RESEARCH ARTICLE

Economic valuation of rangelands in the north of Mexico: A study for its conservation

Octavio T. Barrera-Perales[1], Leticia M. Sagarnaga-Villegas[2], Juan W. Tudela-Mamani[3], Jose M. Salas-González[2], Asael Islas-Moreno[2] and Juan A. Leos-Rodríguez[2]

[1] Universidad Nacional Autónoma de México (UNAM), Centro de Investigaciones en Geografía Ambiental (CIGA). Antigua Carretera a Pátzcuaro 8701, Ex Hacienda San José de la Huerta. 58190 Morelia, Michoacán, Mexico. [2] Universidad Autónoma Chapingo, Centro de Investigaciones Económicas, Sociales y Tecnológicas de la Agroindustria y la Agricultura Mundial (CIESTAAM). Ctra. México-Texcoco Km 38.5, 56230 Chapingo, Estado de México, Mexico. [3] Universidad Nacional del Altiplano, Facultad de Ingeniería Económica. Dirección: Av. Floral 1153, Puno, Puno 51, Peru.

Abstract

Aim of study: To estimate grazing fee and the economic value of the communal rangelands of two groups of ranchers.

Area of study: Ejido Tanque de Arenas (ETA) and ejido Tanque de Dolores (ETD) in Catorce, San Luis Potosí, Mexico

Material and methods: The contingent valuation method with referendum format was used to propose a grazing fee that would allow conservation and continuity in the use of the common resource. The field information was collected by interviews and was processed in the PASW Statistics 22 software NLOGIT Version 5.0.

Main results: Perception of rangeland deterioration, age, size of the herd, and level of income are characteristics of ranchers that influence the willingness to pay. From the coefficient of rangeland of the region (24.2 ha/AU) a monthly grazing fee of USD 7.18 per animal was calculated.

Research highlights: Estimation and payment of grazing fees are an alternative to avoid the deterioration of communal rangelands, without incurring land parcelization.

Additional key words: contingent valuation; willingness to pay; *ejido*; livestock; logistic binomial model.

Abbreviations used: CVM (contingent valuation method); ETA (*Ejido* Tanque de Arenas); ETD (*Ejido* Tanque de Dolores); USD (US dollar); WTP (willingness to pay).

Introduction

In Mexico, *ejido* is a legal entity through which a community of people, not businesses or legal entities, owns a large territorial extension whose objective is the exploitation and the integral use of its natural and human resources, through the personal work of its partners, named *ejidatarios*, for their benefit (CEDRSSA, 2015).

San Luis Potosí, a federative entity located in the north-central region of Mexico has a total area of 6.1 million hectares, of which 4 million hectares are under the social property regime and they include 1,280 *ejidos*

(CEDRSSA, 2015). Of the surface under social property regime, 50% are grazing areas and are located in the Altiplano Potosino region, where during a period of 14 years, 33,216.7 ha of vegetation have been lost, due to overgrazing (Miranda-Aragón *et al.*, 2011). Desert rangelands as social property are resources of common use; therefore, they are not exclusive, but there is rivalry in their use, they lack a market and therefore an exchange price (Parkin & Loria, 2015). For the above, *ejidatarios* have rights for the use of their rangelands, incentives to use the common resource more than others, but not obligations for its conservation (Hardin, 1998), thus causing

the deterioration of this natural resource and with it the detriment of the livestock production (Negrete-Sánchez *et al.*, 2016).

Some studies have approached the conservation of vegetation of arid zones. In Iran, Amiri *et al.* (2015) concluded that public policies are required for the use and preservation of this vegetation and that the WTP is influenced by the income obtained from the sale of plants of pharmaceutical interest. In Mexico, Tudela *et al.* (2011) estimated the WTP for the conservation and care of a natural park, highlighting the income, level of education and environmental perception as the main variables that determine the amount willing to be paid. In the USA, Hof *et al.* (1989), estimated the WTP for access and conservation of public grazing land and concluded that through contingent valuation it is possible to estimate grazing quotas as control over the overgrazing of communal lands.

In this context, the objective of this research was to estimate the economic value of the communal rangelands of the *ejidos* Tanque de Arenas (ETA) and Tanque de Dolores (ETD) and generate a reference to conserve and keep use this natural resource. To this end, the Contingent Valuation Method (CVM) was followed to calculating the monthly willingness to pay (WTP) through the contribution of wages that the producers would make by implementing a program for the preservation and improvement of their communal rangelands.

Material and methods

Study area

The study area is located in Catorce, San Luis Potosí (100°53" W and 23°41" N), in the region called Altiplano Potosino belonging to the Chihuahense Desert region in Mexico (see map in Fig. 1). The average annual rainfall fluctuates between 200 and 500 mm, concentrating in the summer months (June-September) and has an average annual temperature ranging from 16°C to 18°C (INEGI, 2017). The climate is classified as semi-arid, the predominant vegetation is the desert scrub composed of species such as *Larrea tridentata* that covers large areas, succulents such *Agave lechuguilla, Dasylirion wheeleri* and *Yucca* spp (Gómez-Ruiz *et al.*, 2012). Most of the territory, 97% of the land, is not suitable for agriculture and is used as pasture (INEGI, 2017).

In this region, the *ejidos* Tanque de Arenas (ETA) and Tanque de Dolores (ETD) are located. ETA emerged on August 7, 1937; there, *ejidatarios* are currently in a process of parceling out the common grazing areas, because they have seen an improvement in the management of grazing lands in the neighbor *ejido* "El Castañón", where the benefits of the parceling of grazing lands are evident (Negrete-Sánchez, 2016). The surface of ETA is 6,520 ha, of which 5,524 ha are common use grazing lands in process of parceling. ETD emerged on August 17, 1937, and has a total of 16,148 ha, of which 14,980 ha are communal desert rangelands (RAN, 2017). Until the moment of doing this work, in ETA there was no interest in parceling the grazing areas.

Livestock is the most important activity of the *ejidos* from Catorce and is mainly made up of mixed-breed local goats. Other livestock species of minor importance are sheep, cattle, horses, and donkeys. The production system is extensive, focused on goat breeding and elaboration of fresh artisanal cheese. Livestock facilities are rustic corrals are made of stone with roofs of local vegetative material, and are repaired when necessary by employing family and local materials freely collected in the area. The main source of feed is the communal pasture with temporary supplementation, which is the most common practice in arid areas. Self-replacement is practiced in bellies, and two permanent workers provided by the family are required for the functioning of the farm. Newborns are sold 15 to 30 days birth and are classified as normal or supreme, depending on its quality. Newborns and cheese are sold at farm gate and in local markets in the municipality, approximately 15 km away.

Livestock in Mexico is regulated by the Livestock Organizations Law and the Federal Animal Health Law (Congreso de la Unión, 1999, 2007). In the specific case of San Luis Potosí, there is the Livestock Law, passed in 1995, which also stipulates the management and regulation of the use of grazing lands, as well as the conservation of the natural resources available therein (Instituto de Investigaciones Legislativas, 1995).

The assessment scenario that was proposed in this research is derived from the section called: "Rational exploitation, conservation and improvement of resources naturals related to the livestock activity" of the Livestock Law of San Luis Potosí. In Chapter I referring to the Conservation and Management of the Rangelands, Article 66 considers of public interest for the State of San Luis Potosí: I) the rational management, the adequate utilization, the conservation and the improvement of the resources natural related to livestock; II) compliance with the optimum animal load; III) the periodic evaluation and certification of the condition of the grassland; IV) the improvement of deteriorated rangelands, including the control of harmful species and the construction of necessary infrastructure; V) the works and constructions for the conservation of soil and water; VI) the promotion of research and education on the importance and value of conservation of natural resources such as rangelands; and VII) the conservation and promotion of wildlife in order to maintain the balance of the ecosystem.

The focus of this research was mixed, of an exploratory nature, and because it was a contingent valuation
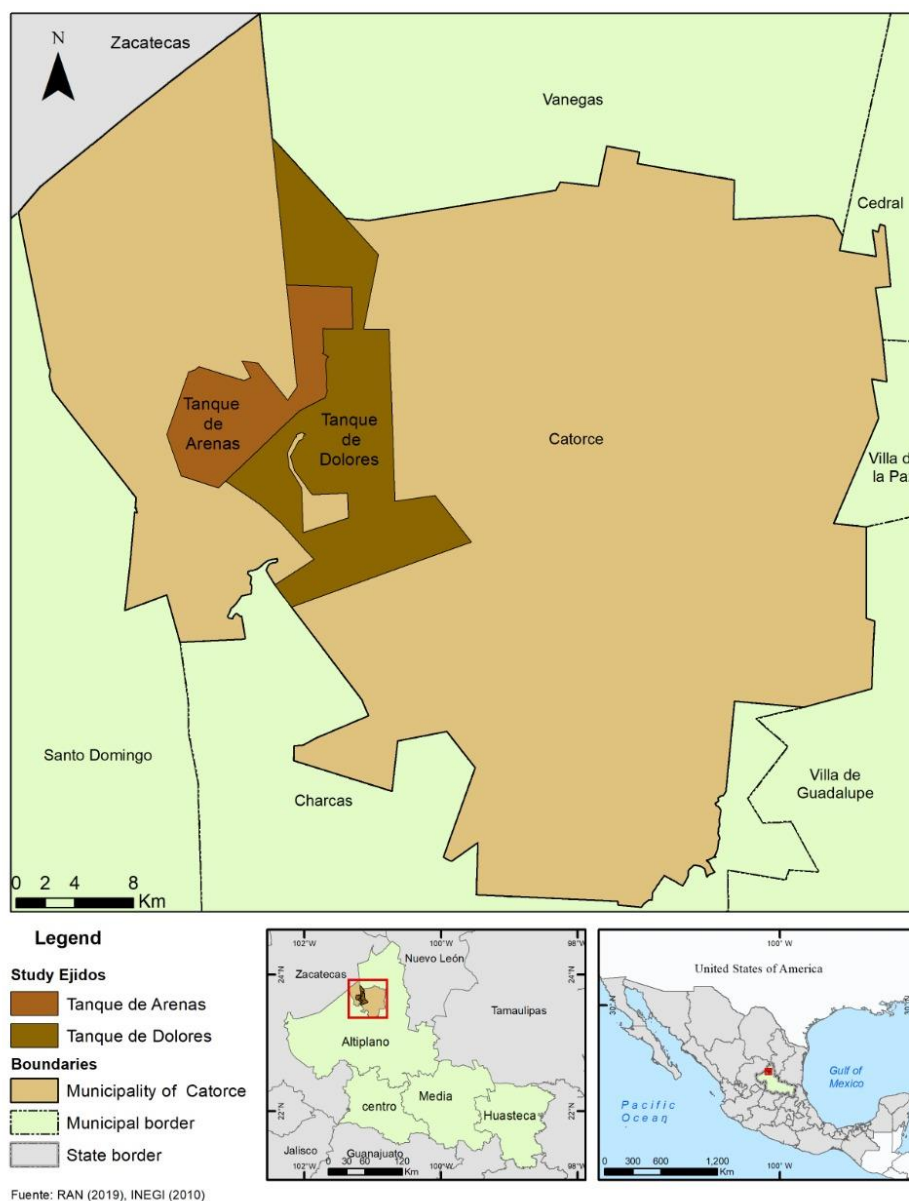
Figure 1. Map of the study area. Edited by Mónica Elena Ortiz Liñán

study it was not experimental. The field information was collected by interviews and was processed in the PASW Statistics 22 software NLOGIT Version 5.0.

Sample size

The sample size was estimated from the number of registered *ejidatarios* of each agrarian nucleus. ETA has 73 *ejidatarios* and ETD has 184 (RAN, 2017).

A probabilistic sampling for a finite population (Sierra, 1995) was carried out with the formula:

$$n = \frac{NZ^2pq}{e^2(N-1) + Z^2pq} \qquad [1]$$

where n = sample size; N= total of elements that make up the population; Z^2= critical zeta: value determined by the confidence level adopted, squared (for a 95% confidence level, the coefficient is equal to 2, then Z^2= 4); e= sampling error: failure that occurs when the sample is taken from the population (generally, it ranges from 1% to 5%; we considered 5%); p= the proportion of elements that present a certain characteristic to be investigated (we assumed that 95% of the *ejidatarios* were interested in the conservation of the desert rangelands); q= the proportion of elements that do not present the characteristic being investigated (we considered that 5% of the *ejidatarios* were not interested in the conservation of rangelands). The values of p and q were defined based on a pilot sampling of 20 *ejidatarios*, 10 for each *ejido*.

Sample size for ETA was 37, but 42 questionnaires were applied due to the cooperative availability of the *ejidatarios*; and for ETD was 52, for the same reason as in ETA, 94 surveys were conducted.

Survey

We collected the main farm-related data such as the herd size, kind of livestock and number of employees. As well as data concerning the *ejidatario* such as age, educational level and agricultural income.

A pilot ranchers survey was conducted from both *ejidos* in January 2018 and included 20 *ejidatarios*; 10 in ETA and 10 in ETD and the final survey was undertaken during the period March to April of 2018. The response rate was 100%. All of the *ejidatarios* surveyed decided to participate because of an agreement made in the ejidal assembly, which is a meeting held by *ejidatarios* every two months to make agreements and deal with legal, productive and organizational issues. We took advantage of this meeting to conduct surveys because attendance at the *ejido* assembly by *ejidatarios* is mandatory. It should be noted that in an *ejido*, the ejidal assembly is the maximum body of authority. We did not have a criterion for selecting the respondents because all of them were volunteers and were interested in the conservation of desert rangelands.

Some variables that we considered to collect in the survey, such as herd size and income obtained from the livestock activity, is because research has shown that these variables influence the WTP of the users of a resource by accessing improvements that benefit their livestock (Hof *et al.*, 1989; Dossa *et al.*, 2008; Omondi *et al.*, 2008; Zander *et al.*, 2009).

On the other hand, the variable perception of environmental deterioration also was included in the survey because it influences the WTP. Due to the fact that when a resource which does not have a market but allows generate economic gains from its use the users are often aware that in order to maximize their benefits it is necessary to conserve that resource, so the perception of deterioration of the resource favors the WTP for its conservation (Valdivia-Alcalá *et al.*, 2011; Amiri *et al.*, 2015; Villanueva *et al.*, 2015).

About the income and educational level of the users of a natural resource without a market, it has been demonstrated in other papers that when the income and educational level of the interviewees is higher, they show a greater WTP for conservation works or access to improvement programs for that resource (Tudela *et al.*, 2011; Valdivia-Alcalá *et al.*, 2011; Chen *et al.*, 2014; Terfa *et al.*, 2015; Giannoccaro *et al.*, 2016; Negassa *et al.*, 2016; Azzi *et al.*, 2018).

Finally, there is scientific evidence that the age of the interviewees negatively influences WTP, *i.e.* people who are older often show less WTP for conservation works or access to improvements related to natural resources without a market (Chen *et al.*, 2014; Terfa *et al.*, 2015; Negassa *et al.*, 2016; Azzi *et al.*, 2018).

The pilot survey was developed in an open question format, it was asked about the number of days they would be willing to work, with the objective of determining the upper and lower limits of the WTP (Tudela *et al.*, 2011).

This previous stage allowed the design of the final survey in a referendum format with answer options to minimize possible biases, and the number of options was defined based on the results of the pilot survey according to recommendations of Johnston *et al.* (2017). The characteristic of the referendum format is that the individual is left alone with the problem of deciding whether or not he or she is willing to pay a certain amount to access the benefits of the environmental policy being offered. The number of wages was distributed proportionally among the number of surveys applied. The number of wages distributed was one, two, three, four, and five per month. It was decided to estimate WTP based on the number of days that people would be willing to work in a program of improvement and conservation of grazing land, because when the interviewees were questioned about their WTP in monetary terms for this program, they were reluctant and argued that they did not have money for it, but that it was easier for them to contribute their labor. By the above, and according to Johnston *et al.* (2017), the number of wages to be contributed was transformed into monetary terms as a payment vehicle to estimate the WTP of the *ejidatarios* for the rangeland conservation program.

The daily wage in the region was USD 7.04. The applied dollar exchange value was $18.04 Mexican pesos per dollar. Respondents were informed about the value of a day's wage, and the pilot survey was applied to 7 and 10 *ejidatarios* from ETA and ETD, respectively.

The questionnaire was integrated into four parts. The first section refers to the data of control and classification of the questionnaires. In the second section it was asked about the perception of the environmental problems the desert rangelands present and about the urgency of preserving them. In the third section, the interviewee was explained the problem that leads to the degradation of grazing lands and then a conservation and improvement project for these areas is proposed. Questionnaires present the baseline or *status quo*, condition, the mechanism of change, and the change to be valued, and the interviewer makes sure the information is understood, accepted, and viewed as credible by respondents (Johnston *et al.*, 2017). Once the scenario is explained, the willingness to cooperate through the working days for the project was posed through the question: how many days of work per month would you be willing to cooperate to protect the common use land of your *ejido* for your and your family's benefit? In the case of a negative response, the reasons were asked for. In the last section, the socioeconomic family information of the respondent was collected.

Design of the econometric model

In this research the contingent valuation method (CVM) was used. CVM provides estimates of the value

and use of a natural resource, based on its environmental attributes and functions, which cannot be inferred through a conventional market and so a hypothetical market is built. This method is based on a survey that collects the WTP for environmental improvements, or their willingness to renounce the consumption of a natural resource (Carson, 2000; Bartlett *et al.*, 2002; Maczko *et al.*, 2011). In this case, a hypothetical scenario constructed about the improvements that would be made in a grazing area of common use when implementing a program of improvement and conservation of desert rangelands.

According to the Panel Guidelines for Value Elicitation Surveys of NOAA (National Oceanic and Atmospheric Administration) of the USA in 1993, the referendum format is the most used in contingent valuation studies (Turner *et al.*, 2008; Tudela *et al.*, 2011).

The theoretical development of the model of WTP of referendum type is based on the theory of welfare economy of random utility "U" that the user of a resource possesses and that depends on his income "Y", of the environmental improvement "Q", and of the socioeconomic characteristics of the individual "S": U (Q,Y,S) (Hanemann, 1984).

In this work, the initial utility function was Q = 0 that represents the desert rangeland in its current state or *status quo*, and Q = 1 was the final situation that would be after implementing the improvement and conservation program, this in the case that the *ejidatarios* were willing to cooperate with a certain number of days labor for the implementation of the program. From this scenario the level of Q will be stated for the utility function of the user.

The *ejidatarios* have to cooperate with days labor "P" if they wish to have access to the benefits of the proposed program. The utility function U_i *(Q,Y,S)* for each of these situations (with and without project) has a deterministic component $V_i(Q,Y,S)$ estimated from information collected in a survey, and a component stochastic not observable, ε_1. The utility function of the individual can be expressed as:

$$U_i = (Q,Y,S) = V_i(Q,Y,S) + \varepsilon_1 \qquad [2]$$

When *i* = 1 is the state with improvement and when *i* = 0 is the unchanged state and the term $\varepsilon1$ is the random variable with zero mean [2]. When the ejidatario interviewed agrees to contribute an amount of days labor (*X*) to obtain the proposed scenario, it must be fulfilled that:

$$V_1(Q = 1, Y - X, S) + \varepsilon_1 > V_0(Q = 0, Y, S) + \varepsilon_{0;} \qquad [3]$$

And:

$$\begin{aligned}&V_1(Q = 1, Y - X, S) - V_0(Q = 0, Y, S) \\ &> V_1(Q = 1, Y - X, S) - V_0(Q = 0, Y, S) > \varepsilon_0 - \varepsilon_1\end{aligned} \qquad [4]$$

where the terms ε_0 and ε_1 are independent random variables and identically distributed, so the utility change will be the

difference between the final utility function minus the initial one; to obtain the benefits of the improved scenario it is necessary to contribute with a certain amount of days labor. This utility change would be expressed as:

$$V = V_1(Q = 1, Y - X, S) - V_0(Q = 0, Y, S) \text{ y } n = \varepsilon_0 - \varepsilon_1. \qquad [5]$$

The answer YES/NO is a random variable so the probability of an affirmative answer YES is given by: $Prob\ (SI) = \Pr(\Delta V > n) = F(\Delta V)$, here F is the cumulative function of the errors (n).

According to Hanemann (1984) and Haab & McConell (2002), the estimate to pay can be calculated from the answers obtained from the dichotomous question and socioeconomic information of the interviewees, assuming that the cumulative function of probability that the respondent answered positively is of logistic type, the probability of having an affirmative answer should be:

$$Prob\ (YES) = Fn\ (\Delta V) = (1 + exp^{-\Delta u})^{-1} \qquad [6]$$

So, a linear functional form for the utility would be:

$$V = \alpha_i + \beta\rho \qquad [7]$$

where α_i = change in utility by the environmental improvement and β = change in marginal utility. It is thereby shown that the payment (p) or WTP would leave the user indifferent since are equal to the change in utility divided by the marginal utility.

$$p = \alpha_i/\beta \ o\ WTP = \alpha_i/\beta \qquad [8]$$

WTP increases with income, which implies that *WTP* = α_i/β *;* the higher the rate to be paid in the survey (ρ), the lower will be *ΔV* and therefore the probability that an individual responds YES will be lower (Tudela *et al.*, 2011; Valdivia-Alcalá *et al.*, 2011)

The decision of the surveyed *ejidatarios* to accept each proposal of the number of days labor that they would contribute analyzed using a binomial logit model according to Hanemann (1991).

In the Logit binomial model, the dependent variable is the probability that the observed binary variable Y is affirmative and therefore takes the value 1, that is, Y = 1 represents the *ejidatarios* acceptance to contribute with the number of proposed workdays. In counterpart, Y = 0 indicates that the ejidatario is not willing to contribute that amount of work. The Logit function is known as a logistic cumulative function (Azzi *et al.*, 2018).

$$P(Y = 1) = \int_{-\infty}^{\beta\prime x} \phi(t)dt = \phi(\beta'x) = \frac{1}{1 + e^{-\beta\prime x}} = 1 - \frac{1}{1 + e^{\beta\prime x}} \qquad [9]$$

where φ is the cumulative density function of a normal one; x is a matrix of the variables that may be related to

the acceptance of the proposed price offer; and β' is a vector of coefficients of the variables in x, where

$$\beta' x = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots \beta_N x_N \quad [10]$$

The coefficients of the estimated model, β, can be used to determine the probability that the binary dependent variable is equal to one (*i.e.* the *ejidatarios* accept the offer of the number days labor) given the specific values of the independent variables *x* (Green, 2007).

The marginal effects (ME) of the explanatory variables were calculated in the mean values of the other variables such as $ME = \Phi(\hat{\beta}x)\hat{\beta}$ (Maddala, 1983). The significance of the regression coefficients such as the ME was tested using the Student's t-statistic. The goodness of fit of the estimated model was measured using the pseudo-R^2 of McFadden. The model was estimated by maximum-likelihood (Haab & McConell, 2002; Green, 2007).

The number of days labor that the *ejidatarios* were willing to contribute was multiplied by the cost of the wage per day (USD 7.04) to have a monetary estimate. To estimate the WTP of the *ejidatarios* to access the benefits of rangeland conservation program will use the following formula by Hanemann (1984, 1991) and Loomis *et al.* (1997):

$$Mean\ WTP = -\frac{\ln\left(1 + e^{\beta_0 + \beta_2 \bar{X}_2 + \cdots + \beta_N \bar{X}_N}\right)}{\beta_1} \quad [11]$$

The marginal effect of each explanatory variable continues xi on the probability of acceptance of a proposed offer of days labor was calculated as Maddala (1983):

$$M\frac{\partial Prob(Y=1)}{\partial_{xi}} = \beta_i \phi(\beta \bar{X}_i) = \beta_i \frac{e^{\beta_0 + \beta_1 \bar{X}_1 + \beta_2 \bar{X}_2 + \cdots \beta_N \bar{X}_N}}{\left[1 + e^{\beta_0 + \beta_1 \bar{X}_1 + \beta_2 \bar{X}_2 + \cdots \beta_N \bar{X}_N}\right]^2} \quad [12]$$

The marginal effect of each explanatory variable x_i in the WTP was calculated as Loomis *et al.* (1997) and Azzi *et al.* (2018):

$$\frac{\partial WTP}{\partial X_i} = \frac{\beta_i}{|\beta_1|} \quad [13]$$

In addition to estimating WTP of the *ejidatarios* for a rangeland's improvement program, based on the econometric model we identified the social, technical, and economic factors related to it. Specific binomial logit econometric model for estimating the WTP of the *ejidatarios* from ETA and ETD is stated as follows:

$$Prob(YES) = \beta_0 + \beta_1 VJOR + \beta_2 PAG + \beta_3 URG + \beta_4 NGAN \\ + \beta_5 HOG + \beta_6 EDAD + \beta_7 EDUC + \beta_8 ING + \varepsilon \quad [14]$$

The dependent binary variable Prob (YES) represents the probability of answering YES to the question about having availability to provide days labor for accessing the benefits of a program of conservation and recovery of grazing lands. This variable depends on the hypothetical number of days labor (VJORN) for accessing the benefits

of the program, the perception of the deterioration of the rangeland (PAG), the urgency of a program of improvement and conservation of grazing land (URG), of the size of the herds (NGAN) and a series of socioeconomic variables: household size (HOG), age of the ejidatario (AGE), educational level (EDU) and income (ING). The explanatory variables of the specified econometric model were obtained directly from the survey. The independent variables included in the model estimated Logit are shown in Table S1.

It should note that the variables "perception of the deterioration of the rangelands" (PAG) and "urgency to conserve the rangelands" (URG) were asked to the *ejidatarios* before explaining the situation of the degradation of the grazing lands and the improvement scenario.

Simulation analysis

In this work, was performed a simulation analysis for some variables of the best-fit logit models, to determine the impact on the predicted probabilities when changing a particular variable over a range of values, when the other variables remain fixed at their mean values. Two scenarios were applied:

Scenario 1: Increase in the NGAN variable by one additional range (in the binomial logit model, herd size is an ordered categorical variable).

Scenario 2: Increase in the respondent's income level by one additional range (in the binomial logit model the income level is also an ordered categorical variable).

Results

The majority of *ejidatarios* of ETA (88%) were >46 years old and ETD (64%) were 26-45 years old; and in both cases, the level of basic education was 90%. In ETD, the income of the *ejidatarios* was 17.3% higher than that in ETA, which partly explains the amount of the estimated WTP.

In ETA, a larger portion of the *ejidatarios* (71.1%), compared to ETD (48.8%), shows WTP for the application of a program to improve and conserve desert rangelands. The above could be due to the rangelands in ETA are in parceling process, while in ETD *ejidatarios* are not interested in parceling. Of the total number of respondents who would be willing to cooperate in the improvement program, 55% in ETA and 65% in ETD would cooperate mainly to improve rangelands through fodder improvement and water conservation works, because they consider that these practices are necessary to sustain livestock production.

In ETA, 15% of the *ejidatarios* were not willing to cooperate because they did not trust their colleagues to

work and 10% thought that their work was not necessary to conserve desert rangelands. Meanwhile, 40% of *ejidatarios* in ETD argued that they do not have time to participate in programs of this type.

Validation of the econometric model

In this work, two logit models were run, one for each *ejido*. In the models, the probability of responding YES to the question of WTP (1 = yes, 0 = no) is always the dependent variable, and the fee to pay is always one of the independent variables. For the selection of the best regressions, the following economic and econometric criteria were used: 1) that the coefficients of the independent variables have statistical significance, 2) that the signs of the coefficients estimated for the explicative variables reflect a logical relationship with the dependent variable, and 3) that the logarithm of maximum likelihood (log-likelihood) be large. The coefficients of each variable and their "t" statistic are presented in Table 1. The best fit models, for both *ejidos* were made up of the independent variables VJORN, NGAN, ING, and AGE.

The marginal effects could be interpreted as follows: if the VJORN is increased by one day, the probability of

WTP is reduced by 5.49% for ETA, while for ETD the probability is reduced by 3.81%. As for the NGAN variable, if the size of the herd in ETA is increased, the WTP in ETA increases by 16.51% and 22.59% for ETD. This trend is observed for the EDUC and ING variables. When *ejidatarios* increase their level of education and income, their WTP for the conservation of their rangelands also increases.

In this type of discrete binary choice models, it is common to use an analogous concept to the coefficient of determination R^2 to explain the overall fit of the model; this statistic is the Pseudo R^2 of McFadden, whose value was 0.3876 for ETA and 0.4785 for ETD, therefore, both models are acceptable according to Valdivia-Alcala *et al.* (2011). The model has a prediction ETA of 81.39% and for ETD of 84.61%. The joint significance is high in both models according to the Likelihood Ratio (LR) statistic since for ETA it was 25.53 and for ETD of 33.90. The chi-square test rejected the null hypothesis that all the estimated parameters are equal to zero.

The variables HOG, EDUC, and GEN were not significant (NS) since they showed a minimum variance, because the majority of *ejidatarios* are men and have a similar educational level. The variable AGE was considered in

Table 1. Estimated regression coefficients of the binomial logit model

| Variable[1] | Models[2] | | | |
| | Logit ETA | | Logit ETD | |
	Coefficient	Marginal effects	Coefficient	Marginal effects
Constant	-3.49452 (0.981)		-0.96899 (-0.301)	
VJORN	-0.01074313 (-3.097)***	-0.0549	-0.00857 (-3.352)***	-0.0381
NGAN	0.562945 (1.885)**	0.1651	0.95105 (2.665)***	0.2259
HOG	-0.71313 (-1.540)	-0.1637	0.20978 (0.542)	0.0466
EDAD	-0.65077 (-0.906)	-0.0591	-0.11961 (-0.209)	-0.0343
EDUC	0.31544 (0.673)*	0.0724	0.26361 (0.425)*	0.0586
ING	1.23804 (1.210)*	0.2086	1.64221 (1.791)*	0.1189
Log of likelihood	-18.24305		-18.47385	
Restricted log likelihood	-29.79370		-35.42582	
Pseudo R^2 McFadden	0.3876		0.4785	
Probability of correct prediction	81.39%		84.61 %	
Likelihood ratio	25.53130		33.90394	

[1] See variables in Table S1 [suppl]. [2] The numbers in parentheses are the statistical t; ***$p<0.01$; **$p<0.05$ and *$p<0.1$. *Source*: Own elaboration based on the results of the N-Logit 5 software.

both models since the sign was the expected one. The variables PAG and URG were not taken into account because 100% of the respondents from both *ejidos* considered that the deterioration of the grazing lands is evident and for this reason it is urgent to intervene with actions for their care and conservation.

Interpretation of the estimated parameters

As expected, the coefficient of the variable VJORN was negative in both models, because as the number of days labor to be contributed to the implementation of the improvement program increased, there would be a lower probability that people would be willing to cooperate. The NGAN variable showed a positive sign, which means that when the *ejidatarios* have more heads of cattle the probability that they respond positively to the WTP is greater, this may indicate that they appreciate the improvement of the desert rangeland for the maintenance of their livestock. The variable ING, for both *ejidos*, had a positive sign, that is, when the respondent has a higher income, the probability that he responds positively to cooperating through the improvement program is greater. Regarding the AGE variable, was observed that when *ejidatarios* were of a more advanced age they were less likely to respond affirmatively to the WTP, it may be because they think that they will no longer take full advantage of the benefits obtained from the implementation of an improvement program in their desert rangelands.

Simulation analysis

A simulation analysis was made for some variables of the binomial logistic models (Tables 2 and 3), to estimate the impact that the change of one variable would have on predicted probabilities while the others remained constant. The simulation analysis was carried out based on the

logit model of the best fit for both *ejidos*. The analyzed variables were NGAN and ING and the proposed scenarios were:

— Scenario 1. An increase of one range on the ordinal scale in the NGAN variable. Table 2 shows that the increase in the size of the herd increases the probability of the *ejidatarios* of both *ejidos* to respond affirmatively to the WTP. In percentage terms, ETA had an increase of 9.3% and ETD of 7.6%, that is, the latter shows lower sensitivity to the WTP even when they have more livestock.

— Scenario 2. An increase of one range on the ordinal scale in the ING variable. When the interviewee´s range of income increases, also the predicted probability of responding YES to the WTP increases, for ETA in 32.55% and ETD in 15.38%. By improving the income of ETA *ejidatarios*, the probability of responding YES to the WTP is higher than in ETD because the estimated WTP for ETD was higher.

Regarding the marginal effects, it was observed that if the hypothetical number of daily wages (VJORN) is increased by one unit, for ETA the probability for the WTP would be reduced by 2.7% and for ETD it would decrease by 1.2%. If the size of the herd (NGAN) is increased by one range on the ordinal scale, there would be a 14% and 21% higher probability of affirmative response for WTP in ETA and ETD, respectively. For the variable ING, it was observed that an increase of one range on the ordinal scale in the income of the *ejidatarios*, would increase the probability of affirmative response to the WTP, 30% in ETA and 37% in ETD.

Calculation of willingness to pay

The WTP for each interviewee in both *ejidos* was calculated based on the best fit econometric model. To do this, were summed the coefficients of the independent variables multiplied by their mean (including the constant)

Table 2. Scenario 1: Simulation of the variable NGAN

| Result | Change in the variable NGAN in ETA | | | |
	Base scenario		Predicted scenario	Change
0	24	55.81%	20	46.51%	-4
1	19	44.19%	23	53.49%	4
Total	43	100.00%	43	100.00%	0

| Result | Change in the variable NGAN in ETD | | | |
	Base scenario		Predicted scenario	Change
0	20	38.46%	16	30.77%	-4
1	32	61.54%	36	69.23%	4
Total	52	100.00%	52	100.00%	0

Source: Own elaboration based on the results of the N-Logit 5 software.

Table 3. Scenario 2: Simulation of the variable ING

| Result | Change in the variable ING in ETA | | | |
	Base scenario		Predicted scenario	Change
0	24	55.81%	10	23.26%	-14
1	19	44.19%	33	76.74%	14
Total	43	100.00%	43	100.00%	0

| Result | Change in the variable ING in ETD | | | |
	Base scenario		Predicted scenario	Change
0	20	38.46%	12	23.08%	-8
1	30	61.54%	40	76.92%	8
Total	52	100.00%	43	100.00%	0

Source: Own elaboration based on the results of the N-Logit 5 software

and the result was divided by the variable VJORN with a negative sign according to the following formulas:

$$WTP(ETA)_i = (-3.494 + 0.562NGANi + 1.238INGi - 0.650EDADi)/0.010$$
$$i = 1,2,\ldots43$$

$$WTP(ETD)_i = (-0.968 + 0.951NGANi - 0.119INGi + 1.642EDADi)/0.008$$
$$i = 1,2,\ldots52;$$

The monthly WTP for the implementation of a program of improvement and conservation of desert rangelands for ETA was three daily wages and for ETD of four, which in monetary terms are USD 21.30 and USD 25.80, respectively (Table 4).

The WTP estimated in this research is an approximation of the value of the fee that could be established in the future, as long as the program for the recovery and conservation of rangelands is viable. One strategy could be to implement differentiated fees; that is, *ejidatarios* with more cattle (> 35 animals) would be charged a relatively higher fee, and cattle ranchers with fewer animals (< 34) could be charged a lower fee. This is based on the average herd size in the study region. In any case, the design of an optimal fee should take into account the estimated confidence interval, which is illustrated in Table 4.

Extrapolating the data of the monthly WTP to the total number of *ejidatarios* according to the *ejido*, the economic value of the grazing lands was estimated. As shown in Table 5, the approximate value that the *ejidatarios* of ETA and ETD give to the communal desert rangeland is USD

18,000 and USD 57,000, respectively. This only if its value of use by livestock is taken into account, if it considered other uses such as the capture of carbon and water, conservation of biodiversity and harvesting of plants of commercial interest (*Opuntia ficus-indica, Agave salmeana, Agave lechuguilla, Dracaena draco*), this value of use could be higher.

Discussion

The contribution that this article makes to the existing literature consisted of estimating the economic value of grazing lands as a source of food for goat herds. This work was carried out through a contingent valuation study applied in two *ejidos* where the main difference lies in the management of the grazing land: common and parceled use. In addition to the economic value of the rangeland, some variables that determine the reasons why *ejidatarios* decide to parcel out the communal grazing areas were identified, as well as their willingness to take part in a program of improvements and conservation of rangelands. Finally, the article illustrates how the estimation and payment of grazing fees is an alternative to the parceling of lands, to achieve the conservation of the common resource.

The implementation of property rights and the definition and validation of collective rules are solutions for the management of common grazing lands in Mexico, with these definitions, forage resources are conceived as a capital that must be preserved (Linck, 1999; Aguirre-Rivera, 2012; Morett-Sánchez & Cosío Ruiz, 2017). When a high number of users has access to the common resource, it is complex to reach agreements, in this case because aspects related to the social status of the *ejidatarios*, derived from the accumulation of livestock and grazing land, prevail over an equitable distribution of the common resource (Barrera-Perales *et al.*, 2018). In the absence of rules limiting access to grazing land, the size of the herds is the criterion that determines the magnitude of individual benefits and the level of appropriation of the fodder resource by each of the ranchers (Hardin, 1998; Coppock *et al.*, 2017).

In Iran, Amiri *et al.* (2015) estimated the monthly WTP for conserving the vegetation of arid zones, this was USD 0.77. In that case, it was low because the population was of limited income for being in a country with war

Table 4. Estimation of the monthly WTP in the logit model (USD)

Variable	Ejido	
	ETA	ETD
Mean	21.30	25.80
SD	6.23	11.73
Minimum	10.29	0.47
Maximum	34.44	42.35
Lower limit*	19.43	22.64
Upper limit*	23.16	28.95
Cases	43	53

*Confidence interval at 95%. *Source*: Own elaboration based on the results of the N-Logit 5 software

Table 5. Environmental assessment of desert rangelands in ETA and ETD (USD)

Ejido	Ejidatarios	Surface (ha)	WTP monthly	WTP annual	WTP added annual	WTP/ha*
ETA	73	5,624	21.30	255.6	18,674.8	3.32
ETD	184	14,980	25.80	309.6	56,966.4	3.80

*Annual benefits/ha. *Source*: Own elaboration based on the results of the N-Logit 5 software

problems, and a variable that influenced the WTP was the perception of environmental deterioration. In this investigation, the perception of the deterioration of the rangelands was unanimous and influenced the interest of the *ejidatarios* to conserve their desert rangelands. When there is a perception of a deteriorated environment, the WTP for environmental improvements is greater as can be observed in the research of Giannoccaro *et al.* (2016), where a WTP for access to water for irrigation of crops in Spain is higher when it foresees a drought. So, it can be concluded that when the deterioration of a natural resource is evident, the users of this resource show a greater WTP for its conservation.

In Ethiopia, rural people in a desert area were willing to pay annually for the implementation of a poultry vaccination program, the WTP was estimated at USD 3.36 and the age and educational level variables determined the fee (Terfa *et al.*, 2015). In this research, the age of the *ejidatarios* was a variable that negatively influenced the WTP for the conservation program of the rangelands, this could be because older *ejidatarios* perceive that they will no longer enjoy the results of an improvement plan. This perception was also found in the province of Chiapas, Mexico, where Sánchez-Toledano *et al.* (2017) reported that when farmers are older, they are less willing to pay for access to improved maize seeds, and it should be highlighted that these farmers are also *ejidatarios*. With this panorama, a relevant fact to take into account is that the average age of *ejidatarios* in Mexico is 49 (CEDRSSA, 2015; INEGI, 2017). In this study, the educational level of the producers did not influence the WTP, although it was expected that higher educational level would make it more likely that environmental improvements will be paid for. However, this same situation was reported by Giannoccaro *et al.* (2016) in Spain, where the WTP for access to water for irrigation was not determined by the level of education.

Regarding income, Amiri *et al.* (2015) found in Iran a positive influence on WTP for the conservation of vegetation in arid areas. Meanwhile, in Mexico, Tudela *et al.* (2011) estimated the WTP for the implementation of a program to improve a national park, by proposing an entrance fee, which was calculated at USD 1.46, a variable that favored it was the income of the interviewee. It seems logical that a higher income associated with the use of a natural resource in deterioration, is a reason to transfer part of that income with a view to conserve the resource and the income derived from its use.

In Mexico, the constitutional reform to Article 27 protects the Program of Certification of Ejido Rights and Land Titling (PROCEDE), which offers the possibility of modifying and institutionalizing the distribution of individual rights over common use lands, through the attribution of differentiated individual extraction quotas and the attribution of an exclusive

usufruct right for one or several groups of *ejidatarios* (CEDRSSA, 2017). In this sense, grazing quotas can be the initial mechanism for a conversion in the management of communal rangelands, as is done on public lands in the USA, where Hof *et al.* (1989) estimated the monthly WTP for grazing an Animal Unit (AU) in public rangelands, which was defined as a grazing fee of USD 15.81. This amount was determined by the income of the ranchers and the condition of the rangeland. Currently, that fee is USD 13.70 for the state of New Mexico (USDA-NASS, 2017).

It should be noted that in the absence of rules limiting access to grazing land, herd size is the criterion that determines the magnitude of individual benefits and the level of appropriation of the forage resource by individual farmers (Hardin, 1998; Mirzabaev *et al.*, 2016; Coppock *et al.*, 2017).

When estimating the monthly grazing quota per AU for ETA and ETD, taking into account the animal charge (24.2 ha/AU) recommended by COTECOCA (1989) and the value of the grazing land per hectare, a quota of USD 7.18 per AU or per cow of 450 kg was obtained. In neighboring *ejidos* an annual quota of grazing of USD 0.11 per cow per month is charged, which was defined by the *ejidatarios* without taking into account any technical criteria. This very low quota has been the cause that the desert rangeland continues to deteriorate (Barrera *et al.*, 2013). It should be noted that as alternatives to the management of common resources, their privatization, the implementation of access tariffs, and self-government through clear rules were mentioned (Ostrom, 2000). In this research, a grazing quota is defined and proposed as a solution to the observed overgrazing. The proposed monthly fee is USD 7.18 AU^{-1} and could be considered as a reference for other arid and semi-arid regions of Mexico with similar conditions.

It should be noted that livestock farming thus plays a significant role as a regulatory element, for the income and savings it provides, by valuing the products derived or simply allowing the use of land with low productive potential. This is a function that in some way has to be maintained by other means when strong restrictions prevent the development of animal husbandry (Linck, 1999). In this sense, the feeding of herds in the pasture gives a comparative advantage (Parkin & Loria, 2015) to extensive livestock farming concerning other mixed or intensive production systems; however, by not assigning an economic value to pasture land and delimiting their property rights, it is overexploited and incurs the problems generated by the use of common resources addressed by Hardin (2009), in the tragedy of commons.

In other regions of Mexico, there is evidence indicating that goat herds tend to grow when their feeding is based on grazing due to its low cost, this causes an

accentuation of the overload and with it the deterioration of the pastures (Martínez-González *et al.*, 2013; Barrera Perales *et al.*, 2018; Santos-Lavalle *et al.*, 2020). It should be remembered that, in general, pastures do not have profitable production alternatives other than cattle raising (Negrete-Sánchez, 2016; Negrete-Sánchez *et al.*, 2016); therefore, this cost would have to be estimated by the capacity to produce milk and meat and then by the environmental services it offers (carbon capture, water capture, wildlife, and landscape protection) among other goods and ecosystem services (Maczko *et al.*, 2011).

In summary, contingent valuation is a tool that makes it possible to estimate the economic value of a common resource such as rangelands. This value is difficult to quantify for the *ejidatarios* in Mexico, a type of ranchers accustomed to not facing limits to access pastures, and who show little or no willingness to disburse a payment in monetary terms to conserve the common resource. This research can constitute a reference for the estimation and payment of grazing quotas as an alternative to avoid the deterioration of the communal rangelands, without having to parcel the land. With the WTP an economic value was estimated for the communal desert rangelands. The *ejidatarios* agree that the deterioration of this natural resource must be stopped because its degradation is evident. The size of the herd, the income and the age of the people are variables that influence the WTP for a program of improvement and conservation of rangelands, so they should be considered in the management strategies of the common natural resource.

It would be interesting to carry out a contingent valuation study for ranchers who do not have land, estimate their WTP to access rangelands, and to compare the results with this research to generate the point of equilibrium of a market made up of *ejidatarios* with rangelands and landless farmers who demand this resource. Likewise, in future studies of economic valuation of desert rangelands, it would be desirable to take into account other goods and services they generate, for example, the wildlife refuge, the harvesting of commercially important plant species and the capture of carbon and water. A more complete assessment of the benefits would show more clearly the importance of its conservation in the economic and environmental dimensions.

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