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Assessing restoration benefit of grassland ecosystem incorporating preference heterogeneity empirical data from Inner Mongolia Autonomous Region

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ARTICLE INFO

Keywords:
Grassland ecosystem
Preference heterogeneity
Benefit evaluation
Choice experiment
Latent class model

ABSTRACT

The evaluation of grassland ecosystem restoration benefit considering herdsmen’s preference is an important reference for the formulation of grassland protection policy. This study aims to evaluate the marginal benefits of grassland ecosystem services by using choice experiment and mixed logit (ML) model, and a latent class model (LCM) is estimated to identify and explain the heterogeneity of herdsmen’s preference for the various functions of the grassland ecosystem, so as to evaluate the benefits of grassland ecosystem restoration in Siziwang Banner and Damao Banner of Inner Mongolia Autonomous Region. The results reveal that the restoration benefit of the grassland ecosystem in the two banners is nearly 341.1 million RMB per year. The application of latent class model highlights three potential segments of the herdsmen with different preferences. The social, economic and environmental attitudinal characteristics of herdsmen have significant impacts on their preferences. Thus, to improve the universality of grassland ecological restoration policy, herdsmen’s preferences should be thoroughly investigated before policy formulation and implementation. Meanwhile, it is important to publicize the grassland ecosystem services, to popularize the role of wildlife in the ecosystem, and to realize the benign interaction between wildlife protection and animal husbandry development.

1. Introduction

Grassland ecological restoration and governance are related to the construction of ecological civilization, national unity, border stability, as well as sustainable and healthy social-economic development of pastoral areas (The State Council, 2011; Shi et al., 2018). Recently, climate change such as global warming and altered precipitation patterns exert great influence on the grassland growth (Chen et al., 2019; Liu et al., 2019; Zhang et al., 2020), and some negative human disturbances, such as overgrazing, agricultural expansion, forest exploitation and land cover change, are also likely to cause grassland degradation (Gang et al., 2018; Zhao et al., 2020). Though the implementation of ecological restoration projects such as conversion of cropland to forest and grassland, management measures of forbid pasturing, fallow pasturing, forage and animal balance, and grassland eco-protection subsidy and incentive policy, the overall grassland ecosystem is still fragile, and grassland ecological security is still the weak link of national ecological security (Han, 2017). Assessing restoration benefit of grassland ecosystem can aid in the design of grassland protection policy and adequate compensation standard.

The ecosystem services approach integrates ecology and economics to help explain the effects of human policies and its impacts both on ecosystem and human welfare (Grunewald et al., 2014). For a long time, the evaluation of grassland ecological value mostly centres on biomass (Xie et al., 2001), while lacking the consideration of human-centered concept of environmental ethics, which easily leads to unsustainable management of grassland ecosystem (Lant et al., 2008). Therefore, assessing the economic values of the grassland ecosystem restoration and incorporating it into the cost-benefit accounting of policy formulation can not only reflect the value of grassland ecosystem services diversification but also aid in improving the allocation efficiency of governance funds (Yao et al., 2017).

The value of grassland ecosystem services has long been concerning scholars. Sala et al. (1997) recognized the non-market services offered

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https://doi.org/10.1016/j.ecolind.2020.106705
Received 25 November 2019; Received in revised form 26 June 2020; Accepted 7 July 2020
Available online 15 July 2020
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by grasslands and estimated the ecological values which are difficult to measure directly. Costanza et al. (1997) divided the 16 biological communities of the global ecosystem into 17 ecosystem services and assessed the functions of grassland ecosystem services, thus estimated the global value of grassland ecosystem services at an average of $232 per hectare per year. Based on this, Xie et al., (2001) established the equivalent factor table of ecosystem service value in China. Later, scholars measured the ecosystem service values of different grassland types in Qinghai-Tibet Plateau and typical steppe in Inner Mongolia, concretizing the principle and method of estimating ecosystem service value in grassland (Xie et al., 2003; Min et al., 2004). Mu (2016) evaluated the ecosystem service value of temperate steppe in Inner Mongolia Autonomous Region quantitatively by using biomass via remote sensing technology and annual precipitation data by spatial interpolation. However, the gross product of ecosystem is mostly calculated from the two aspects of ecological function quantity and ecological economic value quantity in the existing studies (Ouyang et al., 2013). Under the influence of ecological deterioration, population explosion and rapid economic development, ecosystem services are gradually scarce, so assessing the marginal value of ecosystem services change (i.e. the increase or decrease of ecosystem services due to optimization or deterioration) is of more practical significance (Xu et al., 2018). In addition, ecosystem services represent the benefits directly or indirectly derived by human beings from ecosystem functions (Costanza et al., 1997) and are human-centered. Public participation of environmental protection may overcome the shortcomings of market and government regulation and play an irreplaceable role in many aspects of market and government, which provide adequate information for policy formulation (Zhou and Cheng, 2016). Therefore, when calculating the restoration benefits of grassland ecosystem, incorporating public preference is conducive to improving the accuracy of the estimation results.

Choice Experiment (CE), which is based on individual preference and behavior, presents participants with opportunity to choose among alternative hypothetical scenarios that differ in effects, is considered to be an empirical method of non-market valuation in the field of natural resources (Fan and Zhao, 2013; Khan et al., 2018), and is widely used in cultivated land, watershed, wetland, air pollution control, urban ecosystem valuation and policy welfare estimation (Tan et al., 2012; Li et al., 2015; Fan et al., 2016; Yan et al., 2018; Shi et al., 2016a,b). The heterogeneity of individual preference and the difference in ecological product characteristics jointly determine the public’s choice behavior. Considering the heterogeneity of public preferences, latent class model is applied to different domains to study the heterogeneity of individual preferences such as food safety, farmland, wetland and watershed ecosystem respectively (Zhang et al., 2013; Yang et al., 2016; Mao et al., 2018; Shi et al., 2019). However, there are few studies on the evaluation of grassland ecosystem restoration benefits that include the public preference, and most of the existing studies regard herdsmen as behavioral subjects with the same preferences, concealing the heterogeneity of individuals due to their different preferences for grassland ecosystem services, which makes the estimated results of grassland ecosystem restoration benefit deviate from its true values (Garrod et al., 2012).

This study aims to take the preference heterogeneity into account as well as provide policy-makers with much-needed information on the economic value of the grassland ecosystem restoration benefits generated by the sustainable grassland management. Against this background, we took Siziwang Banner and Damao Banner in Inner Mongolia as examples and applied the mixed logit model to quantitatively evaluate the willingness to pay of herdsmen for grassland ecosystem restoration. Moreover, the latent class model was used to explore and account for the possible inter-group differences of sample preferences for grassland ecological attributes, so as to calculate the restoration benefits of grassland ecosystem through weighted groups, and propose effective grassland management policies.

2. Study area

The grassland area of Inner Mongolia Autonomous Region reaches 79 million hectares, accounting for 68.81% of the total land area of the whole region and 35% of the grassland area of the entire country, which is the largest grassland and natural pasture in China and constitutes an important ecological barrier in northern China. The case study of this paper is in Siziwang Banner and Dalhan Maoming’an United Banner (hereinafter referred to as Damao Banner), located in the central part of Inner Mongolia Autonomous Region (Fig. 1). They are both located in the border areas of the ethnic minorities with the combination of agriculture and animal husbandry, and are both typical pure animal husbandry counties. Siziwang Banner is recognized as the only pilot and demonstration area of county-level national main functional areas in the autonomous region, it has 1.856 million hectares of natural pasture, which is significant for the state to strengthen ecological restoration and environmental protection. Damao Banner has a vast territory, with 1.66 million hectares of natural pasture, which is a large resource banner of the border areas of Inner Mongolia Autonomous Region.

The research site belongs to the typical desert steppe area, which is the boundary zone of the transition from grassland to the desert, with poor ecological stability and fragile grassland ecological environment. The protection of grassland ecological environment has become an urgent problem to be solved in the sustainable development of social economy in the whole region and even across the entire country. At present, both banners have implemented the grassland ecological protection compensation mechanism, including Siziwang Banner, which promulgates forage and animal balance and grazing prohibition, and Damao Banner, which implements comprehensive grazing prohibition and ecological immigration measures in pastoral areas. Under this background, accelerating the restoration of grassland ecosystem and improving the function of grassland ecosystem service has become one of the key tasks of ecological environmental protection and construction in the region.

3. Methodological background

3.1. Modelling framework

Choice experiment established based on the theory of Value (Lancaster, 1996) and Random utility (Thurstone, 1927), which hold that consumers gain their utility not from the good itself but rather from...
its attributes. The basic assumption is that consumers make choices to maximize their utility according to the inherent attributes of goods under budget constraints (McFadden and Train, 2000). According to RUT, the individual utility is composed of two components, a systematic (i.e., observable) component and a random term (i.e., unobservable) component, and the observable part is usually composed of selected attributes. In this paper, the attribute set contains a monetary attribute and non-monetary attributes for evaluating the value of grassland ecosystem services. The utility obtained by the interviewed herdsman i in choosing alternative j can be expressed as follows:

\[
U_{ij} = \alpha_i + \beta_i X_{ji} + \epsilon_{ij}
\]

(1)

where ASC is an effect-coded alternative specific constant, is used in case of a status quo option to highlight if respondents have preferences for the no-governance scenario or for avoiding it (Novikova et al., 2017), which is specified equal to 0 when either management scenario A or B was selected, and to 1 when the ‘neither management scenario’ option was selected. \(X_{ji}\) is a vector of attributes to assess the value of grassland ecosystem services, including vegetation coverage, groundwater level, rare wildlife and grassland landscape. \(P_i\) is the payment attribute, \(\alpha_i\), \(\beta_i\) are corresponding parameters to be estimated, \(\epsilon_{ij}\) is a random disturbance term, which is generally assumed to follow a type I extreme value distribution (i.e., Gumbel distribution).

The mixed logit probability is a weighted average of several logit functions \(L(\beta)\), the density \(f(\beta)\) provides the weights. The mixed logit probability is, therefore, a mixture of the logit function \(L(\beta)\) with \(f(\beta)\) as the mixing distribution. Choice models that take into account heterogeneity can make different assumptions about \(f(\beta)\). In most applications that have actually been called mixed logit \(L(\beta)\) is specified to be continuous. The choice probability in this case is:

\[
P_{ij} = \int L_{ni}(\beta_i) f(\beta_i) d\beta_i = \int \frac{e^{\beta_i X_{ji}}}{\sum_{k=1}^{K} e^{\beta_k X_{jk}}} f(\beta_i) d\beta_i
\]

(2)

Even though the ML model can reveal unobservable stochastic preferences, the model still cannot explain the sources of heterogeneous preferences (Novikova et al., 2017). At present, researchers have begun to use LCM as an alternative model to consider preference heterogeneity, of which \(f(\beta)\) is specified to be discrete and does not require any specific assumptions between individuals (Bhat, 1997; Wedel and Kamakura, 1997). The basic theory of LCM holds that individual behavior depends on observable attributes and potential heterogeneity, which changes with unobservable factors, while the part belonging to specific preferences is probabilistic, depending on the social, economic and attitudinal characteristics of respondents. It is assumed that individuals are implicitly sorted into a set of classes, thus effectively avoiding the disadvantage of arbitrary division of artificial demarcation points (Yang et al., 2016), and each class has different preferences, but the characteristics of individuals in the same class are related and have homogeneous preferences. At this time, the probability that the individual \(i\) choose the \(j\)th alternative is expressed as the product of the class member probability and the class member probability under the condition of choosing the alternative \(j\):

\[
P_{ij} = \prod_{s=1}^{S} \left( \frac{e^{\beta_s X_{js} Y_{is}}}{\sum_{k=1}^{K} e^{\beta_k X_{jk} Y_{ks}}} \right)
\]

(3)

where \(S\) is the number of potential classes identified, \(Z_s\) indicates a series of factors that affect the observability of class members, usually the basic socio-economic characteristics of respondents and respondents’ awareness of grassland ecosystem services, etc., and \(\gamma_s\) is the parameter vector of respondents in class \(S\), \(\beta_s\) expresses the marginal utility corresponding to each attribute of class members. And the number of classes is not a priori but is based on statistical and theoretical criteria (Flynn et al., 2010).

The respondents’ willingness to pay (WTP) for different attributes can be further expressed as follows:

\[
WTP = -\frac{1}{Y_i} \left[ \ln \sum_{j=1}^{J} \exp(\beta_j Y_{ij}) - \ln \sum_{j=1}^{J} \exp(\beta_j Y_{ij}) \right]
\]

(4)

Wherein, the \(\beta_s\) and \(\gamma_s\) are the estimated parameters of the price attribute and the ecological attribute, respectively. The estimated parameters can be used to measure the total WTP of herdsman when the grassland ecosystem is restored to a specific situation, that is, the compensating surplus (CS) (Hanemann, 1984):

\[
CS = -\frac{1}{Y_i} \left[ \ln \sum_{j=1}^{J} \exp(\beta_j Y_{ij}) - \ln \sum_{j=1}^{J} \exp(\beta_j Y_{ij}) \right]
\]

(5)

where \(Y_{ij}\) and \(Y_{ij}'\) respectively represent the vector of the environmental attribute levels for no governance measures (status quo) and through governance measures to achieve a specific situation.

3.2. Selection of choice attribute levels

The first step in CE design is to determine the ecological attributes and their levels to be evaluated (Birol et al., 2006). Based on the Millennium Ecosystem Assessment (MA), which defines the four functions of ecosystem, including support, supply, regulation and culture, and also referring to the viewpoints of Sala and Paruelo (1997), Xie et al., (2001) and Liu et al., (2011) that the grassland ecological environment provides the services of forage production, water conservation, biodiversity protection and recreation for human beings, the attributes of grassland ecosystem services in this paper were determined, including vegetation coverage, groundwater level, rare wildlife and grassland landscape four ecological indicators and an ecological payment index (see table 1). Through expert consultations and focus group interviews, 2017–2020 is the governance period. To facilitate communication with the respondents, we identified environmental problems and their relationship with the herdsman wellbeing for each of the attributes, which was set for different levels.

Table 1

| Attribute               | Description                                                                 | Levels                                   |
|-------------------------|-----------------------------------------------------------------------------|------------------------------------------|
| Vegetation Coverage     | The proportion of the vertical projection area of grassland vegetation on the ground to the total area of the whole statistical area expressed in percentage (%), the current situation is 25%. | 25*:50;30;35;40                         |
| Groundwater level       | The improvement of the groundwater level is expressed by the rise of the groundwater level in meters. The current level is the groundwater level does not rise (0 m). | 0*:5;10;15                              |
| Rare Wild Animal        | The number of rare wild animals visible in one month is closely related to grassland biodiversity. The current situation is the number of rare wildlife animals such as Mongolian wolves, yellow sheep and eagles can be seen within one month does not increase. | 0*:10;15;20                             |
| Grassland Landscape     | Good grassland landscape means healthy grassland conditions, can provide functions such as eco-tourism and viewing, which are reflected by stars. The current situation is 0, means without ecological restoration, the improvement degree of grassland landscape is 0. | 0*:1;2;3                                |
| Payment                 | The amount of money each household is willing to pay for improving the grassland ecological environment every year. | 0*:150;200;250;300                      |

Note: * Indicates the change of grasslands when no governance measures are taken by 2020.
arid area, which constitutes the natural “green ecological barrier” in China and plays an irreplaceable and important role in “national ecological security” (Li et al., 2004) and in hindering the erosion in grassland. At the same time, the grassland ecosystem provides basic means of production for animal husbandry development, and animal husbandry provides products for human beings. At present, the average vegetation coverage in the research area is 28% (Song et al., 2018). According to the current situation of grassland vegetation in Siziwang Banner and Damao Banner and the opinions of experts in related fields, this attribute sets four levels, which means that if there are no governance measures, the vegetation coverage of grassland will be reduced to 25% by 2020; if different governance measures are taken, it can be raised to 30%, 35% or 40%.

(2) Groundwater level. Groundwater not only affects grassland ecosystem conditions but also affects the production and life of herdsman. It is inevitable to face the dilemma of protecting the grassland ecosystem and exploiting groundwater to support production, life and social and economic development. Therefore, it is urgent to restrict and regulate the exploitation and management of groundwater for the maintenance of grassland ecosystem services. Currently, 97.54% of herdsman and production units in research area use groundwater for irrigation\(^1\), groundwater depth is 30 to 70 m under the ground, and groundwater distribution is uneven\(^2\). If not harnessed, the depth of groundwater will seriously affect the life of herdsman and the survival of animals and plants, and taking control measures can make the groundwater level rise to varying degrees, specifically 5 m, 10 m, or 15 m.

(3) Rare wild animals. Grassland ecosystem has rich and concentrated diversity of wild plants, animals and microorganisms, which is precious for the biological germplasm resource and species gene pool. As a part of biodiversity, wildlife has intrinsic value and utilization value (Wilson, 1988). However, the conflict between herbivorous wildlife and herdsman is intensifying. Under the condition of limited carrying capacity of grassland resources, coordinating wildlife protection and herdsman's development is also a common problem, which should be included in the evaluation of grassland ecosystem service. At present, it is difficult to see the rare wildlife in the research area, and if no measures are taken, the number of wildlife visible per month will be 0 by 2020; if control measures are taken, by 2020, the monthly visibility of wildlife will be set at 10, 15 and 20 levels.

(4) Grassland landscape. There are thousands of plant and animal species on the grassland, and the traditional culture and customs of nomadic people have distinct characteristics of eco-tourism, providing non-physical ecological services such as recreation, culture and entertainment for human beings. Combined with the actual situation, reflecting the conditions of the grassland landscape by star, the higher the star, the better the grassland landscape.

(5) Payment. The fifth attribute, the monetary one, is a household payment for the improvement of grassland ecosystem. The levels of the payment were determined through an open-ended pilot contingent valuation survey. And the payment is proposed as an annual one for the period from 2017 to 2020. Combined with the current consumption situation of herdsmen and the preliminary statistics of the willingness to pay of the interviewees in the pre-survey. The payment levels are 150 RMB, 200 RMB, 250 RMB and 300 RMB, and if the interviewees choose “no governance”, they do not need to pay.

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\(^1\) Main Data Bulletin No. 2 of the Third Agricultural and Animal Husbandry Census in Damao Union Banner

\(^2\) Overall Implementation Plan for Key Counties of Small-scale Farmland, Water Conservancy and Pastoral Areas in Siziwang Banner, Inner Mongolia Autonomous Region (2014–2016)

### 3.3. Choice task design

The five attributes and their levels result in a large number of combinations (4\(^4\) × 5) impeding a full factorial design. Obviously, it is difficult for respondents to select from such a large number of choice tasks, so the D-efficiency experimental design criteria and implicit price minimization principle were used to reduce the combination of choice sets by Ngene software, resulting in a choice experiment with 24 choice sets randomly divided into 8 blocks, with three choice sets per block and no dominant or redundant alternatives. And the CE applied a three-alternative unlabeled design, including a “non-participation” status quo option with no control and zero cost, and two policy options, “Option A” and “Option B” that provided varying levels of improvement at an unavoidable cost to the household. Designs of this type are among the most common formats for environmental CEs, due to advantages that can include a reduced tendency for serial nonparticipation among respondents (Johnston et al., 2017; Yao et al., 2018). Fig. 2 illustrates an example of a choice set used in the survey.

In the survey, each respondent was asked to make three independent choices. Prior to presenting the questionnaire to respondents, a separate information booklet was used to provide background information about the survey and choice questions, in order to facilitate respondents’ understanding of each attribute and to make the optimal choice.

The questionnaire consists of the following four parts: 1) a set of warm-up questions to address respondents’ attitude and knowledge with grassland ecosystem services; 2) the core of the questionnaire, containing the three choice tasks, along with a sample illustration to help respondents understand the voting process; the choice is needed to identify the preferences of the respondents; 3) individual and family socioeconomic questions; and 4) four rating questions to be completed by the investigators (rather than respondents) to evaluate respondent’s cooperation, motivation, and perceived understanding of the choice tasks, et al.

### 4. Empirical results

#### 4.1. Data collection and sampling characteristics

The survey was implemented from 12 July to 19 July 2017 in Inner Mongolia Autonomous Region. In the early stage, through contact with many departments to obtain information, including the grassland compensation policy and the implementation effect of ecological restoration project in Inner Mongolia Pastoral Area, finally determined the Siziwang Banner in Wulanchabu city and Damao Banner in Baotou city as the investigation points. Then using a stratified random sampling strategy, we finally determined the Sumus and Gachas (Inner Mongolia administrative unit, equivalent to towns and villages in other provinces respectively), and selected 5 to 6 Sumus each banner, and 5 to 6 Gachas each Sumu, and 6 to 10 herdsmen each Gacha. A total of 480 questionnaires (60 copies per version) were sent out, but only 427 questionnaires were collected, including 213 questionnaires in Siziwang Banner and 214 questionnaires in Damao Banner. Based on the research purpose, 366 (85.71% of the 427) valid questionnaires were obtained after eliminating the missing and extreme data, which provided 3294 (366×9) valid observations for the choice model estimation.

Table 2 provides descriptive statistics for the samples. In addition to gender and ethnic groups, the socio-economic characteristics of the sample close to the statistical data of Inner Mongolia Autonomous Region, show the representativeness of selected samples. The proportion of males in the respondents’ gender is 65.57%, which is significantly higher than the statistical data of Inner Mongolia Autonomous Region. To obtain more comprehensive information, we tend to choose heads of households as respondents, while the heads of households are mostly men. Because the selected research sites are concentrated in the pure pastoral areas of Siziwang Banner and Damao Banner, the proportion of
Mongolians in the research area is higher, which explains the difference with the statistical data of the whole region. Considering age and education, the sample is generally low and mainly concentrated in 40–59 years old, which is related to the young labor force going out to work and study. The characteristics of respondents' environmental attitudes include their awareness of grassland ecosystem and their emphasis on the improvement of grassland ecological environment. Respondents’ attitude, awareness and site attachments are very important to determine their environmental protection decision (Khan et al., 2019a; Khan et al., 2019b).

4.2. Mix logit model

Using simulated maximum likelihood estimation of ML model with 500 Halton draws, the coefficients of payment and ASC are specified as fixed, and the coefficients of four ecological attributes, vegetation coverage, groundwater level, rare wild animal and grassland landscape, are set as random with a normal distribution, and then the estimation results are shown in Table 3.

The regression results show that all estimated coefficients are individually statistically significant, as the coefficients of standard deviations. The estimated coefficient of ASC is significantly negative, indicating that refusing to maintain grassland ecological status quo is a common tendency of respondents, and herdsmen expected any possible improvement of grassland ecological environment. A positive value of ASC revealed that respondents preferred the status quo rather than the alternative situation (Khan and Zhao, 2019). The coefficients’ means of vegetation coverage, groundwater level and grassland landscape are significantly positive, suggesting that the increase of vegetation

| Vegetation coverage | Option A | Option B | No-governance |
|---------------------|---------|---------|---------------|
| Increased to 30%    | Increased to 35% | <25%    |

| Groundwater level | Raise 15 meters | Raise 5 meters | >100 meters |
|-------------------|----------------|---------------|------------|

| Rare wild animals | Twenty times in a month | Ten times in a month | Almost invisible |
|-------------------|-------------------------|---------------------|-----------------|

| Grassland landscape | ★★★★         | ★★★★         | ★            |
|---------------------|--------------|--------------|--------------|

| Payment | 200 yuan | 150 yuan | 0 yuan |

Fig. 2. An example of choice set.

Table 2
Main socioeconomic and attitudinal variables of respondents.

| Variables | Description | Proportion | Sample average | Statistical average |
|-----------|-------------|------------|----------------|---------------------|
| Socio-economic characteristics | | | | |
| Gender | Male | 65.57 | 54.21<sup>a</sup> |
| | Female | 34.43 | 45.79 |
| Age | Under 20 years old | 0.23 | 47.78<sup>b</sup> |
| | 20–29 years old | 4.22 | 43.74<sup>a</sup> |
| | 30–39 years old | 18.03 | 43.74<sup>a</sup> |
| | 40–49 years old | 31.85 | 43.74<sup>a</sup> |
| | 50–59 years old | 28.57 | 43.74<sup>a</sup> |
| | Above 60 years old | 17.10 | 43.74<sup>a</sup> |
| Nation | Mongolian nationality | 52.22 | 17.11<sup>c</sup> |
| | Han nationality | 47.78 | 79.54 |
| Education | Primary and below | 42.62 | 43.89<sup>d</sup> |
| | Junior middle school | 40.28 | 46.55 |
| | High school | 13.11 | 7.32 |
| | College and above | 3.98 | 2.25 |
| Income (in RMB) | < 5000 | 4.74 | 25600. |
| | 5000–10000 | 11.61 | 51 |
| | 10000–30000 | 56.64 | 28376<sup>e</sup> |
| | 30000–50000 | 20.38 | 28376<sup>e</sup> |
| | 50000–100000 | 5.69 | 28376<sup>e</sup> |
| | > 100,000 | 0.95 | 28376<sup>e</sup> |

| Environmental Attitudinal Characteristics | | | |
| Environmental cognition | Mean scores of four environmental awareness questions (1–5) | 4.33 | — |
| Environmental importance | Importance of grassland ecological environment improvement to respondents’ families (0–10) | 9.11 | — |

a, d Source: The main data bulletin of the third regional agricultural and animal husbandry census of Inner Mongolia Autonomous Region (No. 5); b, e Source: The main data bulletin of the Sixth National Population Census of Inner Mongolia Autonomous Region; e Source: The Statistical Bulletin of National Economic and Social Development of Inner Mongolia Autonomous Region in 2018, and use the per capita annual income.

Table 3
Mixed logit model results.

| Variables | Coefficient | Standard Error | Z value | [95% Conf. Interval] |
|-----------|-------------|----------------|---------|---------------------|
| Means of fixed parameters | | | | |
| ASC | –6.232<sup>***</sup> | 1.302 | –4.790 | –7.131–3.202 |
| Payment | –0.003<sup>**</sup> | 0.001 | –2.000 | –0.005–0.000 |
| Means of random parameters | | | | |
| Vegetation coverage | 0.093<sup>***</sup> | 0.018 | 5.140 | 0.057–0.128 |
| Groundwater level | 0.113<sup>***</sup> | 0.021 | 5.420 | 0.072–0.154 |
| Rare wild animal | –0.032<sup>∗</sup> | 0.018 | –1.790 | –0.066–0.003 |
| Grassland landscape | 0.597<sup>***</sup> | 0.113 | 5.300 | 0.376–0.818 |
| Standard deviations of random parameters | | | | |
| Vegetation coverage | 0.099<sup>***</sup> | 0.036 | 2.740 | 0.028–0.170 |
| Groundwater level | 0.171<sup>***</sup> | 0.036 | 4.800 | 0.101–0.241 |
| Rare wild animal | 0.150<sup>***</sup> | 0.034 | 4.420 | 0.083–0.216 |
| Grassland landscape | 1.056<sup>***</sup> | 0.170 | 6.200 | 0.722–1.390 |
| Log likelihood | –739.132 | | | |
| Pseudo R² | 0.081 | |

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.
coverage, the rise of groundwater level and the improvement of grassland landscape will increase the probability of the option being selected and generate positive utility impacts on respondents. For example, the average coefficients of grassland landscape and groundwater levels are 0.597 and 0.113 respectively, which means that other conditions remain unchanged, the impact of grassland landscape improvement of one star on herdsmen's welfare is about 5.28 times that of the rise of groundwater level by five meters. The coefficient of rare wild animal is significantly negative, indicating that the increased visibility of rare wildlife will reduce the utility of the herdsmen interviewed, because 40% of the herdsmen interviewed believe that Mongolian wolves and other wild animals will prey on sheep, the increased number may endanger the survival of sheep, which is not conducive to grazing and thus affect family livelihood.

For the standard deviation of random parameters, the herdsmen's preference for vegetation coverage, groundwater level, rare wildlife and grassland landscape are significant at the 1% level, which means that herdsmen's preferences for these attributes have significant heterogeneity and random characteristics. It also reflects the advantages of mixed logit model, which can relax the "independence of irrelevant alternatives" (IIA) assumption, reveal and account for heterogeneity of individual preferences in the restoration of grassland ecosystem (Hensher and Greene, 2003; Khan et al., 2019b; Shi et al., 2016a,b).

### 4.3. Latent class model

An important issue in the empirical application of the latent class model is the number of segments to be used in the analysis (Garrod et al., 2012). The Bayesian Information Criterion (BIC) and the Akaike Information Criterion (AIC) are the most used to identify the correct number of parameters (Acquah, 2010). The best model for data interpretation is the one with the lowest information criterion values (Novikova et al., 2017). Therefore, it was decided that a three-segment model is a preferred specification, with the test values of AIC, CAIC and BIC reached the minimum, and the log-likelihood value was the maximum, as shown in Table 4.

In the LCM, belonging to a segment with specific preferences is probabilistic and depends on the social, economic and attitudinal characteristics of the respondents. Therefore, the socioeconomic and environmental attitudinal variables of respondents are added as the parameters of the segment membership function. The estimation results are listed in Table 5. The log-likelihood and Pseudo $R^2$ indicate that LCM has better fitness than ML, which further proves that herdsmen have different discrete preferences for grassland ecological attributes. The herdsmen interviewed were divided into three distinct segments, accounting for 37.5%, 18.3% and 44.25%, respectively, in which the segment membership coefficients of the third segment are normalized to zero in order to identify the remaining coefficients of the model.

For segment 1, herdsmen can generate positive utility from the improvement of grassland landscape and the increase of vegetation coverage, while the increase of rare wildlife will reduce the utility of herdsmen significantly, and the impact of one star upgrade of grassland landscape on herdsmen's welfare is about eight times that of 5% increase of vegetation coverage, so this kind of herdsmen is called landscape preference. The segment membership coefficients reveal that females, higher age, longer grassland residence and higher environmental cognition increase the probability that the respondent belongs to the first segment. In general, women pay more attention to landscape aesthetics and participate more in domestic production activities, while activities like drilling wells and fetching water are mostly undertaken by men in the family, so they are less sensitive to the rise of groundwater level. The older herdsmen and those who lived in the grassland for a longer period of time rely more on the grassland and could intuitively feel the changes of grassland landscape and vegetation coverage. And they mostly live on grassland grazing, while the increase of Mongolian wolves and other rare wildlife may endanger their sheep, or even hurt herdsmen, which is not conducive to grazing. Therefore, it has a negative effect on the increase in the number of rare wild animals. The reason why the coefficient of groundwater level is insignificant, possibly because the current difficulties in using water may be water intaking, and more modern production tools or technologies are needed to facilitate water intaking.

For segment 2, all estimated coefficients are insignificant, which reflects that these herdsmen don't pay attention to the grassland ecological attributes and fail to recognize the various grassland ecosystem services. This type of herdsmen can be defined as ecological neglect. They think that the increase of vegetation coverage, the rise of groundwater level, the increase of visibility of rare wildlife and the improvement of grassland landscape cannot bring utility to them, which is consistent with the result of segment member function, so the herdsmen with lower environmental attention are more likely to belong to this segment.

For segment 3, the coefficients of the four grassland ecological attributes are significant, while the price attribute is not. Therefore, it is named attribute preference. That is to say, the herdsmen tend to choose the options of increasing vegetation coverage, rising groundwater level, increasing number of rare wildlife and improving grassland landscape, but do not attach great importance to price. The highest proportion of such herdsmen is 44.2%, it means that most of the herdsmen interviewed are very eager to restore the grassland ecosystem. To some extent, the price does not affect their selection of improvement plan, they only pay attention to whether the attributes have been improved.

### 4.4. Estimation of WTP

Willingness to pay can be determined by estimating the marginal rate of substitution between the change in the grassland ecological attribute and the marginal utility of income represented by the coefficient of the payment attribute (Birol et al., 2006).

Table 6 reports the WTP for each of the grassland ecological attributes by the mixed logit model and latent class model. The differences among WTPs for different attributes imply that these generally have different effects on welfare. The results of LCM with better fitness show that all kinds of herdsmen have obviously different payment tendencies, if the marginal willingness to pay and the restoration benefits of grassland ecosystem are simply calculated by ML, some effective information will be lost, which will lead to the deviation of calculation, and ML supposes that the preferences are continuous, which may cover the distributional impacts of benefits generated by grassland ecological attributes.

To demonstrate potential welfare gains from grassland restoration policies, the compensation surplus for target scenarios of the highest level of each attribute in 2020 (that is, vegetation coverage increased to 40%, groundwater level increased by 15 m, rare wildlife can be seen 20 times in a month, grassland landscape improved to three-star level) can be calculated by equation (5). Estimated by mixed logit model, each herdsmen household in the sampled area would be willing to pay 3491

### Table 4

| Criteria for determining the optimal number of segments. |
|-----------------------------------------------|
| **Number of segments** | **Log-Likelihood** | **Number of parameters** | **AIC** | **CAIC** | **BIC** |
|----------------------------|------------------|-------------------------|--------|--------|--------|
| 2                           | $-788.7004$      | 13                      | 1603.401 | 1667.135 | 1654.135 |
| 3                           | $-760.4497$      | 20                      | 1560.899 | 1658.952 | 1638.952 |
| 4                           | $-767.9438$      | 27                      | 1589.88  | 1722.25  | 1695.25  |
| 5                           | $-761.7621$      | 34                      | 1591.324 | 1758.214 | 1724.214 |
| 6                           | $-763.3865$      | 41                      | 1608.773 | 1809.781 | 1768.781 |
| 7                           | $-769.0652$      | 48                      | 1634.13  | 1869.457 | 1821.457 |
5. Discussion and conclusion

5.1. Discussion

The comprehensive evaluation of grassland ecosystem restoration benefits is conducted by choice experiment design, which provides the interviewees with the opportunity to weigh the evaluation attributes and obtain more information about preference, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors. Latent class model is introduced into this paper, and obtains more information about preferences, thus reduces the measurement errors.

As the direct beneficiaries, herdsmen are aware of ecosystem services and give support to policies will affect the final implementation effect of policies. The results also show that there are still some herdsmen who pursue immediate interests and neglect the grassland ecological environment. As researchers have noted, the trade-off between agricultural production and environmental conservation remains a priority for many policymakers around the world (Byrne et al., 2019). There is still a certain conflict between the grassland environmental protection and the herdsmen’s animal husbandry production, which not only affects the grassland protection effect, but also fails to provide sufficient income for herdsmen. Therefore, it is a problem that cannot be ignored in the process of grassland restoration to formulate reasonable ecological compensation standards while balancing grassland ecological protection and socio-economic development of pastoral areas.

5.2. Conclusion

This study aims to evaluate the marginal benefits of grassland ecosystem services by using choice experiment and mixed logit (ML) model, and a latent class model (LCM) is estimated to identify and explain the heterogeneity of herdsmen’s preference for the various functions of the grassland ecosystem, so as to estimate the benefits of grassland ecosystem restoration in Siziwang Banner and Damao Banner of Inner Mongolia Autonomous Region. It contributes to the limited...
literature on the estimation of economic values of grassland ecosystem using choice experiments and is one of the few grassland restoration valuation studies that has been undertaken in Inner Mongolia. The main conclusions are as follows:

1. Considering the heterogeneity of herdsmen’s preference, the restoration benefit of grassland ecosystem is estimated to be 341.1 million per year, which is higher than the welfare estimation of not identifying the latent segment, it indicates that ignoring the heterogeneity of herdsmen’s preference will lead to the underestimation of the restoration benefit of the grassland ecosystem. (2) There are three different preferences among the herdsmen interviewed, landscape preference, ecological neglect and attribute preference, which accounts for 37.5%, 18.3% and 44.2% of the total, respectively, indicating that some herdsmen still have insufficient understanding of the grassland ecosystem services. (3) The social, economic, and environmental attitudinal characteristics of respondents have significant impacts on their preferences. Herdsmen with female, higher age, longer living years in grassland and higher environmental awareness preferred grassland landscape; The herdsmen who pay less attention to the environment are more likely to neglect the grassland ecosystem and are unwilling to pay for the grassland ecosystem; Most herdsmen (44.2%) still preferred the improvement of grassland ecological attributes.

Based on current findings, some policy implications are suggested, in the process of formulating and implementing grassland policies in the future, herdsmen’s preferences for ecosystem services should be fully considered, and grassland ecological attributes with higher willingness to pay of herdsmen should be given priority and to obtain key management. Patterns like these can help policymakers determine which actions may lead to the most considerable welfare improvements. Besides, it is necessary to improve herdsmen’s awareness of grassland ecosystem services, especially in the current situation of COVID-19, the Chinese government should keep the safety line between humans and wild animals and adopt correct strategies to coordinate the conflict between wildlife protection and animal husbandry production. Importantly, the government of China should pay attention to the grazing and environmental needs of different types of grassland herdsmen, and make policies for grassland ecological restoration according to local conditions, and improve the level of animal husbandry technology and industrialization, and strengthen grassland supervision and management capabilities. Thus, the grassland ecosystem can play its ecological, economic and social benefits and contribute to maximize the social welfare of grassland ecosystem.

CRediT authorship contribution statement

Yu Cai: Methodology, Software, Data curation. Minjuan Zhao: Conceptualization, Supervision, Funding acquisition. Yuxing Shi: Formal analysis, Investigation. Imran Khan: Visualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We thank all the members of the Key Research Base of Philosophy and Social Science of Shaanxi Province for data collection. The anonymous referees provided us valuable comments and suggestions. The survey was sponsored and obtained by a Soft science project of National Forestry and Grassland Administration (2019131039). All errors are our own.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolind.2020.106705.

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