654**	1.628***
	(0.354)	(0.417)	(0.328)	(0.351)
Controls variables	No	Yes	No	Yes
Town fixed effects	Yes	Yes	Yes	Yes
R-squared	0.263	0.294	–	–
Observations	664	664	664	664

Note: This table presents the regression of herders' K6 score on natural disaster using OLS (Column 1–2) and negative binomial regression (NBR) models (Column 3–4). Dependent variable is K6 score for herders. Robust standard errors are clustered by village. ***p < 0.01, **p < 0.05, *p < 0.1.

the overall K6 index and shows that the occurrence of natural disaster in a village has a negative impact on herders' mental health. The first column in the table shows results for our simplest specification, which includes only town fixed effects, and a dummy indicator for Village-level natural disaster. In the second column, we also include individual-, household-, and village-level control variables. Results from the OLS estimators in Column 1 and 2 indicate that natural disaster significantly increases herders' distress levels by 0.596 and 1.763, respectively. Given that herders' distress level follows a poisson distribution, we employ a negative binomial regression (NBR) for robustness checks. The marginal effects of NBR in Columns 3 and 4 show that natural disaster significantly increases herders' distress levels by 0.579 and 1.628, respectively, without and with control variables included.

In order to help build intuition about the magnitude of our basic effects, we provide a few benchmarks. First, the magnitude of our basic effect (1.763) corresponds to approximately 21 percent of the mean distress level (8.262). Second, Government GECP compensation can alleviate the pressure on herders, a 1 % increase in GECP is associated with a 0.095 decrease in distress levels (Figure A2 in the appendix). To eliminate the impact of natural disasters, it would require an additional GECP compensation of 790 yuan[1] per household. Third, comparing our estimates to those from other developing regions, we find that the impact of natural disasters on herders may be more severe. Abunyewah et al. (2024) have discussed the impact of drought on farmers' mental health in semi-arid Ghana, finding that drought has a positive relationship with depression (16 %), anxiety (11 %), and stress (8 %).

To address the endogenous concern regarding the reported village-level disasters, Table 2 presents the results of robustness checks using the LASSO prediction of natural disaster[2] and weather shock as the key independent variables. The first column in Table 2 shows the results for the LASSO prediction of natural disaster, indicating that natural disaster significantly increases herders' distress levels by1.395, which is slightly smaller than the OLS result. The second and third columns in Table 2 show results for temperature and precipitation shock, respectively. Only the temperature shock indicates significant negative effects on herders' mental health. This may be because natural disasters in pastoral areas are more related to temperature factors (Smith et al., 2024). The results of temperature shock align with findings from other studies, which indicate adverse climate events harm farmers' mental well-being globally (Atwoli et al., 2022; Austin et al., 2020). Finally, Column 4 presents the results of the IV approach. The Chi-squared statistic from the

Table 2
Robust check for the impacts of natural disaster on herders' distress level.

Variables	LASSO prediction of natural disaster	Temperature shock	Precipitation shock	IVs estimates
	(1)	(2)	(3)	(4)
Different measures of village-level natural disaster	1.395***	2.377**	0.971	2.440*
	(0.404)	(1.110)	(1.212)	(1.443)
Control variables	Yes	Yes	Yes	Yes
Town fixed effects	Yes	Yes	Yes	Yes
Endogeneity test	–	–	–	0.428
R-squared	0.350	0.283	0.281	0.281
Observations	664	664	664	664

Note: This table presents a robust examination of the effects of nature disaster, indicated by LASSO prediction of natural disaster (Col.1), temperature shock (Col.2) or precipitation shock (Col.3), on herders' K6 score through OLS models. In Col. 4, these three variables from Col. 1–3 are utilized as instrumental variables (IVs) for village-level natural disasters. Dependent variable is K6 score for herders. Robust standard errors are clustered by village. ***p < 0.01, **p < 0.05, *p < 0.1.

endogeneity test in Column 4 is not significant, indicating that village-level natural disasters are exogenous to herders' mental health. Additionally, Column 4 shows a significant negative effect on herders' mental health.

Thus, the OLS estimates are reliable. Even after addressing endogeneity concerns, the effects of natural disaster remain positive and significant. This indicates that our findings are robust and not due to unobserved confounding factors. The consistent significance of the results underscores the substantial and detrimental impact of natural disaster on herders' mental health. Considering the intuitiveness of Village-level natural disaster, we will use this variable as the key independent variable for further discussion.

4.2. Heterogeneity

We first tested the heterogeneity of the impact of natural disaster on K6 dimensions. Fig. 2 presents the result for the individual distress indicators and shows that most of the dimensions of mental health in our dataset were negatively affected by the occurrence of natural disaster.

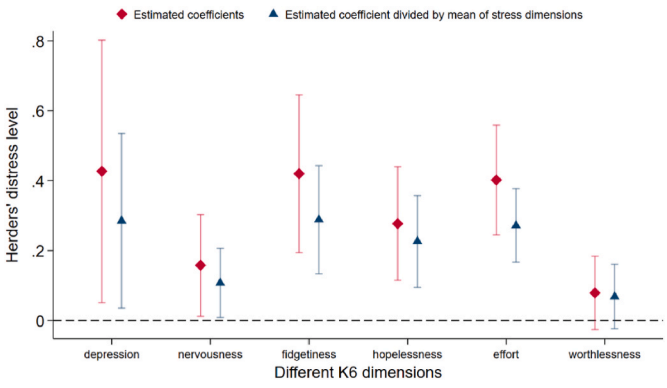

Fig. 2. Regression of different K6 dimensions on natural disaster.
Note: This figure presents the heterogeneity of the impact of natural disaster on different K6 dimensions: depression, nervousness, fidgetiness, hopelessness, everything was an effort (effort) and worthlessness. The key independent variable is "Village-level natural disaster". We present both the estimated coefficients (diamond) and the estimated coefficients divided by the mean of the dependent variable (triangle).

[1] 790 yuan is calculated as (1.763/0.095*4255), where 4255 yuan is the mean GECP compensation per household.

[2] The correlation coefficient between LASSO prediction of natural disaster and the actual occurrence of natural disaster is 5.526, significant at 1 % level. The correlation coefficient between temperature anomalies and the actual occurrence of natural disaster is 0.557, significant at 5 % level. While, the correlation coefficient between precipitation anomalies and the actual occurrence of natural disaster is not significant.

For all but one of the distress indicators from Fig. 2, the point estimates are significant positive, indicating worsened mental health. The conditions most affected are feelings of depression, fidgetiness, hopelessness, and everything was an effort, while nervousness is least affected. The point estimates for feelings of worthlessness are not significant. Overall, these findings highlight the substantial impact of natural disasters on various aspects of mental health.

Second, we discuss the heterogenous impacts of the types, intensity and persistence of natural disasters on herders' mental health. The point estimates in Fig. 3 show that the types of natural disasters that have the greatest impact on herders' mental health are, in descending order, windstorm, flood, snowstorm and drought. When considering the probability of occurrence, the main types of natural disasters that contribute to decreased herders' mental health are, in descending order, snowstorms, droughts, floods, and windstorms. These findings indicate that while "Black Swan" disasters, such as windstorms and floods, have the greatest overall impact, "Grey Rhinoceros" disasters, such as snowstorms or droughts, have the most significant impact on the mental health of herders. This is pertinent in the context of climate change, where these "Grey Rhinoceros" disasters are becoming more common.

Table 3 analyzes the impact of disaster intensity on herders' mental health, showing that as the intensity of disasters increases, the impact on herders' distress levels also increases. The results in Column 1 show that each additional type of natural disaster in one year increases herders' distress level by 0.502. The results in Column 2 show that a 1 % decrease in grassland yield due to disasters increases herders' distress level by 0.016. The results in Column 3 show that a 1 % decrease in livestock production due to disasters increases herders' distress level by 0.036. These findings highlight the significant and varied impacts of disaster intensity on herders' mental health, underscoring the importance of comprehensive strategies to mitigate these effects. Specifically, economic measures aimed at alleviating the negative impacts of natural disasters on grassland and livestock production may be crucial (Smith et al., 2024).

Fig. 4 presents the heterogenous results of the duration of natural disasters on herders' mental health. If the natural disasters lasted for one year, meaning the village did not experience natural disasters in 2018, the occurrence of natural disasters in 2018 leads to a 1.012 increase in herders' distress levels. If natural disasters have occurred continuously for two years, the distress level increases by 1.078, slightly higher than the one-year duration. For a continuous duration of three or more years, the distress level rises significantly by 3.865, much higher than the increases observed for one or two years. The distress levels of herders increase significantly with the prolonged duration of natural disasters.

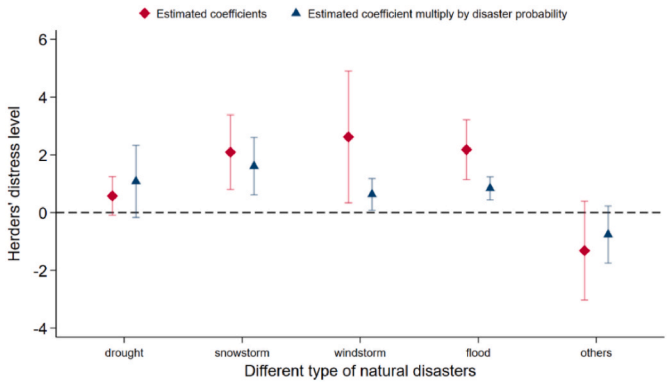

Fig. 3. Regression of herders' distress level on different types of natural disaster.
Note: This figure presents the heterogeneity of the impact of different disaster types: drought, snowstorm, windstorm, flood, and other disasters. We present both the estimated coefficients (diamond) and the estimated coefficients multiplied by the probability of occurrence (triangle).

Table 3
The impacts of natural disaster intensity on herders' distress level.

Variables	Number of disasters	Percentage of grassland yield reduction	Percentage of livestock production reduction
	(1)	(2)	(3)
Intensity of Village-level natural disaster	0.502**	0.016**	0.036***
	(0.195)	(0.008)	(0.013)
Control variables	Yes	Yes	Yes
Town fixed effects	Yes	Yes	Yes
R-squared	0.286	0.284	0.289
Observations	664	664	664

Note: The intensity of natural disasters is measured by the number of disasters, the proportion of grassland yield reduction and livestock production reduction due to disasters, respectively. Dependent variable is K6 score for herders. Robust standard errors are clustered by village. ***p < 0.01, **p < 0.05, *p < 0.1.

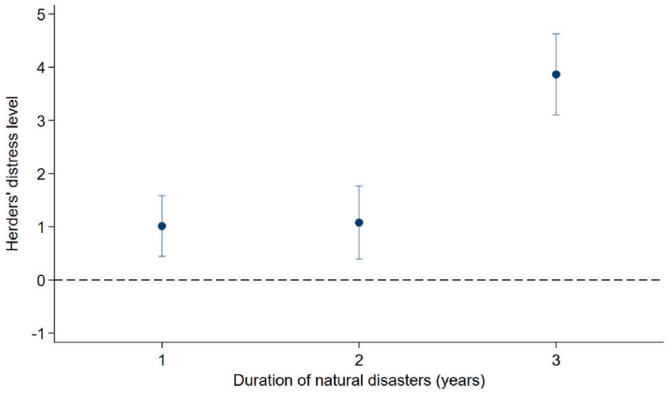

Fig. 4. Heterogeneity in the impact of the nature disaster duration on herders' distress level.
Note: This figure illustrates how the duration of village-level natural disaster impacts herders' K6 scores, showing heterogeneity across different durations: one year, two years, and three or more years.

This finding is an addition to current research, which rarely addresses the socioeconomic impacts of consecutive natural disasters (Cui and Tang, 2024; Wheeler et al., 2019). These insights underscore the importance of considering the long-term mental health effects on communities frequently affected by climate events.

Third, we examine the heterogeneous psychological impacts of natural disasters on herders across three pastoral regions (Inner Mongolia, Xinjiang, and Tibet). As shown in Table A3, herders in Inner Mongolia demonstrate markedly more severe psychological distress responses compared to their counterparts in Xinjiang and Tibet. This pattern persists across most disaster types, with particularly pronounced effects for drought and snowstorms. Several geographic or cultural factors may explain these differential impacts. Inner Mongolia's transitional steppe ecosystem exhibits greater ecological fragility compared to Xinjiang's vertical pastures and Tibet's high-altitude grasslands, potentially amplifying disaster vulnerability. The strong nomadic traditions among Mongolian herders may foster deeper place attachment, making post-disaster displacement particularly traumatic. In contrast, Xinjiang and Tibet benefit from traditional risk-sharing mechanisms and greater livelihood diversification, which appear to buffer psychological impacts. These findings underscore the importance of developing regionally-tailored mental health interventions that account for ecological, economic, and cultural differences in disaster vulnerability.

At last, we estimate heterogeneous effects across individual- and household-level characteristics. Previous research has indicated that specific demographic are more vulnerable to climate change (Atwoli et al., 2022; Wheeler et al., 2019). However, our findings indicate a

homogeneity in impacts across most individual- and household-level characteristics (Figure A3 in appendix). This suggests that herders' mental health issues resulting from natural disasters may not primarily be attributable to personal or familial factors, but rather to broader social dynamics. This will be further discussed in the next section.

4.3. Mechanisms

Indirectly impacts via economic losses. Natural disasters, such as droughts, often lead to reduced grassland productivity (Smith et al., 2024), resulting in increased expenses for livestock feed among herders whose livelihoods strongly rely on grasslands. Consequently, herders may experience a decline in net income from livestock (Feng et al., 2021). Table 4 presents empirical evidence on this mechanism. Column 1 displays the results of a regression of NDVI on natural disaster at the village level, indicating that the occurrence of natural disasters is associated with a nearly 12 % decline in NDVI (0.053 out of 0.457). Column 2 shows that natural disasters are associated with a substantial 73.6 % increase in supplementary feeding expenses. Additionally, Column 3 reveals a 29.1 % decrease in net income from grazing due to the occurrence of natural disasters.

If the above economic losses resulting from increased fodder costs impose psychological pressure on herders, we would first expect to observe more intensified impacts of natural disasters corresponding to higher fodder costs. We utilize the log of fodder costs as the interaction term with village-level natural disasters in the estimation of β_1 in Equation (2). Fig. 5 depicts the β_1 estimates across varying levels of fodder costs, demonstrating a progressive increase in herders' distress levels as fodder costs rise under the influence of natural disasters. Specifically, when fodder costs are around 6000 yuan (50th percentile), there is a 1.5-point increase in the K6 score under the occurrence of natural disasters. When fodder costs rise to approximately 90,000 yuan (90th percentile), the impacts of natural disasters increase to 2.4-points on the K6 score.

In addition to these above empirical evidences, our study captured herders' perceptions of changing climate patterns over the past two decades. Notably, more than 50 % of respondents reported observing increased intensity of both droughts and snowstorms during this period. These subjective accounts align with meteorological records showing climate change impacts in pastoral regions. During field interviews, herders poignantly described the psychological toll of such events, with one participant explaining: "*After losing dozens of sheep to the last severe snowstorm, I lay awake night after night - not just worrying about the immediate financial loss, but terrified that my sons would abandon our family's herding tradition as these disasters become more frequent.*" These qualitative narratives, when combined with our empirical results, reveal a dual pathway through which natural disasters affect mental health: direct economic losses from livestock mortality, and profound anxiety about the intergenerational sustainability of pastoral livelihoods. The compounding effect of these stressors appears to significantly exacerbate psychological distress, suggesting that climate-related mental health interventions must address both immediate financial impacts and longer-term existential concerns about cultural continuity.

Table 4
Explanation from economic losses.

Variables	NDVI	Fodder costs	Graze net income per capita
	(1)	(2)	(3)
Village-level natural disaster	−0.053**	0.736***	−0.291*
	(0.026)	(0.191)	(0.170)
Controls variables	Yes	Yes	Yes
Town fixed effects	Yes	Yes	Yes
R-squared	0.807	0.475	0.584
Observations	104	664	664

Note: This table illustrates the impact of natural disaster on NDVI, fodder costs, and grazed net income per capita. Column 1 represents village-level regression, with 104 observations. Robust standard errors are clustered by village. ***p < 0.01, **p < 0.05, *p < 0.1.

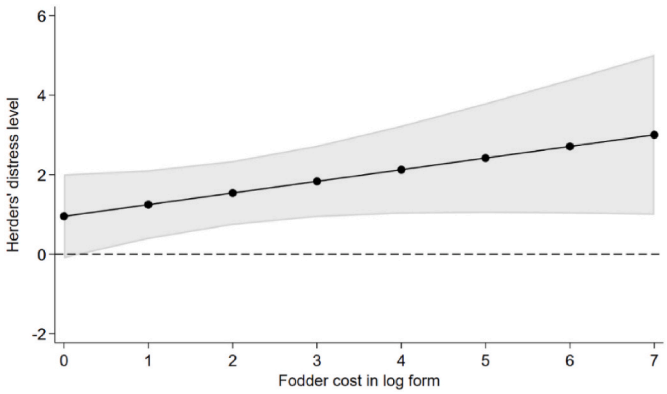

Fig. 5. Heterogeneity in the impact of the nature disaster with different fodder cost.
Note: This figure illustrates the heterogeneous effects of natural disasters on herders' K6 scores with varying fodder costs. The horizontal axis represents a continuous increase in fodder costs in log form.

Indirectly impacts via "social multiplier". The geographical coverage of natural disasters varies by disaster type. For example, drought often occurs in the entire village while flooding may affect specific areas in a village. Moreover, individual household characteristics and resource endowments differ significantly, leading to varying levels of resilience to disasters. Consequently, natural disasters do not necessarily result in equal impact across every household within the same village. As shown in Appendix Table A4, even in villages where no disasters have occurred, 10 % of herders reported experiencing disasters. Conversely, in villages where disasters have occurred, 50 % of herders reported not experiencing disasters.

Households reporting disasters saw a 34 % decrease in pasture yield and a 22 % decrease in livestock production. In contrast, households in villages reporting disasters saw a decrease of 28 % and 12 % in pasture yield and livestock production, respectively, lower than the impacts of disasters reported by households. If economic loss is the primary mechanism, then replacing village-level natural disaster variable with household-level disaster experiences would reveal a greater increase in stress levels and fodder costs. However, our empirical results do not support this hypothesis. The psychological distress caused by household-level disasters is less than that caused by village-level disasters.

Table 5 presents the regression of the K6 score and fodder costs on household-level natural disasters. In Column 1, the coefficient for

Table 5
Regression of herders' distress level on Household-level natural disaster.

Variables	K6 score		Fodder costs	
	(1)	(2)	(3)	(4)
Household-level natural disaster	0.915*	0.763	0.770***	0.716***
	(0.480)	(0.479)	(0.265)	(0.266)
Village-level natural disaster	–	1.736***	–	0.609***
	–	(0.396)	–	(0.178)
Controls variables	Yes	Yes	Yes	Yes
Town fixed effects	Yes	Yes	Yes	Yes
R-squared	0.290	0.300	0.481	0.482
Observations	664	664	664	664

Note: This table presents the regression of herders' K6 scores and fodder costs on household-level natural disasters. The natural disasters reported in this table are documented by herders, reflecting the specific status of each household. The correction between household-level natural disaster and village-level natural disaster is 0.4. Robust standard errors are clustered by village. ***p < 0.01, **p < 0.05, *p < 0.1.

household-level disasters on herders' K6 score is 0.915, nearly half of the village-level disaster estimate. Column 3 indicates that household-level disasters' coefficient on fodder costs is 0.770, larger than the village-level estimate of 0.736. Furthermore, when village-level natural disaster variable is included in both equations, the impact of household-level disaster on the K6 score becomes insignificant (Column 2, Table 5), and its effect on fodder costs decreases by 10 % (Column 4, Table 5). Conversely, the coefficients for village-level disaster remain statistically significant.

Moreover, we created a categorical variable: 0 for no disaster, 1 for household-level disaster only, 2 for village-level disaster only, and 3 for both household and village-level disasters. Fig. 6 presents the regression results of this indicator on K6 scores and fodder costs. Part A of this figure shows that herders experience no additional mental distress when the natural disasters only affected their household and not the entire village. However, they do experience mental distress when village-level natural disasters occur, even if they are not directly affected. The most significant mental distress occurs when both the village-level disasters and their household are directly affected. Part B of this figure presents similar results for fodder costs: herders may not purchase additional fodder if the disaster affects only their household and not the village. In contrast, they tend to buy additional fodder in anticipation of potential disasters that have affected the village. This behavior may be because they can borrow fodder from other villagers when only their household is affected by the disaster.

In conclusion, the evidence indicates that natural disasters affect herders' mental health not only through economic losses but also via a social multiplier effect that amplifies the psychological impact on individual herders. This social multiplier effect nearly doubles the impact of natural disasters on herders' mental well-being. The social multiplier may stem from herders' concerns about the future (Talukder et al., 2021), the shared experience of hardship within the community, and the disruption of social networks (Abunyewah et al., 2024). As articulated by herders during our fieldwork "*Since the grasslands were divided among households, we can no longer move together like before. When disasters come, each family suffers alone. If I see my neighbor's pasture buried in snow or drought, I lie awake worrying when my turn will come.*"

4.4. Mitigations

Fig. 7-A1 illustrates the efficacy of disaster warnings in mitigating the negative impacts of natural disasters on mental well-being. In villages without disaster warnings, the effects of natural disasters on K6 scores remain positive. In contrast, these effects tend to approach zero in villages where disaster warning information is disseminated to herders. We have verified that there is no difference in the intensity of disasters between villages with and without disaster warnings. The reason may be that early disaster warnings can promote quicker emergency responses, enhance access to critical services and resources in advance, and support more efficient disaster management strategies. Moreover, delivering this information can be cost-effective, as the effectiveness of disaster warnings does not vary significantly with different transmission methods. Social media platforms, such as WeChat in China, can be as effective as face-to-face communication in disseminating warning information (Fig. 7A2).

Fig. 7B illustrates the benefits of public investment in mitigating the negative impacts of natural disasters on mental well-being. In villages where public investment is used to enhance production facilities, such as livestock sheds, the adverse effects of natural disasters on mental health tend to diminish. This result may be attributed to the enhanced infrastructure in these villages, which likely contributes to greater resilience against the impacts of natural disasters. Additionally, robust public investment can foster a sense of security and community support, further alleviating the psychological distress associated with natural disasters.

Fig. 7C presents compelling evidence that informal institutions serve as effective mechanisms for reducing psychological distress among pastoral communities facing natural disasters. The effectiveness of these institutions appears remarkably consistent across different levels of formalization, regardless of whether they are codified in written documents or maintained through verbal agreements. Informal institutions, encompassing adherence to social ethics, preservation of public order, engagement in community welfare initiatives, and sustainable grassland

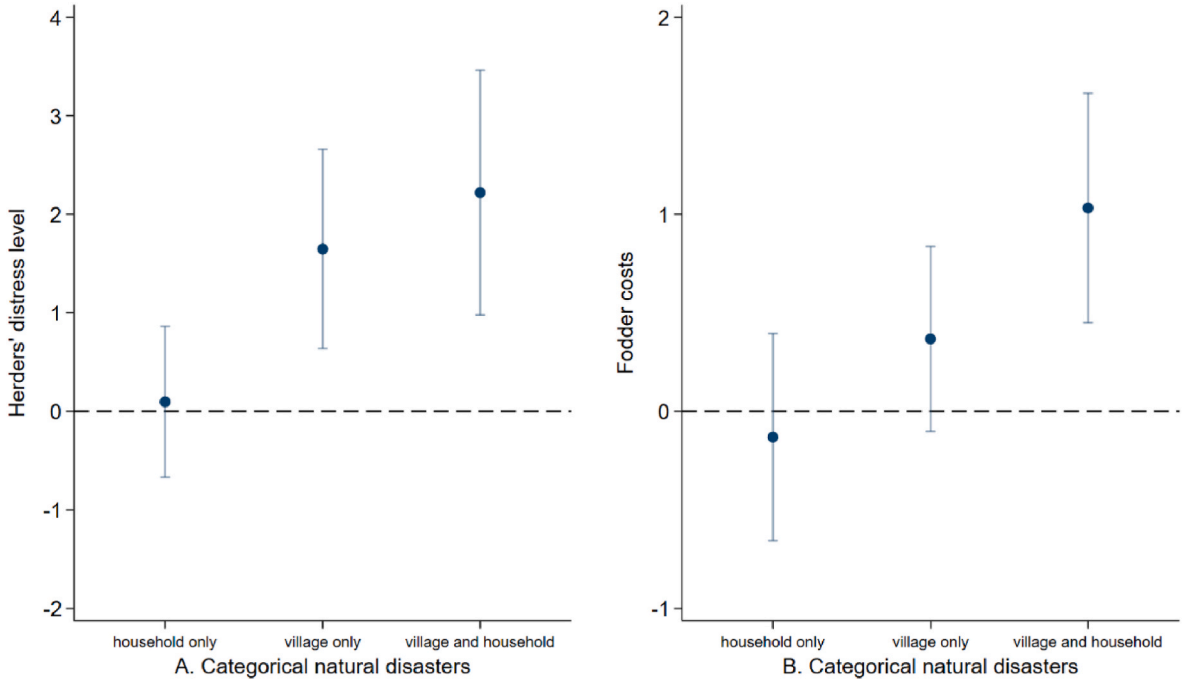

Fig. 6. The impact of village- and household-level nature disaster on K6 scores and fodder costs.
Note: The dependent variables are K6 score (Part A) and fodder costs (Part B), respectively. The independent variable in the horizontal axis is a categorical variable: 1 for household-level disaster only, 2 for village-level disaster only, 3 for both household and village-level disasters, and 0 as the reference group.

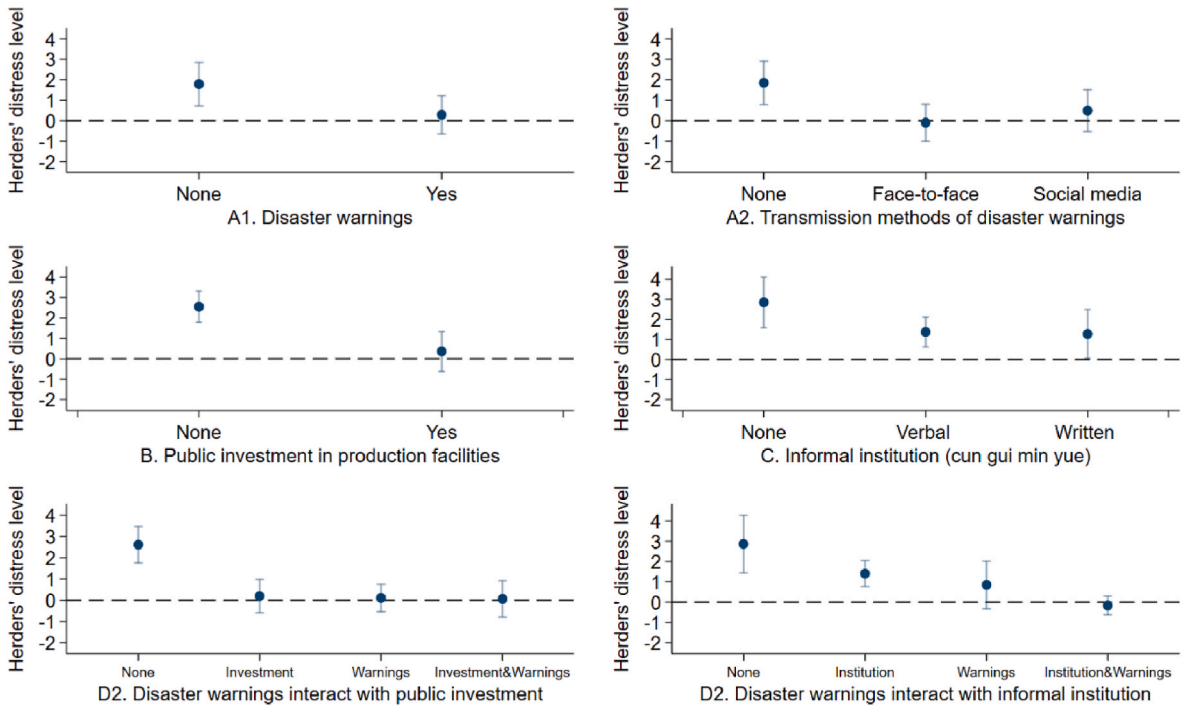

Fig. 7. The effectiveness of several mitigation measures.
Note: This figure illustrates the effectiveness of mitigation measures, including disaster warnings (A1 and A2), public investment (B), informal institutions (C), and the interaction of mitigation measures (D1 and D2) in mitigating the negative impacts of natural disasters.

management practices, adaptively regulate production cycles and daily activities according to local village conditions. These place-based informal institutions mainly emerged after collectivization in China and were established by village committees. Through pasture user groups or herding cooperatives, these informal institutions can promote strong social capital among herders by fostering trust, reciprocity, community cohesion, mutual assistance, effective conflict resolution, cultural continuity, and adaptive capacity (Herrera et al., 2014). Increased social capital contributes immediate relief and emotional support, and facilitates resource sharing and rebuilding efforts post-disaster (Abunyewah et al., 2024). Additionally, these informal institutions have been proven effective in promoting grassland conservation in pastoral regions (Li et al., 2021), providing another ecosystem buffer for herders to adapt to natural disasters.

Fig. 7D reveals synergistic effects of above mitigation measures. We observe a substitutability relationship between disaster warning systems and public infrastructure investments (Fig. 7D1). The reason may be that both address core preparedness needs - warnings through timely risk information and infrastructure through physical protection - making them functionally interchangeable to some degree. Notably, disaster warnings prove more effective than informal institutions alone (Fig. 7D2), reflecting technological systems' advantages in speed and standardization compared to socially-embedded norms. However, their combination reveals valuable complementarity: formal warnings activate informal support networks, while community norms increase warning credibility and compliance. These findings suggest an optimal policy approach that strategically combines infrastructure investments where warnings are impractical, while always pairing technological systems with efforts to strengthen traditional institutions.

In summary, the evidence suggests that mitigation measures such as disaster warnings, public investment, and informal institutions can effectively reduce the negative impacts of natural disasters on herders' mental health. These measures not only enhance resilience and preparedness but also foster a supportive community environment, highlighting the importance of both structural and social interventions in effective disaster management.

5. Discussion and conclusion

The mental well-being of small herders in climate-vulnerable pastoral regions plays a crucial role in achieving sustainable development and climate change adaptation goals (Bonilla-Cedrez et al., 2023). This paper estimates the impact of climate-related natural disasters on mental health and found that the strike of natural disasters at a village harmed herders' mental health. The extent of this effect varies across different dimensions of the mental indicator and changes with the type, intensity and persistence of disasters. The empirical evidence also points to economic losses and social multiplier effect as the two main mechanisms, with the latter nearly doubling the initial effects. By addressing these influential channels, the adverse mental distress can be partially alleviated through mitigations such as disaster warnings, public investment and grassroots governance with informal institutions.

The findings of this paper are consistent with the existing literature that extreme climate events might be partly responsible for the recent deterioration in mental health among small farmers. Natural disasters can have far-reaching consequences for affected populations, confronting them with a range of health, social, and economic challenges. These impacts are particularly severe in low- and lower-middle-income countries (LMICs), where mitigation measures are often limited due to resource constraints and inadequate state support. Australia, due to its highly variable climate and status as a major global agricultural producer, has been one of the most studied countries in this regard (Austin et al., 2020; Berry et al., 2011; Hanigan et al., 2018). In Africa and Central Asia, pastoral communities also face significant challenges related to climate variability, economic instability, and livestock diseases, all of which heighten the risks to mental health (Atwoli et al., 2022; Cho et al., 2025; Nuvey et al., 2020). A comparison with China's pastoral regions reveals both commonalities and specificities. In both regions, herders' mental health is greatly affected by economic stress, particularly the fluctuations in livestock productivity. However, China's pastoral regions, such as Inner Mongolia, face the added complexity of more frequent and severe climate-induced natural disasters, such as droughts and snowstorms, which directly threaten the grazing

ecosystem and exacerbate economic uncertainty (Feng et al., 2021). China's pastoral regions are characterized by a greater diversity of grasslands and pastoral communities, and as such, policy support for these communities differs significantly from that in many African and Central Asian countries. In China, various government programs aim to improve grassland ecosystems (Hou et al., 2021), enhance infrastructure, and promote disaster risk reduction strategies. In addition, informal institutions, such as local community networks and indigenous knowledge systems, play a vital role in coping with these environmental shocks (Li et al., 2021). This discrepancy provides important policy references for regions with similar challenges, suggesting that targeted grassroots governance, investment in infrastructure, and improvement of disaster preparedness can help mitigate the adverse effects of climate-induced disasters on pastoral communities' mental health.

Despite the valuable insights provided by this study, several limitations should be noted. First, as most current studies focus on the socio-economic and environmental impacts and adaptions of natural disasters (Cui and Tang, 2024; Grosset et al., 2023; Smith et al., 2024), it is valuable to consider economic behaviors and health changes within a unified framework to gain a more comprehensive understanding of the interconnected impacts. Second, due to data constraints, we were unable to identify the precise mechanisms through which natural disasters directly impact mental health. Future studies could explore these mechanisms in more detail, potentially using longitudinal data to capture long-term effects. Lastly, while this paper emphasizes preventive measures, addressing existing psychological problems among herders remains challenging. Many barriers and challenges exist to accessing mental health treatment, including issues with health insurance coverage, limited mental health resources in rural areas, and regulators may not understand the challenges faced by those in farming communities (Berry et al., 2011; Doherty et al., 2023). These limitations provide scope for future interdisciplinary research.

CRediT authorship contribution statement

Dongqing Li: Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation. **Alec Zuo:** Writing – review & editing, Conceptualization. **Lingling Hou:** Resources, Project administration, Funding acquisition, Conceptualization.

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Appendix

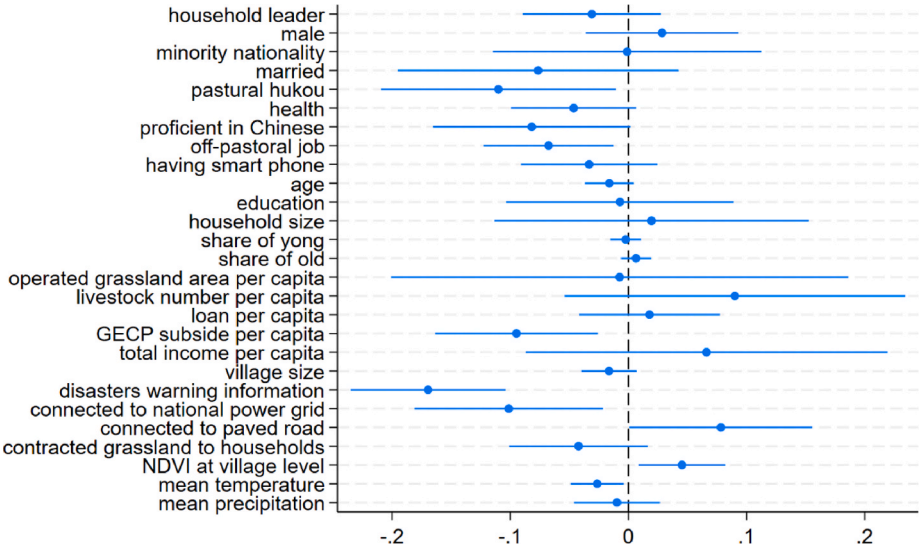

Fig. A2. Regression coefficients of control variables in Table 2

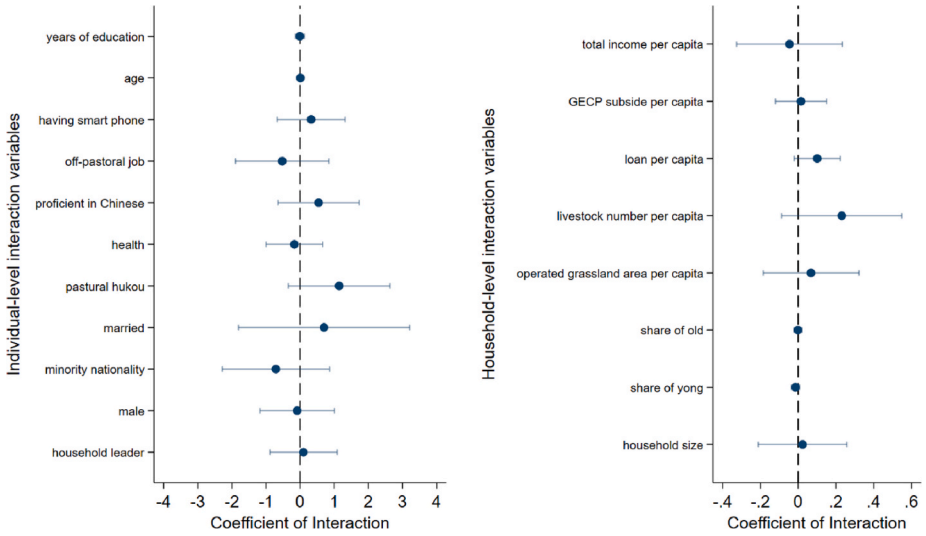

Fig. A3. Heterogenous effects from individual- and household-level characteristics
Note: This figure illustrates the heterogeneous effects of natural disasters across different variables. The horizontal axis displays the regression coefficients of the interaction terms, while the vertical axis represents the individual- and household-level characteristic variables that interact with disaster variables, respectively.

Table A1
Sample size

Province	County	Town	Village	Household
Inner Mongolia	5	17	34	236
Xinjiang	6	18	36	214
Tibet	6	16	34	214
Total	17	51	104	664

Note: In each province, we combined annual income per capita, grassland type and geographical position. We sampled 3–4 townships from each county, 2–3 villages from one township, and 6–9 households are randomly selected from each village.

Table A2
Description of variables

Variables	Obs.	Mean	SD	Min	Max
Variables at personal level					
K6_score (6–30)	664	8.262	2.795	6	22
Depression score (1–5)	664	1.492	0.796	1	5
Nervousness score (1–5)	664	1.471	0.696	1	5
Fidgetiness score (1–5)	664	1.456	0.725	1	5
Hopelessness score (1–5)	664	1.223	0.567	1	5
Everything was an effort score (1–5)	664	1.476	0.751	1	5
Worthlessness score (1–5)	664	1.143	0.438	1	5
Householder or not (1 = yes, 0 = no)	664	0.729	0.445	0	1
Male or not (1 = yes, 0 = no)	664	0.792	0.406	0	1
Minority nationality or not (1 = yes, 0 = no)	664	0.946	0.227	0	1
Married or not (1 = yes, 0 = no)	664	0.965	0.183	0	1
Pastural hukou or not (1 = yes, 0 = no)	664	0.813	0.390	0	1
Health or not (1 = yes, 0 = no)	664	0.676	0.468	0	1
Proficient in Chinese or not (1 = yes, 0 = no)	664	0.273	0.446	0	1
Off-pastoral job or not (1 = yes, 0 = no)	664	0.194	0.396	0	1
Having smart phone or not (1 = yes, 0 = no)	664	0.783	0.412	0	1
Age (year)	664	48.86	12.15	17	84
Education (year)	664	5.480	3.989	0	18
Variables at household level					
Household size (people number)	664	4.697	2.043	1	12
Share of young (1–15 years old, %)	664	16.67	18.09	0	66.67
Share of old (above 66 years old, %)	664	7.847	17.19	0	100
Operated grassland area per capita (ha)	664	112.7	208.0	0	3365
Livestock number per capita (sheep unit)	664	70.78	127.7	0	2714
Total income per capita (1000 yuan)	664	31.00	47.19	0	687.2
GECP subside per capita (1000 yuan)	664	4.255	7.791	0	103.3
Loan per capita (1000 yuan)	664	5.030	13.39	0	112.5
Pastoral income per capita (1000 yuan)	664	14.18	40.52	−78.34	653.7
Fodder spending (1000 yuan)	664	15.45	31.12	0	337

(*continued on next page*)

Table A2 (*continued*)

Variables	Obs.	Mean	SD	Min	Max
Livestock losses number (sheep unit)	664	27.19	400.2	0	10290
Household-level natural disaster (1 = yes, 0 = no)	664	0.221	0.415	0	1
Variables at village level					
Village-level natural disaster (1 = yes, 0 = no)	104	0.442	0.499	0	1
Drought (1 = yes, 0 = no)	104	0.375	0.486	0	1
Snowstorm (1 = yes, 0 = no)	104	0.154	0.363	0	1
Windstorm (1 = yes, 0 = no)	104	0.048	0.215	0	1
Flood (1 = yes, 0 = no)	104	0.077	0.268	0	1
Other natural disasters (1 = yes, 0 = no)	104	0.115	0.321	0	1
Number of disasters during this year	104	0.769	1.007	0	3
Grassland yield reduction due to disasters (%)	104	12.48	22.94	0	80
Livestock production reduction due to disasters (%)	104	5.171	12.29	0	50
Duration of natural disasters (years)	104	1.048	1.47	0	3
Disaster warnings (1 = yes, 0 = no)	104	0.327	0.471	0	1
Village size (household number)	104	186.4	147.0	14	761
Connected to paved road (1 = yes, 0 = no)	104	9.808	1.380	0	10
Connected to national power grid (1 = yes, 0 = no)	104	9.423	2.343	0	10
Contracted grassland to households (1 = yes, 0 = no)	104	9.423	2.343	0	10
Public investment in production facilities (1 = yes, 0 = no)	104	0.183	0.388	0	1
Informal institution (*cun gui min yue*) (1 = yes, 0 = no)	104	0.654	0.478	0	1
NDVI	104	0.467	0.201	0.103	0.852
Mean of precipitation (mm)	104	0.174	3.316	−9.717	6.367
Mean of temperature (centigrade)	104	18.66	8.459	5	36

Table A3
Heterogeneity in the impact of the nature disaster with different provinces

Variables	General disaster	Drought	Snowstorm	Windstorm	Flood
	(1)	(2)			
Effects of Inner Mongolia	2.834***	1.861***	3.084***	7.257***	3.293**
	(0.502)	(0.611)	(0.900)	(2.548)	(1.263)
Effects of Xinjiang (compared with Inner Mongolia)	−2.287***	−1.515*	−2.255**	−3.446***	0.904
	(0.746)	(0.843)	(0.898)	(0.959)	(1.576)
Effects of Tibet (compared with Inner Mongolia)	−2.206**	−0.101	−4.816***	0.000	0.000
	(1.040)	(1.281)	(1.598)	(0.000)	(0.000)
Control variables	Yes	Yes	Yes	Yes	Yes
Town fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.306	0.308			
Observations	664	664			

Note: This table presents the heterogeneous effects of natural disasters on herders' K6 scores across provinces (Inner Mongolia, Xinjiang, and Tibet). Column (1) presents the aggregate effects of general natural disasters, while Column (2) further disaggregates the impacts by disaster type. Robust standard errors are clustered by village. ***p < 0.01, **p < 0.05, *p < 0.1.

Table A4
Correction between village- and household-level disaster variables

household-level	village-level		
	No	Yes	Total
No	334	145	479
Yes	38	147	185
Total	372	292	664

Data availability

Data will be made available on request.

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