

Farmers' Perception of Climate Change in Alpine Ecologically Fragile Areas: A Case Study of the Gannan Plateau (Postprint)

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Abstract

As the most severe challenge currently facing humanity, climate change has already exerted serious negative impacts on the livelihoods of farmers in ecologically fragile regions, and clarifying farmers' perception of climate change is crucial for formulating effective climate change adaptation policies. Taking the Gannan Plateau as the study area and based on household survey data, this study constructs a farmer climate change perception index, analyzes the characteristics of climate change perception among farmers in the Gannan Plateau, and employs econometric models to analyze the key factors influencing farmers' climate change perception. The results show that: (1) Farmers in the Gannan Plateau have a stronger perception of temperature changes than precipitation changes, and have deeper memories of recent extreme weather events that are large-scale and severely impactful; (2) Farmers have relatively strong perceptions of the severity and likelihood of climate change, and also perceive relatively high adaptation costs and adaptation efficacy, but perceive weak self-efficacy. The perception index values for climate change severity, likelihood, adaptation efficacy, self-efficacy, and adaptation cost are 3.76, 3.34, 3.43, 2.85, and 3.53, respectively. Moreover, farmers in agricultural areas have the strongest risk perception and adaptation perception of climate change, followed by those in agro-pastoral areas, with those in pure pastoral areas being the weakest; (3) Climate change information, farmers' objective adaptive capacity, farmers' trust in social discourse, and adaptation incentives all influence farmers' climate change perception, among which adaptation incentive is the most critical influencing factor. It is positively correlated with farmers' perception of climate change adaptation efficacy and self-efficacy perception, but negatively correlated with risk perception and adaptation cost perception. Finally, relevant policy recommendations are proposed on how to improve the accuracy of farmers' climate change perception and enhance their capacity to cope with climate change.

Full Text

Preamble

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Farmers' Perception of Climate Change in High-Cold Ecologically Vulnerable Regions: A Case Study of the Gannan Plateau

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Abstract

Climate change represents one of the most severe challenges facing humanity today, exerting serious negative impacts on the livelihoods of farmers in ecologically vulnerable regions. Clarifying farmers' perceptions of climate change is crucial for formulating effective adaptation policies. This study analyzes the characteristics of climate change perception among farmers on the Gannan Plateau and employs econometric models to identify key factors influencing these perceptions. Based on household survey data from 539 households, we constructed a climate change perception index for farmers. The results reveal that: (1) Farmers' perception of temperature change is stronger than their perception of precipitation change, with 79.96% accurately sensing the warming trend over the past 30 years (consistent with meteorological data), while only 36.92% correctly perceived the precipitation trend (inconsistent with actual data). Farmers have vivid memories of recent extreme weather events with severe impacts. (2) Farmers exhibit strong perceptions of climate change severity, probability, adaptation efficacy, and adaptation costs, but weak self-efficacy perception. The indices for severity, probability, adaptation efficacy, self-efficacy, and adaptation cost perceptions are 3.76, 3.34, 3.43, 2.85, and 3.53, respectively. Farming area households show the strongest perceptions, followed by agro-pastoral areas, with pure pastoral areas showing the weakest. (3) Climate change information, objective adaptive capacity, trust in social discourse, and adaptation incentives all influence farmers' climate change perceptions, with adaptation incentives being the most critical factor. Finally, we propose policy recommendations to improve the accuracy of farmers' climate change perceptions and enhance their adaptive capacity.

Keywords: Gannan Plateau; farmers; climate change; perception; adaptation

Introduction

Global climate change has increased the vulnerability of social and natural ecosystems, posing enormous risks and challenges to human production and life. Developing effective adaptation strategies and models has become an urgent priority. Perception, as the foundation of human responsive action to climate change, influences public adaptation choices and affects the implementation effectiveness of adaptation policies and plans, playing a particularly critical role in human adaptation behavior. Farmers who rely on natural resources for their livelihood represent a vulnerable group in responding to climate change and are severely affected by its impacts. They are not only direct perceivers of climate change but also the choosers and beneficiaries of adaptation actions. Understanding farmers' climate change perception characteristics helps to better comprehend their response actions and formulate effective adaptation policies.

Given the importance of climate change perception to adaptation behavior, numerous scholars have studied public perceptions of climate change. To explain the relationship between climate change perception and adaptation, Grothmann and Patt proposed the Model of Private Proactive Adaptation to Climate Change (MPPACC), which decomposes individual climate change perception into risk perception and adaptation perception. Risk perception includes probability perception (the likelihood of future climate change) and severity perception (the degree of climate change impacts), while adaptation perception includes adaptation efficacy (perceived effectiveness of adaptation actions), self-efficacy (confidence in one's ability to implement adaptation), and adaptation costs (expected costs of adaptation actions). This model, which incorporates previously neglected adaptive capacity perceptions, better explains individual climate change perception characteristics and has been widely applied in climate change adaptation research.

Previous studies show that farmers have high concern for climate change and can accurately perceive recent climate trends and extreme weather changes through observations of temperature and grain production conditions, though this requires time. Most farmers can accurately perceive climate trends and extreme weather changes in recent years, but some have ambiguous perceptions due to individual objective background and environmental factors. Farmers have clearer perceptions of recent extreme weather events and short-term climate trends, but shallower understanding of climate change causes, though they perceive impacts more profoundly. They often judge long-term climate trends based on recent experiences and attribute climate change primarily to urban construction and industrial emissions. Some farmers also recognize impacts on ecosystem service functions. While these studies provide new insights into climate change perception and enhance understanding of cognitive elements in adaptive responses, less attention has been paid to the formation of climate change perception, requiring further investigation into key influencing factors and the roles of various

elements in perception formation.

The Gannan Plateau, located on the eastern edge of the Tibetan Plateau, is a typical high-cold ecologically vulnerable region and a sensitive area for global climate change. It serves as an important water source replenishment area for the upper Yellow River, making farmers' effective adaptation to climate change critical not only for regional sustainable development but also for ecological security in the upper Yellow River basin and even northern China. Climate change has severely impacted farmers' livelihoods in this region. Clarifying farmers' climate change perception characteristics and influencing factors in the Gannan Plateau is essential for formulating practical adaptation policies, selecting effective adaptation strategies, and is crucial for ecological security in the Yellow River basin and global climate change mitigation and adaptation.

Study Area

The Gannan Plateau is situated on the eastern edge of the Tibetan Plateau, with elevations mostly between 3,000–3,600 m. The region features a cold and humid climate with annual precipitation of 400–700 mm and average temperatures generally below 0°C. Vegetation is dominated by alpine meadows, shrubs, and mountain forests. The plateau's Yellow River watershed area reaches 3.057×10^4 km², with multi-year average water resources replenishing the Yellow River at 6.59×10^9 m³, making it not only the most important water source replenishment area for the upper Yellow River but also a key water conservation zone on the Tibetan Plateau whose water replenishment function plays a critical role in regulating water resources throughout the Yellow River basin.

In recent years, under the combined pressures of climate change and human activities, grassland resources have severely degraded, biodiversity has been lost, water conservation capacity has declined, and ecosystem service functions have sharply decreased, seriously affecting ecological security in the Yellow River basin and even northern China. The Gannan Plateau exhibits significant internal differentiation and can be divided into three agricultural ecological zones based on natural geography, resource endowments, and agricultural production characteristics: pure pastoral areas, agro-pastoral areas, and farming areas.

In pure pastoral areas, livelihoods depend primarily on animal husbandry, which accounts for 98.88% of total agricultural output value and 86.62% of total household income. In Maqu County, this proportion reaches as high as 75.77%, with per capita net income at ¥5,910.53. In agro-pastoral areas, households engage in both farming and animal husbandry, with planting and animal husbandry accounting for 56.78% and 32.46% of agricultural output value, respectively. Livestock, farming, and wage income constitute 23.36%, 22.56%, and 51.16% of total income, respectively, with per capita net income at ¥5,704.51. In farming areas, livelihoods depend mainly on crop production, which accounts for 52.05% of agricultural output value. Wage income and farming income con-

stitute 38.93% and 23.64% of total income, respectively, with per capita net income at ¥6,313.41.

[Figure 1: see original paper] Study area and survey points

Data Sources

The research team conducted household surveys in the Gannan Plateau using Participatory Rural Appraisal (PRA) tools including questionnaires and small group discussions to obtain required data and information. Given the dispersed residence of farmers and herders and the difficulty of interviews, stratified random sampling was used to select respondent households. A total of 539 valid questionnaires were collected with a 98.4% effective response rate.

The average age of household heads was 43.24 years, with an average farming experience of 24.15 years. Average household size was 4.78 people, with 2.93 laborers. Average per capita annual income was ¥5,976.15. The education level of laborers decreased progressively from farming areas to agro-pastoral areas to pure pastoral areas, with the proportion of laborers with primary school education or below being 36.16%, 59.72%, and 68.24%, respectively. Comparison with the 2012 Gannan Statistical Yearbook shows that although the number of surveyed households was relatively small, the sample characteristics reflect the basic situation of the study area and are representative.

Meteorological data were obtained from the China Meteorological Data Sharing Service System (<http://cdc.cma.gov.cn/home.do>), including daily climate data from Maqu (102.4°E, 33.59°N), Hezuo (102.9°E, 34.99°N), and Xiahe (104.1°E, 34.26°N) within Gannan, as well as from Linxia (102.98°E, 35.50°N) near Gannan, covering average temperature and precipitation data from 1981-2010.

Characteristics of surveyed households in the Gannan Plateau

Questionnaire Design

Based on Grothmann and Patt' s MPPACC model and preliminary interviews with village officials and farmers, we designed a climate change perception survey. The MPPACC model, grounded in psychology and behavioral economics, decomposes individual climate change perception into risk perception and adaptation perception. Risk perception includes severity perception (degree of climate change impacts) and probability perception (likelihood of future climate change). Adaptation perception includes adaptation efficacy (perceived effectiveness of adaptation actions), self-efficacy (confidence in one' s ability to implement adaptation), and adaptation costs (expected costs of adaptation actions). This model incorporates previously neglected adaptive capacity perceptions, en-

abling better explanation of individual climate change perception characteristics and has been widely applied in climate change adaptation research.

The survey content primarily included: (1) Basic household information (household head age, education level, etc.); (2) Farmers' perception of climate change trends and extreme weather trends, including temperature and precipitation change trends and perceptions of frequently occurring extreme weather such as rainstorms and droughts; (3) Farmers' risk perception of climate change, including severity and probability perceptions; and (4) Farmers' adaptation perception of climate change, including adaptation efficacy, self-efficacy, and adaptation cost perceptions.

Climate Change Perception Measurement

To quantitatively analyze differences in climate change perception among Gannan Plateau farmers, we introduced a Climate Change Perception Index. We used farmers' risk perception (including severity and probability perceptions) and adaptation perception (including adaptation efficacy, self-efficacy, and adaptation cost perceptions) from the MPPACC model as measurement indicators. When calculating the index, we first assigned values to each type of climate change perception, then averaged them across different regions. The formula is:

$$G_j = \frac{1}{n} \sum_{i=1}^n g_{ij}$$

where G_j represents the perception index for issue j , g_{ij} represents the perception value assigned to farmer i for issue j , and n is the number of farmers.

Measurement indicators and assignment values for farmers' climate change perception

Analysis Model of Factors Influencing Farmers' Climate Change Perception

We used multiple linear regression models in SPSS 17.0 to analyze factors influencing farmers' climate change risk perception and adaptation perception. Multiple linear regression models examine linear relationships between a dependent variable and multiple independent variables. The mathematical model is:

$$P = \beta_0 + \sum_{i=1}^n \beta_i X_i$$

where P is the dependent variable, X_i are independent variables, and β_i are regression coefficients. A positive coefficient indicates that the odds increase correspondingly with each unit increase in the independent variable, while a negative coefficient indicates decreasing odds.

Farmers' Perception of Climate Change Trends

Over the past 30 years, temperatures in the Gannan Plateau have shown an overall upward trend of 0.5°C/10a. A total of 79.96% of respondents accurately perceived this warming trend, consistent with meteorological data. The proportion of households perceiving temperature increase was highest in farming areas (84.86%), followed by agro-pastoral areas (80.36%), and lowest in pure pastoral areas (74.73%). Most farmers mentioned they primarily judge temperature increases based on clothing needs, heating timing, river thawing, outdoor ice formation, and timing of grass regrowth and crop planting. Some also mentioned hearing about global warming through mobile phones and television, which reinforced their perception of local warming.

In contrast, precipitation in the Gannan Plateau over the past 30 years showed a weak upward trend of 5.1mm/10a, but farmers' perceptions of precipitation change were inconsistent and unclear. Only 36.92% of respondents accurately perceived this trend. The proportion accurately perceiving increased precipitation was highest in agro-pastoral areas (41.67%), followed by pure pastoral areas (38.17%), and lowest in farming areas (31.35%). Most farmers in the Gannan Plateau have inaccurate perceptions of precipitation trends, deviating from meteorological data. This discrepancy likely arises because the precipitation increase is much smaller than the temperature increase and less noticeable, compounded by uneven spatiotemporal distribution of precipitation and interference from factors such as drought and water scarcity.

[Figure 2: see original paper] Trend of average temperature and precipitation in the Gannan Plateau over the past 30 years

Farmers' Perception of Extreme Weather

Extreme weather events occur frequently in the Gannan Plateau with severe impacts. A total of 72.17% of respondents believe the frequency of extreme weather is increasing, with proportions in pure pastoral, agro-pastoral, and farming areas being 77.38%, 69.89%, and 69.73%, respectively. Rainstorms are perceived as the most significant extreme weather event, with 51.58% of respondents believing they are increasing, and proportions in pure pastoral, agro-pastoral, and farming areas being 47.68%, 43.60%, and 42.86%, respectively.

Meteorological data show that both heavy precipitation and frequency in

the Gannan Plateau have increased over the past 30 years, with increases of 42.41mm/10a and 1.06 days/10a, respectively, making farmers' perceptions of increasing rainstorms relatively consistent with actual conditions. Many farmers noted that rainstorms cause severe damage to crops, houses, and roads, with landslides and debris flows triggered by heavy rainfall posing extreme threats to lives and property. Farmers in Zhouqu County particularly emphasized the enormous threat of landslides and debris flows from heavy rainfall. Farmers have vivid memories of recent extreme weather events but often cannot recall older or smaller-scale events, and some have even forgotten them entirely. For example, most respondents in Maqu County clearly remember the hail disaster in June 2012 that caused direct economic losses of ¥39.938 million and affected over 20,000 people, while respondents in Zhouqu County vividly recall the unprecedented rainstorm disaster in August 2010 and the subsequent massive debris flow.

Farmers' perception of climate change and extreme weather events in the Gannan Plateau

Farmers' Risk Perception of Climate Change

Farmers in the Gannan Plateau have strong severity perception of climate change, with a perception index of 3.76. A total of 62.99% of respondents believe that climate change and increasing extreme weather have seriously negatively impacted their production and life. Farming area households have the strongest severity perception (index 4.05), followed by agro-pastoral areas (3.63), with pure pastoral areas lowest (3.57). The proportions of respondents believing climate change seriously affects their livelihood are 74.05%, 57.8%, and 56.55% for farming, agro-pastoral, and pure pastoral areas, respectively. This strong severity perception stems from frequent extreme weather events such as rainstorms and hail, intensified by unsustainable practices like overgrazing and excessive logging that amplify climate change impacts on livelihoods.

Farmers also have strong probability perception of future climate change, with an index of 3.34. While 41.56% of respondents believe future climate change is unlikely, 15.4% believe it is extremely likely. Farming area households show the strongest probability perception (index 3.46), followed by agro-pastoral areas (3.41), with pure pastoral areas lowest (3.16). The proportions believing climate change is extremely likely are 48.81%, 46.31%, and 30.29% for farming, agro-pastoral, and pure pastoral areas, respectively, while those believing it unlikely are only 9.1%, 18.75%, and 18.64%, respectively.

Farmers' Adaptation Perception of Climate Change

Farmers in the Gannan Plateau perceive relatively strong adaptation efficacy, with an index of 3.43. A total of 47.68% of respondents believe that measures can mitigate negative climate change impacts, while only 13.73% believe they cannot. Farming area households have the strongest adaptation efficacy perception (index 3.82), followed by agro-pastoral areas (3.24), with pure pastoral areas lowest (3.20). The proportions believing measures can mitigate impacts are 69.19%, 37.63%, and 35.12% for farming, agro-pastoral, and pure pastoral areas, respectively. Farmers actively adopt effective measures to avoid climate risks and generally acknowledge the effectiveness of their actions. Most crop farmers report adjusting planting times and increasing irrigation as their most common and effective adaptation measures, while herders report reducing live-stock numbers and early transhumance as most effective.

However, farmers' self-efficacy perception is relatively weak, with an index of only 2.85. Just 16.7% of respondents believe they have strong adaptive capacity. Pure pastoral area households have the weakest self-efficacy perception (index 2.74), followed by agro-pastoral areas (2.89), with farming areas highest (2.9). The proportions believing they have strong adaptive capacity are only 12.5%, 17.2%, and 20% for pure pastoral, agro-pastoral, and farming areas, respectively. This weak self-efficacy contrasts with their strong risk perception, indicating farmers lack confidence in their adaptive capacity despite recognizing climate threats.

Farmers perceive relatively high adaptation costs, with an index of 3.53. A total of 55.84% of respondents believe adapting to climate change requires high costs. Farming area households perceive the highest costs (index 3.75), followed by agro-pastoral areas (3.58), with pure pastoral areas lowest (3.26). The proportions believing adaptation costs are high are 70.27%, 56.55%, and 40.86% for farming, agro-pastoral, and pure pastoral areas, respectively. Most farmers report that adaptation measures such as purchasing feed, pesticides, fertilizers, improved varieties, new technologies, and improving agricultural facilities have increased their production costs and family burdens.

Farmers' risk perception and adaptation perception of climate change in the Gannan Plateau

Relationship Between Climate Change Risk Perception and Adaptation Perception

To further clarify the relationship between risk perception and adaptation perception among Gannan Plateau farmers, we used Pearson correlation analysis to calculate correlation coefficients. Farmers' severity perception and probability perception show significant positive correlation ($r=0.369$, $p<0.01$), indicating

that the more severe farmers perceive climate change impacts on their production and life, the more likely they believe future climate change will occur.

Adaptation efficacy perception, self-efficacy perception, and adaptation cost perception are significantly positively correlated with each other. Adaptation efficacy perception and self-efficacy perception show significant positive correlation ($r=0.184$, $p<0.01$), as do adaptation efficacy and adaptation cost perceptions ($r=0.325$, $p<0.01$), and self-efficacy and adaptation cost perceptions ($r=0.079$, $p<0.01$). Climate change risk perception is significantly positively correlated with adaptation efficacy perception ($r=0.254$ for severity, $r=0.319$ for probability, $p<0.01$) and adaptation cost perception ($r=0.303$ for severity, $r=0.260$ for probability, $p<0.01$), but negatively correlated with self-efficacy perception ($r=-0.076$ for severity, $r=-0.047$ for probability, $p<0.01$). This indicates that stronger risk perception leads to greater confidence in adaptation action effectiveness but also higher expected adaptation costs, while simultaneously reducing confidence in their own adaptive capacity.

Correlation matrix of farmers' risk perception and adaptation perception in the Gannan Plateau

Key Factors Influencing Farmers' Climate Change Perception

Farmers' climate change perception results from the combined effects of social, economic, and environmental factors. In Grothmann and Patt' s MPPACC model, climate change information, personal risk experience, objective adaptive capacity, and adaptation incentives collectively influence individual climate change perception. Personal perception is always influenced by acquired information, past risk experiences, cognitive biases, and intuitive judgments. When climate change information is untimely or inaccurate, individuals may misestimate climate change risks, leading to inappropriate risk and adaptation perceptions, such as underestimating adaptation efficacy or overestimating adaptation costs. Individual perception also depends on social discourse, as farmers often obtain climate risk and adaptation information through social communication. The timeliness and accuracy of information services, as well as trust in climate change social discourse, typically affect their perceptions. Farmers' objective adaptive capacity also plays a key role in climate change perception and adaptation behavior. When lacking objective adaptive capacity, farmers form lower self-efficacy perceptions, constraining effective adaptation actions.

To identify factors influencing climate change risk and adaptation perceptions in the Gannan Plateau, we used climate change severity, probability, adaptation efficacy, self-efficacy, and adaptation cost perceptions as dependent variables. Independent variables included climate change information, objective adaptive capacity, trust in social discourse, and adaptation incentives, with regional dummy variables also introduced.

Climate change information was characterized by the timeliness and accuracy of information acquisition channels. Trust in social discourse was measured by farmers' trust in climate change information released by experts, authorities, and media. Adaptation incentives were characterized by whether the government provides technical extension services, meteorological information services, and climate change early warning services.

Following Nelson et al., we view farmers' adaptive capacity as the expected outcome of various livelihood capitals. Based on the resource endowments, ecological environment, and farmers' livelihood characteristics of the Gannan Plateau, we designed a farmers' livelihood capital measurement index: natural capital was represented by per capita farmland and grassland area; financial capital by per capita income; social capital by number of relatives; human capital by overall household labor capacity and average education level of laborers; and material capital by household fixed asset ownership. All indicators were standardized using the range standardization method before summation and averaging.

Description of model variables

Factors Influencing Climate Change Risk Perception

Examining the relationship between these variables and climate change severity perception, the model fit is 0.216, with the F-statistic significant at the 0.01 level, indicating the selected variables explain 21.6% of variance in severity perception. Climate change information and trust in social discourse are significantly positively correlated with severity perception, while adaptation incentives are significantly negatively correlated. More information channels, timelier information, larger farmland and grassland areas, and more relatives all strengthen severity perception. Greater trust in expert, authority, and media discourse also enhances severity perception. However, access to technical extension, meteorological information, and early warning services reduces severity perception. Adaptation incentives have the greatest impact (standardized coefficient -0.250), followed by climate change information (0.174), both significant at the 0.01 level.

For probability perception, the model fit is 0.205, with the F-statistic significant at the 0.01 level, explaining 20.5% of variance. Climate change information and trust in social discourse are significantly positively correlated with probability perception, while material capital and adaptation incentives are significantly negatively correlated. More information channels, timelier information, higher education levels, and more relatives strengthen probability perception. Greater trust in authority and media discourse also enhances probability perception. However, more household fixed assets and access to technical extension, meteorological information, and early warning services reduce probability perception. Climate change information has the strongest effect (standardized coefficient 0.292), followed by adaptation incentives (-0.258), both significant at the 0.01 level.

The regression coefficients for farming area dummy variables are positive for

both severity and probability perceptions, indicating that farming area households have stronger risk perceptions than agro-pastoral households, while pure pastoral households have weaker perceptions.

Factors Influencing Climate Change Adaptation Perception

For adaptation efficacy perception, the model fit is 0.632, with the F-statistic significant at the 0.01 level, explaining 63.2% of variance. Climate change information, trust in social discourse, and adaptation incentives are all significantly positively correlated with adaptation efficacy perception. More information channels, timelier information, more household laborers, higher education levels, higher income, more relatives, and greater trust in expert, authority, and media discourse all strengthen adaptation efficacy perception. Access to technical extension, meteorological information, and early warning services also enhances adaptation efficacy perception. Human capital has the greatest impact (standardized coefficient 0.411), followed by adaptation incentives (0.218), both significant at the 0.01 level.

For self-efficacy perception, the model fit is 0.364, with the F-statistic significant at the 0.01 level, explaining 36.4% of variance. Climate change information, trust in social discourse, and adaptation incentives are all significantly positively correlated with self-efficacy perception. More information channels, timelier information, more relatives, and greater trust in expert, authority, and media discourse strengthen self-efficacy perception. Access to technical extension, climate change information, and early warning services also enhances self-efficacy perception. Climate change information has the strongest effect (standardized coefficient 0.314), followed by adaptation incentives (0.237), both significant at the 0.01 level.

For adaptation cost perception, the model fit is 0.117, with the F-statistic significant at the 0.01 level, explaining 11.7% of variance. Human capital is significantly positively correlated with adaptation cost perception, while material capital and adaptation incentives are significantly negatively correlated. More household laborers and higher education levels increase perceived adaptation costs, while more household fixed assets and access to technical extension, climate change information, and early warning services decrease perceived costs. Human capital has the greatest impact (standardized coefficient 0.277), followed by material capital (-0.134), significant at the 0.01 and 0.05 levels, respectively.

The regression coefficients for farming area dummy variables are positive for both adaptation efficacy and adaptation cost perceptions, while those for pure pastoral areas are negative, indicating that farming area households have stronger adaptation efficacy and cost perceptions than agro-pastoral households, while pure pastoral households have weaker perceptions.

Model parameters for factors influencing farmers' climate change perception in the Gannan Plateau

Conclusions and Discussion

Clarifying farmers' climate change perceptions is crucial not only for understanding their adaptation actions but also for implementing effective adaptation policies and mitigating livelihood vulnerability under climate change impacts. Based on household survey data, this study analyzed climate change perception characteristics and influencing factors among Gannan Plateau farmers.

The study found that farmers have strong perception of temperature change but weak perception of precipitation change, consistent with Hou Xiangyang's findings in Inner Mongolia that herders perceive temperature changes more accurately than precipitation changes. A total of 79.96% of farmers accurately perceived warming over the past 30 years, basically consistent with meteorological data, while only 36.92% perceived the precipitation trend correctly, deviating from meteorological data. This discrepancy arises because precipitation increases in the Gannan Plateau over the past 30 years are much smaller than temperature increases, less noticeable, and subject to interference from uneven spatiotemporal distribution and drought factors.

Farmers have vivid memories of recent extreme weather events with severe impacts but fuzzy memories of older or smaller-scale events, consistent with Shen Xingju's findings. Human perception is influenced by memory and emotion, with limited recall time for climate change and strong anxiety and crisis feelings under climate risk impacts. Rainstorm perception is particularly strong, with many farmers reporting frequent rainstorms causing severe damage to farmland, houses, and roads, especially landslides and debris flows threatening lives and property. However, responses to drought or extreme weather before 2000 were not strong.

Farmers have profound feelings about negative climate change impacts, believing future climate change is likely and adaptation costs are high, yet remain relatively confident about expected effectiveness of adaptation measures. The indices for severity, probability, adaptation efficacy, self-efficacy, and adaptation cost perceptions are 3.76, 3.34, 3.43, 2.85, and 3.53, respectively. Farming area households have the strongest risk and adaptation perceptions, followed by agro-pastoral areas, with pure pastoral households weakest. Risk perception depends primarily on the degree of climate change impacts on individuals or families. Climate change has intensified grassland degradation, damaged agricultural infrastructure, increased agricultural costs, and threatened life and property safety in farming areas, creating the greatest climate risks and strongest risk perceptions. Farming area households also have relatively higher education levels (only 36.16% with primary school or below) and more diverse income sources and information access, leading to stronger perceived adaptation efficacy and self-efficacy.

In contrast, pure pastoral households depend mainly on grassland resources,

facing primary climate risks of grassland degradation and increased livestock disease incidence, resulting in less strong risk perceptions and lower perceived adaptation costs. However, pure pastoral households have generally low education levels (68.24% with primary school or below), traditional mindsets, poor capacity to accept new things and technologies, single livelihood strategies, limited income sources, and weak objective adaptive capacity, leading to the lowest perceived adaptation efficacy and self-efficacy.

Adaptation incentives are the most critical factor influencing farmers' climate change perceptions. Incentives can enhance farmers' climate change cognition and adaptation. Government-provided climate change information projects and subsidy policies, as well as specific policies developed by experts in particular fields (such as enhanced climate-related communication or insurance network development), enrich farmers' information channels, improve information timeliness and accuracy, increase climate observation frequency, enhance confidence in adaptation, and promote proactive adaptation actions. Even when farmers lack risk awareness, adaptation incentives can motivate adaptation behavior. The study found that adaptation incentives significantly affect all dimensions of climate change perception in the Gannan Plateau. More incentives lead to weaker risk perception, lower perceived adaptation costs, stronger confidence in adaptation effectiveness, and greater self-efficacy. However, 13.7% of respondents reported no meteorological information services in their villages, and few mentioned climate change early warnings via radio or other means, indicating inadequate preparation for climate change and highlighting the urgent need for governments at all levels to improve adaptation incentive mechanisms.

Recommendations and Outlook

How farmers can accurately perceive climate change, enhance adaptive capacity, and reduce adaptation costs is not only a concern for farmers themselves but also a primary consideration for governments in climate change adaptation decision-making. In the future, local governments in high-cold ecologically vulnerable regions should vigorously develop specialized climate change research, improve rural meteorological infrastructure, and provide timely and accurate meteorological information services. They should strengthen extreme weather forecasting and early warning systems, increase publicity and education on climate change knowledge, and enhance farmers' cognitive levels through climate change education activities. Technical extension and skills training should be actively carried out to broaden farmers' income channels and improve adaptive capacity. Cooperative organization construction should be strengthened, with increased assistance and support for disaster-affected farmers and enhanced subsidies.

This study only analyzed the Gannan Plateau, examining farmers' risk and adaptation perception characteristics and briefly analyzing the influence of climate

change information, objective adaptive capacity, social discourse, and adaptation incentives. However, the model fit is relatively low, indicating other factors influence farmers' climate change perceptions. Future research should further explore key influencing factors, analyze how farmers obtain and perceive risk information, clarify the role of various elements in perception formation, investigate the formation mechanism of farmers' climate change perceptions, examine the relationship between perception and adaptation strategy selection, reveal how perception influences adaptation decision-making, and systematically assess climate change impacts on agricultural production and farmers' livelihoods.

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Note: Figure translations are in progress. See original paper for figures.

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