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

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Abstract

Climate change impacts are particularly pronounced for agricultural populations whose livelihoods are based on natural resources. Identifying farmers' climate change adaptation needs is crucial for formulating effective climate change adaptation policies and enhancing farmers' adaptive capacity. Based on 500 farmer survey questionnaires, this study analyzes the climate change adaptation needs of farmers in different regions and with different livelihood strategies in the Gannan Plateau, and employs a binary logistic regression model to examine the key factors influencing farmers' adaptation needs. The results indicate that: (1) In the process of adapting to climate change, farmers in the Gannan Plateau exhibit the strongest demand for infrastructure, followed by information and production technology; (2) Adaptation needs vary among farmers in different regions. Specifically, both pure pastoral area farmers and agricultural area farmers show the strongest demand for infrastructure, while farmers in semi-agricultural and semi-pastoral areas demonstrate the strongest demand for information; (3) Adaptation needs also differ among farmers with different livelihood strategies. Specifically, pure agricultural households have the strongest demand for credit and insurance, while both first-type and second-type diversified households show the strongest demand for infrastructure; (4) Natural capital and physical capital are key factors influencing farmers' demand for production technology, natural capital and human capital are key factors affecting farmers' demand for information, human capital and financial capital are key factors impacting farmers' demand for infrastructure, and natural capital, human capital, financial capital, physical capital, and social capital are all key factors influencing farmers' demand for credit and insurance. Policy recommendations for enhancing farmers' capacity to adapt to climate change are proposed.

Full Text

Preamble

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Adaptation Needs of Farmers to Climate Change in an Ecologically Vulnerable Alpine Region: A Case Study of the Gannan Plateau

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Abstract

Climate change impacts are particularly significant for agricultural populations whose livelihoods depend on natural resources. Understanding farmers' adaptation demands is crucial for developing effective climate change adaptation policies and enhancing their adaptive capacity. Based on 500 household surveys, this paper analyzes the adaptation needs of different regional and livelihood strategy farmers in the Gannan Plateau and identifies key influencing factors using binary logistic regression models. Results show that: (1) In adapting to climate change, infrastructure demands are most intense among Gannan Plateau farmers, followed by information and production technology demands. (2) Adaptation needs vary significantly across regions: both pastoral and farming area farmers show the strongest infrastructure demands, while agro-pastoral area farmers have the most intense information demands. (3) Different livelihood strategies also lead to varying adaptation needs: pure farmers have the strongest credit and insurance demands, while both type I and type II diversified households show the strongest infrastructure demands. (4) Natural and physical capital are key factors affecting production technology demands; natural and human capital significantly influence information demands; human and financial capital are critical for infrastructure demands; and material and social capital are key determinants of credit and insurance demands. Finally, policy recommendations are proposed to enhance farmers' climate change adaptation capacity.

Keywords: climate change; farmer; adaptation needs; livelihood capital; Gannan Plateau

Introduction

Climate change has exacerbated vulnerability in many countries and regions, with particularly pronounced impacts on agricultural populations whose livelihoods depend on natural resources. These communities rely heavily on natural ecosystems for their survival strategies and daily lives, yet lack the necessary financial support and technical capacity to address increasing climate risks [1]. Adaptation has emerged as a key policy option for mitigating negative climate change impacts [2], attracting widespread attention from both academia and policymakers. Major global scientific programs—including the World Climate Research Programme (WCRP), International Human Dimensions Programme (IHDP), International Geosphere-Biosphere Programme (IGBP), and DIVERSITAS—have all identified scientific adaptation to future climate change as a critical principle for sustainable human development [3].

However, planned adaptation does not automatically guarantee successful outcomes, and adaptive capacity does not necessarily translate into effective adaptation. Individuals and collectives face numerous barriers and needs when seeking the most appropriate and sustainable adaptation actions [4]. The UNDP (2007) notes that developing countries face major constraints in planning and implementing adaptation, including limitations in information, protective infrastructure, social security, and disaster risk management systems [5]. Farmers, as the primary economic units in rural areas, bear the most direct impacts of climate change and represent the most important agents of adaptation. Research confirms that information, financial support, and leadership provided by local governments and civil society organizations can effectively enhance farmers' autonomous adaptation mechanisms [6].

Traditional rural public services, based on top-down supply decisions, lack effective expression mechanisms, leading to mismatches between public product supply and farmer expectations and failing to meet demands for public services and products essential for effective climate adaptation [7]. Studies also reveal that the uneven impacts of climate change and unequal adaptive capacities among different groups create significant differences in adaptation needs [8–9], which is crucial for developing effective adaptation policies and successful adaptation planning. There is an urgent need to clarify the specific adaptation needs of different regions and farmer types.

The Gannan Plateau, located on the eastern edge of the Tibetan Plateau, is a typical ecologically vulnerable alpine region highly sensitive to climate change and human activities. In recent years, the region has experienced significant warming and drying trends, severe grassland degradation, accelerated soil erosion, expanding desertification, and biodiversity loss [10]. These changes have intensified the livelihood vulnerability of farmers who depend on cropland, grassland, and medicinal resources, severely constraining sustainable regional development. To enhance farmers' adaptive capacity and mitigate adverse climate impacts, it is essential to identify their adaptation needs. This paper analyzes

the adaptation needs of different regional and livelihood strategy farmers in the Gannan Plateau using household survey data and binary logistic regression models to identify key influencing factors, aiming to provide insights for effective climate adaptation policy in ecologically vulnerable alpine regions.

Study Area

The Gannan Plateau is situated on the eastern edge of the Tibetan Plateau, with most areas at elevations of 3,000–3,600 m. The terrain is higher in the northwest and lower in the southeast, with a cold and humid climate. The annual average temperature is generally below 3°C, with long winters and no summers in most areas, and a frost-free period of less than 140 days. Annual precipitation ranges from 400–700 mm. Vegetation is dominated by alpine meadows, shrublands, and mountain forests. With 127 rivers covering a drainage area of 3.057×10 km², the plateau supplies 65.9×10 m³ of water annually to the Yellow River, making it a critical water source area for the upper Yellow River basin and playing an irreplaceable role in maintaining water resources and ecological security in the region

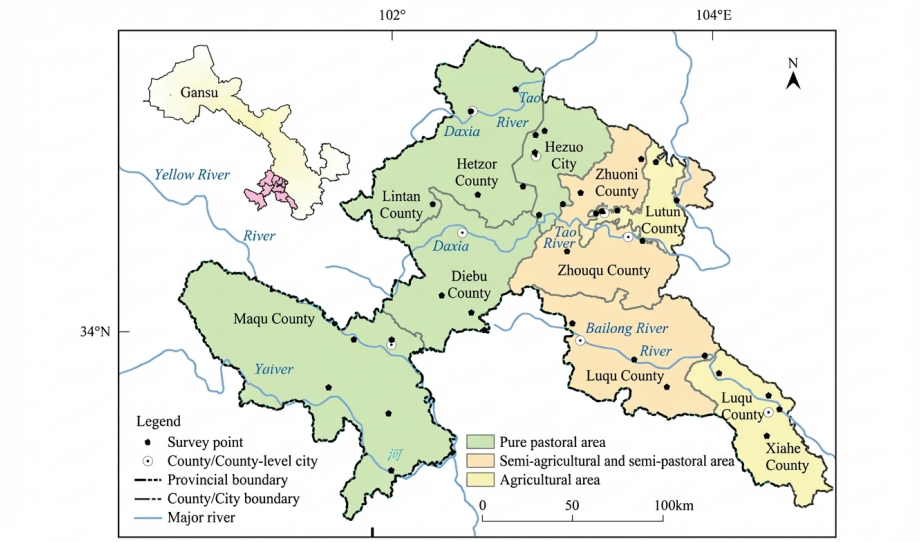

Figure 1: Figure 1

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The total land area of the Gannan Plateau is 4.5×10 km². Influenced by differences in natural and human environments, internal regional differentiation is significant. The Min-Die mountainous area in the southeast has well-developed forests and natural grasslands, with crops maturing twice a year or three times every two years. The northeastern plateau area is dominated by cold-resistant

crops with short growing periods such as highland barley and oats, as well as some legume forage grasses. The western Luma-xia plateau basin is dominated by alpine shrub meadows, with grasslands mostly being steppe meadows. Based on agricultural production conditions, the region can be divided into three agricultural ecological zones: pure pastoral areas, agro-pastoral areas, and farming districts. In pastoral areas, per capita grassland area is 9.55 hm^2, with animal husbandry accounting for 52.05% of total income and per capita net income at ¥4,198.99. In agro-pastoral areas, per capita grassland and cropland areas are 3.79 hm^2 and 0.12 hm^2 respectively, with farming, animal husbandry, and wage income accounting for 32.46%, 23.36%, and 23.64% of total income respectively, and per capita net income at ¥4,313.47. In farming districts, per capita cropland area is 0.13 hm^2, with farming and wage income accounting for 38.93% and 49.69% of total income respectively, and per capita net income at ¥4,094.51.

Data Sources

Field surveys were conducted in the Gannan Plateau in July–August 2014 for over 30 days. County-level data on resources, environment, and socio-economic statistics were first collected, followed by Participatory Rural Appraisal (PRA) using questionnaires and small group discussions. Stratified random sampling was used to select respondent households. Due to the vast territory and low population density, interviews were challenging, with a total of 500 households surveyed. The average interview duration was 2–3 hours per questionnaire. A total of 479 valid questionnaires were recovered (95.8% response rate), including 134 from pastoral areas, 193 from agro-pastoral areas, and 152 from farming districts. To ensure accuracy, 5 Tibetan university students served as translators. The average age of household heads was 43.36 years, with an average farming period of 24.09 years and average household size of 4.42 persons. Per capita annual income was ¥4,198.99. Although the sample size is relatively small, comparison with statistical data shows it is representative of local households .

The questionnaire was designed based on pre-survey interviews with village officials and farmers. Survey content mainly included: (1) Livelihood capital (natural, human, financial, physical, and social capital); (2) Farmers' adaptation needs to climate change, including production technology needs (e.g., improved breeding, pest control, cultivation techniques), information needs (e.g., disaster warnings, agricultural market information, employment information), infrastructure needs (e.g., water, electricity, transportation), and credit/insurance needs (e.g., low-interest loans, pension insurance).

Farmer Type Classification

To analyze adaptation needs across different farmer groups, households were classified based on the proportion of non-agricultural income to total household income, following methods used by domestic and international scholars [11]. Households with less than 10% non-agricultural income were classified as pure

farmers (Type I), those with 10–50% as type I diversified households (Type II), and those with more than 50% as type II diversified households (Type III). In the Gannan Plateau, pure farmers, type I diversified households, and type II diversified households accounted for 20.78%, 47.95%, and 31.27% of the sample respectively.

Livelihood Capital Measurement Indicators and Calculation

The sustainable livelihood framework proposed by DFID classifies livelihood capital into five types: natural, human, financial, physical, and social capital [13]. Drawing on domestic and international livelihood capital quantification studies [14–16] and considering the ecological environment and living customs of the Gannan Plateau, the indicator system was adjusted to suit local conditions.

Natural capital refers to natural resource stocks from which resource flows and services beneficial to livelihoods can be derived. Given that farming district households mainly engage in cropping, agro-pastoral households in both cropping and livestock raising, and pastoral households primarily in animal husbandry, cropland and grassland resources profoundly affect livelihood activities. Therefore, per capita cropland area and per capita grassland area were used to evaluate natural capital.

Human capital refers to knowledge, skills, labor capacity, and health status possessed by individuals. Since male and female labor are equally important in the Gannan Plateau, household labor capacity and education level of adult laborers were used as indicators. Education level is particularly important for accessing non-agricultural livelihoods.

Financial capital refers to cash available for consumption and production, as well as accessible loans and personal borrowings. Given that local financial capital mainly comes from cash income, per capita cash income, access to credit (from formal and informal channels), and access to free cash assistance were used as measurement indicators.

Physical capital refers to material assets used in economic production excluding natural resources, including infrastructure and production tools. Considering local conditions, livestock numbers, housing conditions, and fixed assets (including productive tools and durable consumer goods) were used as indicators.

Social capital refers to social networks utilized for implementing different livelihood strategies. In the Gannan Plateau, kinship networks play significant roles in grassland leasing, management, and protecting herders' rights. Social interaction helps farmers obtain climate adaptation information, and trust in others facilitates cooperation. Therefore, kinship networks, trust in others, and opportunities for social interaction were used as measurement indicators .

To overcome information overlap among indicators, the entropy method was used to determine weights. Since survey data have different dimensions,

ranges, and magnitudes, indicators were standardized using the range standardization method. The livelihood capital index for each category was calculated as:

$$T_i = \sum_j W_{ij} \times I_{ij}$$

where W_{ij} is the weight of the j-th indicator for the i-th capital type, and I_{ij} is the standardized score of the indicator.

Variable Selection

Household or individual capital status is fundamental to understanding available livelihood choices, strategies, and risk response capabilities, and serves as an entry point for rural poverty alleviation and development interventions [17]. Farmers with different livelihood capitals have varying risk response capacities and thus experience different degrees of climate change impacts. Those with more capital typically have more options and can better cope with climate risks, while capital-poor households often lack capacity to address climate shocks and appear vulnerable and helpless [18-21]. Different capital endowments lead to varying adaptation needs [16, 22].

Higher natural capital stock may lead to larger production scales, triggering demands for public goods that enhance agricultural efficiency and reduce climate disaster losses [23-24]. Human capital affects farmers' climate change awareness and adaptive capacity, influencing their public goods demands [25-26]. Financial capital affects payment capacity, leading to differences in effective demand for public goods [27-28]. Physical capital, as both a production tool and household wealth that can be converted into financial capital, influences adaptation approaches and needs [29]. Social capital, embedded in interpersonal relationships, trust, and social networks, significantly impacts income, employment, and risk resistance [30] and also affects adaptation needs.

Farmers' public goods demands are influenced by household head age, education, household income, and diversification level, as well as social networks [10, 31-32]. Based on existing research, this study selects natural, human, financial, physical, and social capital indicators as independent variables, with farmers' primary adaptation need as the dependent variable, and introduces regional dummy variables. Binary logistic models are used to analyze livelihood capital impacts on adaptation needs, with parameters estimated using maximum likelihood. Farmers' primary adaptation needs are categorized as: (1) production technology demand, (2) information demand, (3) infrastructure demand, and (4) credit/insurance demand. The model is specified as:

$$\ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_m x_{im}$$

where P_i is the probability of event y_i occurring, x_{im} are explanatory variables,

and β_m are regression coefficients. Positive coefficients indicate that a one-unit increase in the variable increases the odds ratio, while negative coefficients decrease it.

Results Analysis

Adaptation Needs by Region

In adapting to climate change, Gannan Plateau farmers have the strongest demand for infrastructure (59.04% of households), followed by information services (54.47%) and production technology services (51.64%). This reflects farmers' high sensitivity to climate impacts, given their reliance on agriculture and animal husbandry, combined with low local economic development levels and insufficient production and living infrastructure. Transportation infrastructure deficits are particularly acute, as the region depends entirely on road transport with low technical standards and poor network connectivity. Interviews revealed that about 30% of natural villages lack access roads, and rural highways suffer from numerous bridges and culverts deficiencies, severely constraining effective climate adaptation.

Median tests show significant differences in production technology, infrastructure, and credit/insurance demands across regions (Chi-square test $p < 0.05$). Further analysis reveals that pastoral area farmers have the strongest infrastructure demands (57.18%), particularly for transportation facilities (69.72% of pastoral households), followed by production technology demands (56.29%), especially livestock breeding techniques (51.05% of pastoral households). Agro-pastoral area farmers have the strongest information demands (57.80%), particularly for disaster warning information (49.13%), followed by production technology demands (56.02%), especially cropping and livestock techniques (48.61%). Farming district farmers have the strongest infrastructure demands (67.00%), particularly for transportation (67.54%), followed by information demands (62.44%), especially employment information (54.65%) .

Adaptation Needs by Livelihood Strategy

Median tests show significant differences in information and credit/insurance demands across different livelihood strategies ($p < 0.05$). Pure farmers have the strongest credit/insurance demands (61.90%), particularly for low-interest and interest-free loans (65.95%), followed by production technology demands (56.04%), especially cropping and livestock techniques (51.50%). Type I diversified households have the strongest infrastructure demands (66.02%), particularly for water and electricity facilities (66.35%), followed by information demands (51.46%), especially disaster warning information (55.31%). Type II diversified households also have the strongest infrastructure demands (51.85%), particularly for transportation (58.76%), followed by information demands (51.69%), especially employment information (65.94%) .

Key Factors Influencing Farmers' Climate Adaptation Needs

Logistic regression analysis reveals that multicollinearity among explanatory variables is minimal (correlation coefficients < 0.20). All four models show explanatory power, with Nagelkerke R^2 values of 0.132, 0.118, 0.087, and 0.102 respectively, Chi-square statistics of 44.469, 39.369, 31.225, and 34.886 (all significant at $p < 0.01$), and prediction accuracies of 76.5%, 75.3%, 62.9%, and 70.1% .

Natural and physical capital are positively correlated with production technology demand at the 0.05 and 0.10 significance levels respectively, indicating that higher natural and physical capital stocks increase technology demand. Natural and human capital are positively correlated with information demand at the 0.05 and 0.10 levels respectively, suggesting that increases in these capitals enhance information demand. Farming district farmers have stronger information demands than agro-pastoral area farmers.

Human capital is positively correlated with infrastructure demand at the 0.05 level, while financial capital is negatively correlated at the 0.10 level, indicating that higher human capital increases infrastructure demand, but higher financial capital decreases it. Pastoral area farmers have stronger infrastructure demands than agro-pastoral area farmers.

Natural and human capital are positively correlated with credit/insurance demand at the 0.05 and 0.10 levels respectively, while financial, physical, and social capital are negatively correlated at the 0.05 and 0.10 levels. This suggests that increases in natural and human capital enhance credit/insurance demand, but increases in financial, physical, and social capital reduce it. Farming district farmers have stronger credit/insurance demands than agro-pastoral area farmers .

Discussion

Regional Characteristics and Adaptation Needs

Due to differences in natural environment, resource endowments, and livelihood characteristics across pastoral, agro-pastoral, and farming areas, adaptation needs vary significantly. Farming district farmers have stronger employment information demands than agro-pastoral area farmers because they generally have higher education levels, smaller per capita cropland areas, more surplus labor, and insufficient natural capital output to meet basic living needs, resulting in higher out-migration rates. The survey found that 67.15% of farming district farmers cannot access adequate employment information, relying mainly on relatives and friends, and hope the government can provide relevant information to broaden employment channels—consistent with findings by Chen Zongsheng [33] and Xin Ling [34].

Pastoral area farmers have stronger transportation infrastructure demands due to the vast territory and low population density (e.g., Maqu County' s density is only 0.17 persons/km²), resulting in limited infrastructure coverage. Road conditions are particularly poor, with a city road density of only 0.1 km/km², main highway good-road rate of 57.27%, and local road good-road rate of only 17%. This severely constrains farmers' exchanges with the outside world and timely access to meteorological, market, and social support information. The survey found that 79.71% of pastoral farmers consider travel inconvenient, and 63.37% travel to county seats or markets less than once a month. Since adaptation need fulfillment depends on public goods supply [24] and different regions have varying public goods endowments, adaptation needs differ accordingly [22].

Livelihood Strategies and Adaptation Needs

Pure farmers have stronger demands for agricultural technology and credit/insurance because their income primarily comes from high-risk cropping and livestock raising that are significantly climate-sensitive. They need effective agricultural techniques to address climate change and credit/insurance to mitigate climate risks—consistent with research showing that higher agricultural income shares increase technology demand and insurance willingness [25, 35-36].

Type I diversified households have stronger transportation infrastructure demands because, while still climate-sensitive, they engage in some non-farm activities requiring convenient transport to market products or pursue off-farm work, helping them avoid climate risks and enhance adaptive capacity.

Type II diversified households have stronger employment information demands because they mainly rely on off-farm work, transport, and services. The survey found that 72.84% of type II households consider their work unstable and need to constantly seek new employment opportunities. Livelihood diversification has become an important climate adaptation strategy in developing countries, reducing vulnerability and enhancing response capacity [37-39].

Natural Capital and Adaptation Needs

Farmers with more abundant natural capital have stronger demands for information and credit/insurance, consistent with Zhuang Lijuan [23], Du Peng [25], and Zhou Xiaobin [24]. Larger cropland and grassland areas increase dependence on natural resources and climate change vulnerability, creating greater needs for technology, information, and insurance services to reduce negative impacts. Effective production techniques and climate/market information help mitigate climate impacts, while credit and insurance help farmers recover from meteorological disasters.

Human Capital and Adaptation Needs

Farmers with richer human capital have stronger demands for information, infrastructure, and credit/insurance, consistent with Du Peng [25] and Guo Yu [26]. In the Gannan Plateau, labor quantity is the main source of human capital [16]. Households with more labor are more likely to have surplus workers, increasing employment information demands. Better-educated farmers have deeper understanding of how meteorological information, infrastructure, and credit/insurance can enhance production efficiency and reduce climate risks, thus generating stronger demands for these services.

Financial Capital and Adaptation Needs

Farmers with richer financial capital have weaker demands for infrastructure and credit/insurance, consistent with Zhou Xiaobin [24] and Wang Dingxiang [28]. Higher household income enhances climate risk resistance and reduces disaster impacts, thereby lowering demand for disaster-reduction infrastructure. Greater financial capital also reduces the likelihood of capital shortages and the need for credit/insurance services.

Material Capital and Adaptation Needs

Farmers with richer material capital have stronger production technology demands but weaker credit/insurance demands. In the Gannan Plateau, household fixed assets are generally limited to simple production and living needs and cannot serve as collateral for formal financial institutions [29]. However, households with more livestock have stronger demands for breeding and disease prevention technologies to address climate risks.

Social Capital and Adaptation Needs

Farmers with richer social capital have weaker credit/insurance demands. Social capital embedded in kinship, trust, and social networks is an important resource that can improve borrowers' repayment incentives [40], reduce adverse selection [41] and default risk [42], and function as collateral in financial transactions [43]. Farmers with rich social capital can easily meet capital needs through social networks or informal institutions, reducing demand for formal financial services [44]. Conversely, farmers lacking social capital have stronger demand for formal credit.

Conclusions

Based on household survey data from the Gannan Plateau, this study analyzed adaptation needs across different regions and livelihood strategies and their influencing factors, reaching the following conclusions:

1. In adapting to climate change, Gannan Plateau farmers have the strongest

infrastructure demands, followed by information and production technology demands.

2. Regional differences in adaptation needs exist: pastoral and farming area farmers have the strongest infrastructure demands, while agro-pastoral area farmers have the strongest information demands. Pastoral area farmers have the strongest infrastructure demands followed by production technology; agro-pastoral area farmers have the strongest information demands followed by production technology; farming district farmers have the strongest infrastructure demands followed by information.

3. Livelihood strategy differences also affect adaptation needs: pure farmers have the strongest credit/insurance demands followed by production technology; both type I and type II diversified households have the strongest infrastructure demands followed by information.

4. Natural and physical capital are key factors affecting production technology demands; natural and human capital significantly influence information demands; human and financial capital are critical for infrastructure demands; material and social capital are key determinants of credit/insurance demands.

Recommendations

As a typical ecologically vulnerable alpine region, the Gannan Plateau faces severe challenges from climate warming to both natural and social ecosystems, particularly affecting agricultural and pastoral populations. Given the complexity of adaptation contexts and resource constraints, adaptation strategies must balance multiple objectives and be tailored to regional and livelihood-specific needs and influencing factors. Priority should be given to providing production technology, infrastructure, and credit/insurance services.

For production technology, strengthen guidance and training for pure farmers and large-scale operators in improved breeding, pest control, and field/grassland management. For information services, improve information platforms to disseminate meteorological disaster warnings, employment, and agricultural market information through radio, television, mobile messages, and other channels, with emphasis on disaster warnings for agro-pastoral areas and employment information for farming districts. For infrastructure, prioritize transportation development in pastoral and farming areas and information network construction in agro-pastoral areas, while improving water and electricity facilities.

For credit/insurance, increase government and financial institution provision of small loans, encourage diversified credit and insurance services from non-governmental organizations, and develop credit rating systems that incorporate social capital to avoid information asymmetry problems. Enhancing human capital through vocational education and climate awareness is crucial. Subsidies or installment plans for agricultural facilities can help increase material capital

conversion and cash income. Developing rural cooperatives, agricultural disaster prevention associations, and rural financial mutual aid organizations can broaden social capital sources and enhance climate and market risk response capacity.

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