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# Impact of the Grassland Ecological Compensation Policy on Herders' Development Resilience to Climate Change

Yingjie Zhu, Xiaolong Feng, Huangang Qiu, and Jun Li

We investigate the relationship between herders' development resilience to climate change and grassland ecological compensation policy (GECP). Using a three-period panel dataset of 679 herders in China, we find that the development resilience of 44% of herders is lower than the overall average. Climate change has a nonlinear effect on herders' development resilience, while GECP enhances development resilience and significantly mitigates the adverse effects of temperature change. The mechanism analysis shows that supplementary feeding, nonfarm employment, and grassland transfer are influencing paths, and the synergistic effect of climate change and GECP is realized by influencing herders' grassland transfer.

*Key words:* development resilience, grassland transfer, nonfarm employment, supplementary feeding

## Introduction

Grasslands, which account for 40% of China's area, are a primary natural resource on which local herders rely for their livelihoods and play an essential role in China's national development (Hu, Huang, and Hou, 2019). However, frequent extreme climate emergencies in China's pastoral areas have become common over the past decades, resulting in the degradation of over half of the grasslands and a decline in livestock production efficiency (Zhou et al., 2017; Cao et al., 2018). Feng et al. (2021) argued that net livestock revenue of China's herders will decline by 7,213 yuan (RMB) with each increase of 1°C in annual temperatures.<sup>1</sup> As China's herders facing severe natural risks, particularly climate change, improving their resilience to climate change is essential.

As policy makers and researchers recognize the importance of enhancing individuals' capability to face risks, resilience has emerged as an increasingly emphasized topic in supporting herders' sustainable development. Resilience was first employed by the Food and Agriculture Organization of the United Nations to reflect households' ability to maintain their welfare levels when confronted with external shocks (Holling, 1973). Approaches to measuring resilience vary considerably, and current mainstream methods include the Household Livelihood Resilience Approach (HLRA) and Cissé and Barrett (C&B) Approach. The HLRA calculates a resilience index derived from their

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<sup>1</sup> 1 USD = 6.45 RMB in 2021.

livelihood framework, which has been widely used in empirical studies (d'Errico, Romano, and Pietrelli, 2018; Maltou and Bahta, 2019). However, the HLRA ignores the influence of farmers' pre-management and post-coping behaviors, thus failing to measure the dynamic change of resilience (d'Errico, Romano, and Pietrelli, 2018). To address these drawbacks and allow for nonlinear dynamics of welfare, Barrett and Conostas (2014) proposed the concept of "development resilience" and interpreted it as "the capacity of a household to avoid poverty in the wake of myriad shocks over time." Thus, a household is resilient only if the likelihood of its welfare being above a normative threshold remains high (Cissé and Barrett, 2018). The C&B method solves the disadvantages of the HLRA, which can only investigate the static linear characteristics of welfare, and has been proven to be more predictive of households' well-being if data are sufficiently abundant and frequent (Cissé and Barrett, 2018; Phadera et al., 2019).

Existing studies have noted that development resilience results from multiple internal and external factors (Phadera et al., 2019; Li and Lu, 2022; Zhang and Jiao, 2022; Li, Liu, and Lu, 2024). In terms of internal factors, the age, marital status, health, and education level of the household head as well as family assets have significant positive effects on resilience, whereas indebtedness and family dependency ratio have adverse effects (Phadera et al., 2019; Li and Lu, 2022). Regarding external factors, the institutional environment is an essential driving force of household resilience (Knippenberg, Jensen, and Conostas, 2019). Li and Lu (2022) argued that unconditional cash transfers have a significant positive effect on development resilience. Previous studies have regarded climate change as an essential external risk and focused on resilience to extreme weather hazards, such as droughts and floods (Knippenberg, Jensen, and Conostas, 2019). Only one study has explored the effect of climate change on resilience in China, finding that temperature rise decreases households' development resilience (Li, Liu, and Lu, 2024). However, it ignored the possible nonlinear effects of climate change that other studies have affirmed (Omotoso et al., 2023; Li, Liu, and Lu, 2024). Therefore, while climate change and external policies are essential factors affecting resilience, their simultaneous effects have received insufficient attention, especially in the context of herders (Li and Lu, 2022). Compared with peasant households, herder households appear more fragile and less resistant to external risks (Berhanu and Beyene, 2015). For example, Maltou and Bahta (2019) argued that only 9% of herders in South Africa were resilient to droughts. Therefore, understanding and enhancing Chinese herders' ability to cope with climate change is critical.

The Grassland Ecological Compensation Policy (GECP) is a payments for ecological services policy in China that has become the most influential and far-reaching policy in pastoral areas. Our study used a panel dataset of 679 herders surveyed from three main pastoral provinces (Inner Mongolia, Gansu, and Qinghai) in China. The results not only enrich the theoretical system of development resilience of individuals under climate change but also provide a decision-making reference for improving GECP to enhance herders' ability to cope with climate risks.

## Background

In 2011, China initiated the GECP, a national top-down payment program for ecological services, in eight provinces in order to restore the grassland ecosystem and support herders' livelihoods. The GECP delineates designated zones: a grazing ban zone, where grazing is prohibited, and a forage–livestock balance zone, where limited grazing is permitted (Ministry of Agriculture and Rural Affairs of China, 2011). The grazing ban zone targets severely degraded grasslands unsuitable for livestock grazing, and herders there receive subsidies to compensate for grazing prohibitions (6 yuan/mu). Conversely, the forage–livestock balance zone applies to slightly and moderately degraded areas, enforcing a standardized stocking rate based on grassland quality, and herders there receive relatively fewer rewards for limiting grazing intensity (1.5 yuan/mu) (Qiu et al., 2020). Payments are contracted grassland areas multiplied by the subsidy or reward rate (yuan/mu). Herders acquire grassland rights from the state or village collectives based on grassland quality and household size. The central government determines standardized stocking, subsidy, and reward rates,

**Table 1. Implementation Area and Subsidy Standard of the GECP in Inner Mongolia, Gansu, and Qinghai**

		Inner Mongolia	Gansu	Qinghai
Implementation area	Grazing-banned area	375 million mu	92.1582 million mu	274.05 million mu
	Livestock-forage balanced area	600 million acres	132.4545 million mu	395.89 million mu
Subsidy standard	Grazing-banned area	7.5 yuan/mu	Yellow River Basin in Qinghai-Tibet Plateau: 28.22 yuan/mu	Decided by the county-level government in accordance with the capital budget
			Other areas of the Qinghai-Tibet Plateau region: 21.67 yuan/mu	
	The western desert: 3.56 yuan/mu			
	Yellow River Basin in Qinghai-Tibet Plateau: 3.35 yuan/mu			
Livestock-forage balanced area	2.5 yuan/mu	Other areas of the Qinghai-Tibet Plateau region: 3.35 yuan/mu	Decided by the county-level government in accordance with the capital budget	
		The western desert: 1.96 yuan/mu		

Notes: 1 mu = 1/15 hm<sup>2</sup>.

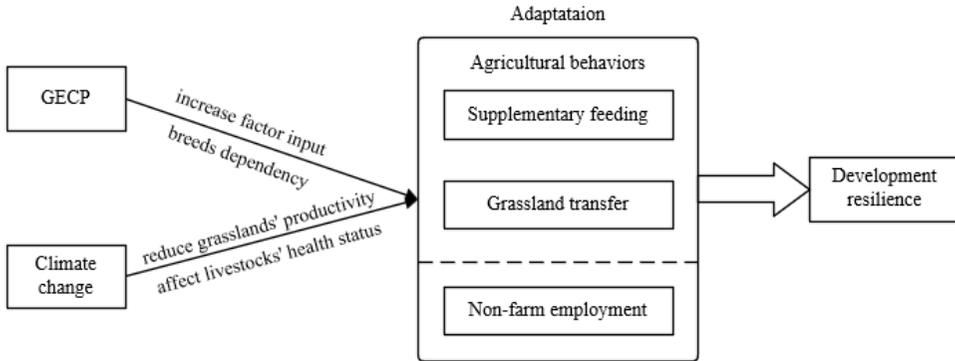
which may be adjusted locally based on grassland quality history. The second round of the GECP, which began in 2016, expanded the program to 13 provinces with increased subsidy rates (from 6 yuan/mu to 7 yuan/mu) and balance rewards (from 1.5 yuan/mu to 2.5 yuan/mu).

Total investment in the GECP was 77.40 billion yuan in the first period (2011–2015) and 69.30 billion yuan in the second period (2016–2020), and the program involved over 12 million herders (MFC, 2016). Considering this large investment and length of time (12 years), several studies have empirically investigated the impact of the GECP on herders' production behavior and welfare. For example, Wang and Huang (2018) found an inverted-U-shaped relationship between the GECP and nonfarm employment, suggesting that high compensation may lead to a higher demand for leisure. Kang, Hong, and Xing (2020) proposed that the program significantly improves production efficiency and herders' welfare. Only one study has explored the effects of the GECP from the perspective of development resilience, finding that the GECP enhances the resilience of herders with medium to large herds (Zhao et al., 2024). However, it ignored the important background of climate change and contained only a static measurement of resilience using cross-sectional data. Thus, the present study is the first to analyze the effects of climate change and the GECP on herders' resilience, considering the nonlinear impact of climate change. The study areas of Qinghai, Inner Mongolia, and Gansu are the main pastoral provinces in which the GECP was implemented in the first round. The GECP is currently in its third round, and its specifics have been adjusted. Table 1 reports the scope of implementation and subsidy standards in our study areas.

### Theoretical Framework and Model Specification

#### *Theoretical Framework*

Climate change is evidenced by changes in temperature and precipitation and extreme weather emergencies, especially abnormal ones (Intergovernmental Panel on Climate Change, 2007). Strong



**Figure 1. Theoretical Framework**

evidence shows that intensified climate change has significantly affected the input and output of animal husbandry, including grassland productivity and livestock health, thus further influencing herders' well-being (Felton et al., 2020). For example, rising temperatures accelerate parasite growth, resulting in livestock disease and death, while increased growing season rainfall variability can reduce rain-use efficiency and affect ecosystem functioning (Felton et al., 2020). Therefore, this study posits that climate change will negatively affect herders' development resilience.

The GECF is among the most prominent policies in China's pastoral areas and has been shown to help transform herders' production and lifestyles by issuing them subsidies and reward funds. Thus, it can be considered an asset transfer policy. Some evidence indicates the possible impact of asset transfer policies on resilience (Phadera et al., 2019; Li and Lu, 2022). Phadera et al. (2019) argued that after implementing an asset transfer policy, the development resilience of herders in rural Zambia improved by 44% by increasing the conditional mean and decreasing the conditional variance of herders' welfare (asset value). The GECF provides direct subsidies to eligible herders without specifying how the funds should be used, thereby easing consumption and improving herders' welfare (Kang, Hong, and Xing, 2020). Therefore, we assume that this policy is conducive to improving development resilience. The GECF's primary purpose is to restore the grassland ecosystem, and existing studies indicate that grassland quality has improved significantly since its implementation. Thus, we can infer that the GECF improves the ecological stability of grasslands and weakens the adverse impact of climate change on herders' production (Hou et al., 2021).

As climate change intensifies, herders have come to prefer to adapt in response to natural hazards, including supplementary feeding, nonfarm employment, and grassland transfer. First, purchasing forage has become the predominant approach among most herders to address the insufficient forage caused by drought or extremely high temperatures during growing seasons and enhance the efficiency and net profits of livestock production (Ma and Yang, 2022). Second, nonfarm employment is the prevailing response to external risks among herders, thus stabilizing the welfare of their families and enhancing their development resilience. This is because it not only provides an extra income source but also significantly improves herders' breeding efficiency, living quality, and social networks (Zhao et al., 2019). Third, grassland transfer refers to the practice of herders with management rights renting/renting out grasslands to maximize their interests, enabling large-scale livestock production and higher economic returns. For farmers, land transfer can enhance the sustainability of farming livelihoods, optimize livelihood strategies, and promote sustainable development (Yang et al., 2023). Therefore, supplementary feeding, nonfarm employment, and grassland transfer are expected to reduce the adverse effects of external shocks and improve development resilience. Figure 1 shows the impact mechanisms of climate change on herders' development resilience.

## Model Specification

### Development Resilience Measurement

This study uses the C&B method to quantitatively assess herders' development resilience, defined as the likelihood that the level of herders' household welfare remains above a certain threshold when external shocks occur. The specific calculation steps are described below.

First, following Li and Lu (2022), we adopt annual per capita consumption among herders as a proxy for welfare by dividing households' total expenditures on clothing, food, housing, transportation, social relationships, religious practices, rent, entertainment, education, and healthcare by the number of family members. Extant literature suggests that consumption provides an accurate measure of household welfare than income (Deaton, 1980). Following Cissé and Barrett (2018), we assume that welfare follows a first-order Markov process. The mean welfare level of household  $i$  at time  $t$  ( $W_{it}$ ) is modeled as a third-order polynomial in the lagged value of itself ( $W_{i,t-1}^j$ ). A vector of household characteristics ( $X_{it}$ ) includes the age, gender, and education level of the household head, grassland area, family size, livestock endowment, temperature deviation, precipitation deviation, and exposure to random shocks;  $\varepsilon_{1it}$  is the random error term; and  $\alpha_{1j}$  and  $\gamma_1$  are the parameters to be estimated. The specific expectation equation is

$$(1) \quad W_{it} = \sum_{j=1}^k \alpha_{1j} W_{i,t-1}^j + \gamma_1 X_{it} + \varepsilon_{1it}.$$

Second, using  $E$  to represent the expectation operator, we assume that the random error term  $\varepsilon_{1it}$  is mean zero ( $E[\varepsilon_{1it}] = 0$ ) and estimate the conditional mean of well-being using ordinary least squares. The conditional mean for household  $i$  at time  $t$  ( $\mu_{1it}$ ) can be predicted as follows:

$$(2) \quad \hat{\mu}_{1it} = E[W_{it} | W_{i,t-1}, X_{it}] = \sum_{j=1}^k \hat{\alpha}_{1j} W_{i,t-1}^j + \hat{\gamma}_1 X_{it}.$$

Third, we capture the residuals from equation (2) ( $\hat{\varepsilon}_{1it}$ ) and take the square to estimate equation (3):

$$(3) \quad \hat{\varepsilon}_{1it}^2 = \sum_{j=1}^k \alpha_{2j} W_{i,t-1}^j + \gamma_2 X_{it} + \varepsilon_{2it}.$$

Similarly, assuming that  $E[\hat{\varepsilon}_{2it}] = 0$ , the variance of household  $i$  at time  $t$  ( $\mu_{2it}$ ) is predicted as follows:

$$(4) \quad \hat{\mu}_{2it} = E[\hat{\varepsilon}_{1it}^2 | W_{i,t-1}, X_{it}] = \sum_{j=1}^k \hat{\alpha}_{2j} W_{i,t-1}^j + \hat{\gamma}_2 X_{it}.$$

Finally, since welfare is a nonnegative constant, this study assumes that herders' welfare follows a gamma distribution. The assumed complementary cumulative density function, which can be used to estimate the possibility of household  $i$  reaching the threshold of welfare at time  $t$ , is

$$(5) \quad R_{it} = P(W_{it} \geq \bar{W}) = \bar{F}[\bar{W}; \hat{\mu}_{1it}(W_{it}, X_{it}), \hat{\mu}_{2it}(W_{it}, X_{it})],$$

where  $\bar{F}(\cdot)$  is the assumed cumulative distribution. Following the mission of the World Bank (2015) to "improve the welfare level of the poorest 40% of the population," this study sets the threshold ( $\bar{W}$ ) as the 40 quantiles of the welfare of surveyed households. Specifically, the relative poverty standard was 7,408 yuan in 2015 and 7,300 in 2017. Equation (1) considers the lagged term of consumption; therefore, the resilience is obtained in both periods (2015 and 2017).

Impact of GECP and Climate Change on the Development Resilience

Given that development resilience must be nonnegative, referring to Phadera et al. (2019), we assume that the dependent variable is distributed binomially and fits the generalized linear model (GLM) logit link regression using maximum likelihood. Thus, the following model is specified

$$(6) \quad R_{it} = a_0 + a_1G_{it} + a_2td_{it} + a_3pd_{it} + a_4X_{it} + \gamma_t + \delta_p + e_{it},$$

where  $R_{it}$  is the development resilience for household  $i$  at time  $t$  and  $G_{it}$ ,  $td_{it}$ , and  $pd_{it}$  are indicators of the GECP, temperature deviation, and precipitation deviation, respectively, where GECP is a continuous variable measured by the subsidy received by herder  $i$  at time  $t$ . Temperature and precipitation deviation reflect the deviations in the annual average temperature and precipitation for 1980 to 2017. Additionally,  $X_{it}$  refers to a vector of household socioeconomic characteristics affecting herders' development resilience, including the age, gender, and education of the household head, household size, livestock endowment, grassland area, grazing ban, government surveillance, co-operative membership, access to credit, disaster experience, terrain conditions, and soil type. Finally,  $\alpha_i$  comprises the following parameters to be estimated:  $\alpha_1$  represents the relationship between the GECP subsidy and development resilience, and  $\alpha_2$  and  $\alpha_3$  represent the effects of temperature and precipitation change on herders' resilience, respectively;  $\gamma_t$  is the time fixed effect;  $\delta_p$  is the province fixed effect; and  $e_{it}$  is the random error term.

Considering the different effects of temperature and precipitation change on herders' resilience, we include a dummy variable for negative temperature deviations and positive precipitation deviations that interact with the temperature and precipitation deviations, respectively. Thus, the following model is specified

$$(7) \quad R_{it} = \beta_0 + \beta_1G_{it} + \beta_2td_{it} + \beta_3td_{it} \times t\_l_{it} + \beta_4pd_{it} + \beta_5X_{it} + \gamma_t + \delta_p + e_{it},$$

$$(8) \quad R_{it} = c_0 + c_1G_{it} + c_2td_{it} + c_3pd_{it} \times p\_h_{it} + c_4pd_{it} + c_5X_{it} + \gamma_t + \delta_p + e_{it},$$

where  $t\_l_{it}$  and  $p\_h_{it}$  are dummy variables indicating whether the temperature faced by herder  $i$  in year  $t$  was lower than the past average and whether the precipitation was higher than the average.  $\beta_2$  measures the impact of temperature change on the resilience of herders who experienced positive temperature deviation that year, and  $\beta_2 + \beta_3$  represent the impact on the resilience of herders who experienced negative temperature deviation.  $c_4$  measures the impact of precipitation change on the resilience of herders who experienced negative precipitation deviation that year, and  $c_3 + c_4$  represents the impact on the resilience of herders who experienced positive deviation that year. The other variables are as in the previous equations. Given the inhibitory effect of the GECP on grassland degradation, it is likely to make herders more resistant to climate change, with a synergistic effect on resilience. Therefore, we introduce the interaction terms between  $G_{it}$  and climate change as follows:

$$(9) \quad R_{it} = \theta_0 + \theta_1G_{it} + \theta_2td_{it} + \theta_3td_{it} \times t\_l_{it} + \theta_4G_{it} \times td_{it} + \theta_5pd_{it} + \theta_6pd_{it} \times p\_h_{it} + \theta_7X_{it} + \gamma_t + \delta_p + e_{it},$$

$$(10) \quad R_{it} = d_0 + d_1G_{it} + d_2td_{it} + d_3td_{it} \times t\_l_{it} + d_4G_{it} \times td_{it} \times t\_l_{it} + d_5pd_{it} + d_6pd_{it} \times p\_h_{it} + d_7X_{it} + \gamma_t + \delta_p + e_{it},$$

$$(11) \quad R_{it} = \theta_0 + \theta_1G_{it} + \theta_2td_{it} + \theta_3td_{it} \times t\_l_{it} + \theta_4pd_{it} + \theta_5pd_{it} \times p\_h_{it} + \theta_6G_{it} \times pd_{it} + \theta_7X_{it} + \gamma_t + \delta_p + e_{it},$$

$$(12) \quad R_{it} = \rho_0 + \rho_1G_{it} + \rho_2td_{it} + \rho_3td_{it} \times t\_l_{it} + \rho_4pd_{it} + \rho_5pd_{it} \times p\_h_{it} + \rho_6G_{it} \times pd_{it} \times p\_h_{it} + \rho_7X_{it} + \gamma_t + \delta_p + e_{it},$$

where  $R_{it}$ ,  $G_{it}$ ,  $td_{it}$ ,  $t\_l_{it}$ ,  $pd_{it}$ ,  $p\_h_{it}$ , and  $X_{it}$  are consistent with the above equations;  $G_{it} \times td_{it} \times t\_l_{it}$  is the interaction term between the GECP subsidy, temperature deviation and negative dummy variable; and  $G_{it} \times pd_{it} \times p\_h_{it}$  is the interaction term between the GECP subsidy, precipitation deviation, and positive dummy variable. The coefficient on the interaction terms  $\theta_4$ ,  $d_4$ ,  $\theta_6$ ,  $\rho_6$  are the key parameters to be estimated. If  $\theta_1$  and  $\theta_4$  are both significantly positive, then  $\theta_2$  is significantly negative. We can infer that the GECP subsidy can compensate for the negative impact of temperature increases on development resilience of herders who suffered positive temperature deviation.

### Influence Mechanism Analysis

Understanding GECP and climate change may affect development resilience by changing herders' adaptive behaviors; therefore, this study explores the influence mechanism by examining how the GECP subsidy and climate change influence herders' adaptive behaviors. The model is specified as follows:

$$(13) \quad Response_{it} = \partial_0 + \partial_1 GE_i + \partial_2 td_{it} + \partial_3 pd_{it} + \partial_4 X_i + \gamma_t + \delta_p + e_{it},$$

where  $Response_{it}$  represents the adaptive behaviors of herder  $i$  at time  $t$ . Supplementary feeding is measured by herders' expenditure on supplementary feeding, nonfarm employment is measured by herders' ratio of nonfarm income to total household income, and grassland transfer is measured by the dummy variable indicating whether herders have rented/rented out grassland area. Other variables are the same as in the above equations, and  $\partial_i$ s represents the parameters to be estimated.

### Data

The data used in this study were collected in 2017 from herders in the provinces of Gansu, Inner Mongolia, and Qinghai, which are typical pastoral areas in China. Data collection followed a multistage sampling procedure. In the first stage, 18 pastoral counties were randomly selected in each province according to grassland area and grazing intensity. The sample provinces show a satisfactory representation of various grassland types, such as temperate steppe deserts, alpine meadows, and temperate meadow-steppe. In the second stage, two townships were randomly selected in each county according to the intensity of livestock production. In the third stage, three villages were randomly selected. Finally, 8–9 herders from each village were selected at random to be interviewed.

The face-to-face interviews were conducted based on a predetermined structured questionnaire at the village and household levels. During the interviews, information was collected for 2013, 2015, and 2017. The village-level questionnaires covered the characteristics of village-level grassland, livestock production, and village regulation. The household-level questionnaires included socioeconomic characteristics of the household, characteristics of the grassland area, animal husbandry production, GECP subsidy, and co-operative membership. The interviews were conducted at the village council building or the herders' residences and completed by household heads with the help of volunteer interpreters who spoke the local language. Excluding the samples with insufficient information, 2,037 observations were obtained from 679 households in 3 years (2013, 2015, and 2017). The annual precipitation and temperature data from 1980 to 2017 were obtained from the Resource and Environment Data Service Center in the Chinese Academy of Sciences (<http://www.resdc.cn/Default.aspx>).

Using the C&B method to estimate herders' development resilience to climate change, the estimations reveal that the mean and variance of resilience in the study area were 0.59 and 0.38, respectively. Table 2 presents the variable definitions and summary statistics. Compared with the past 3 decades, the average temperature in the study area increased by 1.85°C, and the average precipitation decreased by 96 mm. Approximately 44% of herders' development resilience is below

**Table 2. Variable Definitions and Summary Statistics**

Variables	Definition	Mean	Std. Dev.
Resilience	Probability of household welfare reaching the poverty line	0.59	0.38
Welfare	Herders' annual consumption per capita (ten thousand yuan)	1.07	0.95
GECP	GECP subsidy received (ten thousand yuan)	1.39	3.43
Supplementary feeding	Herders' expenditure on purchased forage for the year (yuan)	13,589.81	41,906.29
Non-farm employment	Proportion of non-farm income in total income of herder household in that year (%)	0.13	0.25
Grassland transfer	= 1 if the herder household transferred grasslands during the year, and 0 otherwise	0.24	0.43
Temdev	Deviation in that year's temperature from the mean of 1980–2017 (°C)	1.85	1.86
Predev	Deviation in that year's precipitation from the mean of 1980–2017 (hundred mm)	-0.96	0.08
Tem_l	= 1 if that year temperature is lower than the average of the past three decades, and 0 otherwise	0.94	0.24
Pre_h	= 1 if that year precipitation is higher than the average of the past three decades, and 0 otherwise	0.95	0.22
Age	Age of household head (years)	46.87	11.17
Education	Schooling years of the household head	4.22	4.08
Gender	= 1 if a household head is male, and 0 otherwise	0.91	0.29
Household size	Number of members in a family	5.06	1.46
Livestock endowment	Livestock number at the beginning of the year (sheep units)	409.48	794.903
Grassland area	The area of the herders' grassland (mu)	7,251.56	20,540.84
Grazing ban	= 1 if herders are forbidden to graze, and 0 otherwise	0.43	0.5
Government surveillance	= 1 if a household is under government surveillance on their stocking rates, and 0 otherwise	0.36	0.48
Cooperative membership	= 1 if a household has cooperative membership, and 0 otherwise	0.12	0.33
Credit access	= 1 if herders borrowed money that year, and 0 otherwise	0.28	0.45
Disaster	= 1 if herders were hit by a natural disaster that year, and 0 otherwise	0.3	0.46
Terrain	Terrain of grasslands (1 = 0–0.5%; 2=0.6–2%; 3 = 2.1–5%; 4 = 5.1–8%; 5=8.1–16%; 6 = 16.1–30%; 7 = 30.1–45%; 8 > 45%)	3.21	8.94
Soil type	The type of soil	13.47	5.12
Year	= 1 if year is 2015 and 2 if year is 2017	1.5	0.5

*Notes:* Livestock numbers are converted into sheep units using the following conversion scheme: 1 sheep = 1 sheep unit, 1 lamb = 0.5 sheep units, 1 goat = 0.9 sheep units, 1 young goat = 0.4 sheep units, and 1 cattle = 5 sheep units (Fernández-Giménez, Batkhishig, and Batbuyan, 2012).

average, with a mean resilience of only 0.2, while that of the other herders is above average, at 0.9, indicating a large difference in resilience among these households. Moreover, 94% of herders report experiencing increased temperatures, while 95% report decreased precipitation. Further, 91% of the household heads are male, with an average age of 47 years and an average education of 4.2 years. The mean household size is 5.06, almost 43% are covered by the grazing ban, 36% are under government surveillance, and only 12% are members of co-operatives. The mean area of grassland is 7,252 mu and the mean livestock number is 409 sheep units. The average annual consumption per capita is 10,700 yuan.

## Results and Discussion

### *Impact of the GECP on Herders' Development Resilience to Climate Change*

Since a GLM with binomial family and logit link function is used to estimate the average marginal treatment effect, the quantitative relationship between the explained and explanatory variables is

$$(14) \quad \text{Logit}(y) = \ln\left(\frac{y_i}{1 - y_i}\right) = \beta_0 + \beta_i X_i ;$$

$$(15) \quad y_i = \frac{1}{1 + e^{-(\beta_0 + \beta_i x_i)}} ;$$

$$(16) \quad \frac{dy}{dx} = \beta_i y_i (1 - y_i) .$$

According to equation (14), we assume that the sample is at the mean when other conditions remain unchanged; for each unit change in  $x_i$ , the percentage change in the expected count is  $y_i$  is  $\beta_i \bar{y}_i (1 - \bar{y}_i)$  units.

Column 1 in Table 3 reports the estimated average marginal treatment effects of GECP subsidies and climate change on development resilience. To mitigate potential mutual effects among herders in the same village, robust standard errors are clustered at the village level. The coefficient for GECP subsidies on development resilience is statistically significant at the 5% level. Simultaneously, the coefficients for temperature and precipitation deviations are both statistically significant and negative, indicating that development resilience tends to increase with higher GECP subsidies, and greater changes in temperature and precipitation correspond to lower development resilience. Quantitative analysis shows that development resilience increases by 0.016 ( $0.0675 \times 0.59 \times 0.41 = 0.016$ ) for every 10,000 yuan increase in GECP subsidies received. Conversely, it decreases by 0.019 ( $0.0769 \times 0.59 \times 0.41 = 0.019$ ) for every 1°C increase in the average temperature deviation and by 0.029 ( $100 \times 0.0012 \times 0.59 \times 0.41 = 0.029$ ) for every 100 mm increase in average precipitation deviation in the sample period, holding all other variables constant. These findings align with those of existing studies on peasant households in China and herders in Zambia (Phadera et al., 2019; Li and Lu, 2022).

Columns 2 and 3 of Table 3 show that the coefficient of the interaction between the temperature deviation and negative indicator is insignificant, whereas the coefficient of the interaction between the precipitation deviation and positive indicator is significantly positive. These results indicate that the impact of precipitation deviation on the resilience of herders differs between those who experienced a precipitation level above or below the average. Higher precipitation deviation harms the resilience of herders who face lower precipitation levels; however, this negative effect turns positive among those who experience higher precipitation levels.

Table 4 illustrates the synergistic effect of GECP and climate change on development resilience. Column 1 reveals that the coefficient of the interaction between GECP subsidies and temperature deviation is significantly positive, whereas that of temperature deviation alone is significantly negative. This suggests that increasing GECP subsidies mitigates the adverse impact of temperature deviation on the resilience of herders facing above-average temperatures. Conversely, this synergistic effect is not observed for precipitation. A potential explanation is that higher temperatures may reduce grassland productivity or increase livestock mortality, which can be alleviated by using GECP subsidies to purchase hay or veterinary care (Felton et al., 2020). Conversely, the adverse impact of precipitation on livestock production may be mitigated by costly engineering interventions that are not effectively supported by GECP subsidies, such as well digging and shed construction.

**Table 3. Regression Results for the Impact of the GECP and Climate Change on Resilience**

Variables	Resilience	Resilience	Resilience
	1	2	3
GECP	0.0675** (0.0295)	0.0745** (0.0310)	0.0616** (0.0278)
Temdev	-0.0769** (0.0380)	-0.0803** (0.0385)	-0.0763** (0.0380)
Predev	-0.0012* (0.0007)	-0.0012* (0.0007)	-0.0018** (0.0007)
Temdev × Tem_l		0.2542 (0.3977)	
Predev × Pre_h			0.0083** (0.0039)
Age	-0.0016 (0.0043)	-0.0015 (0.0043)	-0.0017 (0.0042)
Education	0.0506*** (0.0148)	0.0504*** (0.0148)	0.0486*** (0.0146)
Gender	-0.1005 (0.1557)	-0.1071 (0.1561)	-0.0895 (0.1564)
Household size	-0.2948*** (0.0379)	-0.2961*** (0.0380)	-0.2914*** (0.0380)
Grassland area	0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)
Livestock endowment	0.0003 (0.0003)	0.0003 (0.0003)	0.0003 (0.0002)
Credit access	-0.1542 (0.1237)	-0.1595 (0.1241)	-0.1503 (0.1235)
Grazing ban	-0.0375 (0.0939)	-0.0459 (0.0948)	-0.0370 (0.0934)
Government surveillance	0.2666*** (0.1020)	0.2781*** (0.1028)	0.2657*** (0.1016)
Cooperative membership	0.1309 (0.1420)	0.1283 (0.1421)	0.1313 (0.1410)
Disaster	0.1348 (0.1135)	0.1344 (0.1134)	0.1555 (0.1138)
Terrain	0.0311 (0.0396)	0.0311 (0.0395)	0.0435 (0.0393)
Soil type	0.0130 (0.0103)	0.0126 (0.0103)	0.0100 (0.0103)
Year fixed effects	yes	yes	yes
Province fixed effects	yes	yes	yes
Cluster	Village	Village	Village

Notes: Values in parentheses are robust standard errors clustered at the village level. Single, double, and triple asterisks (\*, \*\*, \*\*\*) indicate significance at the 10%, 5%, and 1% levels, respectively.

**Table 4. Regression Results for the Synergistic Effect of the GECP and Climate Change on Resilience (N = 1,358)**

Variables	Resilience 1	Resilience 2	Resilience 3	Resilience 4
GECP	0.0157 (0.0405)	0.0763** (0.0306)	0.0571* (0.0311)	0.0695** (0.0352)
Temdev	-0.1089** (0.0425)	-0.0780** (0.0386)	-0.0792** (0.0389)	-0.0792** (0.0391)
Temdev × Tem_l	-0.3898 (0.5091)	-0.5248 (0.8048)	0.1243 (0.4028)	0.1441 (0.4280)
GECP × Temdev	0.0273* (0.0153)			
GECP × Temdev × Tem_l		0.1033 (0.0982)		
Predev	-0.0019** (0.0007)	-0.0018** (0.0007)	-0.0017** (0.0008)	-0.0017** (0.0007)
Predev × Pre_h	0.0084** (0.0039)	0.0078** (0.0039)	0.0087** (0.0041)	0.0086** (0.0044)
GECP × Predev			-0.0002 (0.0004)	
GECP × Predev × Pre_h				-0.0003 (0.0010)
Age	-0.0017 (0.0043)	-0.0017 (0.0043)	-0.0015 (0.0043)	-0.0017 (0.0042)
Education	0.0488*** (0.0146)	0.0496*** (0.0147)	0.0491*** (0.0146)	0.0484*** (0.0146)
Gender	-0.0839 (0.1565)	-0.0819 (0.1571)	-0.0947 (0.1569)	-0.0931 (0.1568)
Household size	-0.2921*** (0.0382)	-0.2914*** (0.0381)	-0.2918*** (0.0382)	-0.2922*** (0.0381)
Grassland area	0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)
Livestock endowment	0.0003 (0.0002)	0.0003 (0.0002)	0.0003 (0.0002)	0.0003 (0.0002)
Credit access	-0.1508 (0.1237)	-0.1498 (0.1238)	-0.1510 (0.1240)	-0.1538 (0.1240)
Grazing ban	-0.0370 (0.0943)	-0.0359 (0.0944)	-0.0425 (0.0948)	-0.0422 (0.0946)
Government surveillance	0.2817*** (0.1025)	0.2677*** (0.1026)	0.2755*** (0.1026)	0.2718*** (0.1027)
Cooperative membership	0.1422 (0.1413)	0.1319 (0.1409)	0.1307 (0.1410)	0.1313 (0.1412)
Disaster	0.1741 (0.1141)	0.1689 (0.1143)	0.1559 (0.1140)	0.154 (0.1139)
Terrain	0.0417 (0.0392)	0.0394 (0.0394)	0.0429 (0.0392)	0.0434 (0.0392)
Soil type	0.0109 (0.0103)	0.0107 (0.0104)	0.0098 (0.0103)	0.0098 (0.0103)
Constant	0.9763** (0.4108)	0.9511** (0.4105)	0.9681** (0.4110)	0.0695** (0.0352)
Year fixed effects	yes	yes	yes	yes
Province fixed effects	yes	yes	yes	yes

Notes: Values in parentheses are robust standard errors clustered at the village level. Single, double, and triple asterisks (\*, \*\*, \*\*\*) indicate significance at the 10%, 5%, and 1% levels, respectively.

**Table 5. Heterogeneous Impacts on Livestock-Forage Balance and Grazing-Banned Herders**

Variables	Livestock-Forage Balance Herders ( <i>N</i> = 768)			Grazing-Banned Herders ( <i>N</i> = 590)		
	Resilience	Resilience	Resilience	Resilience	Resilience	Resilience
GECP	0.0626* (0.0328)	0.0504 (0.0378)	0.0571* (0.0336)	0.0445 (0.0415)	-0.0199 (0.0374)	0.1217** (0.0575)
Temdev	-0.1360** (0.0598)	-0.1527** (0.0624)	-0.1388** (0.0593)	-0.0128 (0.0523)	-0.0588 (0.0617)	-0.0158 (0.0524)
Predev	-0.0027*** (0.0009)	-0.0027*** (0.0009)	-0.0026*** (0.0009)	0.0001 (0.0007)	-0.0001 (0.0007)	-0.0006 (0.0008)
GECP × Temdev		0.0134 (0.0138)			0.0323** (0.0158)	
GECP × Predev			-0.0002 (0.0003)			0.0009 (0.0007)
Age	-0.0048 (0.0083)	-0.0049 (0.0083)	-0.0050 (0.0083)	0.0009 (0.0077)	0.0010 (0.0078)	0.0001 (0.0077)
Education	0.0499* (0.0260)	0.0498* (0.0260)	0.0499* (0.0261)	0.0405 (0.0269)	0.0389 (0.0269)	0.0399 (0.0267)
Gender	-0.1432 (0.2044)	-0.1436 (0.2047)	-0.1453 (0.2027)	-0.1075 (0.3493)	-0.1043 (0.3464)	-0.1414 (0.3520)
Household size	-0.3165*** (0.0765)	-0.3178*** (0.0768)	-0.3170*** (0.0766)	-0.2571*** (0.0708)	-0.2601*** (0.0708)	-0.2521*** (0.0716)
Grassland area	0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)
Livestock endowment	0.0002 (0.0002)	0.0002 (0.0002)	0.0002 (0.0002)	0.0008** (0.0003)	0.0008** (0.0003)	0.0008** (0.0003)
Credit access	-0.0456 (0.2448)	-0.0472 (0.2455)	-0.0462 (0.2450)	-0.2677 (0.2803)	-0.2908 (0.2805)	-0.2641 (0.2804)
Government surveillance	0.3679*** (0.1371)	0.3770*** (0.1361)	0.3663*** (0.1380)	0.3099 (0.1884)	0.3523* (0.1884)	0.2937 (0.1861)
Cooperative membership	0.1887 (0.2097)	0.1906 (0.2084)	0.1920 (0.2096)	0.0054 (0.2920)	0.0086 (0.2936)	0.0248 (0.2896)
Disaster	0.1210 (0.1485)	0.1262 (0.1476)	0.1127 (0.1504)	0.1160 (0.1805)	0.1338 (0.1798)	0.1244 (0.1818)
Terrain	0.1153* (0.0663)	0.1154* (0.0659)	0.1165* (0.0660)	-0.0899 (0.0791)	-0.0868 (0.0788)	-0.0793 (0.0808)
Soil type	0.0244 (0.0206)	0.0245 (0.0206)	0.0245 (0.0207)	-0.0117 (0.0176)	-0.0112 (0.0175)	-0.0120 (0.0176)
Constant	0.5219 (0.6254)	0.5550 (0.6294)	0.5365 (0.6224)	1.8465** (0.7475)	1.8661** (0.7426)	1.7618** (0.7679)
Year fixed effects	yes	yes	yes	yes	yes	yes
Province fixed effects	yes	yes	yes	yes	yes	yes

Notes: Values in parentheses are robust standard errors clustered at the village level. Single, double, and triple asterisks (\*, \*\*, \*\*\*) indicate significance at the 10%, 5%, and 1% levels, respectively.

### *Heterogeneity Analysis*

Differences in subsidy levels and livestock reduction requirements result in variations in responses to climate change and the GECP among herders in grazing-banned areas and those in livestock–forage balance areas, creating different effects on their resilience. Therefore, this study conducts a regression on the resilience of herders in the grazing balance and grazing ban areas, respectively. The results are shown in Table 5.

Columns 1–3 of Table 5 report the impact of the GECP on livestock–forage balance households. The coefficient of the GECP is significantly positive, the coefficients of temperature deviation and precipitation deviation are significantly negative, and the coefficients of the interactions term are both insignificant. This demonstrates that, for grazing-banned households, increasing GECP subsidies is related to higher resilience, whereas the GECP cannot alleviate the negative effects of temperature and precipitation deviation on resilience. Columns 4–6 of Table 5 report the impact of GECP on the resilience of grazing-banned households. The synergistic effect of the GECP and temperature deviation on resilience is significantly positive, demonstrating that the GECP mitigates the inhibitory effect of temperature change on resilience for grazing-banned households.

The possible reasons for the heterogeneous influence of climate change are as follows: First, according to the rules, grazing-banned households must continue animal husbandry production activities in livestock barns because grazing is not allowed in their area of the grasslands. Compared with grazing in natural grasslands, feeding livestock in barns is less sensitive to climate change. Livestock–forage balance households continue herding in the grasslands; therefore, their livestock income is highly dependent on the natural environment, and increased GECP subsidies encourages them to adapt to climate change, thus increasing their resilience. Second, although the subsidy standard of grazing-banned households is higher than that of livestock–forage balance households, it is still insufficient to compensate for the loss caused by grazing prohibition. Thus, it fails to promote adaptive behaviors in grazing-banned herders. Third, the GECP may mitigate the inhibitory role of temperature change on grazing-banned herders' resilience because they have changed the original grazing grassland into clipping grassland, which is used for harvesting forage to feed livestock. When high temperatures lead to the reduction of forage, the GECP bonus can become a supplementary fund to purchase forage, thus weakening the adverse effects of temperature rise.

### *Mechanism Analysis*

Since the log of supplementary feeding expenditure and ratio of nonfarm income to total income are restricted above 0 and grassland transfer is a binary variable, this study employs a GLM with a binomial family and log link function to examine the effects of the GECP and climate change on supplementary feeding and nonfarm employment. Simultaneously, a probit model is used to measure their effects on grassland transfer. The results are presented in Tables 6–8.

Table 6 presents the impact of the GECP and climate change on supplementary feeding. The coefficient of the GECP on supplementary feeding is significantly positive, indicating that the policy provides financial support to purchase forage, while the coefficient of precipitation deviation is significantly negative and that of temperature deviation is significantly positive. We can infer that when the annual temperature increases and annual precipitation decreases, compared with past average levels, herders' supplementary feeding expenditure will increase accordingly. This conclusion is consistent with our assumption that the herders often purchase more forage to maintain livestock production when they experience forage shortages caused by heat or drought.

Table 7 presents the impact of the GECP and climate change on nonfarm employment. The coefficient of the GECP and temperature deviation on nonfarm employment are both significantly negative, demonstrating that the ratio of nonfarm income to total income decreases with increasing GECP subsidies and temperature deviation. The inhibitory effect of the GECP on nonfarm employment has been affirmed by previous research, indicating that the GECP increases herders' reliance on subsidies and reduces their enthusiasm for going out for work (Wang and Huang, 2018).

**Table 6. Regression Results for the GECP and Climate Change on Supplementary Feeding (N = 1,358)**

Variables	Supplementary Feeding 1	Supplementary Feeding 2	Supplementary Feeding 3
GECP	0.1027*** (0.0293)	0.1020*** (0.0347)	0.0853*** (0.0262)
Temdev	0.1269** (0.0503)	0.1257** (0.0505)	0.1126** (0.0534)
Predev	-0.0023** (0.0010)	-0.0023** (0.0010)	-0.0017 (0.0013)
GECP × Temdev		0.0006 (0.0096)	
GECP × Predev			-0.0003 (0.0003)
Age	0.0123** (0.0059)	0.0123** (0.0058)	0.0120** (0.0058)
Education	0.0773*** (0.0266)	0.0773*** (0.0264)	0.0775*** (0.0265)
Gender	0.3638** (0.1731)	0.3636** (0.1712)	0.3570** (0.1760)
Household size	-0.1113 (0.0731)	-0.1114 (0.0734)	-0.1146 (0.0723)
Grassland area	0.0001*** (0.0001)	0.0001*** (0.0001)	0.0001*** (0.0001)
Livestock endowment	0.0003*** (0.0001)	0.0003*** (0.0001)	0.0003*** (0.0001)
Credit access	0.4181* (0.2138)	0.4180* (0.2133)	0.4175** (0.2085)
Grazing ban	-0.8462*** (0.1919)	-0.8466*** (0.1955)	-0.8553*** (0.1855)
Government surveillance	0.1457 (0.0983)	0.1468 (0.1117)	0.1544 (0.0959)
Cooperative membership	0.2601 (0.1898)	0.2601 (0.1895)	0.2612 (0.1911)
Disaster	-0.0407 -0.1263	-0.0399 -0.13	-0.0573 -0.1312
Terrain	-0.1381 -0.114	-0.1384 -0.1167	-0.1385 -0.1136
Soil type	0.0355* -0.0205	0.0354* -0.0202	0.0355* -0.0204
Constant	7.9721*** -0.6131	7.9762*** -0.6369	8.0812*** -0.5692
Year fixed effects	yes	yes	yes
Province fixed effects	yes	yes	yes

Notes: Robust standard errors clustered at the village level are in parentheses; \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively.

Additionally, the dampening effect of high temperatures on off-farm employment of herders can be attributed to herders' low level of education and inability to speak Mandarin, which makes them less competitive in the labor market. These findings are consistent with those of Shayegh, Manoussi, and Dasgupta (2021), who found that the supply of low-skilled labor responds negatively to high exposure to rising temperatures.

Table 8 presents the impact of the GECP and climate change on grassland transfer. The coefficient of precipitation deviation is negative, indicating that increased precipitation inhibits herders from transferring grassland. A possible explanation is that when the climate is warm and dry, herder households' income from animal husbandry tends to be relatively stable or can even increase with increasing precipitation. This discourages herders from changing their production scale, thereby further decreasing the possibility of transferring grassland. Simultaneously, the positive coefficient of the interaction between the GECP and temperature deviation implies that increased GECP subsidies can compensate for decrease in livestock income caused by high temperatures, thereby weakening the adverse impact of temperature rise on grassland transfer.

In conclusion, the synergistic effect of the GECP and climate change on herders' resilience is realized by changing their adaptive behavior. The GECP encourages herders to purchase forage but hinders them from going out for work, ultimately contributing to resilience. Increasing temperature variability promotes supplementary feeding and hinders nonfarm employment, which is inconducive to resilience. Increased precipitation variability restrains supplementary feeding and grassland transfer, thus decreasing resilience. Moreover, the synergistic effect between climate change and the GECP is realized by facilitating change in herders' grassland transfer.

### Conclusion and Policy Implications

This study is the first to focus on the effects of the GECP and climate risks on herders' development resilience while considering the nonlinear characteristics of climate change effects and their synergy. We also compare the effects of the GECP on herders in different policy implementation areas and explore the influence mechanism. The main findings are discussed below.

First, climate change plays a negative role in herders' development resilience. Temperature change decreases development resilience among all herders, while precipitation change plays a nonlinear role in herders' resilience, decreasing the resilience of herders who experience below-average rainfall and enhancing that of herders who experience above-average rainfall. The GECP can improve development resilience and weaken the adverse effects of rising temperatures. Second, the positive effect of the GECP and negative effect of climate change are only observed in livestock-forage-balanced households, whereas their synergistic effect is significant for grazing-banned households. Finally, the GECP improves herders' development resilience by encouraging them to increase forage feeding but inhibits nonfarm employment. Temperature change reduces development resilience by preventing nonfarm employment, which the positive role of temperature change in supplementary feeding can alleviate. Precipitation deviation decreases development resilience by preventing grassland transfer; however, the positive effect on nonfarm employment compensates for this to some extent.

Based on the above findings, we make the following policy recommendations. First, the government should increase GECP subsidies to provide a stronger guarantee for the livelihood of grazing-banned herders. Second, the government should intensify investment in construction for weather warning and post-disaster safeguard mechanisms, including meteorological monitoring stations and irrigation facilities. Third, the government should use financial tools such as tax cuts or credit aid to provide subsidies for herders to purchase hay when extreme climate events occur, as well as organize skill training to broaden their sources of income and promote the standardized transfer of grassland rights to help herders actively adapt to climate change.

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**Table 7. Regression Results for the GECP and Climate Change on Nonfarm Employment (N = 1,358)**

Variables	Non-Farm Employment 1	Non-Farm Employment 2	Non-Farm Employment 3
GECP	-0.1749*** (0.0415)	-0.1241*** (0.0327)	-0.1471*** (0.0276)
Temdev	-0.0758* (0.0412)	-0.0345 (0.0453)	-0.0729* (0.0415)
Predev	0.0019*** (0.0006)	0.0020*** (0.0006)	0.0016** (0.0007)
GECP × Temdev		-0.0410*** (0.0156)	
GECP × Predev			0.0006 (0.0005)
Age	0.0015 (0.0059)	0.0015 (0.0060)	0.0014 (0.0059)
Education	0.0364** (0.0184)	0.0369** (0.0182)	0.0362** (0.0183)
Gender	0.2206 (0.3868)	0.2190 (0.3873)	0.2177 (0.3865)
Household size	0.0947** (0.0391)	0.0974** (0.0392)	0.0955** (0.0391)
Grassland area	-0.0001 (0.0001)	-0.0001 (0.0001)	-0.0001 (0.0001)
Livestock endowment	0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)
Credit access	-0.0958 (0.1498)	-0.0793 (0.1503)	-0.0871 (0.1504)
Grazing ban	0.1731 (0.1100)	0.1918* (0.1122)	0.1828* (0.1108)
Government surveillance	-0.2713** (0.1198)	-0.2953** (0.1217)	-0.2791** (0.1203)
Cooperative membership	-0.1653 (0.1744)	-0.1746 (0.1739)	-0.1656 (0.1751)
Disaster	-0.0376 (0.1452)	-0.0512 (0.1438)	-0.0296 (0.1457)
Terrain	0.1727*** (0.0572)	0.1720*** (0.0568)	0.1733*** (0.0571)
Soil type	-0.0221* (0.0116)	-0.0226** (0.0115)	-0.0225* (0.0116)
Constant	-3.1887*** (0.6436)	-3.2376*** (0.6520)	-3.2114*** (0.6461)
Year fixed effects	yes	yes	yes
Province fixed effects	yes	yes	yes

Notes: Values in parentheses are robust standard errors clustered at the village level. Single, double, and triple asterisks (\*, \*\*, \*\*\*) indicate significance at the 10%, 5%, and 1% levels, respectively.

**Table 8. Regression Results for the GECP and Climate Change Effects on Grassland Transfer (N = 1,358)**

Variables	Grassland Transfer 1	Grassland Transfer 2	Grassland Transfer 3
GECP	0.0012 (0.0494)	-0.0340 (0.0631)	-0.0158 (0.0538)
Temdev	-0.0274 (0.0671)	-0.0598 (0.0743)	-0.0337 (0.0665)
Predev	-0.0020** (0.0010)	-0.0020** (0.0010)	-0.0017 (0.0011)
GECP × Temdev		0.0224* (0.0136)	
GECP × Predev			-0.0004 (0.0005)
Age	-0.0164** (0.0071)	-0.0164** (0.0071)	-0.0164** (0.0071)
Education	-0.0037 (0.0268)	-0.0047 (0.0267)	-0.0032 (0.0266)
Gender	0.4938 (0.3797)	0.4899 (0.3786)	0.4929 (0.3793)
Household size	-0.0161 (0.0649)	-0.0186 (0.0649)	-0.0187 (0.0652)
Grassland area	-0.0001 (0.0001)	-0.0001 (0.0001)	-0.0001 (0.0001)
Livestock endowment	0.0002 (0.0002)	0.0002 (0.0002)	0.0002 (0.0002)
Credit access	0.2731 (0.2590)	0.2626 (0.2605)	0.2689 (0.2593)
Grazing ban	-0.4805*** (0.1836)	-0.4966*** (0.1835)	-0.4916*** (0.1856)
Government surveillance	0.4867*** (0.1471)	0.5175*** (0.1469)	0.4913*** (0.1449)
Cooperative membership	0.2914 (0.2339)	0.2971 (0.2328)	0.2922 (0.2333)
Disaster	-0.2027 (0.1674)	-0.1866 (0.1673)	-0.2099 (0.1695)
Terrain	-0.0445 (0.1127)	-0.0445 (0.1125)	-0.0451 (0.1127)
Soil type	0.0156 -0.0253	0.0159 -0.0253	0.0156 -0.0252
Constant	-0.9598** -0.4548	-0.9152** -0.4533	-0.9232** -0.4588
Year fixed effects	yes	yes	yes
Province fixed effects	yes	yes	yes

Notes: Values in parentheses are robust standard errors clustered at the village level. Single, double, and triple asterisks (\*, \*\*, \*\*\*) indicate significance at the 10%, 5%, and 1% levels, respectively.

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