Herders' willingness to accept for grassland grazing ban in northwest China[1]

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Abstract

Payment for Ecosystem Services (PES) has been widely acknowledged as an effective tool for mitigating grassland degradation and enhancing ecosystem services provision. However, critical factors such as herders' willingness to accept (WTA) preferences and their compensation expectations, are often overlooked, leading to insufficient effectiveness of PES initiatives. This study focused on grassland ecological compensation policy (GECP), quantifying herders' WTA compensation for grassland grazing bans. Through face-to-face surveys and employing the contingent valuation method, we estimated households' WTA for participating in a grassland conservation program aimed at bolstering ecosystem service provision. Our findings indicate that herders required an average compensation of 237 CNY mu^{-1} yr^{-1} to engage in the grazing ban program. Notably, our study revealed that herders' environmental awareness positively influenced their willingness to participation, whereas larger family sizes were negatively correlated with WTA. Additionally, herders in better health, with higher livestock incomes or categorized as semi-herders, tended to accept lower compensation levels. These insights are crucial for improving the effectiveness of GECP and provide valuable reference points for similar analyses in economically disadvantaged and ecologically fragile regions.

Keywords: anchoring effect, conditional value method, double-bounded dichotomous choice model, ecosystem services, grassland system, willingness to accept

1. Introduction

Grasslands play a pivotal role in global ecosystem services conservation. They provide a wide range of valuable ecosystem services that contribute to the well-being of humans (TEEB 2010). For example, grasslands make a significantly contribution to food security by providing part of the feed requirements of ruminants used in meat and milk production (O'Mara 2012). Additionally, most herders worldwide graze their animals on the grasslands, hunt wild animals and collect medicinal plants from grasslands (Sala and Paruelo 1997). Moreover, grasslands have been recognized as a critical source of non-market ecosystem services such as soil carbon sequestration (Lee *et al.* 2010; Bossio *et al.* 2020), maintenance of biodiversity, and climate regulation (Peciña *et al.* 2019).

The decline in ecosystem services due to grassland degradation is widespread in China and globally, leading to severe environmental issues. Finding solutions to halt and reverse grassland

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degradation is urgent. Many believe that the decline in economic value and material welfare from grassland ecosystem services results from a lack of effective institutions managing the supply and demand of these services. Payment for ecosystem services (PES) has been widely recognized as a valuable tool to address this issue. Enhancing grassland ecosystem services requires protection through restoration and conservation measures. In response, China launched the Grassland Ecological Compensation Policy (GECP) in 2011 to combat grassland degradation and improve the supply of ecosystem services.

However, compared to traditional PES schemes, the GECP has shown limited effectiveness in promoting grassland ecosystem service provision and transforming herders' livestock production methods. Studies indicate that while the GECP has increased grassland cover and quality to some extent, it has not yet met expected levels (Sun *et al.* 2024). Similarly, Min and Li (2019) found that the GECP did not enhance the supply of grassland ecosystem services in Sichuan Province. From 2010 to 2015, the average annual growth rate of its ecosystem service value was 0.1%. Moreover, although the implementation of the GECP has somewhat increased herders' income, it has not significantly transformed their livelihood, which predominantly rely on grazing (Wang and Huang 2018). The primary reason for this is that the top-down GECP inadequately considers herders' WTA. The payment standards are insufficient to incentivize herders to adopt new livestock production practices aligned with sustainable development goals. Therefore, further exploration of herders' WTA regarding grassland grazing ban policies is necessary to optimize and enhance the effectiveness of the GECP.

To determine herders' willingness to be compensated for participating in grassland grazing ban policies aimed at improving grassland ecosystem service, we employed a conditional value method (CVM) based on a double-bounded dichotomous choice (DBDC) format. This inquiry format simulates scenarios similar to cheap talk in real markets. Although CVM is commonly used to value public goods or ecosystem services without market values (Cummings and Taylor 1999), few studies have focused on grassland ecosystems (Lv *et al.* 2022). For instance, Chu *et al.* (2020), using the CVM method in a payment card format, determined that the willingness to accept compensation for afforestation projects in the Bashang Plateau averaged 478 CNY mu^{-1} yr^{-1}. This method is considered superior to continuous questionnaires and is widely used in the valuation of public goods (Arrow *et al.* 1993; Boyle *et al.* 1996). The National Oceanic and Atmospheric Administration (NOAA) guidelines also recommend using this format (Johnston *et al.* 2017).

The objectives of this study are twofold: i) to quantify herders' compensation expectations for participation in grassland grazing ban programs aiming at improving ecosystem services, thus establishing reasonable compensation standards to incentivize active participation in such programs; ii) to identify potential influential factors, including social, economic, and environmental determinants that affect their WTA and comprehensively assess their impact on herders' decision-making. The results revealed that herders require an average compensation of 237 CNY mu^{-1} yr^{-1} to participate in the grazing ban program aimed at improving the provision of grassland ecosystem services. This estimate is 10 to 55 times higher than current actual compensation levels, indicating a significant gap between the current compensation standards and herders' actual needs. Herders who closely follow environmental protection news require a compensation of 147 CNY mu^{-1}, a lower amount compared to their counterparts. Additionally, semi-pastoral herder households, smaller families, and those with higher incomes are more inclined to participate in grassland grazing bans at lower compensation levels.

This study contributes significantly to the literature in two ways. First, it is one of the few studies to explore herders' perspectives on the compensation required for grassland grazing bans aiming at improving ecosystem services. Existing studies on WTA for ecological protection primarily focus on forests (Vedel *et al.* 2015), wetlands (Xiong *et al.* 2019) or farmlands (Zuo *et al.* 2020), with few addressing compensation for improving grassland ecosystem services and herders' preferences. Second, our research involves a large-scale survey of herders in the northwest region, filling a notable gap in the existing literature. While the GECP is widely implemented across China, the quality of grasslands varies. However, most studies focus on specific provinces (Li *et al.* 2021; Yang *et al.* 2022) or counties (Yang *et al.* 2006; Zhen *et al.* 2014), with relatively few large-scale GECP studies conducted. This survey not only provides valuable first-hand data but also offers new perspectives and opportunities for in-depth analysis of herders' perceptions of grassland ecosystem services and the ecological environment in this region.

2. Background

This study was conducted in the northwest pastoral region, encompassing the Gansu province, Qinghai province, and the Xinjiang Uygur Autonomous Region (hereafter referred to as "Gansu", "Qinghai" and "Xinjiang" respectively). This region is a vital hub for livestock production in China, boasting expansive grasslands that cover 96.04 million hectares, accounting for 35.5% of the country's total grassland area. Livestock farming is the primary economic activity for local herders, contributing nearly 80% to their income and playing a pivotal role in their livelihoods. However, the grasslands in the study area are continuously degrading, leading to a fragile grassland ecosystem and a significant insufficiency in the provision of ecosystem services. In response to the ongoing degradation of grasslands and to ensure the sustained provision of ecosystem services, this region has successively implemented two rounds of GECP.

As one of the core measures of the GECP, the grazing ban policy aims to promote the restoration and protection of grassland ecology by restricting or completely prohibiting grazing activities on the grasslands. However, since many herders depend on grassland grazing as their primary livelihood, the grazing ban policy directly impacts their economic sources and lifestyles, leading to significant disagreements on the acceptance and support of the policy. Herders have diverse opinions on the compensation levels for the grazing ban, the fairness of the compensation mechanism, and the long-term effects of the policy, all of which exacerbate the complexity and challenges of policy implementation. Therefore, as a crucial measure within the GECP, the design and implementation methods of the grazing ban policy urgently need further optimization to enhance the overall effectiveness of the policy.

3. The methodology and survey design

3.1 DBDC model

We employed the DBDC model, as introduced by Hanemann *et al.*(1991), to evaluate the WTA levels of the surveyed herders. The DBDC model assumes that there are no changes in the underlying WTA distribution between the initial bid (prior WTA) and the second bid (posterior WTA). Additionally, this model allows for the inclusion of anchoring effect and shifting effect caused by the second question. Apart from the basic DBDC model, which assumed no anchoring or shifting effects (where prior equals posterior WTA), we also estimated two additional DBDC models: one with anchoring effects and another with both effects (where prior differs from posterior WTA).

In the DBDC model, a second bid was proposed to the herders. If herder i answered yes to the first bid, the second bid was lower; otherwise, it was higher. The basic DBDC model assumed that WTA was independent of both the first bid and the second bid. The prior WTA of the independent was defined as follows:

$W_{i1} = X_i\beta + u_i, \quad u_i \sim NID(0, \sigma^2)\#(1)$

where X_i is a vector of herders' characteristics that influence their WTA (Table 1), β is a vector of parameters and u_i is the error term, which is assumed to be normally distributed with a mean of zero and a standard deviation σ.

However, the second discrete answer may be subject to bias. Firstly, the first bid may induce a starting point bias, as herders may anchor their WTA on this bid, perceiving it as indicative of the "correct" price. Consequently, herders integrate their prior WTA, with the first bid to form a revised or posterior WTA. To address this issue, Herriges and Shogren (1996) introduced a DBDC model with constant anchoring, where the WTA is defined as a convex combination of the prior WTA and the first bid such that:

$W_{i2} = (1-\gamma)W_{i1} + \gamma b_{i1}\#(2)$

where W_{i1} and W_{i2} represent the prior and posterior WTA of the ith herder, respectively. b_{i1} is the first bid presented to the ith herder, and γ is a factor ranging between zero and one, indicating the extent of the anchoring effect.

Secondly, the second bid may induce behaviors such as yea-saying or incentive incompatibility. These phenomena are typically manifested as a shift in herders' responses between the first and second dichotomous question (Schwarzinger *et al.* 2009;Tapsuwan *et al.* 2010). Shifting effect is defined as a WTA that is independent of the initial bid.

$$W_{i2} = W_{i1} + \delta\#(3)$$

where δ represents the "shift effect" parameter. This parameter can be positive, as indicated by yea-saying behavior (Whitehead 2002) or negative, as a result of incentive incompatibility (Alberini *et al.* 1997).

Alberini *et al.* (1997) introduced a DB model with a shift parameter, postulating that the posterior WTA was derived from the true prior WTA, adjusted by a shift parameter. Formally, the econometric model is defined as follows:

$$W_{i2} = (1-\gamma)W_{i1} + \gamma b_{i1} + \delta\#(4)$$

Both the prior WTA and the posterior WTA are not directly asked for. When each herder is presented with two bids, there are four possible answers: "yes-yes", "yes-no", "no-yes" and "no-no". Based on Eq. (1) and Eq. (2), the probability of a 'yes' to the first bid and a 'yes' to the second bid is calculated as:

$$P_i^{YY} = \Pr(W_{i1} < b_{i1}, W_{i2} < b_{i2}) = \Phi\left(\frac{b_{i2} - \gamma b_{i1} - \delta}{(1-\gamma)\sigma_i} - \frac{X_i\beta}{\sigma_i}\right)\#(5)$$

where $\Phi(.)$ is the normal cumulative distribution function (c.d.f.) since error terms are assumed to be normally distributed.

The probabilities corresponding to the other possible pairs of response are calculated in the same way:

$$P_i^{YN} = \Pr(W_{i1} < b_{i1}, W_{i2} > b_{i2}) = \Phi\left(\frac{b_{i1} - X_i\beta}{\sigma_i}\right) - \Phi\left(\frac{b_{i2} - \gamma b_{i1} - \delta}{(1-\gamma)\sigma_i} - \frac{X_i\beta}{\sigma_i}\right) \#(6)$$

$$P_i^{NY} = \Pr(W_{i1} > b_{i1}, W_{i2} < b_{i2}) = \Phi\left(\frac{b_{i2} - \gamma b_{i1} - \delta}{(1-\gamma)\sigma_i} - \frac{X_i\beta}{\sigma_i}\right) - \Phi\left(\frac{b_{i1} - X_i\beta}{\sigma_i}\right) \#(7)$$

$$P_i^{NN} = \Pr(W_{i1} > b_{i1}, W_{i2} > b_{i2}) = 1 - \Phi\left(\frac{b_{i2} - \gamma b_{i1} - \delta}{(1-\gamma)\sigma_i} - \frac{X_i\beta}{\sigma_i}\right) \#(8)$$

Accordingly, the log-likelihood function is defined as follows:

$$\ell(y;\ \beta, \gamma, \delta, \sigma) = \sum_i^n [I_i^{YY}\, Ln(P_i^{YY}) + \ I_i^{YN} Ln(P_i^{YN}) + I_i^{NY}\, Ln(P_i^{NY}) + I_i^{NN} Ln(P_i^{NN})] \qquad (9)$$

where $I_i^{YY}, I_i^{YN}, I_i^{NY}$ and I_i^{NN} are dummy variables. $I_i^{YY} = 1$ if the ith herder's response is "yes-yes", and zero otherwise.

3.2 Bivariate probit model

An alternative method for estimating DBDC data is to use the bivariate probit model with looser constraints (Cameron and Quiggin 1994). This model imposes fewer constraints by relaxing the assumption of complete independence between the two responses, allowing for varying latent WTA for each of the questions. The bivariate probit model can be specified as follows (Cameron and Quiggin 1994; Tapsuwan *et al.* 2010):

$$y_1^* = X_1\beta_1 + \gamma_1 bid_1 + \varepsilon_1,\ \ y_1 = 1\ if\ y_1^* > 0,\quad 0\ \text{otherwise}\#(10)$$

$$y_2^* = X_2\beta_2 + \gamma_2 bid_2 + \varepsilon_2,\ y_2 = 1\ if\ y_2^* > 0,\quad 0\ \text{otherwise}\#(11)$$

where y_1, y_2 denote the binary responses to the bid offers (bid_1, bid_2), respectively; if the latent variable $y_2^* > 0$, the herders will be willing to accept the bids, and 0 otherwise. X_1, X_2 is a vector of herder's characteristics, similar to those in Eq. (1). β_1, β_2, γ_1, γ_2 are the parameter vectors to be estimated. ε_1 and ε_2 are random disturbance terms, following a bivariate joint normal distribution. The correlation coefficient between the two disturbance terms is denoted as ρ, defined as:

$$\begin{pmatrix}\varepsilon_1\\ \varepsilon_2\end{pmatrix} \sim N\left\{\begin{pmatrix}0\\0\end{pmatrix}, \begin{pmatrix}1 & \rho\\ \rho & 1\end{pmatrix}\right\}\#(12)$$

if $\rho \neq 0$, it indicates that the two latent variables, y_1^* and y_2^*, are related to each other and are not independent. Accordingly, the probabilities of the four possible responses of the sample herders to the two questions can be expressed as follows:

$$\begin{cases} P(\ y_1 = 1, y_2 = 1) = P(y_1^* \le bid_1, y_2^* \le bid_2) \\ P(\ y_1 = 1, y_2 = 0) = P(y_1^* \le bid_1, y_2^* \ge bid_2) \\ P(\ y_1 = 0, y_2 = 1) = P(y_1^* \ge bid_1, y_2^* \le bid_2) \\ P(\ y_1 = 0, y_2 = 0) = P(y_1^* \ge bid_1, y_2^* \ge bid_2) \end{cases} \#(13)$$

The likelihood function for estimating relevant parameters is constructed as follows:

$$L = P(\ y_1 = 1, y_2 = 1) \times P(\ y_1 = 1, y_2 = 1) \times P(\ y_1 = 1, y_2 = 1) \times P(\ y_1 = 1, y_2 = 1)(14)$$

Following Alberini (1995), we also employed a bivariate probit model for this DBDC data estimation. This approach allowed us to assess the sensitivity and stability of the estimated parameters in the DBDC model, thereby validating the robustness of the results. The estimation results from both models were presented in Table 3 and Table 4 respectively.

The parameters in the equation above are estimated using the maximum likelihood method. Next, the delta method is applied to estimate the herders' WTA and the standard error. The mean WTA can be predicted as follows:

$$WTA = \frac{\sum(\beta\overline{X})}{-\gamma} \#(15)$$

3.3 Survey implementation

We conducted face-to-face surveys in Gansu and Qinghai in October 2020 and in the Xinjiang in September 2021. A stratified random sampling strategy was used to select herders. Specifically, four counties in Gansu, six counties in Qinghai and six counties in Xinjiang were selected based on annual income per capita. Then, three townships were chosen from each county according to per capital grassland area. Similarly, two villages were further sampled from each township, and six herders were randomly selected from each village. Finally, we surveyed 580 herders in 96 villages, 48 townships, and 16 counties.

To address potential biases and enhance the reliability and effectiveness of our study, we implemented several measures during the questionnaire design and survey phase, drawing on the approach by Frey and Pirscher (2019) and Chu *et al*. (2020). Firstly, a pre-survey was conducted to establish a reasonable bid range and minimize the bias in the bidding start point. Secondly, the grassland grazing ban program and the status of grassland degradation were introduced to herders to avoid information bias and imaginary bias. Lastly, to reduce investigation method bias and investigator bias, we employed face-to-face interviews and ensured investigators underwent training before the formal survey.

To ensure the accuracy and reliability of the survey, a pre-survey was conducted and improvements were made in the final version of the questionnaire. The finalized questionnaire primarily incorporates three sections: 1) The basic information of herders, including gender, age, education level, as well as the family situation, mainly encompassing the livestock situation and grassland area. 2) Herders' awareness and satisfaction with grassland ecosystem services. In this part, a series of questions were set for herders to indicate their understanding and satisfaction toward each grassland ecosystem services after a brief description. 3) Herders' WTA for participating in a grassland grazing ban program aimed at improving corresponding services.

The third section was the core of the questionnaire aimed at estimating the WTA of herders using the DBDC format. The first and central question in this section was, "if the government offers you a certain amount of compensation to participate in a grazing ban program aimed at improving grassland ecosystem services, and you determine the duration and the area of grassland participating in this program, would you like to join?" Here, "a certain amount of compensation" referred to the initial bid value. Then, a second dichotomous choice question was required based on the responses to the first question. If the herder responded "yes" to the initial bid, the second bid given to the herder was somewhat lower than the first bid. However, if the answer was 'no' to the first question, then a higher bid would be given in the second question.

The initial bid values were set as follows: 3, 8, 20, 80, 170 and 300 CNY mu^{-1} yr^{-1}. These values were determined for two main reasons. Firstly, the GECP has broad coverage, encompassing various types of grasslands, resulting in significant differences in grassland quality and consequent varying losses for herders due to the GECP. Secondly, by integrating the actual subsidy standards of the GECP with the economic value of grassland ecosystem services, the current range of bid values was established. Currently, the minimum subsidy standard under the GECP is 1.5 CNY mu^{-1} (Hu *et al*.

2019), whereas the economic value of primary ecosystem services for grassland is approximately 500 CNY mu^{-1} (Liu *et al.* 2022).

4. Results

4.1 Descriptive statistical analysis

Table 1 shows the family characteristics of the herders surveyed. In this survey, a total of 545 valid questionnaires from an initial pool of 576, resulting an effective response rate of 94.62%. The primary reasons for invalid questionnaires were missing answers, incomplete data, or inconsistent responses. Of these valid questionnaires, 36.15% came from Qinghai, 37.98% from Xinjiang, and the remaining from Gansu. The distribution of the sample size is considered reasonably representative, especially when taking into account the proportional grassland area of the three provinces, which follow a ratio of 3:3:2.

The average family size among the herders was 5 individuals, and an overwhelming majority of herders (77.25%) relied solely on livestock grazing for sustenance. The majority of the interviewed herders were males, with an average age of 49 years, indicating that they served as the primary workforce with decision-making authority and significant influence over their family's agricultural activities. On average, the surveyed herders possessed approximately 6,392 mu of grassland and maintained an average livestock count of 226. Their annual income amounted to around 60,783 CNY.

The health status of the herders was measured using a Likert scale, ranging from 1 (very poor) to 5 (very good). With an average value of 3.769, it indicated that the health status of the herders was generally good. Furthermore, the proficiency in the Mandarin among herders may influence their decision to work in towns, thereby indirectly affecting their participation in the grazing ban programs. This proficiency was measured on a scale from 1 (not proficient) to 3 (very proficient), with an average of 2.261, indicating that most herders had limited proficiency in the Mandarin.

Table 1
Descriptive statistical analysis of variables[1)]

Variables	Definition	Mean	Std.	Min	Max
Dependent variable					
First bid	The first bid value (*CNY* mu^{-1} yr^{-1})	94.812	106.727	3	300
First answer	Answer to the first question. 1=Yes, 0=No	0.371	0.483	0	1
Second bid	The second bid value (*CNY* mu^{-1} yr^{-1})	110.760	128.651	1.5	480
Second answer	Answer to the second question. 1=Yes, 0=No	0.389	0.488	0	1
Family characteristics					
Population	Family size	4.606	1.715	1	12
Gender	Herder's gender. 1=Male; 0=Female	0.892	0.311	0	1
Age	Herder's age (*years*)	49.741	11.498	15	76
Healthy	Health status of the herder. 1=Very bad, 2=Bad, 3= Neutral, 4=Good, 5=Very good	3.769	1.204	1	5
Mandarin	The Mandarin proficiency of the herder. 1=Not at all, 2= Little, 3=Fluent	2.261	1.482	1	3
Occupation	Herder's occupation. 1=Herder, engaged in grazing fulltime; 0= Semi-herder, engaged in both grazing and farming	0.772	0.420	0	1

Area	The grassland area owed by the herder (*mu*)	6392	17796	0	190000
Income	Total annual livestock income (*CNY yr*$^{-1}$)	60783	109299	0	1105000
Livestock	The number of sheep units kept by the herder (*head*)	226.318	226.531	0	1650
Province dummy					
Gansu	1= Herders from Gansu, 0=Other	0.259	0.438	0	1
Qinghai	1= Herders from Qinghai, 0= Other	0.361	0.486	0	1
Xinjiang	1= Herders from Xinjiang, 0= Other	0.380	0.481	0	1
Environmental awareness characteristics					
News	Attention to environmental protection news. 1= Yes, 0= No	0.840	0.367	0	1
Importance	Importance of grassland ecosystem services. 1=Unimportant, 2=Neutral, 3=Important, 4=Very important	3.752	0.545	1	4
Score	The status of the community ecological environment. 1=Very bad, 2=Bad, 3=Neutral, 4=Good, 5=Very good	4.070	0.945	1	5

1) 1 ha=15 mu

The herders' environmental awareness and their perception of the importance of grassland ecosystem services were described in the last three rows of Table 1. The results showed that a significant portion of herders, accounting for 84.21%, demonstrated a high level of concern regarding environmental protection news. The importance of grassland ecosystem services was measured using a 1-4 ordinal scale, ranging from unimportant to very important, with an average score of 3.752. This suggests that a majority of herders place considerable emphasis on the ecosystem services provided by grasslands. Additionally, herders rated the ecological environment of their community with an average score of 4.07 (on a scale of 1-5).

Furthermore, we also investigated herders' awareness and satisfaction regarding 13 different grassland ecosystem services (Fig. 1). As depicted in Fig. 1a, apart from aspects such as climate regulation, pollination, biological pest control, and genetic diversity, over 60% of the herders displayed a high level of awareness of the various ecosystem services. The least recognized service was pollination, with less than one-third of herders being aware of it. Similarly, less than 50% acknowledged that the biological control and genetic diversity services were provided by grasslands. Despite the relatively low awareness of specific services like pollination, biological pest control, and biodiversity, the overall results indicate a strong general understanding of grassland ecosystems among herders.

Regarding satisfaction levels (Fig.1b), most herders expressed contentment with ecosystem services including water supply, food, raw materials, air quality, erosion control, water regulation, waste treatment, and recreational and aesthetic services, with around 80% satisfaction. However, the service that received the lowest satisfaction rating was pollination, with less than 60% of herders considering it satisfactory.

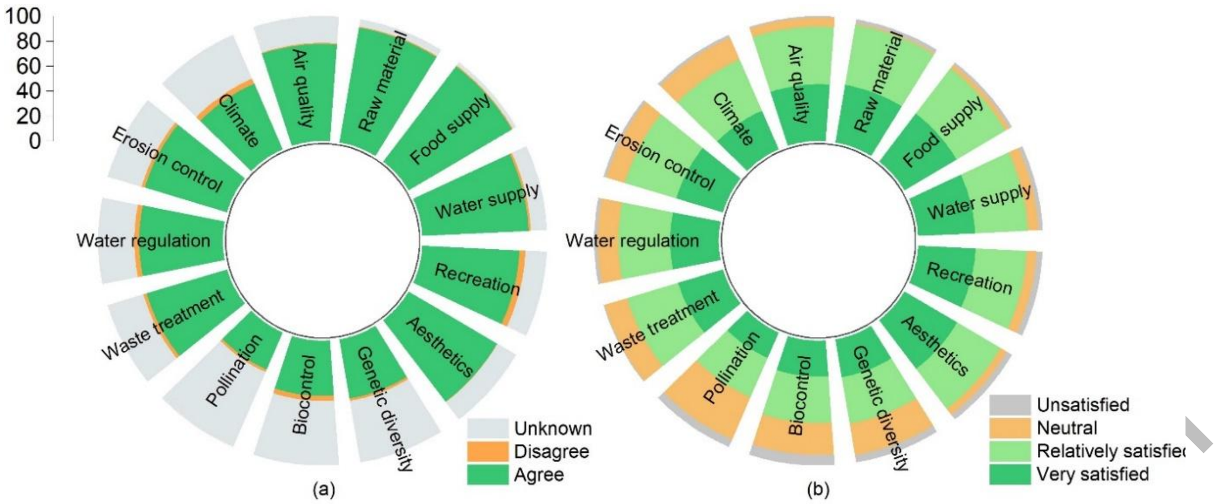

Fig. 1 Herders' perceptions (A) and satisfaction (B) with grassland ecosystem services.

4.2 Herders' responses to different compensation levels

In our survey, we implemented six bidding schemes with initial bid values set at 3, 8, 20, 80, 170, and 300 CNY mu^{-1} yr^{-1}, respectively. The proportion of valid questionnaires for the six bidding options was approximately equal, at around 17% for each. This equal distribution of bid options enabled us to more effectively examine the impact of bid value on herders' choices while avoiding potential systematic bias due to an imbalanced distribution of bid options.

As shown in Table 2, the proportion of responses that passed both the first and second questions was roughly consistent, standing at 37% and 39%, respectively. This consistency implies that the initial response did not significantly influence the choice in the second round, and the herders were able to independently consider each question, basing their decisions on personal preferences and needs during the second round of our DBDC experiment. Furthermore, as anticipated, an increase in bid value led to a higher propensity for herders to choose "yes" as their preferred option. This trend demonstrates a positive correlation between the bid value and the likelihood of herders opting for "yes", affirming our hypothesis regarding bid value's influence on decision-making in this context.

Table 2 The number of responses from herders for six bidding options

NO.	Bids (CNY mu^{-1} yr^{-1})			Number of herders answering the first question			Number of herders answering the second question		
	Initial bid	Lower bid	Higher bid	Yes	No	Total (%)	Yes	No	Total (%)
①	3	1.5	8	14	75	89 (16.3%)	21	68	89 (16.3%)
②	8	3	20	31	65	96 (17.6%)	39	57	96 (17.6%)
③	20	8	80	25	68	93 (17.1%)	37	56	93 (17.1%)
④	80	20	170	34	54	88 (16.1%)	32	56	88 (16.1%)
⑤	170	80	300	43	49	92 (16.9%)	39	53	92 (16.9%)
⑥	300	170	480	55	32	87 (16.0%)	44	43	87 (16.0%)
			Total	202	343	545 (100%)	212	333	545 (100%)

In our analysis of herders' reasons for non-positive WTA reactions, detailed in Fig. 2, we found that out of the 545 valid questionnaires, 239 herders (43.9%) expressed unwillingness to accept compensation for participating in a grassland grazing ban program. On one hand, of these zero WTA responses, a significant portion (80.75%) represented genuine zero responses. Within this subset, 66% of the herders believed that the compensation for the grazing ban was insufficient to offset potential economic losses. Reasons such as "Having nothing to do after grazing prohibition" and "Grazing prohibition would reduce income" accounted for approximately 18% and 16%, respectively. Only two herders stated that "the grassland quality was in very good condition and no improvement was needed", indicating satisfaction with the current stat of the grassland.

On the other hand, 19% of the zero WTA responses were protest answers, primarily because they believed that grazing represents their culture and way of life, which cannot be adequately compensated with money. The rest believed that grassland protection should be the responsibility of the government, or that the state of the grassland environment had minimal impact on their lives. We believe that herders who gave protest responses genuinely have no WTA, whereas those with genuine zero responses might develop a positive WTA if their income constraints are alleviated or if the condition of the grassland deteriorates.

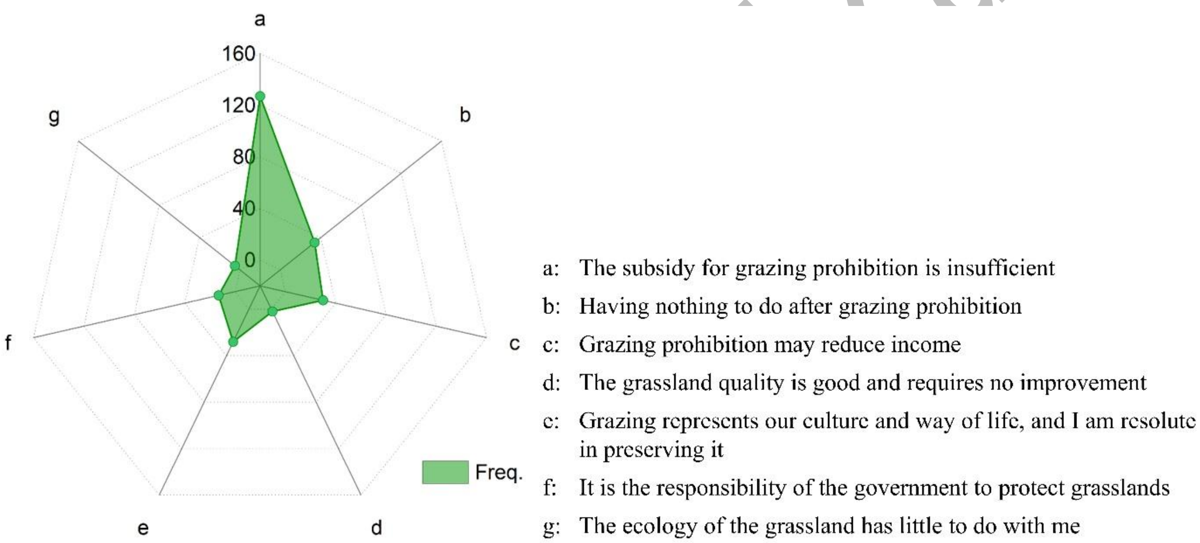

Fig. 2 Reasons for the non-positive WTA responses.

4.3 Factors affecting herders' WTA

Table 3 presents the outcomes of the three econometric models employed to analyze the DBDC data: the basic DBDC model (Model 1), the DBDC model accounting for the anchoring effect (parameter γ) (Model 2), and the DBDC model considering both the anchoring effect (parameter γ) and the shifting effect (parameter δ) (Model 3). In models 2 and 3, the parameter γ was significantly positive at 0.631 ($\mathrm{p} < 0.0001$), indicating the presence of the anchoring effect. Conversely, the shifting effect δ at 1.047($p > 0.1$), was not statistically significant. However, in some related literature calculating WTP, this value is significantly negative (Alberini *et al.* 1997), which means that the follow-up questions are incentive incompatible. As Table 3 illustrates, the regression outcomes of Model 2 and Model 3 were congruent. Therefore, the results derived from Model 3 are primarily reported.

Out of 15 variables examined, four socioeconomic characteristics of herders, family population, herder's healthy status, herder's occupation, and livestock income were significantly associated with their willingness to participate in the grazing ban program (P<0.1). Both healthy status and livestock income exhibited a negative correlation with WTA. Specifically, herders in good health had a WTA 45 CNY mu^{-1} lower than their less healthy counterparts, likely because those with poorer health conditions require higher compensation to counterbalance potential economic losses from diminished labor and grassland use.

Notably, families with higher income levels exhibited a lower WTA, possibly due to their lesser reliance on grazing and greater financial security, diminishing their need for compensation. In contrast, lower-income families may depend more on compensation to meet basic living needs or handle unexpected economic pressures, resulting in a higher WTA.

Additionally, a positive and significant correlation was observed between family size and WTA. The results indicated that for each additional family member, herders request an increase of 34 CNY mu^{-1} in compensation. The occupation of herders also profoundly influenced their WTA; specifically, pure herders demanded a significantly higher WTA of 97 CNY mu^{-1} compared to semi-herders.

Regional attributes of herders also affected their WTA, with those from Xinjiang displaying a significantly lower WTA of 219 CNY mu^{-1} than their counterparts from Gansu province. However, other socioeconomic factors, such as gender, age, Mandarin proficiency, livestock, and grassland area, did not show a significant correlation with WTA (p> 0.10)

Regarding herders' awareness of grassland conservation, variables like the perceived importance of the grassland ecosystem (*importance*) and the status of the community ecological environment (*score*) did not significantly impact their WTA (p>0.10, Table 3). Conversely, attention to environmental protection news (*news*) had a significant negative effect on WTA. Herders more attuned to environmental news exhibited a WTA 147 CNY mu^{-1} lower than those less attentive. This trend might be attributable to environmentally conscious herders having a greater appreciation of the benefits of healthy grasslands, thus showing more willingness to engage in grazing ban programs at a lower WTA.

Table 3 The regression results of the DBDC model

	Model 1		Model 2		Model 3	
Variables	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Population	13.726**	5.798	34.059**	13.325	34.060**	13.324
Gender	-21.054	36.887	-57.266	72.933	-57.125	72.918
Age	-1.245	0.932	-2.366	1.933	-2.362	1.933
Healthy	-24.426***	9.146	-45.003**	19.834	-45.034**	19.836
Mandarin	-5.169	8.839	-9.688	18.255	-9.666	18.259
Occupation	42.477*	24.122	96.845*	51.871	96.831*	51.860
Area	488.187	0.488	698.663	1.115	697.888	1.115
Income	-166.860*	0.097	-398.631**	0.202	-398.511**	0.202
Livestock	41.296	0.056	64.236	0.108	64.123	0.108
Qinghai	39.854	35.008	75.085	70.321	75.179	70.327
Xinjiang	-110.897***	32.877	-218.733***	77.966	-218.763***	77.980
News	-75.863**	32.476	-147.363**	68.246	-147.240**	68.239
Importance	1.622	20.432	13.549	39.929	13.618	39.935
Score	-8.410	11.724	-20.464	23.150	-20.426	23.151

Qinghai	39.854	35.008	75.085	70.321	75.179	70.327
Xinjiang	-110.897***	32.877	-218.733***	77.966	-218.763***	77.980
Constant	354.387***	119.287	543.755**	256.643	540.885**	256.504
Anchoring effect γ			0.631***	0.073	0.632***	0.073
Shifting effect δ					1.047	0.740
Log likelihood	-764.053		-734.122		-733.027	
Observations	545		545		545	

***, ** and * are significant at the 1, 5 and 10% levels, respectively.

4.4 The regression result of the bivariate probit model

The estimation results of the bivariate probit model, which employs more relaxed constraints, are depicted in Table 4. Model 4 represents an unconstrained binary probit model, allowing distinct regression equation coefficients for each response. The significance of the correlation coefficient ρ (P=0.009), which measures the interrelation between the two response equations, highlights the necessity of employing the bivariate probit model.

Additionally, a coefficient consistency test conducted on the two response equations of Model 4 yielded insufficient evidence to reject the null hypothesis, with $\chi^2(16) = 24.98$ and $P = 0.07$. Consequently, the regression parameters for the two response equations in Model 5 were constrained to be identical, resulting in a more optimal model fit. Equations 8 and 9 demonstrate that anchoring effects are accounted for by incorporating the first bid as an explanatory variable in the second response equation for both models.

Table 4 illustrates that the regression coefficient of 'bid1' in Model 5 is significantly positive, affirming the presence of anchoring effects. This finding aligns with the results obtained from Models 2 and 3. Moreover, given that the regression outcomes of Model 5 are consistent with those of Model 3, we will not reiterate these results here.

Table 4 The regression results of the bivariate probit model

	Model 4				Model 5			
	First answer		Second answer		First answer		Second answer	
Variables	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
First bid	0.004***	0.001	0.001	0.001	0.003***	0.000	-0.001*	0.000
Second bid			0.001	0.001			0.003***	0.000
Population	-0.125***	0.038	-0.023	0.036	-0.076***	0.028	-0.076***	0.028
Gender	0.278	0.213	-0.073	0.199	0.107	0.158	0.107	0.158
Age	0.004	0.006	0.008	0.006	0.006	0.005	0.006	0.005
Healthy	0.141**	0.058	0.067	0.055	0.105**	0.044	0.105**	0.044
Mandarin	-0.007	0.057	0.073	0.055	0.033	0.043	0.033	0.043
Occupation	-0.217	0.163	-0.347**	0.154	-0.292**	0.123	-0.292**	0.123
Area	-0.000	0.004	-0.005	0.004	-0.002	0.003	-0.002	0.003

Income	0.002**	0.001	0.000	0.001	0.001**	0.001	0.001**	0.001
Livestock	0.001*	0.000	0.000	0.000	-0.000	0.000	-0.000	0.000
News	0.364**	0.185	0.385**	0.178	0.373***	0.140	0.373***	0.140
Importance	-0.001	0.122	-0.005	0.113	-0.013	0.091	-0.013	0.091
Score	0.034	0.075	0.070	0.071	0.053	0.057	0.053	0.057
Qinghai	-0.407*	0.220	0.165	0.213	-0.123	0.167	-0.123	0.167
Xinjiang	0.404*	0.209	0.903***	0.204	0.656***	0.160	0.656***	0.160
ρ	0.3047**				0.4108***			
Log likelihood	-614.026				-628.355			
Observations	545				545			

***, ** and * are significant at the 1, 5 and 10% levels, respectively.

4.5 The herders' estimated WTA

Table 5 presents the herders' estimated WTA using Model 1, Model 3, and Model 5. The mean WTA derived from the basic model (Model 1) was 163 CNY mu^{-1}. However, this value increased to 237 CNY mu^{-1} when accounting for both the anchoring effect and the shifting effect (Model 3), with a confidence interval ranging from 174 CNY mu^{-1} to 301 CNY mu^{-1}. Additionally, this study calculated the WTA using the bivariate probit model (Model 5), resulting in a mean WTA of 204 CNY, with a confidence interval from 154 CNY mu^{-1} to 253 CNY mu^{-1}. The confidence interval for Model 5 partially overlaps with that of Model 3, indicating that despite differences in point estimates, the results estimated by these two methods are statistically consistent.

Table 5

The mean WTA estimates of different models (CNY mu^{-1} yr^{-1})

Model	WTA	S.E.[1)]	z	*P*-value	[95% conf.	Interval]
Model 1	163.050	11.296	14.43	0.000	140.910	185.190
Model 3	237.194	32.443	7.31	0.000	173.607	300.781
Model 5	203.863	22.225	8.08	0.000	154.423	253.303

1) S.E., standard error

5. Discussion

5.1 Comparison of the WTA with other studies

While the mean WTA of 237.19 CNY mu^{-1} for a grassland grazing ban program may seem substantial compared to the current GECP in our country, it is not unattainable. The WTA for participating in grazing ban programs demonstrates a strong correlation with factors such as the opportunity cost of forgoing revenues, regional endowment effects, herders' experience with grazing ban programs, and environmental awareness (Kingsbury and Boggess 1999). Consequently, the comparatively higher compensation demands from herders in the northwest pastoral areas can be attributed to several underlying factors, including the extended growth cycle and reduced productivity of Tibetan livestock, the impact of protective measures on grassland productivity, and potential income losses associated with conserving grassland ecosystem services.

Some studies examining the costs incurred by agricultural producers and landowners support a correlation between the forgone income and the level of compensation needed. For instance, a study conducted by Amigues *et al.* (2002) revealed that farmers in south-central France, engaged in crop production on their land, required an amount of US$96 per acre to conserve a riparian strip ranging from 33 to 164 feet wide. The compensation levels sought by land managers align with the potential revenues derived from crops cultivated within the riparian strip. Similarly, Kaczan *et al.* (2013) discovered that the average WTA values sought by land managers in North Eastern Tanzania for enrolling in a PES program were found to be similar to the average opportunity cost of maintaining land uses. Other studies, such as those conducted by Yan *et al.* (2021) and Tao *et al.* (2023), have also explored the relationship between the opportunity cost of relinquishing land production and the required compensation levels. Thus, the level of grassland compensation may be influenced by forgone profits and additional expenses related to conservation practices.

The estimated compensation required by herders to enroll in the proposed grazing ban program facilitating ecosystem services was 10 to 55 times larger than the payment offered by the GECP. The average payment for grassland grazing ban offered by the GECP ranged from 4.3 to 24.7 CNY mu^{-1} yr^{-1} depending on local conditions (Hu *et al.* 2019). However, the compensation standard offered for grazing ban in GECP was significantly lower compared to compensation standards provided in other ecological projects. For example, compensation in programs such as the Grain-for-Green program and the Three-North Shelterbelt Program launched by the Chinese government varied from 90 to 500 CNY mu^{-1} yr^{-1}. The substantial reduction in subsidies for GECP has greatly diminished the enthusiasm of herders for the protection of grasslands.

Inadequate compensation levels can lead to dissatisfaction among herders, thereby undermining the effectiveness of policy implementation. For example, Li *et al.* (2021) noted that in the current GECP in Inner Mongolia, herders placed emphasis on subsidies and rewards, with their satisfaction level significantly impacting their perception and the program's implementation effectiveness. Moreover, several studies have suggested that herders' dissatisfaction with the compensation levels of the current GECP (Wang *et al.* 2019; Li *et al.* 2021). Zhang *et al.* (2019) highlighted that the dissatisfaction among herders as the compensation was insufficient to cover their additional efforts and did not meet their livelihood expectations. Thus, a higher compensation level might be necessary to incentivize herders to promote better implementation of the program and to achieve long-term conservation goals for increasing the future availability of grassland ecosystem services (Jayalath *et al.* 2021).

5.2 The determinants of WTA

By comparing existing studies that apply WTA to ecosystem services, it is evident that these values are influenced by social, economic, and multidimensional environmental factors (Chu *et al.* 2020; Jayalath *et al.* 2021; Tang *et al.* 2022). In our study, we found that the mean WTA value was negatively affected by healthy status and income, while it was positively affected by population and herders' occupation. Herders with higher incomes were better equipped to cope with the losses caused by grazing ban programs. Based on long-term considerations, high-income herders were willing to participate in a grazing ban program, consistent with the findings of Yang *et al.* (2006). On the contrary, a larger household population led to a higher level of WTA, as confirmed in many literatures (Xiong *et al.* 2019; Tang *et al.* 2022), which meant that participation in grazing bans may lead to labor surplus in the family. Therefore, accelerating the transfer of surplus labor in pastoral area may also promote the smooth progress of grazing ban programs. Another noteworthy finding was that the WTA among pure herder in the survey was much higher than that among semi-herder. This insight could provide some inspiration for selecting the implementation sites of grazing ban programs.

In terms of herders' environmental awareness, we noted a significant negative correlation between their attention to environmental news and WTA, which was in consistent with findings from similar studies. For example, research by Chu *et al*. (2020) reported that that environmental consciousness was a determinant of WTA for ecological protection policies in central China, with higher environmental awareness associated with lower compensation amounts. Further support for this can be found in the study of Motta and Ortiz (2018), which highlighted the importance of environmental knowledge among Brazilian herdsmen in their decision to participate in a PES program. Therefore, promoting herders' environmental awareness is vital to reduce the WTA required for their participating in a grazing ban program.

5.3 Hypothetical bias

Existing studies have shown that hypothetical bias not only leads to biased estimates but also has inconsistent effects on WTP and WTA (Liu and Tian 2021; Vossler *et al.* 2012). Many studies have found that hypothetical bias tends to result in an overestimation of WTP, meaning that respondents' WTP is higher than what they would pay in actual transactions (List and Gallet 2001; Murphy *et al.* 2005a; Liu and Swallow 2016). However, there is no consistent conclusion regarding the impact of hypothetical bias on WTA. Research indicates that hypothetical bias may either overestimate or underestimate respondents' WTA (Felardo and Hindsley 2021; Luo *et al.* 2022). Even in the field experiment by Penn and Hu (2021) involving honey containers, no hypothetical bias was confirmed.

Existing techniques for mitigating hypothetical bias primarily include cheap talk (Cummings and Taylor 1999; Murphy *et al.* 2005b) and certainty scale calibration (Morrison and Brown 2009; Beck *et al.* 2016). Additionally, in incentive-compatible situations, the concept of consequential statements becomes applicable, and thus hypothetical bias can be eliminated (Herriges *et al.* 2010). This is because when respondents recognize that their answers will impact the outcome, they tend to express their preferences more truthfully (Carson and Groves 2007).

To address possible hypothetical bias in the stated preference approach, we adopted a DBDC question elicitation format. This approach has been shown to yield no significant difference between real and hypothetical WTA estimates based on binary choice questions (Smith and Mansfield 1998). The scenario simulated by the DBDC format is similar to cheap talk in the real market (Xie *et al.* 2019), which helps to mitigate hypothetical bias to some extent. This approach not only avoids the fatigue associated with repeated bidding games but also significantly reduces the complexity of valuing public goods (Boyle *et al.* 1996). From a technical perspective, this elicitation technique encourages respondents to express their true preferences (Hoehn and Randall 1987), thereby enhancing the credibility and reliability of the survey.

6. Conclusion and policy implications

This study aimed to analyze herders' WTA compensation for enrolling into a grassland grazing ban program, while also identifying influencing factors and herders' perceptions of grassland ecosystem services. Our findings regarding herders' WTA compensation suggested that an amount of 237 CNY mu^{-1} yr^{-1} would likely incentivize their participation in the program. This estimated WTA value was significantly higher (10 to 55 times) than the actual compensation offered in GECP. However, compared to compensation levels in other ecological projects, the compensation provided for grassland grazing ban programs was notably lower, indicating potential for improvement. To garner greater support for the grazing ban program and ensure improved provision of grassland ecosystem services, the government should consider increasing the compensation amount appropriately.

We endeavored to provide comprehensive explanations for the factors influencing herders' WTA values, encompassing social, economic, and environmental considerations. Additionally, we sought to devise new indicators for these influencing factors. Specifically, we found that herders' perceptions of the importance of grassland ecosystem services, the ecological environment within their community, and their engagement with environmental protection news were indicative of their environmental awareness. Our findings revealed significant associations between WTA values and herders' family size, health status, occupation, livestock income, and their attention to environmental news.

The negative influence of herders' health status on their WTA underscores the positive impact of a robust healthcare coverage system in reducing WTA values. Furthermore, surplus labor resulting from larger family sizes may hinder the implementation of grassland grazing ban programs. Therefore, it is crucial for the government to expedite the transfer of surplus labor in pastoral areas to attract more herders to participate voluntarily. Moreover, compared to herders who depend solely on grazing, semi-herders showed greater inclination to participate in grazing ban programs at a lower WTA due to their diversified sources of income. Targeting semi-herders for the implementation of grassland grazing ban policies could potentially reduce government expenditure during policy execution.

The findings further illustrated that herders' environmental awareness played a significant role in their engagement with grazing ban programs. This discovery provides crucial insights for policy development. Therefore, it is imperative for the government to actively enhance public awareness of the significance of grasslands in enhancing ecosystem services and environmental protection. These efforts would contribute to the successful implementation of grassland grazing ban policies. The findings of this study can provide inputs for the formulation of ecological compensation standards and help guide agricultural policymaking. They can also serve as a reference for land use decision in other similar economically backward and ecologically fragile regions.

Despite the encouraging results of this study, we acknowledge its limitations. Firstly, due to hypothetical bias, herders' WTA for grassland grazing bans may be biased to some extent, despite our efforts to present detailed and realistic scenarios and use the cheap talk inquiry method. Future research should consider adopting policy consequential or payment consequential designs to obtain more accurate WTA estimates. Secondly, despite China's abundant and diverse grassland resources, our model selection faced challenges due to herders' limited familiarity with grassland classification. Future research should encompass a wider geographical scope and include more diverse grassland characteristics to enhance result accuracy.

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Declaration of competing interest

The authors declare that they have no conflict of interest.

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