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# The impact of the reform of grassland property rights system on the allocation of production factors for herders in Qinghai, China

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This study conducted field visits across six prefectures in Qinghai Province, China, where grassland animal husbandry is the main mode of production and operation. Through discussions with government departments and surveys of 137 herder households, combined with local government survey archives from previous years, a fixed-effects model was established from the herders' perspective across four time periods to examine how Qinghai's grassland property rights reform and its supporting policies have influenced herders' production factor inputs. The results show that: Property rights reform has a positive impact on the investment in available natural grasslands and artificial forage lands. However, as time progresses, the positive effect on natural grassland input is suppressed, while the impact on artificial grasslands strengthens over time. The reform has a significant positive effect on the input of labor for technical and managerial personnel, and this positive impact continues to grow as the reform advances. Conversely, the impact on labor input for herding is negative, but the negative effect gradually weakens with the progression of the reform. Property rights reform increases the breeding costs of the basic livestock herd, but this effect weakens over time. The reform has a significant positive impact on the input for forage and disease prevention, with the positive effect intensifying as the reform progresses. The impact on the input for basic livestock equipment is negative. The reform has a positive effect on grassland management techniques and livestock feeding practices, though the effect on the input of information technology is not significant. Additionally, the accompanying policy reforms, the characteristics of pastoral households, and transportation conditions also have varying degrees of influence on the input of production factors.

KEYWORDS

**grassland, herder, input, production factors, property rights**

## Introduction

The grassland is one of the most important terrestrial ecosystems globally, playing an indispensable role in maintaining ecological balance, providing food, and regulating climate (Tuo et al., 2024). China is one of the countries with the largest grassland area and the highest pastoral population in the world. The total grassland area in China is 264 million hectares, accounting for about 12% of the global grassland area and 42% of China's land area. Qinghai Province, located in the core region of the Tibetan Plateau, has a grassland area of 31.6 million hectares, making it one of China's five major pastoral regions (Liu et al., 2022). For the country, grassland is a resource; however, for pastoralists, it is an asset. These dual attributes of grassland determine its crucial role in economic and social development (Zhang et al., 2024a). Property rights are the legal form of economic ownership relations, encompassing ownership, possession, control, use, income, and disposal rights of legitimate property (Wu et al., 2025). Zhou and Li (2019) conducted a case study in China's grassland areas, examining the definition of grassland property rights and its impact on ecological protection and social equity. They demonstrated that clear land property rights and defined land use rights are fundamental for promoting the rational use of grassland resources and ecological protection. Xu and Li (2020) discussed the transformation of land ownership systems in China's pastoral areas and found that property rights reform directly affects the management and utilization of land resources. Clearly defining grassland property rights—especially clarifying the holders of various rights and their boundaries—is key to achieving the sustainable use of pastoral land resources. Since 1949, the reform of grassland property rights in Qinghai has undergone several stages: Mutual Aid Cooperatives (1949–1958), People's Commune System (1958–1981), Household Joint Production Responsibility System (1982–2008), and Grassland Livestock Cooperatives System (2009 to present). Each period had its own historical context (Gou et al., 2025). After 1995, with the gradual increase in the pastoral population and the expansion of market economic activities, the "three pastoral issues" became increasingly severe, particularly reflected in the worsening ecological environment in pastoral areas, the sharp rise in pastoral costs, and the growing hardship of pastoral livelihoods (Wu et al., 2017; Harris, 2009).

The increasingly deteriorating grassland environment has attracted widespread attention both domestically and internationally. Numerous studies have been conducted on grassland ecology, grazing management, and the restoration of degraded grasslands, as well as on improving forage productivity (Austrheim et al., 2016; Wang et al., 2022; Zheng et al., 2015). Scholars have conducted extensive research in regions such as Tibet, Sichuan, Qinghai, and Gansu. The vast majority of domestic and international researchers attribute part of the cause to the property rights system reforms that began in the 1980s. They argue that the implementation of the "Household Joint Production Responsibility System" led to small-scale family-run operations, where cattle and sheep were confined to small plots of grassland. This restriction limited their ability to migrate long distances according to seasonal changes, climate, and grassland conditions. Continuous overuse without rest led to the degradation of the grasslands (Adams et al., 2003). In 2008, in response to issues such as the narrow grazing range, the registration and certification of land-use rights (An, 2021), grassland degradation, and low agricultural productivity, the central government began to emphasize the transfer of land-use rights. The 17th National Congress of the Communist Party of China adopted the "Decision on Major Issues Concerning Rural Reform and Development," which proposed granting farmers more secure and comprehensive land-use rights and establishing a sound land transfer market (Shi and Zhao, 2023). Since then, land transfer has been recognized and prioritized by local governments (Yuan and Luo, 2022). In 2008, Qinghai Province took the lead in introducing the "Measures for the Transfer of Grassland Contract Management Rights in Qinghai Province" and launched pilot projects for ecological animal husbandry across the province (Gai, 2005). These initiatives aimed to incentivize investment through clearer property rights definitions and rights allocation, integrate grassland contract management rights to achieve moderate-scale operations, optimize resource allocation, and improve the income levels of pastoralists (Zhou and Wu, 2023; Li and Chen, 2021).

North (1990) elaborated on the decisive role of property rights institutions as fundamental frameworks shaping economic performance. He emphasized that clearly defined and effectively enforced property rights can reduce transaction costs, provide incentives, and thereby promote capital investment and technological innovation. According to the research by (Wu et al., 2025), the implementation of the new round of land certification has improved the efficiency of cross-sectoral allocation of rural labor, particularly between agricultural and non-agricultural industries. This finding suggests that land certification facilitates the optimal allocation of labor resources across sectors, thus promoting the diversification of rural economies. Zhang et al. (2024b) pointed out that the perceived security of grassland contracting rights significantly influences herders' behavior regarding grassland transfer. The clarity of herders' understanding of their contracting rights directly determines their enthusiasm for land circulation and their willingness to make long-term investments. Shi and Zhao (2023) further explored the social capital factors affecting herders' grassland leasing-in behavior, emphasizing the critical role of relational networks and social interactions in the process of grassland transfer. Effective social networks can reduce the transaction costs of participation, enhance trust among herders, and thereby promote the optimal allocation of grassland resources. Zhou and Wu (2023) highlighted in their study on

the high-quality development of farmers' and herders' cooperatives in Qinghai, noted that cooperatives, as key organizational forms of herders' economies, not only enhance the efficiency of production factor allocation but also promote the sustainable use of grassland resources through specialized management and technical support. Deininger and Feder (2009) systematically summarized a large body of empirical evidence on land registration reforms worldwide, highlighting that well-functioning land titling and registration systems can enhance land-related investments, improve access to credit (through collateral), promote land transfer (optimizing labor allocation), and reduce disputes (lowering transaction costs). These studies collectively provide theoretical support for the present research, indicating that the implementation of property rights reforms and accompanying policies can, through multiple optimization mechanisms, encourage herders to achieve a positive transformation in both grassland resource utilization and labor allocation.

The grassland property rights reform in Qinghai Province is based on the fundamental institutional framework of "state ownership of grasslands and household contracting and management rights (Huang et al., 2018)." Within this framework, cooperatives have realized the joint ownership and reorganization of property rights. While the ownership of grasslands remains vested in the state, herders voluntarily form cooperatives and entrust their individual grassland contracting and management rights—namely, the rights of use—to the cooperative for unified planning and utilization. The cooperative then distributes the returns based on the amount of production materials contributed by each member, thereby altering the structure of income and benefit rights. Since the initiation of the reform in 2008, Qinghai's property rights reform has been implemented continuously for 15 years (2008–2023). Existing studies on the reform's impact on herders' input of production factors have primarily focused on short-term effects, case studies, or qualitative analyses, with a lack of quantitative assessment of the long-term impacts. In particular, there remains no systematic understanding of how the reform has influenced the structure of labor and technological investment over time. Most prior research has concentrated on the initial policy response mechanisms, neglecting the cumulative effects and marginal diminishing trends of factor allocation that have emerged over the 15-year period of continuous reform. Therefore, it is imperative to conduct an analysis based on longitudinal (panel) data to systematically examine the dynamic effects of property rights reform on herders' allocation of production factors. Especially under the institutional context where stabilized grassland contracting rights coexist with cooperative-based large-scale operations, it is crucial to explore the process of labor transition from traditional grazing to non-pastoral employment and specialized livestock production. Based on this, this paper conducts a field study involving visits to government departments such as the Forestry and Grassland Bureau, Animal Husbandry Bureau, and Veterinary Bureau in six counties, as well as surveys of 137 herder households. It analyzes the research archive data from government departments and organizes the findings from the team's field visits, this research adopts a micro-level perspective and divides the reform period into four stages (Respectively, 2009; 2014; 2019; 2023) to construct an econometric model. The model empirically examines how the grassland property rights reform and its supporting policies since 2008 have affected herders' input in land, capital, labor, and technology, aiming to provide both theoretical foundations for future research and empirical evidence to support government decision-making in deepening property rights reform.

# Materials and methods

## Study areas

The grassland animal husbandry operation in Qinghai Province is mainly concentrated in the six autonomous prefectures shown in the map, namely: Haixi Prefecture, Haibei Prefecture, Hainan Prefecture, Huangnan Prefecture, Guoluo Prefecture and Yushu Prefecture. Two villages were selected from each prefecture-level city for on-site visits and investigations (Figure 1). And a detailed description of the situation of each village within the state was provided.

Haixi Prefecture: Meilong Village, after the establishment of the cooperative, the winter and spring pastures were divided into 25 rotational grazing areas, with a grazing period of 205 days. The autumn grassland is divided into 31 rotational grazing areas, with a grazing period of 90 days. The summer grassland is divided into 31 rotational grazing areas, with a grazing period of 70 days. Haxiwa Village is a purely pastoral village with a total of over 90,500 ha of grassland, of which 22,700 ha can be utilized. After the establishment of the cooperative, the principle of "determining livestock based on grassland" was adhered to, and the number of livestock in the entire village decreased from nearly 50,000 to 10,000.

Haibei Prefecture: Dayu Village is a typical pastoral village. After the shareholding system reform of the cooperative, 6,300 ha of grassland and 5,512 livestock were integrated. It actively integrated into the secondary and tertiary industries and built new tourist hotels, etc. Ningxia Village is 42 km away from the county seat and is a pure pastoral village. The cooperative has integrated 13,200 ha of grassland in the form of 50 mu of grassland as one share and 10 sheep as one share, including 5,750 ha of winter and spring grassland and 7,513 ha of summer and autumn grassland. The total number of livestock in stock is 18,900 heads (sheep, horses).

Hainan Prefecture: Lade Village is a traditional pastoral village with a grassland area of 24,700 ha. After the

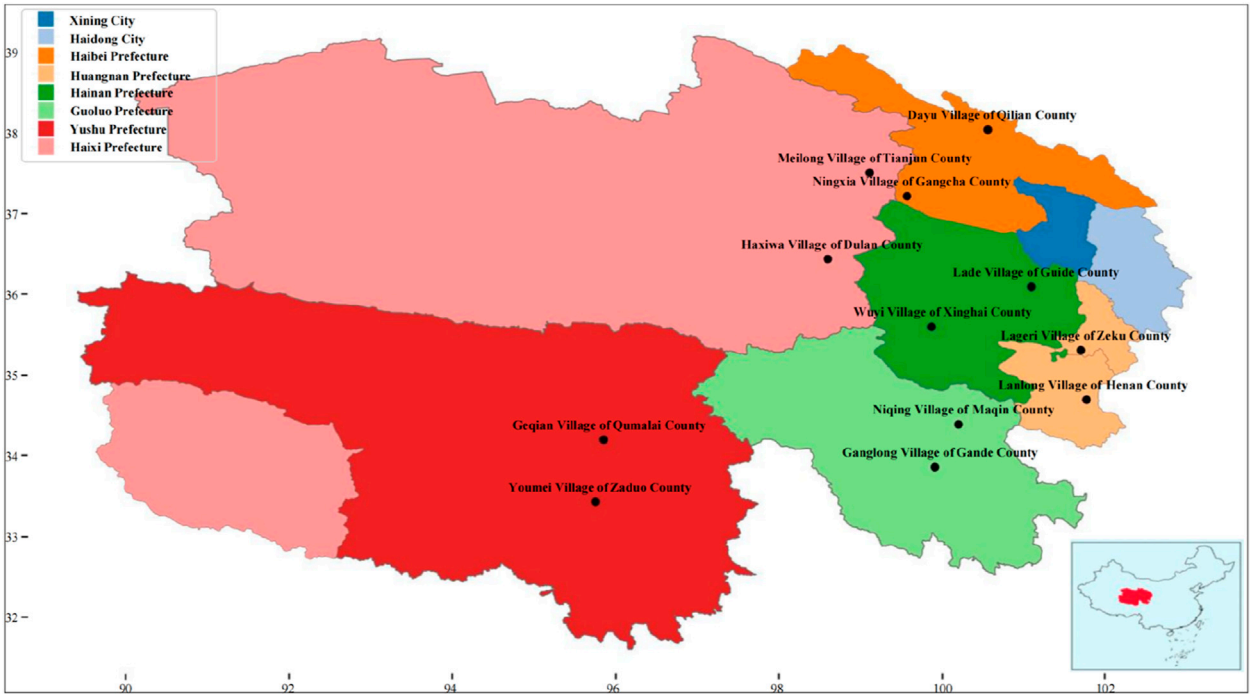


FIGURE 1
Geographical location of the study area.

establishment of the cooperative, the village has implemented rotational grazing based on winter-spring grassland and summer-autumn grassland. At the same time, the livestock breed has been updated from Ora sheep to Tibetan Xi sheep, and the wool, skin and meat have been deeply processed to extend the industrial chain and increase the output value. Wuyi Village Cooperative has invested in 3,511.8 ha of grassland. The 133 ha of farmland it has invested in and transferred will be used to grow 120 ha of oats and 13 ha of barley. A total of 3,981 sheep were invested. Among the 2,753 ewes that were invested, they were divided into four breeding groups and a rotational grazing model based on zoned areas and a combination of pen feeding and grazing were implemented.

Huangnan Prefecture: Lageri Village is a typical pastoral village. Lageri Village has 4 cooperatives under its jurisdiction, with a grassland area of 6,013 ha and 6,404 livestock. The cooperatives also run 1 hotel, 1 restaurant, 1 direct-sale store for livestock products, and 2 pen feeding bases. Lanlong Village is 19 km away from the county seat. The village has 12,400 ha of available grassland and currently has 10,226 livestock in stock. It is an observation base for organic livestock products industry and a demonstration site for ecological organic animal husbandry industry in Qinghai Province.

Goluo Prefecture: Niqing Village is a purely pastoral village where Tibetan people live in clusters. It is about 150 km away from the county seat, with an average altitude of 4,200 m. The village has a grassland area of 45,900 ha. The cooperative vigorously develops the industrialized breeding of white Tibetan sheep and at the same time processes livestock products such as butter, yogurt, beef and mutton on a large scale. Ganglong Village with an average altitude of 3,950 m. After the establishment of the joint-stock cooperative, the grassland was classified into three types: prohibited grazing, available and black soil beach. According to the principle of 6.67 ha of available grassland as one share, the total shares of the cooperative amount to 51,133 shares. At the same time, develop the secondary and tertiary industries, and establish fresh milk processing plants, milk source bases, vegetable greenhouses, etc.

Yushu Prefecture: Youmei Village is a purely pastoral village with an altitude of over 4,500 m. It is the main area for yak grazing. The cooperative has integrated a total of 11,300 ha and adopted a management approach of group breeding, unified rotational grazing, and unified market release, achieving large-scale and scientific development in animal husbandry. Geqian Village has an average altitude of about 4,500 m. It centrally manages 1,500 yaks and 2,280 Tibetan sheep, forming an integrated industrial system covering livestock breeding, processing and sales of livestock products. Its business scope includes characteristic agricultural and livestock products such as Cordyceps sinensis, ginseng fruit, dried meat and butter.

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TABLE 1 Statistics of basic data of the surveyed samples.

| Study area | Study site | The start time of the reform | Cooperative operation mode | Joined the cooperative (household) | Surveyed households (household) |
|---|---|---|---|---|---|
| Haixi Prefecture | Meilong village | 2008 | Shareholding cooperative management model | 72 | 12 |
| | Haxiwa village | 2009 | Integrated development of diversified operations | 41 | 15 |
| Haibei prefecture | Dayu village | 2009 | Shareholding cooperative management model | 50 | 12 |
| | Ningxia village | 2008 | Shareholding cooperative management model | 78 | 10 |
| Hainan prefecture | Lade village | 2010 | Shareholding cooperative management model | 71 | 15 |
| | Wuyi village | 2010 | Shareholding cooperative management model | 47 | 12 |
| Huangnan prefecture | Lagri village | 2011 | Shareholding cooperative management model | 181 | 15 |
| | Lanlong village | 2010 | Shareholding cooperative management model | 119 | 10 |
| Goluo prefecture | Niqing village | 2010 | Shareholding cooperative management model | 35 | 8 |
| | Ganglong village | 2009 | Proxy grazing management model | 178 | 11 |
| Yushu prefecture | Youmei village | 2009 | Proxy grazing management model | 197 | 7 |
| | Geqian village | 2010 | Shareholding cooperative management model | 45 | 10 |

Approximately 90% of the surveyed cooperatives adopt the shareholding cooperative development model, hence the majority of sampled cooperatives operate under this model. ① The shareholding cooperative development model is characterized by herders contributing livestock and contracted grassland management rights as shares, implementing specialized labor division, quantifying production indicators, compensating labor based on work performed, and distributing profits according to shareholding proportions. ② The contract grazing development model (also referred to as the proxy grazing model) is defined by unified internal management within the cooperative. Some members lease their contracted grassland to livestock producers for paid use or entrust livestock to them for grazing. Profit-sharing arrangements are mutually agreed upon, and livestock producers manage production independently. ③ The integrated diversified development model involves unified internal management by the cooperative, where both the shareholding and contract grazing systems coexist. This model exhibits strong pastoral characteristics, high replicability, and clear developmental orientation, representing an integrated and adaptive form of grassland livestock management in pastoral areas.

## Data selection

From May 2024 to May 2025, field investigations and interviews were conducted with staff members from the Forestry and Grassland Bureau, Animal Husbandry Bureau, and Veterinary Bureau across six autonomous prefectures in Qinghai Province, where grassland animal husbandry serves as the primary mode of production. Historical survey data from government archives for the years 2009, 2014, and 2019 were collected, to compile panel data for these 3 years. Based on recommendations from local officials, a sample of 137 pastoral households was selected for field visits within villages under each prefecture's jurisdiction to collect 2023 data (Table 1). It is important to note that while only 137 household heads were statistically recorded, all family members participated in the survey process. With an average of five members per household, more than 650 herders were involved in the field investigation. It should be noted that the selection of these 4 years is based on their correspondence with the four key stages of grassland property rights reform. The reform was implemented starting in 2008, with 2009 marking the first year after its implementation. From 2009 to 2014, the government strengthened the property rights reform, promoting large-scale transfer of grassland use rights, which represented the mid-stage of the reform. After 2014, the registration of grassland contract management rights gradually began, and following the consolidation of land use rights transfer, the rights of herders, such as their usufruct rights, were subsequently adjusted. Therefore, 2019 represents the stage of institutional consolidation, while 2023 is the most recent year before the survey, offering a better reflection of the outcomes of property rights reform over the past 15 years.

TABLE 2 Variable description and definition.

| Influencing factors | Variables | Variable definition | Variable description |
|---|---|---|---|
| Characteristics of herders | Age of the head of household | Continuous variable | The average age of the respondents |
| | The occupation type of the household head | 0: Herders; 1: Cadre | Subject to household registration |
| | The educational level of the household head | 0: Below junior high school; 1: Junior high schooland above | Received by the respondents |
| Natural Resources input | The average area of natural grassland per household | Average value | Annual average value |
| | The average area of artificial grassland per household | Average value | Annual average value |
| Labor input | Herders' labor force (person-days) | Continuous variable | Annual average value |
| | Technical personnel labor force (person-days) | Continuous variable | Annual average value |
| | Management personnel labor force (person-days) | Continuous variable | Annual average value |
| Capital input | Breeding cost of basic livestock herds (yuan) | Continuous variable | Annual average value |
| | Feed input (yuan) | Continuous variable | Annual average value |
| | Mechanized equipment | Continuous variable | Annual average value |
| | Epidemic prevention and control | Continuous variable | Annual average value |
| Technical Input | Grassland management technology | 1: Get better; 2: No change; 3: Deterioration | Compared with that before 2008 |
| | Livestock breeding techniques | 1: Get better; 2: No change; 3: Deterioration | Compared with that before 2008 |
| | Information technology | 1: Get better; 2: No change; 3: Deterioration | Compared with that before 2008 |
| Supporting reforms | Property rights reform | 0: Not started; 1: Start | Compared with that before 2008 |
| | Implementation of supporting policies | 0: No; 1: Yes | Compared with that before 2008 |
| | Traffic conditions | 1: Get better; 2: No change; 3: Deterioration | Compared with that before 2008 |
| | Market information | 1: Get better; 2: No change; 3: Deterioration | Compared with that before 2008 |

## Variable settings

In this study, the term grassland property rights reform primarily refers to the clarification of ownership and usage rights, the stabilization of contracting rights, the liberalization of operational rights, and whether the registration and certification of contracted management rights have been carried out, as well as whether such rights have been transferred or integrated. The input of production factors is analyzed from four dimensions: grassland input, labor input, capital input, and technology input. Grassland input includes the average area of natural grassland available for grazing and the average area of artificial forage land cultivated per household. Labor input covers herding labor (daily grazing, feeding management, and epidemic prevention), technical labor (veterinarians, breeders, and grassland management specialists), and managerial labor (farm managers, marketing staff, and cooperative supervisors). Capital input consists of the breeding costs of the basic herd (core breeding animals such as bulls, rams, and foundation females), forage and feed expenditures, investments in infrastructure and equipment (hay sheds, barns, mowers, balers, milking machines, etc.), and spending on epidemic prevention and control (vaccines, veterinary drugs). Technology input includes grassland management techniques (rotational grazing, rest grazing, reseeding, fertilization), feeding technologies (scientific feed formulation, stage-based feeding, introduction of superior breeds, artificial insemination, genetic improvement), and information technologies (GPS-based grazing tracking, Io T monitoring). In addition, supporting policy reforms are considered, including the implementation of complementary measures such as mortgage loans secured by grassland management rights, livestock insurance, and grassland ecological compensation policies, as well as external factors like transportation conditions (distance and road quality to county seats) and market information flow (price and demand forecasts). Details are shown in Table 2.

## Econometric model

The dataset used in this study is a short (unbalanced) panel, with herders "$i = 1, \ldots, 137$" as the cross-sectional units and years ∈ {2009, 2014, 2019, 2023} as the time dimension. The dependent variable "$y_{it}$" represents the input indicator of herder "$i$" in year "$t$". The key explanatory variable "$policy_{it}$" denotes the property rights reform, participation in the reform, or policy intensity (represented by a dummy variable). The control variables "$x_{it}$" include time-varying household or environmental characteristics (e.g., implementation of supporting policies, transportation conditions, and access to market information). Strictly time-invariant variables (such as gender) are absorbed by individual fixed effects and therefore excluded from the baseline regression (Fisher, 1922). Variables that may vary over time (e.g., education level or occupational type) are included in "$x_{it}$" using their period-specific values (Mundlak, 1978). To control for unobserved individual heterogeneity and common year shocks, a two-way fixed effects (FE) model is employed:

$$y_{it} = \beta x_{it} + \gamma policy_{it} + \theta_i + \lambda_t + \varepsilon_{it}$$

where "$\theta_i$" is the herder fixed effect (Herder FE) and "$\lambda_t$" is the year fixed effect (Year FE). The coefficients $\beta$ and $\gamma$ are identified from within-herder variation over time, thereby mitigating bias from time-invariant omitted variables. The year fixed effects absorb contemporaneous macro-level shocks such as aggregate price changes and overall policy intensity. The control variable "$x_{it}$" specifically includes Household size (number of family members), controlling for labor supply differences; Years of education of the household head, reflecting human capital levels; Livestock size (measured in sheep units), capturing production scale and resource endowment; Grassland contract area, representing land resources and utilization capacity; Reform participation (dummy variable), accounting for the influence of social organization and market access; Distance to the county seat, controlling for market accessibility and transaction cost differences. These variables are selected based on prior empirical studies on grassland management and herder economic behavior (e.g., Li et al., 2019; Wang et al., 2021) to mitigate heterogeneity in resources, production conditions, and environments that may confound policy effect estimates.

Since residuals may exhibit serial correlation and heteroskedasticity within herders, the baseline model employs herder-level clustered robust standard errors. For robustness checks, higher-level clustering (e.g., at the village or cooperative level) and wild-cluster bootstrap methods are also reported to test robustness under a limited number of clusters. Including both a linear time trend and year dummies would lead to perfect collinearity, as the linear trend would be fully absorbed by year fixed effects (Wooldridge, 1999). Therefore, the baseline specification omits the global linear trend. The policy timing and duration are instead represented by segmented dummy variables to capture dynamic effects, avoiding collinearity while illustrating pre- and post-policy trajectories. A Hausman test is used to compare fixed and random effects models, with results supporting the fixed effects specification (test statistics and p-values are reported in the Appendix) (Wallace and Hussain, 1969). The study reports Within, Between, and Overall $R^2$ and $F$-statistics, and conducts diagnostics for intragroup correlation and heteroskedasticity, with clustered robust standard errors applied accordingly.

# Results

## Qualitative descriptive analysis of survey results

### Changes in the age of household heads engaged in grassland animal husbandry

According to our survey statistics, the average household size among the sampled herder families is five persons. The age of household heads engaged in grassland animal husbandry is mainly concentrated between 30 and 55 years (Figure 2), with a mean age of approximately 45. Over time, as the years of property rights reform progressed, the average age of household heads gradually decreased. Notably, after 2015, with the deepening of the reform, local governments within the prefectures began to recognize that the effective management of cooperatives required educated personnel. Consequently, administrative departments restructured the leadership of cooperatives under their jurisdiction, appointing returned college graduates as principal managers. This shift has contributed to a visible trend of younger cooperative leaders and herder household heads. In our survey, the youngest household head was 30 years old, indicating a gradual rejuvenation of the population engaged in animal husbandry. The grassland livestock cooperative system, which has emerged through the process of property rights reform, has optimized the local industrial structure and established a "company + cooperative + herder" operational framework. This model has attracted an increasing number of young people to participate in grassland livestock production, promoting both industrial modernization and generational renewal in pastoral areas.

### Educational attainment of household heads

Before 2019, the educational level of household heads was generally at or below junior middle school. After 2019, however, the distribution gradually shifted toward junior middle school and above (Figure 3).

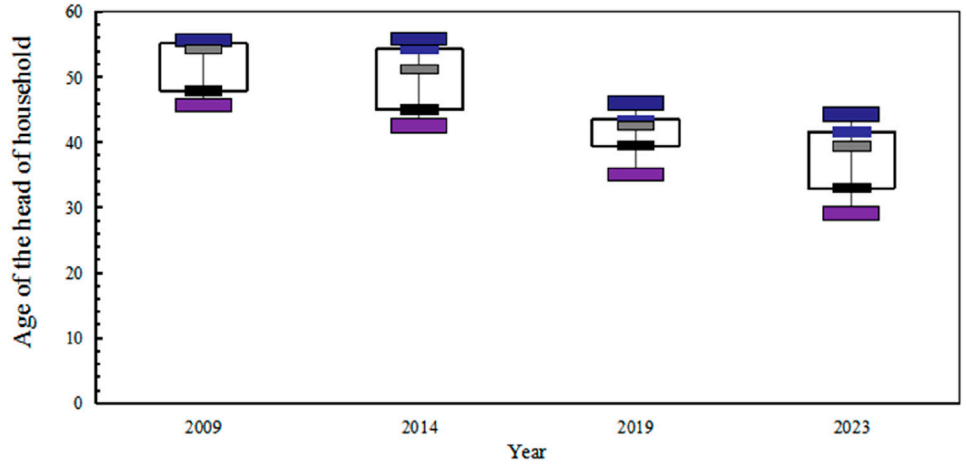


FIGURE 2
The change of the age of the head of household.

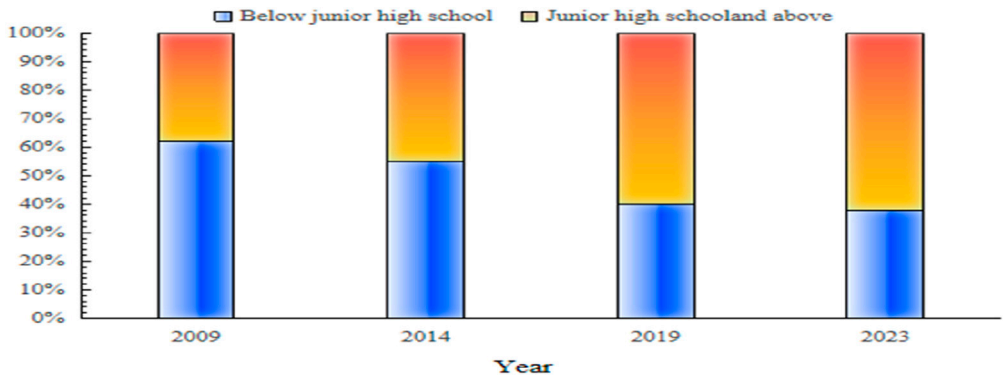


FIGURE 3
The change in the educational level of the household head.

This change is largely attributable to government initiatives that provided preferential policies for returning college graduates. For instance, local governments offered low-interest entrepreneurship loans to graduates of technical and vocational colleges who returned to their hometowns to start businesses. Many of these returnees were appointed as principal managers of local cooperatives. As a result, a number of unemployed or underemployed vocational and junior college graduates were drawn back to engage in cooperative-based livestock production. Although the proportion of household heads with education at or above junior middle school has increased, the majority remain concentrated at the secondary vocational (technical school) level. Many of them entered vocational schools directly after junior middle school without progressing to high school. Only a small fraction of household heads have completed high school or full-time university education. In particular, in Guoluo Prefecture and Yushu Prefecture, communication during our fieldwork was often challenging, as many herders were not fluent in Mandarin Chinese.

## Changes in grassland inputs for grazing

According to our survey data, along with the progression of property rights reform, the usable grassland area among the 137 sampled households ranges from a minimum of 13.33 ha to a maximum of 53.33 ha. The local government conducts grassland productivity assessments every three to 5 years and implements grazing bans or closures on severely degraded pastures, designating them as non-usable areas. For grasslands that are moderately degraded or in good condition, the government determines the number of rotational grazing days and establishes a theoretical livestock carrying capacity based on grass-livestock balance principles (Peng, 2015). Livestock

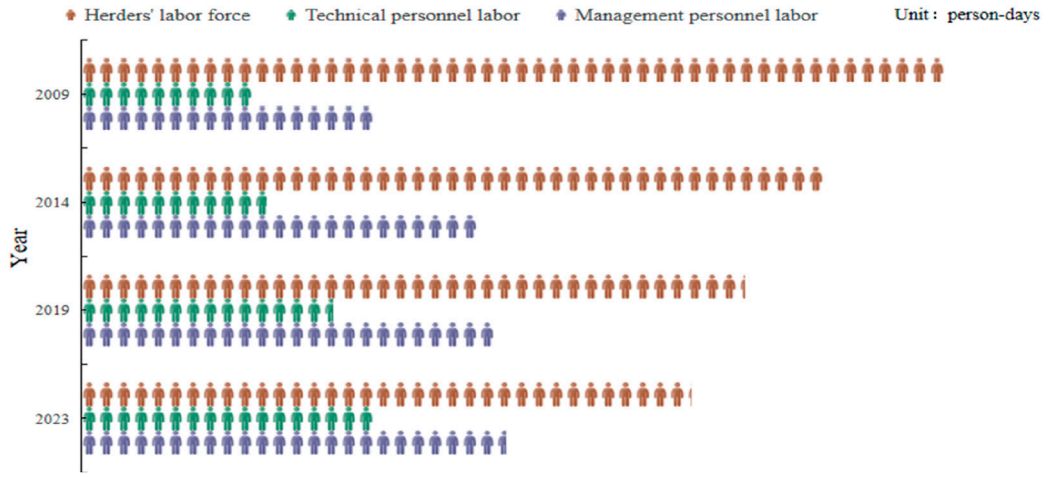


FIGURE 4
Changes in labor input.

exceeding the approved carrying capacity are required to be sold or removed from the system. As a result, the sustainable utilization capacity of natural grasslands has continuously improved over the past 15 years. Herders have gradually recognized the importance of developing artificial forage grasslands, leading to a steady expansion in cultivated forage areas. Among the 137 surveyed households, 23 have no artificial grassland and rely on purchasing forage and feed for supplementary feeding. For the remaining 114 households, the area of cultivated grassland ranges from 0.087 ha to 0.93 ha. The main forage crops planted include Elymus nutans (awnless brome), oats, and barley.

## Changes in labor input among herding households

According to the survey statistics, labor input from herders engaged directly in grazing accounts for approximately 88%–96% of the total labor input among sampled households (Figure 4). Over time, with the advancement of property rights reform, the proportion of labor devoted to grazing has gradually declined. This shift can be attributed to the establishment of cooperatives, which, through democratic elections, selected experienced herders to serve as full-time herding personnel responsible for livestock management. As a result, part of the household labor force has been freed from daily grazing activities and has shifted to secondary and tertiary sectors, such as livestock product marketing and service industries. The labor input of technical personnel has shown a steady increase since the early stage of property rights reform, reaching 2.1 times its 2009 level by 2023. This increase is closely related to the supporting policies implemented alongside the reform. The Qinghai provincial government dispatched approximately 1,000 scientific and technical personnel, each required to spend around 180 days per year working in pastoral areas to support herders' cooperatives. These experts provided point-to-point technical guidance, services, and training, addressing specific challenges in livestock breeding and grassland management. The labor input of management personnel has also increased gradually—from 185 person-days in 2009 to 238 person-days in 2023—although its growth rate is smaller than that of technical personnel. This reflects the gradual professionalization of cooperative management structures and the growing demand for administrative oversight within pastoral production systems.

## Changes in capital investment

The property rights reform precipitated significant shifts in capital investment. First, the cost of foundation breeding stock increased annually (Figure 5), rising from 32,358.41 RMB (Approximately 4,565.77 US dollars) in 2009 to 73,009.77 RMB (Approximately 10,301.68 US dollars) in 2023, a 2.25-fold increase. Second, investment in feed and forage also grew steadily, climbing from 13,425 RMB in 2009 to 45,154.17 RMB in 2023, a 3.36-fold increase. This escalation in feed costs is closely linked to the reform. Previously, grassland animal husbandry was heavily reliant on natural pastures. Supplemental feed purchases were minimal, primarily intended only to help livestock survive harsh winters (Jun et al., 2013). This weather-dependent grazing model often trapped producers in a vicious cycle described as "full in summer, fat in autumn, thin in winter, and dead in spring" (Zhang and Li, 2009). Following the reform, cooperatives promoted a new "grazing + supplementary feeding" production model. As the duration and scale of supplementary feeding gradually expanded, feed costs

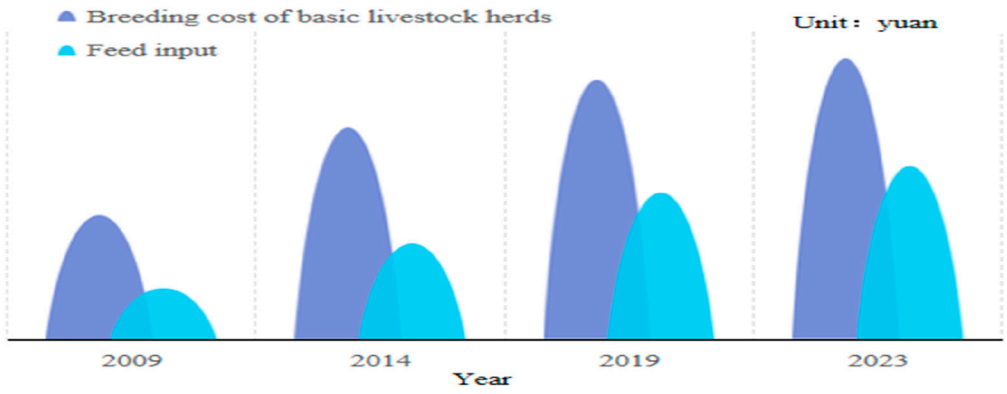


FIGURE 5
Changes in capital investment.

TABLE 3 The grassland input among pastoral households.

| Variable | The average area of natural grassland per household | The average area of artificial grassland per household |
|---|---|---|
| Time of property rights reform (t) | 0.1862* | 0.3106** |
| | (0.0201) | (0.0142) |
| Age of head of household | −0.0049 | 0.0311** |
| | (0.0038) | (0.0123) |
| The occupation type of the household head | 0.5025 | 0.1039 |
| | (0.3230) | (1.0490) |
| The educational level of the household head | 0.5083*** | 0.4534 |
| | (0.1666) | (0.5410) |
| Implementation of supporting policies | 0.7051*** | 0.6320*** |
| | (0.0709) | (0.2302) |
| Traffic conditions | −0.0623 | 0.1074** |
| | (0.0704) | (0.2288) |
| Market information | 0.3053*** | 0.5674* |
| | (0.1020) | (0.3314) |
| $R^2$ | 0.8750 | 0.6279 |

*, **, and *** respectively represent significance at the 10%, 5%, and 1% levels. The errors in parentheses are standard errors. Number of herders: 137; Years:4; Observations: $\sum_i T_i$.The time-invariant variable is absorbed in FE; significance is based on the robust standard error of clustering by herders; If the variable only changes in individual years or undergoes a one-time transition, it has been handled through event time or grouped dummy variables.

rose accordingly, but this was coupled with a crucial benefit: a consistent annual decline in livestock mortality rates. Investment in infrastructure—such as fodder storage sheds, livestock pens, and mechanization—also increased, though this surge was most pronounced during the initial construction phase of the reform (Sun et al., 2020). Our survey samples illustrate this trend: In Lade Village (Guide County, Henan Prefecture), 8.75 million RMB in state poverty alleviation funds were leveraged at the inception of their cooperative to construct five high-standard ecological animal husbandry cooperatives. In Niqing Village (Maqin County, Guoluo Prefecture), policy support from prefectural, county, and township levels facilitated the purchase of white Tibetan sheep and the construction of infrastructure, including five sheep pens (960 $m^2$) and three

fodder sheds (280 $m^2$). In Meilong Village (Tianjun County, Haixi Prefecture), 64 livestock sheds and 48 fodder storage sheds have been built to date. Furthermore, disease prevention and control capabilities improved annually. Following the property rights reform, cooperatives consolidated livestock, assigned dedicated herding staff, and designated specific grazing areas. This organized structure facilitated the systematic, batch administration of routine vaccinations and common deworming treatments. Consequently, this model not only streamlined disease prevention logistics but also significantly enhanced the overall effectiveness of disease control among the livestock.

## The impact of property rights reform on the input of production factors by herders

### The grassland input

The implementation of grassland property rights reform has a positive effect on the average household's investment in natural grassland, with a coefficient of 0.1862, significant at the 10% level (Table 3). However, this positive effect has been gradually weakened over time. As natural grassland represents the primary means of production for pastoral households engaged in grassland-based livestock production, the initial clarification of grassland contractual management rights during the early stage of reform enhanced households' expectations of tenure stability, thereby increasing their motivation to invest and encouraging the transfer and leasing of grassland use rights. Nevertheless, as property rights became increasingly clarified and individualized, the overemphasis on private ownership while neglecting community co-management mechanisms weakened the households' incentives for long-term investment. The education level of the household head, supporting policy measures, and the circulation of market information all have positive and significant effects on natural grassland investment, with coefficients of 0.5083, 0.7051, and 0.3053, respectively, each significant at the 1% level. Conversely, the household head's age and transportation conditions have negative but insignificant effects, while the household head's occupation type shows a positive but insignificant effect, with coefficients of −0.0049, −0.0623, and 0.5025, respectively.

The reform also has a positive and significant effect on investment in artificial forage grassland, with a coefficient of 0.3106 significant at the 5% level. Moreover, this positive influence strengthens over time, as pastoral households gradually recognize that artificial grass cultivation can alleviate grazing pressure on natural grasslands. The forage produced plays a vital role in ensuring adequate winter feed for livestock. Field investigations provide supporting evidence: in Meilong Village, Tianjun County, Haixi Prefecture, a 6.67-ha forage planting base has been established, yielding 20,000 kg of hay annually. Similarly, in Wuyi Village, Xinghai County, Hainan Prefecture, 133.33 ha of arable land were consolidated-120 ha planted with oats and 13.33 ha with highland barley-providing sufficient forage for semi-intensive livestock feeding and laying a solid foundation for efficient animal husbandry. The implementation of supporting policies has a positive and highly significant impact on artificial grassland cultivation (coefficient 0.6320, significant at the 1% level). The age of the household head and transportation accessibility also show positive and significant effects (coefficients 0.0311 and 0.1074, significant at the 5% level). Similarly, market information circulation has a positive and moderately significant effect, with a coefficient of 0.5674 significant at the 10% level. The household head's occupation type and education level both exhibit positive but statistically insignificant effects on artificial grassland investment.

### The labor input

The implementation of property rights reform promoted labor input in both technical and managerial positions, with coefficients of 0.0332 and 0.0103, respectively (Table 4). The increase in technical labor input is significant at the 5% level, while that of managerial labor input is significant at the 1% level. Conversely, the reform exerted a negative and significant effect on herding labor input, with a coefficient of −0.0211, significant at the 10% level. However, over time, the influence of property rights reform on herding labor input tends to weaken, whereas its impact on technical and managerial labor input continues to strengthen, with the effect on technical labor growing more prominently than that on managerial labor.

The age of the household head negatively affects herding labor input (−0.0010, significant at the 5% level) and technical labor input (−0.0893, significant at the 1% level), but positively affects managerial labor input (0.0110, significant at the 10% level). The household head's occupation type has a strong positive effect on technical labor input (4.8964, significant at the 1% level), but shows no significant impact on herding or managerial labor input. The education level of the household head is negatively correlated with herding labor input (−0.2247, significant at the 5% level). This finding aligns with field observations: children from herder families who achieve higher educational attainment generally seek off-farm employment rather than returning to engage in local animal husbandry, which helps explain the aging workforce observed in pastoral production. In contrast, education has a positive and significant impact on managerial labor input (1.3840, significant at the 1% level), but its effect on technical labor input is insignificant. The implementation of supporting policies exerts a positive and significant effect on managerial labor input (0.5387, significant at the 1% level), but shows no significant influence on herding or technical labor input. Transportation conditions have no significant effect on any type of labor input.

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TABLE 4 The labor input among pastoral households (person-day).

| Variable | The labor force of herders | Technical personnel labor force | Managerial personnel workforce |
|---|---|---|---|
| Time of property rights reform (t) | −0.0211* | 0.0332** | 0.0103*** |
| | (0.0409) | (0.0239) | (0.0314) |
| Age of head of household | −0.0010** | −0.0893*** | 0.0110* |
| | (0.0024) | (0.0154) | (0.0065) |
| The occupation type of the household head | −0.2572 | 4.8964*** | −0.6760 |
| | (0.2012) | (1.3181) | (0.5543) |
| The educational level of the household head | −0.2247** | 0.6012 | 1.3840*** |
| | (0.1038) | (0.6798) | (0.2858) |
| Implementation of supporting policies | −0.0115 | −0.2706 | 0.5387*** |
| | (0.0442) | (0.2893) | (0.1216) |
| Traffic conditions | 0.0103 | −0.1525 | −0.1939 |
| | (0.0439) | (0.2875) | (0.1209) |
| Market information | 0.0825 | 1.2522 | 0.2551*** |
| | (0.0636) | (0.4165) | (0.1751) |
| $R^2$ | 0.6469 | 0.8024 | 0.7719 |

*, **, and *** respectively represent significance at the 10%, 5%, and 1% levels. The errors in parentheses are standard errors. Number of herders: 137; Years:4; Observations: $\sum_i T_i$. The time-invariant variable is absorbed in FE; significance is based on the robust standard error of clustering by herders; If the variable only changes in individual years or undergoes a one-time transition, it has been handled through event time or grouped dummy variables.

Market information circulation also shows no significant effect on herding or technical labor input, yet it has a positive and highly significant effect on managerial labor input (0.2551, significant at the 1% level).

## The capital input

The implementation of property rights reform has a positive impact on pastoral households' investment in basic herd reproduction costs, with a coefficient of 0.0213, significant at the 10% level (Table 5). However, this positive influence gradually weakens over time. The reform also exerts a significant positive effect on forage feed input and disease prevention and control investment, with coefficients of 0.0494 and 0.0427, respectively, both significant at the 5% level. In contrast, it has a negative and significant effect on investment in breeding facilities and equipment, with a coefficient of −0.2381, significant at the 5% level. Over time, the negative effect on facility and equipment investment tends to diminish, while the positive effects on forage feed and disease prevention inputs continue to strengthen. This pattern can be explained by the fact that investments in facilities such as forage storage sheds, barns, and mechanized equipment were largely concentrated in the early stages of the reform, after which little new construction took place. In contrast, expenditures on basic herd reproduction, forage feed, and disease prevention are continuous in nature, and as the reform deepens-leading to more scaled and standardized grassland livestock production-investments in these three areas tend to increase steadily.

The age of the household head has no significant effect on basic herd reproduction costs but exerts negative and significant impacts on forage feed input (−0.0893) and disease prevention investment (−0.0317), both at the 1% significance level, while showing no significant impact on facility investment. The household head's occupation type has a positive and significant influence on forage feed input (4.8964) and disease prevention investment (1.8596), both at the 1% significance level, and a positive effect on breeding facility investment (1.8131, significant at the 5% level). The education level of the household head has positive and significant effects on forage feed input (0.6012), breeding facility investment (0.1558), and disease prevention investment (0.0296), all significant at the 5% level. These results suggest that higher educational attainment enhances households' capacity to manage production efficiently, adopt preventive measures, and make rational capital allocation decisions. Supporting policy measures positively affect basic herd reproduction cost investment (0.7751, significant at the 5% level) but negatively influence facility and equipment investment (−0.3529, significant at the 5% level). This indicates that while policy support may strengthen livestock

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TABLE 5 The capital input among pastoral households.

| Variable | Breeding cost of basic livestock herds | Feed input | Mechanized equipment | Epidemic prevention and control |
|---|---|---|---|---|
| Time of property rights reform (t) | 0.0213* | 0.0494** | −0.2381** | 0.0427** |
| | (0.0109) | (0.0144) | (0.1001) | (0.0023) |
| Age of head of household | −0.0267 | −0.0893*** | 0.0096 | −0.0317*** |
| | (0.0188) | (0.0154) | (0.0002) | (0.0066) |
| The occupation type of the household head | −1.6113 | 4.8964*** | 1.8131** | 1.8596*** |
| | (1.6075) | (1.3181) | (0.7141) | (0.5680) |
| The educational level of the household head | 0.8050 | 0.6012** | 0.1558** | 0.0296** |
| | (0.8290) | (0.6798) | (0.0071) | (0.2929) |
| Implementation of supporting policies | 0.7751** | −0.2706 | −0.3529** | −0.0758 |
| | (0.3528) | (0.2893) | (0.1423) | (0.1247) |
| Traffic conditions | −1.4839 | −0.1525 | 0.2116 | −0.2856 |
| | (0.3506) | (0.2875) | (0.0118) | (0.1239) |
| Market information | −1.2356** | −1.2522*** | 0.5387** | −0.4192** |
| | (0.5079) | (0.4165) | (0.2314) | (0.1795) |
| $R^2$ | 0.8547 | 0.8024 | 0.6901 | 0.8097 |

*, **, and *** respectively represent significance at the 10%, 5%, and 1% levels. The errors in parentheses are standard errors. Number of herders:137; Years:4; Observations: $\sum_i T_i$. The time-invariant variable is absorbed in FE; significance is based on the robust standard error of clustering by herders; If the variable only changes in individual years or undergoes a one-time transition, it has been handled through event time or grouped dummy variables.

reproduction and herd expansion, it may also discourage redundant investment in physical infrastructure once the necessary facilities are established. Transportation conditions have no significant impact on any form of capital input. However, market information circulation has negative and significant effects on basic herd reproduction costs (−1.2356) and disease prevention investment (−0.4192), both significant at the 5% level, as well as on forage feed input (−1.2522, significant at the 1% level). In contrast, it exerts a positive and significant effect on mechanized equipment investment (0.5387, significant at the 5% level). This suggests that as households gain better access to market information, they may optimize production strategies, reduce recurrent input costs, and increase investment in modern equipment to enhance production efficiency.

## The technological input

The implementation of property rights reform exerts a positive impact on pastoral households' investment in grassland management technologies and livestock breeding technologies, with coefficients of 0.3327 and 0.3481, both significant at the 5% level (Table 6). However, the reform's influence on information technology adoption is statistically insignificant. The positive effects on grassland management and breeding technologies intensify over time, suggesting that as the reform deepens and the definition of property rights becomes clearer, the resulting changes in rights distribution and income derived from the transfer of grassland use rights encourage herders to place greater emphasis on improving grassland management practices and livestock breeding techniques.

The age of the household head negatively affects the adoption of grassland management technology (−0.0278, significant at the 5% level) and information technology (−0.0142, significant at the 1% level), but positively influences livestock breeding technology adoption (0.1454, significant at the 10% level). This pattern indicates that older household heads may be less receptive to new technologies in grassland management and digital systems but remain experienced and active in livestock breeding practices. The household head's occupation type shows no significant effect on technological investment. In contrast, the education level of the household head has positive and significant impacts on investments in grassland management technology (0.4935) and information technology (0.4239), both significant at the 5% level, and a positive but moderately significant impact on livestock breeding technology (0.2817, significant at the 10% level). These results imply that higher education levels enhance pastoral households' capacity to acquire, apply, and integrate modern agricultural technologies. Supporting policy measures also have positive and significant effects on technological inputs. Specifically, the coefficients for grassland management, breeding,

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TABLE 6 The technological input among pastoral households.

| Variable | Grassland management technology | Breeding techniques | Information technology |
|---|---|---|---|
| Time of property rights reform (t) | 0.3327** | 0.3481** | 0.4423 |
| | (0.2134) | (0.1742) | (0.1104) |
| Age of head of household | −0.0278** | 0.1454* | −0.0142*** |
| | (0.0119) | (0.0103) | (0.0112) |
| The occupation type of the household head | −2.4429 | −1.2531 | −0.9516 |
| | (1.0144) | (0.0911) | (0.7914) |
| The educational level of the household head | 0.4935** | 0.2817* | 0.4239** |
| | (0.5231) | (0.1004) | (0.3211) |
| Implementation of supporting policies | 0.2927** | 0.1584** | 0.3141** |
| | (0.2226) | (0.0732) | (0.1237) |
| Traffic conditions | −0.0545 | −0.2534 | −0.2102 |
| | (0.2212) | (0.1513) | (0.1436) |
| Market information | 0.5919* | 0.3639* | 0.4421* |
| | (0.3205) | (0.1504) | (0.1053) |
| $R^2$ | 0.6520 | 0.6673 | 0.7784 |

*, **, and *** respectively represent significance at the 10%, 5%, and 1% levels. The errors in parentheses are standard errors. Number of herders: 137; Years:4; Observations: $\sum_i T_i$. The time-invariant variable is absorbed in FE; significance is based on the robust standard error of clustering by herders; If the variable only changes in individual years or undergoes a one-time transition, it has been handled through event time or grouped dummy variables.

and information technologies are 0.2927, 0.1584, and 0.3141, respectively, all significant at the 5% level. This finding suggests that complementary policy reforms and technical extension programs play a crucial role in facilitating technological adoption among herders. Transportation conditions are found to have no significant influence on technological inputs. Meanwhile, market information circulation exerts positive and significant effects on all three categories of technology investment-grassland management (0.5919), livestock breeding (0.3639), and information technology (0.4421)-each significant at the 10% level. The availability of timely and accurate market information enhances herders' awareness of technological innovations and strengthens their motivation to invest in improved production and management methods.

## Discussion and conclusions

The grassland property rights reform in Qinghai Province serves as a core component in promoting the province's rural revitalization strategy and achieving comprehensive rural social development (Xu and Tian, 2018). Based on field survey data, this study first conducted a qualitative analysis of the reform's impact on the four major production factor inputs, followed by a quantitative econometric examination of its influence on pastoral households' input decisions. The empirical results indicate that property rights reform exerts a positive impact on the average household's investment in natural grassland, with a coefficient of 0.1862, significant at the 10% level. However, this positive effect has gradually weakened over time. In the early stages of reform, the clarification of grassland contractual management rights enhanced households' expectations of tenure stability, which in turn increased their production incentives and encouraged the transfer or leasing of grassland use rights. Yet, as the reform progressed, the increasingly individualized definition of property rights—focusing exclusively on private ownership while neglecting community co-management mechanisms—has dampened herders' willingness to make long-term investments. These findings are consistent with (Jacoby et al., 2002), who empirically demonstrated that in rural China, farmers' perceived risks of land readjustment and insecure tenure significantly discourage long-term land investment, reflecting similar patterns observed in this study. Moreover, the reform has a positive and significant impact on investment in artificial grassland establishment, with a coefficient of 0.3106, significant at the 5% level. The positive influence of reform continues to strengthen over time, as pastoral households gradually recognize that cultivating artificial forage can alleviate grazing pressure on natural grasslands and provide essential fodder for livestock overwintering. Yu and Kasymov

(2020) argued that changes in property rights systems not only reshape resource ownership and entitlements, but also reconfigure relationships among stakeholders. As policy interventions evolve over time, they modify institutional rules and redistribute rights among actors. The increasing investment in artificial grassland thus exemplifies how property rights reform transforms the structure of resource relations within pastoral economies (Xu et al., 2017).

The reform of property rights grants herders long-term and stable grassland contract rights, while cooperative operations promote the transfer of grassland management rights (Ye and Zhou, 2019). This enables herders to gain income rights from grassland equity participation, allowing them to obtain more reliable returns and stimulating enthusiasm for labor input. Meanwhile, the reform of property rights also releases surplus rural labor, reducing barriers to cross-regional and cross-industry labor mobility and optimizing the allocation of labor resources (Zhang et al., 2022). Using data from Ghanaian farmers, Besley (1995) demonstrates that more secure land tenure significantly increases farmers' long-term investment in land by reducing the risk of expropriation, which is closely related to the long-term allocation of both capital and labor inputs and enhances the expectation of long-term returns. This finding is consistent with the results of this study. Further analysis of the effects on labor input shows that the impact is most significant on managerial labor input, followed by technical labor input, and least on herding labor input. After the grassland property rights reform, grassland animal husbandry cooperatives adopted enterprise-style management structures, establishing independent boards of directors and boards of supervisors, and formulating internal regulations suited to local conditions. Member assemblies democratically elect herders who are skilled and experienced in livestock management to serve as full-time herders, while the remaining laborers are released to engage in livestock product sales, service industries, and other secondary and tertiary sectors—facilitating the transfer of herding labor. At the same time, the province-wide implementation of the Science and Technology Commissioner Service Program brings technical experts directly into cooperatives, increasing technical labor input (Zhou and Qiao, 2020). As a result, labor input in grassland animal husbandry has gradually transformed from purely physical labor to a combination of physical and technical labor, marking a structural shift toward more skilled and efficient labor use.

The impact of property rights reform on capital investment has both positive and negative effects. The implementation of the reform has a significantly positive impact on the breeding cost of basic livestock herds, with a coefficient of 0.0213, significant at the 10% level. However, this positive effect tends to weaken over time as the reform progresses. The reform also has a significant positive impact on feed input and disease prevention and control investment, with coefficients of 0.0494 and 0.0427, respectively, both significant at the 5% level. In contrast, the impact on investment in breeding facilities and equipment is negative, with a coefficient of −0.2381, also significant at the 5% level. Over time, the negative effect on investment in livestock facilities and equipment continues to decline, while the positive effects on feed and disease prevention investment gradually strengthen. This pattern can be explained by the evolution of policy emphasis during different stages of reform. In the early phase, both central and local governments actively guided cooperatives to transform traditional production and management models, shifting from extensive, low-efficiency operations to intensive and specialized management. As a result, herders increased their investment in hay storage sheds, livestock pens, and mechanized equipment, promoting the standardization and scaling-up of grassland animal husbandry. As the reform deepened, the investment in basic livestock infrastructure gradually declined—aside from regular maintenance and equipment renewal—since major fixed assets had already been established. Meanwhile, the continuous investment in basic herds, feed, and disease control remained steady or even increased. With the limited carrying capacity of natural grasslands, the duration of stall-feeding has gradually extended, leading to more frequent supplementary feeding and consequently higher feed input. Furthermore, as breeding practices became increasingly standardized, the renewal frequency of breeding males rose to enhance reproductive efficiency, and disease prevention and control became a routine part of livestock management.

With the advancement of property rights reform, investments in grassland management technology and livestock breeding technology have shown continuous improvement. The implementation of property rights reform exerts a positive and significant impact (at the 5% level) on herders' investment in these two types of technologies, while its effect on information technology input is insignificant. This result can be explained by the time dimension of institutional effectiveness—management and breeding technologies can yield visible outcomes through short-term training, whereas the adoption of information technology requires more time and broader enabling conditions. Due to the geographical remoteness of Qinghai Province and the limited penetration of digital tools into production practices, coupled with the generally low education level of herders, the adoption and promotion of information technology remain challenging. In our survey sample, for instance, in Ningxia Village, Gangcha County, Haibei Prefecture, the adult livestock mortality rate before property rights reform was 10%, and the lamb mortality rate reached 60%, with breeding females accounting for only 40% of the total herd. After the reform, through technical training programs and guidance from scientific personnel, herders'

production concepts have shifted toward scientific and standardized livestock management. As of now, mortality has decreased by 90%, and breeding females constitute 80% of the herd. This transformation toward scientific breeding has led to higher economic returns, reduced grassland pressure, and notable ecological improvements. Hall and Harhoff (2012) discussed how the intensity, breadth, and duration of property rights implementation influence technological investment and diffusion. The study found that the gradual advancement of land tenure reform enhances farmers' income stability and security, thereby stimulating the adoption of advanced and green production technologies to improve resource allocation efficiency and agricultural performance—findings that are consistent with the results of this research. Moreover, supportive policy measures, improved transportation infrastructure, and market information circulation have resonated synergistically with the effects of property rights reform, collectively reinforcing technological investment and innovation in pastoral production systems.

In addition to the direct effects of property rights reform, several supporting policies and contextual factors—such as the implementation of complementary institutional measures, improvements in transportation infrastructure, enhanced market information flows, as well as herders' age, occupation, and education level—have also exerted varying degrees of influence on the allocation of production factors. Although the empirical analysis in this study indicates that, apart from a few negative effects, most of the factor inputs have been positively influenced by the reform, certain limitations remain. Due to data availability constraints, some potentially important variables—such as government subsidies, market fluctuations, and technological diffusion—were not incorporated into the econometric model. This omission may affect the depth of interpretation for certain findings. Looking forward, it is necessary to further deepen the reform of property rights and improve the supporting mechanisms of the grassland tenure system. Particular emphasis should be placed on strengthening the technical extension and service system, especially by enhancing the training and support for information technology applications to improve herders' digital literacy and capacity for informed decision-making. In view of the issues identified in this study, several policy recommendations are proposed in the following section.

## Policy recommendation

Since the implementation of property rights reform in 2008, 17 years have passed. To more effectively enhance the positive institutional effects, mitigate potential negative impacts, and achieve both income growth for herders and sustainable grassland resource use, this study proposes the following policy recommendations based on the empirical findings.

### Enhance herders' participation

The property rights reform in Qinghai has been conducted under the premise of maintaining the collective ownership of grasslands, while strengthening the registration and certification of grassland use rights to stabilize herders' contract and management rights. This approach provides herders with long-term and stable expectations, ensuring secure use and usufruct rights. The reform aims to encourage grassland contractors to transfer their contract and management rights to specialized cooperatives or large-scale livestock households, thereby promoting moderate-scale operations. However, during implementation, many herders remain hesitant or inactive, and those with smaller grassland areas are often marginalized in the process. It is therefore recommended that herders with limited grassland resources be allowed to participate in cooperatives through alternative forms of contribution, such as technical expertise or fixed assets, rather than land-based shares alone. This would promote diversified and moderate-scale operations, improve resource utilization efficiency, and enhance herders' income-generating capacity. Ultimately, expanding participation channels would increase engagement in the reform process and strengthen the overall effectiveness of property rights reform.

### Strengthen the empowering effects of property rights reform

To enhance the empowering effects of property rights reform, it is necessary to synchronize supporting policies such as "Returning Grazing Land to Grassland", rotational grazing, and rest grazing. These measures should be dynamically managed according to local grassland ecological restoration conditions. A performance evaluation system should be established for both herders and local governments, with incentives for effective conservation of natural resources and maintenance of grassland ecosystems. Herders should be guided to use compensation funds from supporting policies for feed supplementation, silage, and artificial forage grassland construction, thereby reducing grazing pressure on natural pastures and promoting stall-feeding during cold seasons. Furthermore, training programs on grassland management technology, breeding technology, and especially information technology should be strengthened, while investments in breeding facilities and equipment should be continuously updated. These measures will optimize production input structures, enhance livestock productivity, and achieve coordinated ecological and economic development. Meanwhile, improving the legal and regulatory framework is essential to expand the scope of grassland property rights subjects and clarify the rights and obligations of all stakeholders. This would effectively protect herders' rights of income and disposal, ensuring that

institutional benefits are fully realized and sustained over the long term.

### Broaden the income sources for herders

Although the development of eco-animal husbandry cooperatives in Qinghai has facilitated the aggregation of production factors, optimization of resource allocation, and coordination of production labor, thereby increasing the utilization efficiency of surplus rural labor, it has also enabled herders to obtain stable incomes (through dividends) by contributing grasslands, livestock, or other assets as cooperative shares. However, this model also results in a portion of experienced individuals being selected to engage full-time in livestock production and management, which in turn frees up a large number of laborers. Consequently, labor redundancy has emerged as a potential issue, increasing social stability costs in some pastoral areas. To address this challenge, it is recommended that, following the integration of property rights, local governments actively promote the development of characteristic industries suited to regional conditions. By nurturing such industries, the reform can truly "take root and yield results," creating more local employment opportunities for surplus laborers—thus realizing the goal of "bringing employment in." At the same time, it is essential to improve labor transfer mechanisms and strengthen skill training programs for workers preparing to move to other regions or sectors. These efforts would help expand employment channels and enable surplus laborers to "go out" for employment, achieving two-way mobility. Through these complementary approaches, the reform of grassland property rights and its supporting measures would not only broaden herders' income sources but also increase non-pastoral income related to grassland animal husbandry, thereby enhancing overall social and economic benefits in pastoral regions.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

## Ethics statement

This study employs questionnaire surveys to collect data from adult participants. The research does not involve clinical trials, animal experiments, or vulnerable groups, and thus does not require ethical approval. All participants provided informed consent prior to participation, and their personal information and survey data have been strictly kept confidential and desensitized.

## Author contributions

YG: writing – original draft, data curation, formal analysis, investigation. LH: writing – review and editing, conceptualization, formal analysis methodology, visualization. WS: writing – review and editing, conceptualization, investigation methodology, language correction. XJ: writing – review and editing, conceptualization, investigation methodology, validation. AZ: writing – review and editing, conceptualization, methodology, supervision. HM: writing – review and editing, conceptualization, methodology, supervision. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

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