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Analysis of selectional preference for grassland ecological compensation methods under the perspective of herders differentiation

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Introduction: Exploring herders' preferences for grassland ecological compensation methods provides a decision-making basis for strengthening the incentive effects of grassland ecological compensation policies.

Methods: The research utilized survey data of 372 herders from three prefecture-level cities in Inner Mongolia, and comprehensively applied grey relational analysis (GRA) and multinomial logit (MNL) model to empirically analyze herders' selectional preferences for grassland ecological compensation methods and influencing factors from the perspective of herders differentiation.

Results: The findings revealed: (1) More than two thirds (69.28%) of the herders preferred simple and convenient "financial compensation" in addition to existing forms of compensation; 10.22%, 10.48%, and 11.02% of the herders preferred in-kind compensation, technological compensation, and policy-based compensation, respectively. (2) Compared with individual and livestock operation characteristics, herders' differentiated behavioral attitudes and family characteristics were more strongly associated with their preferences for compensation methods. (3) Compared with direct financial compensation, herders' gender and transport distance to the nearest marketplace significantly influenced the choice of in-kind compensation; herders' age, livestock numbers, grazing area, and dependence on subsidy and reward policies significantly influenced the choice of technological compensation; herders' gender, age, number of family laborers, level of part-time income, willingness for professional transformation, and perception of the rationality of compensation types significantly influenced the choice of policy-based compensation.

Discussion: To optimize compensation modes for grassland ecological conservation, a "diversified & differentiated" positive incentive system should be constructed according to herders' preferences and differentiated characteristics in order to facilitate voluntary livestock reduction, meanwhile a negative incentive should be incorporated to constrain herders' overgrazing behavior.

KEYWORDS

herders differentiation, ecological compensation methods, selectional preferences, grey relational analysis, multinomial logit model

1 Introduction

The development and utilization of natural ecosystems often give rise to economic externalities. Payment for ecosystem services (PES) transforms the non-market, externality-based value of ecosystem services into financial incentives for conservationists (Engel et al., 2008; Le et al., 2024; Wunder et al., 2018; Yu et al., 2020). Internationally, well-established PES programs tend to focus on the conservation of farmland or forests, examples of which include Costa Rica's Pago Por Servicios Ambientales Program (PSA), and the United States' Conservation Reserve Program (CRP) and Environmental Quality Incentives Program [EQIP] (Jack et al., 2008; Oliveira et al., 2019; Pagiola, 2008). The Chinese government has also launched and implemented several large-scale PES policies, including the Grassland Ecological Compensation Policy [GECP] (Hou et al., 2021), the largest grassland-focused PES program worldwide. By providing herders with ecological protection subsidies and incentive funds, the GECP is designed to direct pastoralists to rationally allocate livestock to reach a dynamic balance between the carrying capacity of the grasslands and quantity of livestock breeding (Liu G. H. et al., 2023; Liu J. et al., 2023; Liu M. et al., 2023), realizing dual goals of restoring grassland ecology and promoting herders' income generation (Pan et al., 2021).

The current GECP policy has yielded notable environmental and social benefits (Yang et al., 2022; Zhang et al., 2025); however, its implementation continues suffer from a number of constraints (Qiu et al., 2024), including the low level of forbidden grazing subsidies and grass-livestock balance rewards, relatively single and limited compensation methods, low penalty costs for overloading by herders, and insufficient supervision and management by relevant departments (Hu et al., 2016; Li, 2015; Liu and Sun, 2024; Ye et al., 2020). Collectively, this has resulted in herders failing to consciously reduce their livestock in strict accordance with the policy implementation plan, with widespread persistence of overgrazing continuing in pastoral areas. The underlying reason is that the GECP, as a typical "top-down" administrative dominant policy tool, has limited funds, a laborious fiscal monetary compensation method, and may neglect the real demands of herders as stakeholders, making it difficult to stimulate their response to the policy. A reasonable monetary compensation standard is the core method to effectively incentivize stakeholders to participate in grassland environmental protection and construction (Zhang S. Y. et al., 2023; Zhang Z. H. et al., 2023); excessively low compensation may undermine the initiative and even reduce positive environmental protection behaviors that were originally based on the spontaneous generation of altruism (Sommerville et al., 2009). Therefore, merely raising compensation standards to address inherent issues within the ecological compensation mechanism is not a panacea. Instead, devising diversified compensation methods that align with the demands of herders and specific features of the project area is crucial for enhancing the effectiveness of the implementation of compensation measures.

Agricultural ecological compensation can be categorized into various approaches and methods based on the nature of the compensation. Internationally, there are two primary compensation modes distinguished by the degree of restriction on property rights: rights transfer, focusing on the transfer of land development rights, and rights compensation, involving mainly cash subsidies, tax reductions or exemptions, and fiscal transfers (Linkous, 2016). Based on the public attributes of the compensation elements, compensation methods can be divided into two categories: government and market compensation [or vertical and horizontal compensation, respectively] (Ye et al., 2020). Based on the differences in compensation channels, China's research team on ecological compensation mechanisms and policies subdivided compensation methods into four categories: monetary, in-kind, intellectual, and policy-based (Task Force Eco-Compensation Mechanisms and Policies, 2007). The academic community has conducted fruitful explorations of farmers' responses to agricultural ecological compensation methods and the influencing factors involved. The scope of related research primarily focuses on diverse practical contexts, such as cultivated land protection, farmland ecological conservation, watershed ecological preservation, and the adoption of reduction and substitution technologies (Deng et al., 2024; Kirwan et al., 2005; Liu G. H. et al., 2023; Liu J. et al., 2023; Liu M. et al., 2023; Montoya-Zumaeta et al., 2021; Yu et al., 2021). Numerous studies have revealed that farmers tend to prefer cash or direct compensation when choosing agricultural ecological compensation methods (Cui et al., 2020; Luo et al., 2015), whereas a few studies have indicated that farmers have a greater preference for policy and technical compensation (Yu and Liu, 2022). Scholars have examined the factors influencing farmers' choices of ecological compensation methods from perspectives such as farmers' preferences, rationality, and capability capital (Cui et al., 2020; Li et al., 2018; Qiu, 2024), concluding that individual characteristics, livelihood capital, and regional features significantly influence the choice of compensation methods.

Despite existing research recognizing the necessity of diversified compensation methods, a number of gaps still exist. First, studies have mostly examined horizontal market-based compensation modes from the perspective of the compensation subjects, but have seldom explored the preference for compensation methods based on the actual needs of compensated subjects. Second, studies on the preference for ecological compensation methods have tended to focus on specific areas or ecosystems, such as farmland, arable land, and ecological protection red-line zones (Li et al., 2018; Luo et al., 2015; Qiu, 2024; Yang et al., 2020), leaving room for supplementary research on the behavioral responses and preferences of pastoral communities regarding grassland ecological compensation methods. Additionally, in recent years, the acceleration of national industrialization and urbanization, implementation of grassland ecological protection compensation policies, and urgent need for transformation in agriculture and animal husbandry have prompted pastoral households to differentiate into heterogeneous groups with distinct characteristics (Dong et al., 2023; Hussain et al., 1994). This differentiation has created certain variations among pastoral households in terms of socioeconomic status, animal husbandry management methods, and behavioral attitudes, which in turn affect the degree of their responses and decision-making regarding grassland ecological compensation policies, as shown in Figure 1. Therefore, based on the perspective of herders differentiation and relying on investigation data from compensated subjects—that is, herders–this study conducted an in-depth analysis of herders' specific preferences for grassland ecological compensation methods by comprehensively employing grey relational analysis (GRA) and a multinomial logit (MNL) model to empirically test correlations among herders' differentiated characteristics and grassland ecological

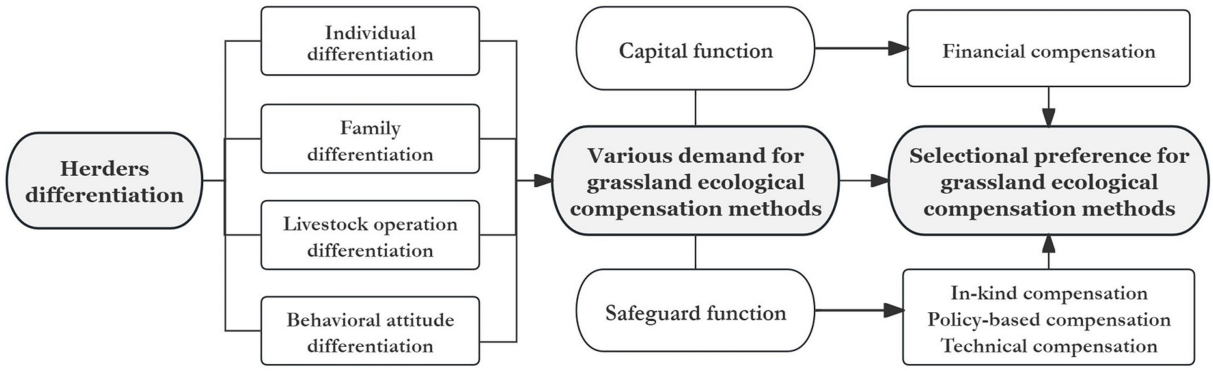

FIGURE 1
Analytical framework for the effect of herders' differentiation on the selectional preference for grassland ecological compensation methods.

compensation methods. The results of this study provide a reference for policy development and the design of scientific and reasonable grassland ecological compensation methods.

2 Materials and methods

2.1 Overview of the study area

The Inner Mongolia Autonomous Region (or, Inner Mongolia) is the most extensive and comprehensive ecological functional area in northern China and serves as an essential ecological defense line in the "Three Norths" region of China. The grasslands of Inner Mongolia span an extensive expanse, with a total area of 54,374,200 hm^2, accounting for 45.96% of the region's total land area (Internet Information Office of Inner Mongolia Autonomous Region, 2021). The zonal distribution characteristics of the region's grassland ecosystems are remarkably distinct, exhibiting a gradient formation from east to west: temperate meadow steppe, temperate typical steppe, and temperate desert steppe. This spatial differentiation fundamentally shapes the regional diversification of animal husbandry development models: In the eastern and central regions with superior grassland quality, seasonal rotational grazing systems have been established based on their higher primary productivity, while the western desert steppe areas have developed intensive livestock production systems characterized by "housing feeding with pen feeding" to adapt to the fragile ecological conditions. To protect and ensure the sustainable utilization of grassland resources, 68 million hm^2 of grasslands in Inner Mongolia have been included in the scope of the GECP, of which 27 million hm^2 of desertified and degraded grasslands have been retained and recuperated through a system of forbidden grazing, and 41 million hm^2 of grasslands have been reasonably utilized through a system of grass–animal balance, benefiting more than 1.4 million households and 4.9 million farmers and herders across the region every year (Han, 2021). However, while the effective implementation of grassland ecological compensation and reward policies has alleviated overloading or overgrazing in pastoral areas, it has been challenging to meet the diversified and differentiated practical demands of herders using a singular monetary compensation method. Herding communities in Inner Mongolia vary markedly in terms of natural resource endowment, grazing methods and habits, and regional economic development level depending on the region and grassland type; moreover, there are increasingly apparent differences within herder communities. Consequently, the mismatch between supply and demand in compensation methods has led to a lack of motivation for herders to voluntarily reduce livestock, which has prevented the policy's intended effects and goals from materializing.

2.2 Data sources and analyses

2.2.1 Questionnaire design and data sources

Based on the research objectives of this paper, the questionnaire design primarily encompasses the following four dimensions: (1) basic economic and social characteristics of herders, including respondents' age, gender, education level, family labor structure, economic income level, travel distance to the nearest marketplace, etc.; (2) livestock assets and pasture resources, including the scale of breeding (meat, beef, sheep, and other livestock), area of grazing land, grazing-prohibited land owned by herders, etc.; (3) livestock operation and management situation, including herders' professional and concurrent occupation backgrounds, costs of animal husbandry operations, sales situations, etc.; and (4) herders' subjective perception of grassland ecological compensation policies and behavioral responses to decision-making, etc.

The data used in this study originated from an in-depth field investigation conducted by the research team from July to August 2021 on the actual situation in various pastoral areas in 2020. In terms of the selection of the research area, considering the differences in grassland types and livestock breeding methods in Inner Mongolia, pure pastoral prefectures and cities with different grassland types were chosen for on-site research—Hulun Buir City (temperate meadow steppe), Chifeng City (temperate desert steppe), and Xilin Gol League (temperate typical steppe), systematically covering the three main grassland types in the entire region. A combination of random and typical sampling methods was adopted. Specifically, two pure pastoral banners were randomly selected from each league and city, and to 2–3 sumu (townships) were selected from each pastoral banner for field research. Final data were obtained from 406 questionnaires collected from 3 leagues and cities, 6 pure pastoral banners, and 14 sumu (townships). This study excluded responses with missing core data or abnormal variable values, and finally obtained a dataset of 372 valid questionnaires

with a total sample validity rate of 91.63%. The sample size meets the requirements of the Scheaffer formula for a sampling error of 0.06 ($n = 372 > n/(n-1) \times \delta^2 + 1$), ($\alpha = 0.06$), ensuring statistical rigor and representativeness. The sample area and distribution are shown in Table 1.

2.2.2 Sample characteristics analysis

Through sorting out the survey data, the basic situation of the research sample is summarized in Table 2. Male respondents significantly outnumbered females (71.77% vs. 28.23%), over three-quarters (72.31%) aged above 40 years, and more than half of the participants (52.69%) had only completed 7–9 years of formal education, indicating a predominance of middle-aged and elderly male herders and highlighting limited educational attainment within this group. Household labor force sizes were concentrated within 1–3 members (93.82%), with household incomes most frequently falling into the 100,001–200,000 yuan and 200,001–500,000 yuan brackets (62.91%), and transportation distance to the nearest market was predominantly between 21 and 100 kilometers (66.40%), suggesting that herder families have limited labor resources, a relatively wide disparity in income levels, and moderate transportation accessibility.

TABLE 1 Sample distribution within the research area.

Province	City or league	Banner	Sample size
Inner Mongolia autonomous region	Hulun Buir City	Xin Barag Left Banner	75
		Chen Barag banner	56
	Chifeng City	Bairin Right banner	52
		Hexigten Banner	56
	Xilin Gol League	Abag Banner	68
		Sonid Right Banner	65
Total	–	–	372

TABLE 2 Basic characteristics of sample.

Characteristic	Option	Sample size	Proportion (%)
Gender	Female	267	71.77
	Male	105	28.23
Age	≤30 years old	19	5.11
	31–40 years old	84	22.58
	41–50 years old	113	30.38
	51–60 years old	123	33.06
	≥61 years old	33	8.87
Education level	≤6 years	95	25.54
	7–9 years	196	52.69
	10–12 years	55	14.78
	≥12 years	26	6.99
Labor force size	1 laborer	48	12.90
	2 laborers	249	66.94
	3 laborers	52	13.98
	4 laborers	20	5.38
	5 laborers	3	0.81
Household income	≤100,000 yuan	96	25.81
	100,001–200,000 yuan	96	25.81
	200,001–500,000 yuan	138	37.10
	≥500,000 yuan	42	11.28
Transport distance to the nearest market	≤20 km	72	19.35
	21-50 km	132	35.49
	51-100 km	115	30.91
	≥100 km	53	14.25

2.3 Model construction and variable selection

2.3.1 Model construction

This study employed gray relational analysis to examine correlations among differentiated characteristics of herders and their compensation method preferences. Furthermore, an MNL model was established to evaluate the impact of these differentiated characteristics on the choice preferences for compensation methods.

2.3.1.1 GRA

GRA quantifies the degree of association between factors based on the similarity or dissimilarity of their developmental trends, and is also referred to as the "grey relational degree" (Zhao et al., 2024). The analytical steps include (1) identifying the reference sequence and comparative sequences; (2) performing dimensionless processing of indicator data (initialization, mean normalization, etc.); (3) calculating the relational coefficients in accordance with the difference sequence, minimum difference, and maximum difference; and (4) computing the grey-weighted relational degree and ranking the results. In this study, the grassland ecological compensation method variable was defined as the reference sequence X_0, $X_0 = \{X_0(1), X_0(2), \ldots, X_0(n)\}$, where n is the total number of samples, the differentiated characteristic variables of the herders represent the comparative sequences X_m, $X_m = \{X_m(1), X_m(2), \ldots, X_m(n)\}$, and m is the number of measurement indicators. The specific calculations were as follows. Firstly, the raw data of each indicator was dimensionlessly processed to generate the mean image $X_i^{'}$ (Equation 1):

$$X_i^{'} = \frac{X_i}{\frac{1}{n}\sum_{i=1}^{n} X_i} = \left\{X_i^{'}(1), X_i^{'}(2), \ldots, X_i^{'}(n)\right\} \tag{1}$$

Secondly, the absolute discrepancy $\Delta_m(k)$ (Equation 2) between the mean image of the reference sequence and that of the comparative sequences was calculated, followed by the determination of the two-level minimum absolute discrepancy $\Delta_{\min}$ (Equation 3) and maximum absolute discrepancy $\Delta_{\max}$ (Equation 4):

$$\Delta_m(k) = \left| X_0^{'}(k) - X_m^{'}(k) \right| \tag{2}$$

$$\Delta_{\min} = \min_m \min_k \left| X_0^{'}(k) - X_m^{'}(k) \right| \tag{3}$$

$$\Delta_{\max} = \max_m \max_k \left| X_0^{'}(k) - X_m^{'}(k) \right| \tag{4}$$

Then, the correlation coefficient γ (Equation 5) between the corresponding quantity of the reference sequence and that of each comparative sequence was calculated:

$$\gamma\left(X_0(k), X_m(k)\right) = \left(\Delta_{\min} + \rho\Delta_{\max}\right) / \left(\Delta_m(k) + \rho\Delta_{\max}\right) \tag{5}$$

Finally, the degree of correlation, R (Equation 6), was determined using a weighted averaging process.

$$R_{0m} = \frac{1}{n}\sum_{k=1}^{n} \tilde{a}\left(X_0(k), X_m(k)\right) \tag{6}$$

where $i = 0,1,2,\ldots,m$; $k = 1,2,\ldots,n$; ρ is the discrimination coefficient ($0 < \rho < 1$, typically set to $\rho = 0.5$).

2.3.1.2 MNL model

MNL models are enhanced selection models grounded in the disaggregate logit model (also termed the "evaluation model"), incorporating multiple factor variables for selections. MNL models are applicable when the dependent variable is unordered and can be categorized into three or more classes. Given that the grassland ecological compensation method in this empirical study served as a multicategory, unordered categorical variable, it is appropriate to adopt an MNL model for regression analysis in order to explore the specific impacts of herders' differentiated characteristics on their preferences for grassland ecological compensation. An MNL model can be viewed as a joint estimation of multiple binary logistic regression models formed by a series of pairwise comparisons of all selection behaviors within the dependent variable. Here, the model specifications were as follows (Equation 7).

$$\ln\left[\frac{P\left(Y = j|X_1, X_2, \cdots, X_k\right)}{P\left(Y = J|X_1, X_2, \cdots, X_k\right)}\right] = \alpha_j + \sum_{k=1}^{k} \beta_{jk} X_k + \varepsilon \tag{7}$$

where $\frac{P\left(Y = j|X_1, X_2, \cdots, X_k\right)}{P\left(Y = J|X_1, X_2, \cdots, X_k\right)}$ represents the probability ratio of herders choosing the jth compensation method over the Jth method, with J serving as the reference category; X_k denotes the kth factor affecting the herders' choice of grassland ecological compensation methods; β_{jk} is the regression coefficient of the independent variable; α_j is the intercept term; and ε represents the random error term. If option *rrr* is appended, the output of Stata presents the odds ratio (*OR*) corresponding to all coefficient estimates. *OR* (Equation 8) indicates the probability of an alternative being selected relative to the base group when X_k changes and other variables are constant.

$$rrr_k = OR = \exp\left(\Delta X_k \beta_{jk}\right) \tag{8}$$

when $\Delta X_k = 1$, $rrr_k = \exp\left(\beta_{jk}\right)$, which represents the probability of the selected alternative occurring compared with the base group owing to one-unit change in X_k.

2.3.2 Variable selection and descriptive statistical analysis

2.3.2.1 Variable selection

(1) Explained variable

This study explains the grassland ecological compensation method. In accordance with the practical requirements of herder participation in the compensation mechanism and actual grassland compensation policy in the Inner Mongolia Autonomous Region, herders' choices of grassland ecological compensation methods were categorized into four main types: (1) Financial: compensation in the form of direct monetary payments such as grants, rewards, and subsidies; (2) In-kind: specific material products or services as compensation, including livestock production materials and living supplies for pastoralists; (3) Technical: technical consultation, training, or educational services related to production techniques or management to compensated subjects; and (4) Policy-based: compensation through the provision of preferential policies tailored to recipient groups, including tax incentives, preferential loans, and social security benefits for livelihoods.

(2) Explanatory variables

Herders differentiation refers to the process by which herders, influenced by factors such as industrialization, urbanization, grassland ecological subsidies, reward policies, and the transformation and development of agriculture and animal husbandry, shift from homogeneity to heterogeneity in terms of occupation, economic income, and social status (Duan, 2018; Sonam, 2017). Building on existing research related to the differentiated characteristics of agricultural and pastoral households as factors influencing behavioral decision-making (Fan, 2023; Liu G. H. et al., 2023; Liu J. et al., 2023; Liu M. et al., 2023; Liu et al., 2020; Su et al., 2016; Wang et al., 2015; Yang, 2014; Zhang S. Y. et al., 2023; Zhang Z. H. et al., 2023), this study defined the manifestation of herders differentiation into four core dimensions. (1) Individual characteristic variables, including gender, age, and educational level. Differences at the individual level shape, directly or indirectly, herders' understanding, acceptance, and preference for ecological compensation policies. (2) Family characteristic variables, including labor force size, household income, and distance from residence to the nearest market. As a crucial backdrop for herders' decision-making, a family's labor resources, economic status, and social structure profoundly influence herders' weighing of options and considerations in selecting compensation modes. (3) Livestock operation characteristic variables, including livestock number, grazing area, forbidden grazing area, whether the herders have a part-time income, and the willingness for professional transformation. The scale of livestock, grassland area, and professional planning are directly related to herders' production methods, economic benefits, and ecological pressures, serving as crucial considerations for understanding the logic behind herders' compensation mode selection decisions. (4) Behavioral attitude characteristic variables, including the rationality of compensation types, satisfaction with outcomes of the compensation mechanism, extent of improvement of production and living by the compensation policies, and degree of dependence on the compensation policy. These variables explore psychological and behavioral factors such as herders' cognitive depth, emotions, and behavioral tendencies towards grassland compensation policies, reflecting the impact of their intrinsic values and action logic on decisions regarding ecological compensation modes. Table 3 presents the specific variables.

2.3.2.2 Descriptive statistical analysis

(1) Basic characteristics of interviewed herders

The average gender value of the surveyed herders was 0.72, with males accounting for 71.77% and females only 28.23%, reflecting a male-dominated workforce in pastoral operations. The age structure of the interviewed herders clearly leaned towards middle-aged and elderly (average age was 47.80): 30.38% were aged 41–50 years, and 41.94% were over 50, generally indicating an imbalanced age structure and persistent issue of labor aging in pastoral areas. Herders averaged 8.60 years of schooling (equivalent to junior to senior high school levels), over half (52.69%) had completed junior high school and a substantial portion (25.54%) had only primary school education or below, suggesting an overall low level of education, with relatively limited cultural literacy and knowledge reserves among herders in the surveyed region.

(2) Family characteristics of interviewed herders

Surveyed herder households maintained an average of 2.14 laborers per family, with dual-laborer households constituting the overwhelming majority (66.94%), while those with one or three laborers accounted for 12.90 and 13.98% respectively, revealing the typical configuration pattern of both spouses contributing as the primary labor force in pastoral families. The average distance from households to markets was 71.40 km (with a significant range 0.5–350 km), and most residences were located 21–50 km (35.49%) or 51–100 km (30.91%) from markets, while 19.35% were within 20 km and 14.25% beyond 100 km, indicating that most families live at a relatively moderate distance from the market, yet substantial geographic dispersion and transportation challenges faced by remote families. Logarithmic income values showed a mean of 11.99 (SD = 1.14). The annual income of herders' households was most commonly within the 200,001–500,000 yuan bracket, comprising 37.10% of the sample, followed by incomes of ≤100,000 and 100,001–200,000 yuan, both at 25.81%, and incomes above 500,000 yuan at 11.28%, illustrating a predominantly middle-to-high income distribution among interviewed herders.

(3) Livestock operation characteristics of interviewed herders

The average livestock inventory per household stood at 425.55 sheep units (SD = 316.96). Nearly half (49.20%) of the interviewed herders' households owned livestock numbers ranging between 200 and 500 sheep units, with 22.04% owning fewer than 200 sheep units and 28.76% owning more than 500 sheep units, generally indicating a medium-scale breeding level in the surveyed area. The mean value for "whether the herders have part-time income" was 0.23 (where "yes" = 1), meaning 76.61% of respondents relied solely on livestock income. This stark proportion highlights the heavy dependence on animal husbandry as the primary economic source, with limited alternative income streams, reflecting a relatively undiversified economic structure. The mean value for occupational transition willingness was 2.82 (between "unwilling" and "general"). Notably, 34.14 and 38.98% of the interviewed herders claimed that they were "relatively willing" and "willing" to embark on professional transformation (e.g., they preferred a novel mode of corporate joint management models or cooperative societies), demonstrating the

TABLE 3 Variable definition and descriptive statistical analysis.

Variable type	Variable name	Variable meaning and assignment	Mean	Standard deviation	Minimum	Maximum
	Compensation method	Which compensation type will you prefer to receive besides the current compensation method? Financial compensation = 1, In-kind compensation = 2, Technical compensation = 3, Policy-based compensation = 4	1.642	1.051	1	4
Individual characteristics	Gender	Female = 0, Male = 1	0.718	0.451	0	1
	Age	Actual age of the surveyed herders /year	47.798	10.459	21	87
	Education level	Years of education received by the surveyed herders /year	8.599	2.759	2	16
Family characteristics	Labor force size	Number of households who can engage in labor production or work / person	2.142	0.733	1	5
	Household income	ln (Average annual income of the household)	11.987	1.142	6.215	14.514
	Transport distance to the nearest market	Distance from the herders' residence to the nearest market /km	71.398	75.904	0.5	350
Livestock operation characteristics	Livestock number	Number of livestock raised by the households /sheep unit	425.554	316.957	0	1998
	Grazing area	ln (1 + the grazing land area owned by the herders)	6.169	3.295	0.000	9.898
	Forbidden grazing area	ln (1 + the forbidden grazing land area owned by the herders)	0.487	1.669	0.000	8.594
	Whether the herders have part-time income	No = 0, Yes = 1	0.234	0.424	0	1
	Willingness to professional transformation	Very unwilling = 1, Unwilling = 2, General = 3, Relatively willing = 4, Very willing = 5	2.820	0.933	1	5
Behavioral attitude characteristics	Rationality of compensation types	Very unreasonable = 1, unreasonable = 2, General = 3 Relatively reasonable = 4, very reasonable = 5	2.390	0.720	1	4
	Satisfaction with the compensation mechanism results	Very dissatisfied = 1, Dissatisfied = 2, General = 3, Relatively satisfied = 4, Very satisfied = 5	3.277	0.929	1	5
	Improvement extent of production and life by compensation policies	Greatly worsened = 1, A little worsened = 2, No change = 3, Improved a bit = 4, Greatly improved = 5	3.449	0.719	1	5
	Dependence degree on the compensation policies	Completely not dependent = 1, Not dependent = 2, General = 3, Relatively dependent = 4, Completely dependent = 5	2.401	1.045	1	5

10.3389/fsufs.2025.1512088

recognition and pursuit of modernized and scaled-up management strategies. Additionally, considerable variation exists in grazing and grazing-prohibited land areas owned by herder households. These disparities in natural resource endowments directly affect available farming resources, contributing to the substantial income differences observed among pastoral households.

(4) Behavioral and attitudinal characteristics of interviewed herders

The perceived reasonableness of subsidy types scored an average of 2.39 (between "unreasonable" and "general"), with 45.97 and 40.05% of surveyed herders describing the subsidy categories as "unreasonable" and "general." Satisfaction levels averaged 3.277 (between "general" and "relatively satisfied"), 35.22 and 44.09% held the attitude of "general" and "relatively satisfied" towards the subsidy and reward mechanism. The perceived improvement from subsidies averaged 3.45 (between "no change" and "improved a bit"), 39.52% believed that their production and life had not positively changed as a result of the subsidy and reward policy, while 49.19% felt that it had only "improved a bit." Dependence on subsidies averaged 2.40 (between "not dependent" and "general"), 24.19, 28.76, and 30.91% of herders were "completely not dependent" "not dependent," and "general" with respect to the subsidy and reward policies. In summary, herders' perceptions and attitudes towards grassland subsidy policies were polarized, but the majority agreed that the types of compensation currently provided were not sufficiently diverse, the current policy had a limited role in improving production and livelihoods, their satisfaction with the compensation mechanism was relatively neutral, and the degree of reliance on the compensation policy was relatively slight.

3 Results and analysis

3.1 Herders' preferences for grassland ecological compensation methods

Herders' demands for compensation exhibited diverse patterns. Up to 69.28% of the interviewed herders preferred financial compensation in addition to existing compensation forms, making it the most favored compensation method. This preference stems primarily from the fact that monetary funds, as liquid assets, are the most direct and swiftest means of increasing economic income, and can be freely disposed of without restrictions. In addition, because of their remarkable features of directness and transparency, monetary funds simplify the compensation process, minimize the complexity and uncertainty of intermediary links, and dramatically reduce the risk of compensatory funds being intercepted or withheld by third parties during their circulation. Of the herders, 10.22% opted for in-kind compensation in the form of living and production materials as supplementary compensation. The government's supply of livestock production materials effectively facilitates production for herders and alleviates the issues of "difficulty in purchasing and high prices" in the market procurement process. Of the respondents, 10.48% attached high priority to technical compensation, which serves as the internal core force of production operations and industrial development. According to the adage, "it is better to teach a man to fish than to give him a fish"; technical compensation enhances herders' production skills and management capabilities, and promotes green development, transformation, and upgrading in the livestock industry, ultimately yielding long-term production and economic benefits. Finally, 11.02% of the respondents favored policy-based compensation methods, including financial loan concessions, tax reductions and exemptions, and social security incentives. Not only do these measures provide substantial economic support, but they are also usually accompanied by sound institutional safeguards and regulatory evaluation mechanisms, which build strong government credibility and policy incentive effects owing to the soundness of the scheme and fairness, impartiality, and effectiveness of the implementation process. Information on the preferences for compensation methods is shown in Figure 2.

3.2 Correlations among herders' differentiated characteristics and compensation methods

MATLAB 2024a was used to calculate the grey relational degree. Initially, the index values of various herders' differentiation

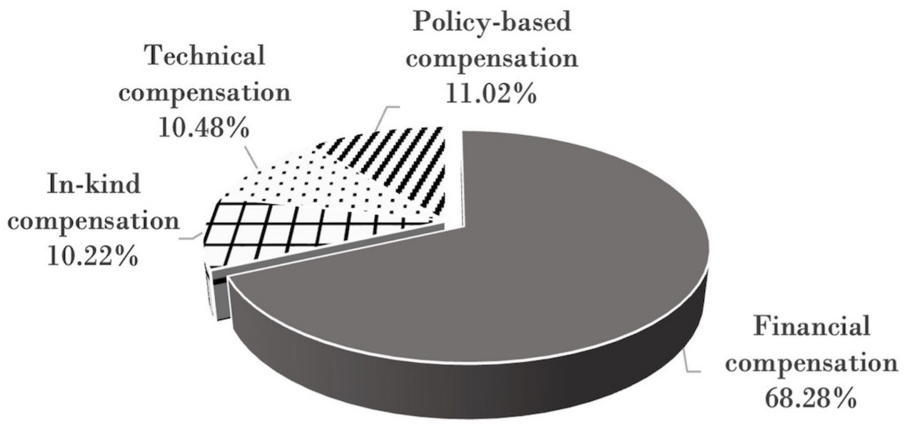

FIGURE 2
Selectional preferences of herders for grassland ecological compensation methods.

TABLE 4 Grey relational degrees between herders' differentiated characteristics and the choice of compensation methods.

Herders differentiation characteristic variables		Relational degree on the choice of compensation methods	Sorting results
Individual characteristics	Gender	0.9166	12
	Age	0.9396	5
	Education level	0.9396	5
Family characteristics	Labor force size	0.9384	7
	Household income	0.9425	1
	Transport distance to the nearest market	0.9151	13
Livestock operation characteristics	Livestock number	0.9303	10
	Grazing area	0.9257	11
	Forbidden grazing area	0.8608	15
	Whether the herders have part-time income	0.8631	14
	Willingness to professional transformation	0.9380	8
Behavioral attitude characteristics	Rationality of compensation types	0.9423	2
	Satisfaction with the compensation mechanism results	0.9386	6
	Improvement extent of production and life by compensation policies	0.9398	3
	Dependence degree on the compensation policies	0.9315	9

characteristic variables and selectional preference values were quantified by the mean method for dimensional normalization, specifically adopting the maximum–minimum normalization approach; we then introduced the grey relational coefficient formula to calculate the relational degree by weighted averaging. The results of these calculations are listed in Table 4. The level of the grey relational degree reflects the extent to which each indicator influences the choice of compensation method. Notably, all evaluated indicators in this study exhibited a gray relational degree of > 0.5, indicating a strong correlation between herders' differentiated characteristics and the selection of compensation methods, and confirming the reasonableness and reliability of the indicators selected in this study.

Correlation analysis between the various herders' differentiation characteristic variables and their preferences for compensation methods revealed that the grey relational grade of herders' individual characteristic variables ranged from 0.9166 to 0.9396, that of family characteristic variables ranged from 0.9151 to 0.9425, that of livestock management characteristic variables ranged from 0.8608 to 0.9380, and that of behavioral attitude variables ranged from 0.9315 to 0.9423. Family income, rationality of subsidy and reward types, and improvement extent of production and living by the compensation policies ranked in the top three (0.9425, 0.9423, and 0.9398, respectively). Overall, the grey relational degrees between herders' household-differentiated characteristics and choice of compensation methods were generally high, but there were still notable differences among the different differentiated characteristics. Behavioral attitudes demonstrated the highest correlation with grassland ecological compensation methods, followed by family, individual, and livestock management characteristics. As cognition and behavior theory emphasizes the role of cognitive activities in psychological or behavioral issues, herders' attitudes and perceptions towards grassland ecological compensation policies affect their enthusiasm for participating in ecological protection and adjusting their production and living behaviors. In the specific behavioral decision-making process, herders weigh the pros and cons based on the degree of satisfaction of their needs and their cognition of grassland compensation policies, and ultimately select the most suitable compensation method. It can be seen that behavioral attitude is one of the most direct psychological driving forces in the decision-making process, directly impacting on an individual's behavioral intentions and choice preferences. Therefore, compared with the external influence of personal and family socio-economic characteristics, behavioral attitudes and cognition play a relatively stronger role in the selection of grassland ecological compensation methods.

3.3 Impact of herders' differentiated characteristics on the choice of compensation methods

This study employed Stata SE 16.0 to conduct a multivariate unordered logistic regression analysis, constructing a MNL model with financial compensation as the reference category to explore the primary factors influencing herders' preferences in selecting grassland ecological compensation methods. For multicollinearity assessment, this study provisionally adopted the variance inflation factor (VIF) test to examine each independent variable individually. The results indicate that the maximum VIF value was 1.618; as this is less than the judgment criterion of 10, it suggests no multicollinearity among the independent variables in the model, thereby fulfilling the basic requirements for regression analysis. Regarding model validation, the −2 log-likelihood value was 625.046, the LR chi^2 (45) value was 98.918, and the likelihood ratio chi-square test result was 0. 000,

TABLE 5 Estimation results of the multinomial logit model.

Variable	Model 1 Logit (in-kind compensation/ financial compensation)			Model 2 Logit (technical compensation/ financial compensation)			Model 3 Logit (policy-based compensation/financial compensation)		
	Coef.	Std. Err.	RRR	Coef.	Std. Err.	RRR	Coef.	Std. Err.	RRR
Gender	−0.723*	0.392	0.485	−0.194	0.394	0.824	0.852*	0.500	2.345
Age	0.008	0.020	1.008	−0.045**	0.020	0.956	−0.075***	0.023	0.928
Education level	−0.065	0.077	0.937	−0.115	0.077	0.891	−0.105	0.081	0.900
Labor force size	−0.037	0.264	0.964	0.204	0.238	1.226	−0.643*	0.328	0.526
Household income	−0.085	0.203	0.918	−0.154	0.195	0.857	0.069	0.235	1.072
Transport distance to the nearest market	0.004**	0.002	1.004	−0.004	0.004	0.996	−0.003	0.003	0.997
Livestock number	−0.001	0.001	0.999	0.001**	0.001	1.001	0.000	0.001	1.000
Grazing area	0.003	0.063	1.004	0.180**	0.080	1.197	−0.057	0.061	0.945
Forbidden grazing area	−0.052	0.116	0.950	−0.188	0.201	0.829	0.044	0.117	1.045
Whether the herders have part-time income	0.268	0.420	1.307	0.278	0.435	1.320	0.886**	0.401	2.424
Willingness to professional transformation	0.031	0.224	0.970	−0.029	0.202	1.029	0.513***	0.197	0.599
Rationality of compensation types	0.278	0.257	1.320	0.138	0.260	1.148	0.463*	0.264	1.589
Satisfaction with the compensation mechanism results	−0.330	0.213	0.719	0.378	0.255	1.459	0.204	0.248	1.226
improvement extent of production and life by compensation policies	−0.362	0.258	0.697	−0.139	0.295	0.870	−0.363	0.294	0.696
Dependence degree on the compensation policies	−0.149	0.197	0.862	−0.380**	0.188	0.684	−0.077	0.194	0.926
_cons	1.423	2.850	4.148	1.012	2.872	2.750	0.444	3.230	1.559
Log likelihood	−312.523								
LR chi^2(45)	98.918***								
Pseudo R^2	0.137								
Number of observations	372								

***, **, and * denote significance at the 1, 5, and 10% levels, respectively.

demonstrating a good fit for the MNL model. The estimated results for each parameter are listed in Table 5.

3.3.1 Impact of individual characteristics

In Model 1, the negative impact coefficient of herders' gender on the choice of compensation methods, significant at the 10% level, indicated that in comparison to financial compensation, female herders were more willing to accept in-kind compensation than were male herders. Females may attach greater emphasis to the practicality and specific needs of items in daily life or production, such as livestock feed, production tools, and other necessities, which can directly address their actual demands in the family's livestock production. Additionally, females generally exhibit higher interest and activity levels in shopping and consumption, which potentially enhances their acceptance of in-kind compensation.

In Model 2, the negative impact coefficient of herders' age on the choice of compensation method was significant at the 5% level, suggesting that in comparison to financial compensation, younger herders prefer technical compensation compared with older herders. Elderly individuals tend to be more conservative and less receptive to new things, favoring "immediate and tangible" economic compensation. Conversely, young and middle-aged herders have a higher sensitivity to and acceptance of new technologies and methods, with a stronger innovative spirit and long-term planning awareness. They prioritize the enhancement of pastoral productivity and long-term economic benefits through technological means; as such, they favor technological compensation.

In Model 3, the positive impact coefficient of herders' gender and negative impact coefficient of age on the choice of compensation methods, significant at the 10 and 1% levels, respectively, revealed that in comparison to financial compensation, male herders prioritized policy-based compensation over female herders, and young herders prioritized it over older herders. Policy-based compensation, such as preferential loans, not only provides immediate financial support, but also offers a range of development opportunities, policy dividends, and long-term benefits. Males and young herders with relatively more aggressive and adventurous personalities may be more willing to attempt new policy tools and development pathways to pursue greater economic gains and better development opportunities.

Overall, the influence of individual characteristic variables in herders differentiation on the choice of ecological compensation method was primarily controlled by gender and age. Compared with direct financial compensation, female herders preferred more intuitive and practical in-kind compensation over male herders, young herders were more receptive to technical compensation focused on skill and capability enhancement than were older herders, male and young herders attached greater importance to the potential benefits and opportunities offered by policy-based compensation compared with female and older herders.

3.3.2 Impact of family characteristics

In Model 1, the positive impact coefficient of the distance from herders' residence to the nearest market on the choice of compensation method was significant at the 5% level, suggesting that, in comparison to financial compensation, pastoralists residing farther from marketplaces were more focused on obtaining in-kind compensation. Geographical remoteness prompts these herders to choose a form of in-kind compensation that can directly cater to their livelihood or production needs. Since pastoralists' life and production activities are closely tied to animal husbandry, there is an urgent demand for tangible items such as feed, veterinary drugs, and daily necessities. In-kind compensation effectively reduces intermediate links and transaction costs in material procurement, enhancing the convenience and practicability of the herders' production and life. Furthermore, in-kind compensation MAY evoke a higher degree of trust and security, as physical supplies are more reliable and stable, especially in dealing with uncontrollable risks such as natural disasters and disease outbreaks, and can swiftly provide the necessary aid and support.

In Model 3, the negative impact coefficient of household labor force size on the choice of compensation method was significant at the 10% level, indicating that among financial and policy-based compensation, herders' households with a larger labor force tended to opt for the more direct and convenient monetary compensation, whereas herders' households with fewer laborers leaned towards policy-based compensation. Households with a larger labor force often possess stronger productive capacity and higher economic capital demands, along with a wider range of economic activities and investment options. For them, financial compensation provides the most direct and efficient financial support, enabling them to expand production scale, improve living conditions, or engage in other forms of investment or activities. Conversely, in households with a relatively small labor force, the scarcity of internal labor resources prompts them to seek interventions that can stabilize the family's economic foundation and protect against potential risks. Therefore, opting for foundational policy safeguards, such as minimum living security and social security benefits, is not only a preventive strategy for the future of households but also a vital means of ensuring that the quality of life of family members is protected against external economic fluctuations.

Overall, the influence of family characteristic variables on herders' differentiation in the choice of ecological compensation methods was primarily manifested in the distance from herders' residences to the nearest market and size of the household labor force. Compared with direct financial compensation, the farther a herding household lived from the nearest marketplace, the higher its preference for visible and tangible in-kind compensation, meanwhile households with relatively fewer laborers were more inclined towards foundational policy incentives and social security compensation.

3.3.3 Impact of livestock operation characteristics

In Model 1, the positive impact coefficient of the livestock number and grazing area owned by herders on the choice of compensation method was significant at the 5% level, demonstrating that, in comparison to financial compensation, herders with a large amount of livestock and extensive grazing areas exhibited a stronger preference for technological compensation. As livestock size expands and grazing territories increase, the management difficulties and challenges faced by herders deepen, and traditional grazing patterns may be unable to cope with the surge in resource demand, prompting them to seek more efficient innovative breeding and management technologies. Technology compensation can help enhance livestock survival, breeding, and slaughter rates by offering advanced farming techniques and management methodologies, thereby significantly improving pastoral productivity, reducing production costs, and ensuring sustainable utilization of grassland resources while stabilizing the economic revenue of the livestock industry.

In Model 3, the positive impact coefficients of herders' part-time income and willingness for professional transformation on the choice of compensation methods were significant at the 5 and 1% levels, respectively, suggesting that, in comparison to financial compensation, herders with diverse income streams and stronger desires for transformational shifts were more willing to try policy-based compensation. Concurrent herders, who have income sources other than animal husbandry, usually have a solid economic foundation. This relative economic stability enables them to better withstand the uncertainties and risks associated with the transformation process. Thus, they are more likely to proactively seek policy-based compensation to support their transformation. Herder groups with a pronounced desire for professional transformation are often dissatisfied with their current production and operational modes. Thus, they aspire to achieve higher economic efficiency and sustainable development through professional transformation. Policy-based compensation provides technical training, market information, policy concessions, and a series of resources and services that can contribute to the success of professional transformation; therefore, for herders with a strong aspiration for professional transformation and clear transformation direction, policy-based compensation emerges as the preferred choice.

Overall, the influence of livestock operation characteristic variables on the choice of ecological compensation methods was primarily controlled by livestock number, grazing area, level of part-time income, and willingness for professional transformation. Compared with direct financial compensation, herders with a large amount of livestock and extensive grazing areas favored technological compensation, and those with concurrent income and a strong willingness for professional transformation were inclined towards policy-based compensation that facilitated transformation and development.

3.3.4 Impact of behavioral attitude characteristics

In Model 1, the negative impact coefficient of herders' dependence on subsidy and reward policies on the choice of compensation methods was significant at the 5% level, implying that among financial and technical compensation, a greater reliance on subsidy policies led herders to prefer direct and simplified financial compensation, whereas those with less dependence tended to favor technical compensation methods. The degree to which pastoralists rely on compensation policies primarily depends on their economic structure and revenue sources. Herders who are heavily reliant on subsidy policies are likely to have a simplistic economic structure, with compensation funds as the mainstay of their livelihoods; thus, they might be more concerned about the direct economic effects of the policies, and because of inertial thinking, they would be more inclined to maintain the original compensation path centered on financial subsidies. In contrast, herders with less dependence are likely to achieve relatively stable incomes through other channels and are more inclined to focus on enhancing production efficiency by upgrading their production capabilities and technical skills.

In Model 3, the negative impact coefficient of the rationality of compensation types on the choice of compensation methods was significant at the 10% level, suggesting that, compared with financial compensation, when compensation policy types exhibited higher rationality and variety, herders were more inclined to choose policy-based compensation. As subsidy types diversify and their designs become more refined, herders can select the most suitable compensation projects based on their individual circumstances and needs. This increased choice enables herders to opt for policy-based compensation that not only aligns with their interests but also addresses practical issues rather than relying solely on financial compensation. Furthermore, the richness of subsidy types enhances the attractiveness of the policies and herder satisfaction. When confronted with a diverse range of subsidy options, herders recognize the flexibility and inclusiveness of policies, which fosters greater trust and support for policy-based compensation.

Overall, the influence of behavioral attitude characteristic variables on herders' choice of ecological compensation methods was primarily controlled by the level of dependence on subsidy policies and rationality of compensation types. Compared with direct financial compensation, as herders' reliance on subsidy policies gradually diminished, they tended to favor technical compensation methods that can substantially enhance production capacity and efficiency. Meanwhile, as subsidy policies offered a richer and more rational range of options, pastoralists' preference for policy-based compensation became more pronounced.

4 Conclusion and discussion

4.1 Conclusion

This study explored the preference tendency of herders in the autonomous region regarding their participation in grassland compensation methods, and constructed a GRA and MNL model to empirically analyze the main factors affecting herders' preferences for compensation method selection. The conclusions are as follows.

(1) Herders' actual preferences for grassland ecological compensation methods exhibit diverse features. Over two-thirds are more inclined to accept financial compensation, while the remaining hold roughly comparable preferences towards in-kind compensation, technical compensation, and policy-based compensation methods. The current grassland ecological compensation framework is primarily reliant on monetary transfers. Therefore, there is a critical need to tailor compensation packages to the livelihood requirements of herders, diversify compensation methods, and enhance the efficiency of fund utilization.

(2) There is a notable correlation between herders' differentiated characteristics and their choice of grassland ecological compensation methods. From high to low, the correlation intensity can be ranked as follows: behavioral attitude, family, individual, and livestock operation characteristics. Therefore, to enhance the efficiency of ecological compensation and optimize the selection of compensation models, it is imperative to improve herders' awareness of grassland ecological conservation and differentiate the characteristics of herders differentiation, thereby establishing more tailored and heterogeneous compensation mechanisms that align with the specific needs of pastoralist communities.

(3) The different characteristics of herders have a significant impact on their choice of grassland ecological compensation methods. In comparison to financial compensation, the propensity to opt for in-kind compensation is notably affected by gender and transport distance to the nearest marketplace; the preference for technical compensation is associated with age, livestock numbers, grazing area, and degree of dependence on subsidy and reward policies; the choice of policy-based compensation is substantially driven by gender, age, number of family laborers, level of part-time income, willingness to professional transformation, and rationality of compensation types. This study provides critical theoretical underpinnings for adjusting grassland ecological compensation approaches and establishing diverse and differentiated grassland ecological compensation mechanisms.

4.2 Discussion

This study revealed significant differences in herders' preferences regarding grassland ecological compensation methods, with the formation of such preferences closely associated with differentiating factors, including decision-maker characteristics, household operational features, and livelihood strategies. This conclusion is corroborated by comparable research (Li et al., 2018; Yang et al., 2020; Yang and Cai, 2012), which collectively illuminates the shared

demands of farming and herding communities towards ecological compensation policies, simultaneously prioritizing the capital function for short-term livelihood security and institutional safeguard function for long-term resource rights. Notably, herders' preference for monetary compensation (69.28%) in this study was significantly lower than that of farmers (81.31%) (Yang et al., 2020). This disparity may stem from fundamental differences in production modes, resource dependencies, and policy response mechanisms between the two groups. Herders must balance long-term ecological protection with livestock production sustainability, whereas farmers should focus on immediate returns from production investments.

This study has several limitations. (1) Limitations of the study sample: The total sample size was relatively small, and the study area was limited to regions where livestock husbandry primarily relies on grazing. Although all major grassland types in Inner Mongolia were considered, the "stall feeding and pen rearing" method prevalent in the western region of Inner Mongolia was overlooked. As such, the generalizability of the research findings requires further verification. (2) Divergence in differentiation dimensions: This study was relatively dispersed in the dimensions of socio-economic characteristics (individual and family characteristics), livestock operation characteristics, and behavioral attitude characteristics. Further research should focus on income differentiation caused by differences in factor endowments and occupational differentiation resulting from differences in the allocation of production factors. For example, herders could be classified into four archetypal categories based on occupational differentiation—pastoral households, mixed-operation households, non-operational pastoral households, and non-pastoral households—to explore compensation preference patterns across different herder types.

Currently, grassland ecological compensation in China relies primarily on financial compensation. However, issues such as mismatch between financial compensation and herders' needs, inadequate regulatory mechanisms, and "free-riding" in ecological compensation often arise (Hu et al., 2019; Liu et al., 2025). These issues result in inefficient use of grassland ecological compensation funds, gradually transforming the original incentive policy for grassland protection into a "subsidy for the benefit of the people" policy in pastoral areas, thereby deviating from the policy objective of the grassland ecological compensation mechanism. Establishing a composite compensation policy system that combines "economic compensation incentives with non-monetary support" is a crucial path to achieving synergistic evolution between grassland ecological protection goals and societal development needs. Therefore, this study proposes the construction of diversified and differentiated compensation methods to address the current reliance on a single form of financial compensation. With regards to this issue, Li et al. (2014) suggested that grassland ecological compensation policies require adaptive adjustments to compensation standards, incorporating poverty alleviation and social security policies during implementation, while guiding herders to reform operational structures and upgrade industries. Zeng et al. (2017), from a mechanism transformation perspective, proposed building a multidimensional support system anchored in financial compensation—encompassing policies, technology, knowledge and projects—to transition grassland ecological compensation from short-term "blood transfusion-type" relief to long-term "hematopoietic" development. The one-size-fits-all compensation strategy is not conducive to the full exertion of policy incentives, inevitably provoking a reduction in the efficiency of policy implementation and irrational or inefficient allocation of limited financial resources (Luo et al., 2015). In contrast, if a variety of compensation methods that align with the objective laws of grassland pastoral areas and actual production and living needs of herders are implemented, this will contribute to improving the well-being of herders, encouraging them to voluntarily reduce livestock to achieve reasonable stocking rates, facilitating the realization of the core objectives of grassland ecological compensation policies. Therefore, there is an urgent need to innovate the design concept of grassland ecological

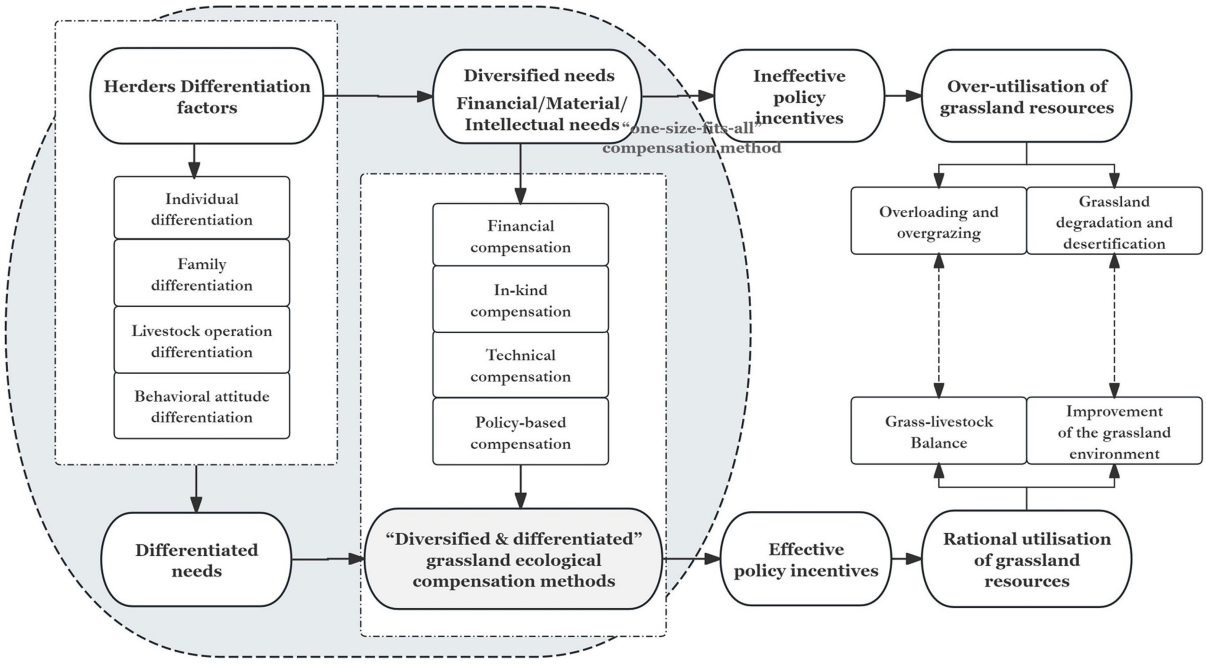

FIGURE 3
Conceptual model of diversified & differentiated grassland ecological compensation methods.

compensation, and to construct and advocate diversified & differentiated grassland ecological compensation methods; the corresponding conceptual model is shown in Figure 3. Firstly, in addition to the existing financial form of compensation, diversified compensation methods such as in-kind material compensation measures, social security systems, tax reductions and exemptions, loan preferential policies, and technical support should be provided as supplements; secondly, by considering factors related to herders differentiation and preference information, differentiated compensation strategies should be designed for herders in different regions and of different types. This will enable the supply of various compensation methods to maintain a dynamic balance between diversified and differentiated compensation demands at a high level. Specifically:

(1) Diversified methods

Based on our analysis of herders' preferences, the majority of herders still prefer an intuitive and immediate "financial compensation" method in addition to the current compensation form, and so the government should consider increasing the input of ecological compensation funds and raising the compensation standards of subsidies and rewards, such as providing additional fence subsidies, forage subsidies, and warm shelter subsidies. To avoid the negative effects of herders relaxing livestock management owing to subsidies, a conditional reward and penalty mechanism can also be introduced, where subsidies are distributed based on herders' compliance with grassland stocking regulations. Furthermore, future policies should be accompanied by a variety of incentives such as subsidies for basic living and production materials, support for basic social security systems, tax reductions and interest subsidies, training and consultation on barn feeding techniques, and the combination of different economic compensation methods to reduce policy implementation resistance, such as "rural social security & financial compensation" and "in-kind material compensation & financial compensation".

(2) Differentiated methods

Apart from being delineated on the basis of different grassland types and geographical regions (Liu and Zhang, 2018), this study, based on empirical results, argues that the design of grassland ecological compensation policy schemes should be fully integrated with differentiated characteristics of herders' socioeconomic backgrounds, livestock assets and natural resource endowments, livestock farming and concurrent employment situations, willingness to transition to other professions, and cognition and attitudes towards reward and penalty policies and types. For instance, providing daily necessities and livestock production materials to female herders who play crucial roles in family management and daily procurement, and to herders' households with remote locations and inconvenient transport; providing technical support for production, breeding, and operation to middle-aged and young herders with strong learning and acceptance abilities, herders' households with large-scale livestock farming and extensive grazing lands, and large-scale herders with strong economic strength who are not overly reliant on the reward and penalty policies; and providing policy compensation assistance to radical, adventurous male, middle-aged and young herders who are concurrently engaged in other professions, as well as to herders' households with imbalanced family labor structures and limited sizes, and who prefer the "cooperative or enterprise & herders household" professional transition.

Moreover, when optimizing grassland ecological compensation methods, a combination of positive and negative incentive strategies can be adopted. Besides advocating diversified compensation methods such as in-kind material compensation, technical support, and policy-based compensation, constructing differentiated compensation schemes based on herders' household differentiation and heterogeneity characteristics, and other positive incentives to encourage herders to consciously reduce their livestock, it is also necessary to utilize negative incentive methods to constrain herders' non-compliant breeding behaviors and reduce the frequency of overgrazing. Negative incentives can be implemented by increasing penalties for herders who violate overloading regulations through fines and confiscation of illegal income, improving the allocation of grassland management personnel, enhancing the grassland management staff system to strengthen supervision, establishing a grassland ecological protection credit evaluation system to incorporate violations into personal or corporate credit records, and launching a "snap and report" reward scheme to encourage the public to report violations and strengthen social supervision and other measures, thereby reducing herders' speculative behavior and improving policy implementation effectiveness.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the studies involving humans because the research did not require further ethics committee approval as it did not involve animal or human clinical trials and was not unethical. In accordance with the ethical principles outlined in the Declaration of Helsinki, all participants provided informed consent before participating in the study. Participants' anonymity and confidentiality were guaranteed and participation was entirely voluntary. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JH: Data curation, Formal analysis, Project administration, Writing – original draft, Writing – review & editing. YL: Investigation, Methodology, Writing – original draft, Writing – review & editing. XZ: Project administration, Supervision, Writing – review & editing. JZ: Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research 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) declare that no Gen AI was used in the creation of this manuscript.

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