Responses of grazing households to different levels of payments for ecosystem services

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ABSTRACT

Introduction: Payments for Ecosystem Services (PES) programs have been implemented globally to protect ecosystems while securing the well-being of affected people. Reasonable payment standards are key to successful PES programs. Although some approaches are available for determining payment standards, few studies have applied them for grassland conservation with location indicators and socioeconomic contexts properly considered.

Methods: Using China’s first pilot Grassland Ecological Compensation Policy (GECP) as an example, we analyzed the effects of payment levels, other natural and socioeconomic factors on herdsmen’s willingness to participate in the GECP in Damao County in Inner Mongolia where grassland degradation is happening at an alarming rate due to overgrazing and cropland expansion.

Outcomes: Our results show that households with lower herding income, older age, higher education, larger grassland areas, and worse social relationships are more inclined to participate in the GECP. Conservation payment level, as well as natural and socioeconomic contextual factors, significantly affect the response of herdsmen, and a reasonable grassland payment standard with a 95% policy compliance rate should be 8.8 yuan mu⁻¹.

Discussion and Conclusion: Our findings can inform governments to develop effective PES programs to balance the need of human well-being improvement and grassland conservation in China and beyond.
payment would be unfair for the providers. Therefore, the establishment of appropriate payment standard is the key to effective management (van Noordwijk et al. 2012; Matthies et al. 2015). A fair deal under PES needs to consider two types of values: the opportunity cost borne by ES providers and the economic value of ES. Usually, the latter is higher than the former. A fair payment standard should take the ES types, ES values, and location indicators into account to reflect the spatial heterogeneity of ES provision (Willaarts, Volk, and Aguilera 2012; Richards et al. 2015; Sarkki and Karjalainen 2015). Besides, a more essential determinant of payment standard is the willingness of the ES buyers and sellers to make the deal (Liu et al. 2014; Ren et al. 2020). In addition, due to the possible changes of the ES value and stakeholders’ demand under different circumstances, socioeconomic development factors (e.g., household income) should also be considered in the establishment of payment standard (Jin, Huang, and Peng 2009; Engel et al. 2015; Fan and Chen 2019). Respondents with higher-income occupations are more willing to participate in the PES programs and pay more (Peng et al. 2018). Due to those complexities, determining a fair payment standard is far from being straightforward (Jin, Yang, and Li 2014; Liu and Liu 2014). Therefore, it is crucial to develop an efficient way to determine reasonable payment standards for PES programs.

Methods for estimating payment standards for ES can be classified into three categories: the benefit compensation method, the cost compensation method, and the willingness to pay (WTP) or willingness to accept (WTA) method (Sun, Dang, and Zheng 2017; Ren et al. 2020). The benefit compensation method is based on the economic value of the ecosystem services provided. Based on the market value method (MVM), the payment standard could solve downstream-upstream problems in watersheds, working as an efficient conflict-resolution approach (Kosoy et al. 2007). The cost compensation method is widely used. The basis of this method is opportunity cost, which is an appropriate cost measure indicating the social cost of environmental protection (Adams, Pressey, and Naidoo 2010). For example, Knoke et al. (2008) estimated the opportunity costs for protecting the secondary forest in Monte Carlo, Chile is 375 USD ha\(^{-1}\) year\(^{-1}\) (1 USD = 6.46 yuan as of July 2021) and the local government used that as the standard to compensate the owners of the forests. The WTP/WTA method evaluates payment standards by investigating respondents’ willingness to pay/accept for environmental goods or services under different assumptions (He et al. 2016). Compared with WTA, WTP is often underestimated when evaluating the value of the same ecological goods or services (Viscusi and Huber 2012; Ren et al. 2020). Alcon et al. (2019) investigated preferences and WTP of farmers in a choice experiment at plot and irrigation district level. To support the implementation of water saving measures, farmers were willing to pay higher water prices of 0.32 USD m\(^{-3}\) and 0.22 USD m\(^{-3}\), respectively. Mashayekhi et al. (2016) showed that the coastal communities in southern Iran had a mean WTA of 2026 USD household\(^{-1}\) year\(^{-1}\) by quantifying the opportunity cost of conservation.

In China, PES has been extensively implemented at national and local scales for more than 20 years. On account of the severe drought in 1997 and the heavy floods in the Yangtze river basin during 1998, China began to implement the Sloping Land Conservation Program (SLCP) and the Natural Forest Conservation Program (NFCP) (Zhou et al. 2022). SLCP paid farmers for converting croplands to forests or grassland while NFCP paid county governments, local households, or state-own enterprises for activities to prevent forest loss (Yang and Lu 2018). Chinese scholars have also made some efforts to estimate the ecological payment standard. Zhou et al. (2015) established the upper limit standard of the ecological compensation by assessing the ES value of the Middle Route Project of the South-to-North Water Transfer from 2002–2010. Sun, Dang, and Zheng (2017) determined the MVM-based payment standard of 876.23 yuan mu\(^{-1}\) year\(^{-1}\) (1 ha = 15 mu) for the Middle Route Project of the South-to-North Water Diversion Project in China. Gao et al. (2018) determined the payment standard of the Dongjiang River Basin was approximately 2057.90 yuan mu\(^{-1}\) based on ES assessment. XU et al. (2012) measured WTP and WTA of the respondents in Liaohe River Basin were 160.72 yuan person\(^{-1}\) year\(^{-1}\) and 255.97 yuan person\(^{-1}\) year\(^{-1}\) using the nonparametric and parametric methods, respectively. Liu et al. (2019) developed a dynamic eco-agriculture payment standard by coupling the opportunity cost and WTA of farmers. Chu et al. (2020) applied the contingent valuation method (CVM) to analyze residents’ WTA for participating in afforestation projects. The results indicated that 477.91 yuan mu\(^{-1}\) year\(^{-3}\) was an appropriate amount of compensation.

Most PES programs are government-dominated in China, which lead to poor effectiveness, low efficiency, and unfairness (Shang et al. 2018; Yang and Lu 2018). Governments often represent the ES buyers to pay the ES providers (e.g., farmers and herders), too high compensation amount is a heavy economic burden to the government, while too low conservation investments will worsen the effectiveness of PES programs by reducing the willingness to participate (Liu et al. 2014). Although there are many implemented PES programs in forests, wetlands, and grasslands (Gao et al. 2016), quantitative studies on payment
standards are still relatively few, especially for grasslands. In the existing studies of grassland ecosystems, due to the inconsistent estimation methods, the calculation results of ecological payment standards in varied regions are largely different. Yang et al. (2006) estimated that the average WTA for grassland grazing prohibition in Xilinguole League of Inner Mongolia was 5.73 yuan mu\(^{-1}\) according to the willingness survey method. The psychological compensation standard for herders in Xilinguole League was estimated as 18 yuan mu\(^{-1}\) with the field survey data (Qi et al. 2016). Using survey data, Hu et al. (2017) adopted the opportunity cost method to calculate the grazing prohibition compensation standards for three counties in Inner Mongolia, with 5.97 yuan mu\(^{-1}\) for Siziwang County, 7.77 yuan mu\(^{-1}\) for Alxa Left County, and 10.90 yuan mu\(^{-1}\) for Old Barag County. The inconsistent results in the above studies of grasslands compensation standards might be due to the separation of compensation standard from economic and social contexts and did not adjust the impacts of socioeconomic indicators (Fan and Chen 2019). In addition, they reflect deficiencies in different estimation approaches. Specifically, the benefit compensation method can only calculate the upper limit of compensation; the cost compensation method requires extensive and long-term socioeconomic investigation, which easily causes incomplete and inaccurate estimation; the WTP/WTA method is difficult to adjust the contradiction between the WTP and the WTA (Liu and Yang 2019; Yang et al. 2020; Pan and Song 2021; Sun et al. 2021). Therefore, establishing a credible and reasonable grassland ecological payment standard is essential for achieving the dual goals of Grassland Ecological Compensation Policy (GECP).

Meanwhile, the current grassland ecological payment standards are based on the financial capability of the government and determined by top-level government agencies. Thus, the current payment standard cannot reflect the actual needs of herdsmen and is generally underestimated. Since the implementation of the grazing bans in 2008, the grassland area in Damao, Inner Mongolia has made progress in preventing grassland degradation. Nevertheless, in recent years, many herdsmen have moved back to the original grassland to graze again, which prompts the government to raise the existing grassland compensation standard.

To reflect the actual demands of herdsmen for GECP, we aim to: (1) understand the characteristics of relocated households (i.e., households participate in the program but still choose to graze) and non-relocated households (i.e., households participate in the program and do not graze); (2) analyze the effects of different conservation payments on the grazing willingness of herdsmen; and (3) explore the impacts of other natural and socioeconomic factors on the herdsmen’s willingness to graze. Our findings reveal the driving factors behind the herders’ returning to pasture, which may guide policymakers to formulate a more reasonable payment standard to promote grassland recovery.

**Materials and methods**

**Study area**

Damao County (N 41°20’ – 42°40’, E 109°16’ – 111°25’) is one of the 19 border counties close to the north border of Inner Mongolia (Figure 1). It has a total area of 18,177 km\(^2\) and administrates 7 pastoral townships and 5 non-pastoral townships. Residents (approximately 20,000 in 6620 households) in pastoral townships live within and around the grasslands. The income of local households mainly depends on livestock husbandry (e.g., cattle, sheep, horses), cropping, and government subsidies (e.g., pasture prohibition subsidies, land acquisition subsidies, pensions and subsistence allowances).

The sensitivity to climate change and human intervention makes Damao County an ecologically fragile region (Wang et al. 2004; Zhou et al. 2014). In the 1990s, the grasslands of Damao County have been severely desertified and degraded due to factors such as drought and over-grazing. Therefore, to reduce grazing pressure and recover grassland productivity, since 2008 Damao County has fully implemented the GECP, with 6620 pastoral households signed the contracts to participate. It was also the first pilot area in China that completely implemented enclosure and grazing prohibition. The payment standard of the GECP varied across years (Table 1). The subsidies were designed to motivate herdsmen to comply with the GECP, conserve the grassland ecosystems, and increase pastoral household incomes (Hu, Huang, and Hou 2019; Yin et al. 2019). Since the implementation of the grazing prohibition policy, the grassland conditions of Damao County has improved significantly. By the end of 2020, the average height and vegetation coverage of natural grassland in the whole county were 15.5 cm and 6.9% higher than those before the grazing prohibition, respectively (Figure 2).

**Data collection and pre-processing**

We conducted household surveys from May to August 2017 in Damao County. Since the householders or their spouses are often the decision makers who are familiar with household affairs.
Therefore, we chose them as our interviewees. Details of survey design were listed in Supplementary Material. We adopted the stratified random sampling method and selected 251 households (Figure 1). The selected pastures were also randomly sampled from 7 pastoral townships, covering 7 pastoral townships, and corresponding to the 251 households in the questionnaire. We collected household data on household demographic and economic status, social networks (cash gift and maximum amount of money can be borrowed from relatives and friends), and the responses of households to different payment levels. We obtained annual average precipitation map with 1000 m resolution, elevation map with 30 m resolution from the Institute of Geography, 

Since 2008, Damao County has implemented the GECP on 23.57 million mu of grassland (An, 2011). In the end of 2007, the average grass height of the county was 11.9 cm, and the average vegetation coverage was 22.1% (Zhang, 2017). The GECP could be divided into four stages based on different payment standards (see Table 1 for details). The grassland conditions in different stages were as follows:

- **Phase I: 2008.1-2010.12, payment standard of 4.8 yuan mu⁻¹**
  By the end of 2010, the average height of natural forage grass in Damao County was 9.5 cm, and the average coverage of natural grassland vegetation was 18% (An, 2016).

- **Phase II: 2011.1-2013.12, payment standard of 6.0 yuan mu⁻¹**
  By the end of 2013, the average grass height was 21.7 cm, and the average coverage of natural grassland vegetation was 23% (Enheteduqin, 2014).

- **Phase III: 2014.1-2015.12, payment standard of 6.5 yuan mu⁻¹**
  By the end of 2015, the average grass height was 21 cm, and the average coverage of natural grassland vegetation was 21% (Enheteduqin, 2016).

- **Phase IV: 2016.1-2020.12, payment standard of 7.5 yuan mu⁻¹**
  By the end of 2020, the average grass height increased to 27.4 cm, and the average coverage of natural grassland vegetation reached 29% (Liu, 2021).

**Figure 1.** Map of Damao County.

**Figure 2.** Grassland conditions of Damao County under different payment standards.
Table 1. General information of the PES program in Damao County.

| Item                        | Subsidy and reward mechanism for grassland ecological protection |
|-----------------------------|------------------------------------------------------------------|
| Beginning date              | 2008                                                             |
| Duration                    | Phase I: 2008.1–2010.12; Renewed phase II: 2011.1–2013.12; Renewed phase III: 2014.1–2015.12; Renewed phase IV: 2016.1–2020.12 |
| Legal mechanism             | National Grassland Ecological Compensation Policy                |
| Targeted area               | Damao County                                                     |
| Targeted households         | Farmers and herdsmen engaged in grassland animal husbandry production and workers engaged in agriculture and animal husbandry with the right to contract management of grassland or the right to joint household management |
| Implemented area            | 23.57 million mu from 6620 households                           |
| Payment standard            | 4.8 yuan per mu per year from 2008.1 to 2010.12; 6.0 yuan per mu per year from 2011.1 to 2013.12; 6.5 yuan per mu per year from 2014.1 to 2015.12; 7.5 yuan per mu per year from 2016.1 to 2020.12 |

In fact, from Jan. 2016 to Dec. 2017 the compensation was 6.5 yuan per mu per year due to the new round of implementation documents had not been approved. After the documents were approved, the subsidy in Jan. 2016 was increased to 7.5 yuan per mu per year at the end of 2017. We surveyed the questionnaire in the summer of 2017, while the compensation was 6.5 yuan per mu per year.

Chinese Academy of Sciences. We calculated the slope of every grassland patch from the elevation map. We combined those 251 household survey data with geodatabase of pasture parcels. There were 212 (84.5%) matched households with spatially-explicit pasture information.

Measurements

Considering data availability and insights from relevant literature (Chen et al. 2009), we selected fourteen associated indicators (Table 2) to measure the impacts on households’ willingness to graze. These indicators represent financial, human, natural, and social capital aspects (Liu et al. 2012). Economic factors such as conservation payment, herding income, and livestock directly affect households’ willingness to graze. Since men are the main herding labor, we used the number of male laborers for pasture monitoring activities. A laborer is defined as an individual between the age of 15 and 59 (Yang et al. 2013b). Age and education affect an individual’s attitude and behavior (Rustagi, Engel, and Kosfeld 2010). Since adults are decision makers in household affairs, we used the average age of all adult members and the average education level of all adult members except for current students. Natural factors such as aspect and precipitation largely determine the quality of pastures. Besides, steeper slope reduces human access and thus reduces grazing and pasture degradation. Larger grassland area means more government subsidies, and thus lower chance of grazing. Members of the same subgroup are more likely to enforce each other’s trust than they are not of the same subgroup. Since relatives and friends can be regarded as the same subgroup of a household, we used cash gift and average maximum potential loans from relatives and friends to measure social capital (Frank and Yasumoto 1998).

Data analysis

We assumed that herdsmen were willing to re-graze in their grasslands if the utility of re-grazing was greater than the utility of no-grazing in a new round of policy. That is, \( U_i^0 > U_i^1 \), where \( U_i^0 \) and \( U_i^1 \) are the utilities of the decision maker in the new and old rounds, respectively.

Table 2. Descriptive statistics of variables used in the model.

| Characteristics                | Independent variables               | Mean  | S.D.  |
|--------------------------------|-------------------------------------|-------|-------|
| Conservation payment           | Conservation payment (yuan mu\(^{-1}\)) | 7.80  | 7.70  |
| Household economics            | Herding income (1000 yuan)          | 51.18 | 52.28 |
|                                | Livestock of moving in (100 sheep)  | 1.13  | 1.43  |
|                                | Change of livestock (100 sheep)     | –2.87 | 2.60  |
| Demographic conditions         | Male laborers                       | 1.26  | 0.57  |
|                                | Age (years)                         | 48.49 | 8.36  |
|                                | Education (years)                   | 7.34  | 2.99  |
| Geographic conditions          | Slope (degrees)                     | 7.12  | 1.19  |
|                                | Aspect (0 = due north; 180 = due south) | 175.74 | 8.52  |
|                                | Precipitation in 2007 (cm)          | 246.42| 29.85 |
|                                | Variation of precipitation (cm)     | –68.16| 27.16 |
| Land plot features             | Area (100 mu)                       | 38.05 | 26.27 |
| Social networks                | Cash gift (1000 yuan)               | 11.11 | 7.50  |
|                                | Average maximum potential loans from relatives and friends over three years (1000 yuan) | 16.34 | 24.52 |

N = 414. Variance inflation factors were tested to be < 5 in the model.
are the utilities of sample \( i \) going re-grazing and no-grazing in the new policy, respectively. The utility function \( U(\cdot) \) is unobservable; however, there is a probability of participating in the PES program and choosing not to graze. This can be given by:

\[
Pr(Y_i = 1) = Pr(U_i^1 > U_i^0)
\]

(1)

where \( Y_i = 1 \) if the choice was to participate in the program under the hypothesized scenario; otherwise \( Y_i = 0 \).

According to the actual results of the questionnaire, not all households answered all four questions. For example, in the scenario of reducing subsidies, households chose to answer one, two, or three questions, and thus we set different weighting for the unbalanced sampling. The response of grazing households to different levels of conservation payments was empirically modeled with a random-effects weighted logit model:

\[
\ln \frac{Pr(Y_i = 1|X_i, \varepsilon_i)}{1 - Pr(Y_i = 1|X_i, \varepsilon_i)} = W_i X_\beta + \varepsilon_i = X_i^{new} \beta + \varepsilon_i
\]

(2)

where \( Pr(Y_i = 1) \) is the probability of the \( i \)th sample not grazing; \( W_i \) is a weighting vector which integrates the multiple choices of the \( i \)th sample, in the case of reducing subsidies where households answered one, two, or three questions, the weighting is going to be one, a half, and one-third, respectively; \( X_i \) represents all variables of the \( i \)th sample, including conservation payment, household economic, demographic conditions, and geographic conditions, land plot features, and social networks; \( X_i^{new} \) represents the new \( i \)th sample after integration; \( \beta \) is a parameter vector associated with the independent variables; and \( \varepsilon_i \) represents the unobserved random effects associated the \( i \)th sample.

In the weighted logit model, the marginal effects of continuous variables are given by:

\[
\frac{\partial Pr(Y = 1)}{\partial x_j} = \frac{\partial Pr(Y = 1)}{\partial X} \cdot \beta_j = \frac{\exp(X_\beta)}{(1 + \exp(X_\beta))^2} \beta_j
\]

(3)

where \( x_j \) represents the \( j \)th model variable; \( X \) represents all model variables; \( \beta_j \) is the coefficient of \( x_j \); and the partial derivative is calculated at the mean of all the explanatory variables in the model.

We preprocessed the data and analyzed the rationality of the model. We combined the data points from two scenarios of reducing subsidies and increasing subsidies. We first combined with correlation test and the effect of model fitting, to decide which variables can be put in our model. We then used the percentiles method (upper percentile = 97.5%), standardized residuals (> 2.5), and Cook’s Distance (> 1) to eliminate outliers. Finally, we select four sets of data representing different annual incomes for multiple comparisons (See Supplementary Material for more details of data analysis).

Results

Descriptive statistics of relocated and non-relocated households

Our results show that the grazing households that relocated to the pasture to graze owned larger grassland area, higher herding income, more male household members, lower age, higher education, and higher loans than those of non-relocated households (Table 3). In our sampled 212 households, 127 households moved out of the pastures when the grazing prohibition policy began, and among which 123 households (96.85%) moved back to their grasslands to graze again. Only 6 households (2.83%) did not relocate to pasture, and the rest, including those who did not move out before, were still grazing. Table 3 shows that the average herding income of households who grazed (52.56 thousand yuan) was almost half more than those who did not graze (36.00 thousand yuan). The male rate and age of relocated households were slightly higher and lower than those of non-relocated households, respectively. However, the average education in non-relocated households was almost two years lower than that of relocated households. Many residents who did not graze were older, and they were happy to retire after receiving the subsidies. Besides, relocated households had 842 mu larger grassland area and around a third more loans than those of non-relocated households on average (Table 3).

Effects of different levels of conservation payment on non-grazing

Our results also show that conservation payment had a significantly positive effect on respondents’ willingness to not graze in the GECP, with an S-shaped growth relationship (Table 4 and Figure 3). When all other variables are controlled at their mean values, an additional yuan per mu per year of conservation payment will increase the odds of non-grazing in the GECP by 26.9 times. Specifically, an additional 0.1 yuan based on 7.80 yuan mu\(^{-1}\) (Table 2) will on average increase the households’ willingness to not graze by 7.88% (Table 4).

Households are more willing to support the GECP when conservation payment increases. Conservation payment has the largest marginal effect of approximately 50% on the non-grazing rate when the payment is 7.9 yuan mu\(^{-1}\) by our calculation, where the marginal effects of conservation payment are smallest with the payment of 10.7 yuan mu\(^{-1}\) and 0 yuan mu\(^{-1}\), where 99.99% and none of the households would participate in the GECP, respectively (Figure 3a). According to our model, under the
Table 3. Descriptive statistics of variables for relocated and non-relocated households.

| Characteristics                       | Independent variables | Relocated Mean | Relocated S.D. | Non-relocated Mean | Non-relocated S.D. |
|---------------------------------------|-----------------------|----------------|-----------------|--------------------|--------------------|
| Household economics                   | Herding income (1000 yuan) | 52.56          | 54.90           | 36.00              | 54.57              |
|                                       | Off-herd income (1000 yuan) | 43.00          | 40.16           | 33.78              | 16.96              |
|                                       | Livestock of moving out (100 sheep) | 4.05           | 2.89            | 4.53               | 3.37               |
|                                       | Livestock of moving in (100 sheep) | 1.17           | 1.42            | 0.00               | 0.00               |
|                                       | Change of livestock (100 sheep) | −2.88          | 2.70            | −4.53              | 3.37               |
| Demographic conditions                | Household size         | 2.73           | 1.16            | 2.50               | 1.22               |
|                                       | Male laborers          | 1.26           | 0.56            | 1.00               | 0.63               |
|                                       | Male ratio of house    | 0.49           | 0.16            | 0.40               | 0.20               |
|                                       | Age (years)            | 48.36          | 8.45            | 52.75              | 6.37               |
|                                       | Education (years)      | 7.34           | 2.99            | 5.63               | 4.59               |
| Geographic conditions                 | Elevation (hm)         | 13.92          | 1.64            | 13.11              | 1.79               |
|                                       | Slope (degrees)        | 7.12           | 1.20            | 8.10               | 1.34               |
|                                       | Aspect (0 = due north; 180 = due south) | 175.82         | 8.55            | 171.25              | 5.86               |
|                                       | Precipitation in 2007 (cm) | 246.81         | 30.04           | 234.78              | 33.90              |
|                                       | Precipitation in 2015 (cm) | 178.45         | 48.00           | 176.77              | 74.04              |
|                                       | Variation of Precipitation (cm) | −68.36         | 27.24           | −58.01              | 40.61              |
| Land plot features                    | Area (100 mu)          | 38.09          | 26.26           | 29.67               | 20.52              |
| Social networks                       | Cash gift (1000 yuan)  | 11.10          | 7.52            | 13.67               | 7.53               |
|                                       | Average maximum potential loans from relatives and friends over three years (1000 yuan) | 17.00 | 25.50 | 12.00 | 15.23 |

N = 212.

Figure 3. Response curve of non-grazing ratios and payments. 1 ha = 15 mu.
existing payment level of 6.5 yuan mu\(^{-1}\), the proportion of herders not grazing was only 0.80%. However, when the payment rose to 7.5 yuan mu\(^{-1}\) and 8.5 yuan mu\(^{-1}\), the proportion of non-grazing could increase to 18.48% and 86.37%, respectively. This indicates that herders are very sensitive to payment increase. This also indicates that the current compensation of the PES policy does not meet the expectations of most households and the payment standards should be improved. Among those grassland plots under the grazing prohibition policy, more than half can be prevented from being grazed with the payment of 7.9 yuan mu\(^{-1}\) (Figure 3b). Moreover, if the current grassland ecological compensation in Damao County can be renewed with the payment of 8.6 yuan mu\(^{-1}\), 90% of grassland plots could be protected from overgrazing (Figure 3b). Maps of the probability of non-grazing under four different conservation payments across grazing prohibition policy implemented area also support our point of view (Figure 4). Figure 4 shows that, as the amount of compensation increases, the probability of herdsmen not grazing is getting higher and higher.

Figure 3 also indicates the minimum payment levels to achieve different non-grazing policy goals. Taking government’s willingness into account is a useful complement to formulate scientific policies (Jin et al. 2019). For instance, if the government in Damao County wants more than 95% of grassland plots be saved from overgrazing, then the payment standard should be increased to at least 8.8 yuan mu\(^{-1}\) (Figure 3b). The impacts of different compensation standards on grazing pressure (measured by stock capacity, Figure S1) show that with the increase of compensation standard to 8.8 yuan mu\(^{-1}\), the range of grazing pressure in the pastoral area will be reduced from 0 ~ 0.87 sheep mu\(^{-1}\) to 0 ~ 0.04 sheep mu\(^{-1}\). In 2019, the grassland bureau reported that the reasonable stock capacity of grassland should be limited to no more than 0.04 sheep mu\(^{-1}\) (Wei and Wu 2019), which is coincidently matched with our results of 95% of non-grazing (Figure S1). Figure 5 shows the spatial distributions of pasture subsidies predicted by our model under the 50%, 75%, 90%, and 95% of non-grazing goals, respectively. The conservation payment is overall higher in the west and lower in the east, which is consistent with the distribution of annual herding income (Figure 6).

![Figure 4. Maps of the spatial configuration of probability of non-grazing under different conservation payments in Damao County, China (a: 70% of current payment; b: 100% of current payment; c: 130% of current payment; d: 150% of current payment).](image-url)
The predicted results of our model are not only consistent with the current pasture income of herders, but also meet the pastoral subsidy expectations of the herders in the questionnaires. When herders receive subsidies and are banned from grazing, they can have other livelihoods to make a living (e.g., go out to work). In this way, there is no significant difference between the sum of the two parts of income (i.e., predicted subsidies and salaries) and the current actual pasture income (i.e., grazing and subsidies), and the expected subsidies in their questionnaires, respectively (Figure 7). Therefore, these results also suggest that the predicted results of our model are reasonable.

Effects of other factors on non-grazing

Household economic status has an important effect on the response of herders to the policy (Table 4). For instance, herding income has a significantly positive effect on households’ willingness to graze ($p < 0.001$). With all other relevant factors controlled at their mean values, an increase of herding income by 1,000 yuan increases the willingness of grazing by 2.2%. This result indicates that households with more income from herding previously were more likely to choose not to participate because they expected benefits from grazing being higher than the compensation from participating in the program. We also found that when the herders moved back to the pasture after the policy implementation, the amount of livestock had a significantly negative effect on households’ willingness to graze ($p < 0.01$). The more livestock there were on the pasture when the herders moved back, the more subsidies herders would expect to reduce the amount of livestock or even not graze. The difference between the old and new compensation amounts should at least make up for the amount of livestock that each household could sell after policy implementation. Therefore, the impact of the amount of livestock at the time of relocation on the willingness to graze was directly linked to the amount of compensation. In addition, the change in the number of livestock owned by each household when the herders move in and out had a significantly positive effect on households’ willingness to graze ($p < 0.05$). When herders resettled to the pasture, a decrease of livestock by 100 sheep based on the original moving out reduced the proportion of households’ willingness to resume grazing by 6.7%.

For the demographic conditions, the average age of adults and the average education level of non-students in grazing households showed significant effects in our model. Specifically, older and higher educated households were more likely to participate in the program. One additional year of a household’s average age and education increased the probability of non-grazing by 2.3% and 7.2%, respectively (Table 4). Considering demographic conditions comprehensively, on average a household with the age of

**Table 4.** Estimate of conservation payments and other characteristics and their marginal effects on the grazing households’ response.

| Characteristics | Independent variables | Coefficients | SE  | Odds ratios | Marginal effects |
|-----------------|-----------------------|--------------|-----|------------|-----------------|
| Conservation payment | Conservation payment (yuan mu$^{-1}$) | 3.330*** | 0.648 | 27.942*** | 0.788*** |
| Household economics | Herding income (1000 yuan) | −0.094*** | 0.025 | 0.910*** | −0.022*** |
| | Off-herd income (1000 yuan) | | | | |
| | Livestock of moving out (100 sheep) | 0.864** | 0.313 | 2.373** | 0.205** |
| | Livestock of moving in (100 sheep) | | | | |
| | Change of livestock (100 sheep) | −0.283* | 0.126 | 0.754* | −0.067* |
| Demographic conditions | Household size | | | | |
| | Male laborers | −1.034 | 0.695 | 0.356 | −0.245 |
| | Male ratio of house | | | | |
| | Age (years) | 0.098* | 0.045 | 1.103* | 0.023* |
| | Education (years) | 0.305* | 0.129 | 1.357* | 0.072* |
| Geographic conditions | Elevation (m) | 0.321 | 0.312 | 1.378 | 0.076 |
| | Slope (degrees) | | | | |
| | Aspect (0 = due north; 180 = due south) | −0.109* | 0.047 | 0.897* | −0.026* |
| | Precipitation in 2007 (cm) | −0.017 | 0.014 | 0.984 | −0.004 |
| | Precipitation in 2015 (cm) | | | | |
| | Variation of Precipitation (cm) | 0.041* | 0.016 | 1.042* | 0.010* |
| Land plot features | Area (100 mu) | 0.027* | 0.013 | 1.028* | 0.006† |
| | Social networks | Cash gift (1000 yuan) | −0.102† | 0.055 | 0.903† | −0.024† |
| | | Average maximum potential loans from relatives and friends over three years (1000 yuan) | −0.004 | 0.017 | 0.996 | −0.001 |
| Constant | | −5.241 | 10.008 | 0.005 | |

Log likelihood = −38.762276, Pseudo $R^2 = 0.8427$, N = 414, †p < 0.1; *p < 0.05; **p < 0.01; ***p < 0.001.
Figure 5. Maps of the spatial configuration of predicted conservation payment which herders expect for under different probability scenarios in Damao County (a: probability = 50%; b: probability = 75%; c: probability = 90%; d: probability = 95%). 1 ha = 15 mu.

Figure 6. Distribution map of annual herding income of herders in Damao County.
45.00 and education of 8.00 had the same likelihood of non-grazing as that of the age of 48.13 and education of 7.00 (Table 4).

Furthermore, our results demonstrate that pasture area had nonlinear and significant effects on non-grazing (Table 4). Since the area of each household’s grassland determined the amount of payment one could receive directly, it had a significantly positive effect on households’ willingness to graze (p < 0.05). The larger the area, the more subsidies, and thus the willingness to graze was naturally lower when the household participated in the program. Again, controlling all other variables at their mean values, one hundred more mu of grassland reduced the probability of grazing by 0.6% (Table 4). The effects of aspect and variation of precipitation were also significant (Table 4).

Nevertheless, social relationships (measured by the amount of gift income) had negative effects on non-grazing. It is estimated that 1,000 yuan of more gift income led to 2.4% of higher willingness to re-graze (Table 4). According to our field investigation, if the herders’ social relationships were better, once they heard that their relatives and friends had moved back to re-graze, they were more likely to join them and graze again (Table 4). This result is consistent with the observed social network effect on collective action and resource outcome in Wolong Nature Reserve for giant pandas, where households are inclined to follow the behaviors of their relatives and friends, especially those local leaders (Yang et al. 2013b).

**Discussion**

Designing an effective payment standard is crucial for sustainable rural development, particularly in poverty-stricken areas with fragile ecological and economic systems. PES program with sound design and implementation can be an efficient instrument for poverty alleviation and sustainable regional development (Zhang, Yang, and Yu 2009; Kemkes, Farley, and Koliba 2010; Gao et al. 2019; Jin et al. 2019). We estimated households’ response curves to different payment standards in Damao County using the weighted logit model. Our findings suggest that households with lower herding income, older age, higher education, larger grassland area, and worse social relationships are more inclined to participate in the GECP. The impacts of conservation payment, herding income, livestock, household age and education, aspect, precipitation, and area of grassland on the response of herders can be substantial. Based on our results, we provide the following recommendations for further improvements of the GECP and other similar PES programs.

First, reasonable compensation standards and diverse compensation sources are essential for the region’s grassland resource management. According to our study, we found that increasing the compensation amount to 8.6 yuan mu⁻¹ year⁻¹ or 8.8 yuan mu⁻¹ year⁻¹ would encourage 90% or 95% of households to participate in the GECP and not graze, respectively. The average grassland compensation standard estimated by Hu et al. (2017) through opportunity cost was 8.21 yuan mu⁻¹, which was consistent with ours. Nevertheless, Qi et al. (2016) estimated the reasonable compensation as 18 yuan mu⁻¹, which was much higher than ours. The reasons for such difference might be due to the different estimation methods and Qi et al. (2016) did not control the impacts of grazing pressure and financial capital. Besides, it is also necessary to diversify compensation sources and enrich compensation methods (e.g., industrial compensation and education compensation). Currently, most of the PES fund comes from the central government. It is crucial to establish partnership funds with other stakeholders (e.g., tourism companies, animal husbandry and processing
companies, and sandstorm-affected regions such as Beijing and Hebei Province) that benefit from grassland protection. Meanwhile, except for subsidies, industrial compensation can provide alternative livelihoods for herders. Education compensation can enhance herders’ environmental awareness and increase herders’ other non-pastoral employment opportunities, and thus eventually reduce herders’ dependence on pastures.

Second, expanding non-agricultural sources of income of herdsman and reducing the proportion of agriculture income in total household income can be an effective measure for increasing PES program compliance. Specifically, the government and environmental organizations could provide skill training and guidance on local and migrant workers. For the poor or senior herdsman whose compensation income is insufficient to maintain the normal household income and who are unable to obtain other sources of income, the government should provide basic social welfare protection via relevant national and regional policies. The above alternative livelihood measures have also been proposed by some other studies (Yang et al. 2013a, 2018; Wu et al. 2019).

Third, PES programs should be integrated into China’s rural governance through the rural revitalization plan and ecosystem product value realization strategy (Gao et al. 2020; Ouyang et al. 2020; Tong et al. 2020; Jin et al. 2021). For example, the gross ecosystem product (GEP) accounting has recently been integrated into the System of Environmental-Economic Accounting – Ecosystem Accounting framework of the United Nations (United Nations 2021). In China, recently GEP accounting has been used in PES programs to demonstrate ecological effectiveness, evaluate government officials, improve spatial planning, and design policy tools for the market transaction of ecosystem services. The obtained economic benefits from ecosystem service transactions are then shared with local rural households (Gao et al. 2020; Ma et al. 2020; Ouyang et al. 2020).

As the core logic of the PES program relies on the reallocation of ecological and socioeconomic costs and benefits among different stakeholders, the long-term success of PES programs should be ecologically effective, economically efficient, and socially equal (Yang and Lu 2018). Our study helps to understand participating households’ responses to different payment amounts and other socioeconomic and ecological contexts. It also clearly demonstrates the number of conservation funds required to achieve different policy targets. However, as macro-socioeconomic contexts change and local households interact with their dependent ecosystems, households’ responses would also vary. Thus, for future research, it is important to monitor the long-term dynamics of influencing factors and their corresponding impacts on households’ conservation behaviors and resource outcomes. As policymakers are often less interested in what have occurred and more eager to obtain operational solutions to address existing problems, it is important to construct coupled human and natural systems models to simulate different ecological, economic, and social outcomes under different policy scenarios.

**Conclusion**

A scientifically sound payment standard is important to achieve ecological effectiveness, economic efficiency, and social equity for PES programs in the long term. Taking Damao County in Inner Mongolia as an example, we find that households who are willing to participate in the PES program are those with lower herding income, older age, higher education, larger grassland area, and worse social networks. Payment standards, along with other socioeconomic and natural factors such as herding income, livestock, age, education, aspect, precipitation, and area of grassland significantly affect households’ willingness to not graze. Our results also show that the payment standard at the survey time (6.5 yuan mu$^{-1}$) only has a 0.8% policy compliance rate and is far below the expectation of most households. Increasing the payment standard to 8.8 yuan mu$^{-1}$ could attract 95% of households to participate in the PES program. Conservation policy planning and implementation are complex processes (Yang et al. 2013a). Our findings demonstrate the quantitative and nonlinear responses of households to different levels of payments for ecosystem services. Our study also suggests that ecological effectiveness, economic efficiency, and social equity of PES programs can be improved by proper regulation of conservation payments, socioeconomic conditions, demographic trends, and ecological contexts. The methodology and findings of our study may also guide the design and implementation of conservation policies in many other places across China and the rest of the world.

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