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Feasibility of the adoption of soil erosion mitigation technology on farmland and pastures in northern Mexico

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ABSTRACT

Objective: To identify the socioeconomic factors which determine the adoption of soil erosion mitigation technologies in the Nazas-Aguanaval watershed region in the state of Durango, Mexico.

Design/methodology/approach: During 2018, 61 semi-structured surveys were applied to farmers in the region. The variables associated with the willingness to adopt or not were analyzed with a maximum likelihood binomial Logit regression model.

Results: Perception of the soil erosion problem, location of the watershed or agricultural unit, and economic activity were the most influential variables in the model. The main variable that conditions the willingness to adopt technologies to improve the soil is the perception of soil erosion in production areas, with a marginal effect of 45.03%.

Limitations on study/implications: The results of this survey may only be applicable to the study area.

Findings/conclusions: Training is necessary to promote and increase the perception, understanding and acceptance of soil erosion mitigation technologies.

Keywords: Natural resource economics, environmental impact, logit regression, environmental sociology.

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INTRODUCTION

Validation, transfer and adoption of technologies for natural resource management and productivity are complex processes that require interdisciplinary participation in order to have a greater impact on regional development (Borja-Bravo *et al.*, 2020). The accelerating degradation process of natural resources due to anthropogenic practices and the resulting environmental impact pose new challenges beyond the creation of technology; they also require its application by users who intervene in the production chain (Cottler *et al.*, 2007).

Soil erosion is one of the most frequent and important degradation processes of natural resources and implies a complex process of soil particle detachment, movement and deposition, mainly by rainwater and wind (Bolaños *et al.*, 2016). In the past few decades, different soil management practices have been evaluated with the goal of mitigating soil erosion, not only because of the repercussions of a decrease in profitability, but also in order to improve ecosystem services. Management practices such as: rainwater catchment and soil moisture retention systems (Cruz-Martínez *et al.*, 2016); use of water retaining agents and pasture restoration (Yáñez-Chávez *et al.*, 2018); use of cover crops (Huerta-Olague *et al.*, 2018); and tillage systems (Velásquez-Valle *et al.*, 2015).

Also, there is a wide variety of technologies that can be considered conservation practices, which can maintain or improve soil fertility and reduce erosion (Soule *et al.*, 2000). Technical innovation includes presenting new ways of using an established technology, which can be subject to social processes that determine its adoption or adaptation to it or, ultimately, its rejection (Ruíz *et al.*, 2006). This study's objective was to identify the socioeconomic factors that determine the adoption of soil erosion mitigation technologies for better decision-making towards the improvement of soil management in agricultural lands.

MATERIALS AND METHODS

Geographic location of the study area. The study was conducted in the municipalities of Mapimí, San Pedro del Gallo and San Luis del Cordero, which are part of the middle and lower Nazas-Aguanaval watershed in the state of Durango, Mexico (23° and 27° N and 106° and 102° W) at an altitude of 1,176 m, with average rainfall of 304 mm, and a maximum recorded temperature of 44 °C and a minimum of 10.2 °C (Medina, 2005).

Sample size. To collect the necessary information, a survey was designed with a total of 28 questions grouped into four sections: tenure and land use; soil management carried out by producers and perception of the erosion problem; willingness to adopt soil erosion mitigation technologies; and, socioeconomic conditions of the subject population (WOCAT, 2016).

The target population was predominantly livestock farmers registered with each municipality's Center for Rural Development Support (Centros de Apoyo al Desarrollo Rural, CADER). The size of the sample was calculated with the formula for finite population, when the total number of observation units that form it is known (Aguilar-Barojas, 2005):

$$n = \frac{N + Z_x^2 + p + q}{d^2 (N-1) + Z_x^2 + p + q}$$

Where, n=sample size; N=total population (580); Z=confidence level (1.645); p=probability of success or expected proportion (0.5); q=probability of failure ($1-p$); and d=accuracy, referring to the maximum admissible error in terms of proportion (0.1).

The sample sizes calculated were 19.26 and 18 producers in the Mapimí, San Pedro del Gallo and San Luis del Cordero municipalities, respectively.

Econometric model. In regards to the willingness of the producer to invest or not in soil improvement practices, the answer is dichotomous: 0 in case of a negative response and 1 in case of a positive response. Based on this, a regression model with a cumulative logistic probability function is assumed (Haab & McConnell, 2002):

$$Pr(si) = \frac{1}{1+e^{-x}}$$

Where, *Pr*=Probability of adoption of the soil erosion mitigation technology, which was estimated using the maximum likelihood method.

Variables measured. The variables measured were: willingness to adopt the technology, with a value of 0 in the case of a negative response and a 1 in the case of a positive response (dichotomous); main economic activity of the producer, where: 1=agriculture, 2=livestock production and 3=mixed; type of land tenure, where: 1=owned, 2=rented, 3=mixed; perception of erosion: 1 (yes), 2 (no); management, where 1=implements some type of practice, 2=no practice is implemented, and 3=is unaware of any type of practice.

Data analysis. To estimate the regression parameters, the Statistical Analysis System (SAS) software was used; to calculate the margin of error, NLOGIT 4.0 was utilized. A binomial Logit regression model was used since it is the most appropriate method for this type of study (Tadesse & Belay, 2004; Calatrava *et al.*, 2007; Mekuriaw *et al.*, 2018).

RESULTS AND DISCUSSION

Land tenure and use. For the majority of producers (89.7%), the land tenure is private property and only 3.3% rent the land, while 6.8% of the land tenure is mixed: owned and rented. In the cases where the surveyed parties were owners, 13.5% declared the land as smallholding, 76.9% as ejido land, while 3.8% as communal land and the remaining 5.8% as a combination of *ejido* and communal land. Of the farmers, 77.6% carry out both agricultureal and livestock production activities, 10.3% carry out agricultural activities exclusively, and 12.1% exclusively livestock production (Figure 1).

The type of land tenure system is revealed as the determining variable in the relationships that impact soil erosion mitigation practices. Udayakumara *et al.* (2010) indicate that security in land tenure has a positive effect upon the decision of farmers to invest in soil conservation methods. Soule *et al.* (2000), report that the impact of land tenure can depend on the time and magnitude of costs and yields generated by the practice of soil conservation. For agricultural activity, 72.5% of the people surveyed carry out their activities on less than 15 ha, 21.7% on 19 to 40 ha, while 5.8% carry out their activities on more than 41 ha. The main crops are corn, oats and different species of grasses, for which 87.9% are rainfed, 5.2% are irrigated with well water, and 6.9% use a combination of irrigation and rain water. In regards to livestock production, 50% of those surveyed carry out their activities on less than 18 ha, 29.2% on 19 to 66 ha, 4.2% on 67 to 150 ha, 8.4% on 151 to 200 ha, 6.1% on 201 to

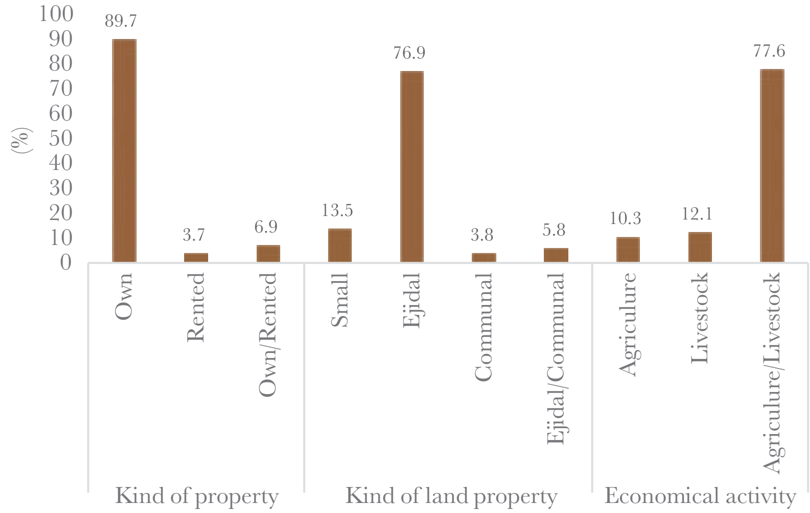

Figure 1. Land tenure type and system and economic activity of the surveyed farmers in the municipalities of Mapimí, San Pedro del Gallo and San Luis del Cordero in the state of Durango.

500 ha, and only 2.1% on more than 500 ha (Figure 2). The vast majority of producers raise cattle (96%) and only 4% raise ovine and caprine livestock, where 30% are self-sufficient in regards to fodder; 17.3% use pastureland and 17.3% produce and purchase fodder. The rest of the livestock producers use a combination of pasturing, production, and purchase of fodder.

The size of the agricultural production units demonstrates a decisive relationship to soil conservation. The possible explanation is that the larger units can be associated with greater wealth and availability of capital, which increases the probability of investment in soil conservation practices (Mekuriaw *et al.*, 2018). However, Soule *et al.* (2000) clarify that the size of the plot of land can have different magnitudes of correlation when each type of tenure is analyzed separately.

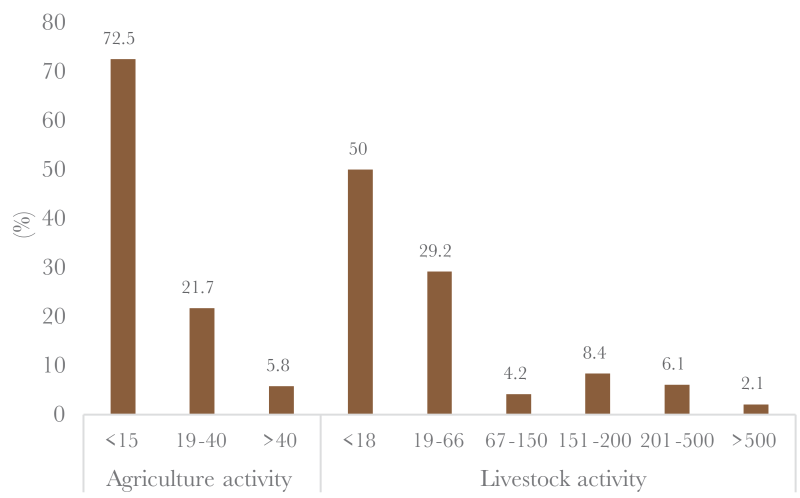

Figure 2. Land extension in hectares by type of economic activity carried out by farmers of the Mapimí, San Pedro del Gallo and San Luis del Cordero municipalities in the state of Durango.

Perception of the soil erosion problem and management practices. Of the respondents, 71.5% do recognize that the soil is eroded by sediment dragging due to torrential rains which result in the increase of exposed ground and lack of topsoil, turning it into unproductive land; however, 26.6% are unaware of this problem. Within this framework, 71% affirmed implementing some type of soil management practice to mitigate the problem, while 27.4% denied implementing any type of management and the remaining 1.5% declared being unaware of any kind of practice of this nature. The building of mounds or levees is the most generalized soil management practice (83.3%), while only 2.4% practice reforestation and 14.3% mention carrying out other practices. Of the surveyed population, 66.7% associate the soil erosion problem to rainwater runoff; 9.5% to the effects of the wind; 16.7% to the combined effects of rainfall and wind; and only 2.4% to animal overload.

By analyzing the perception of the soil erosion problem, regardless of its cause, the study identified that a vast majority of the producers perceive that this process affects productivity negatively. According to Hammad & Tumeizi (2012), the perception of soil erosion is seen as a consequence of natural factors, besides anthropogenic practices, and in any case as having negative economic impacts on production. If soil erosion reduces agricultural benefits, it is more likely for conservation practices to be adopted (Calatrava *et al.*, 2007).

The location of the watershed, the willingness to accept technology and the perception of erosion were the only variables significantly different from zero ($P \leq 0.05$) (Table 1). As such, we can say that the variables that influence the adoption of technologies for environmental damage mitigation are given by the geographic location (watershed), the economic activity and whether or not there is the perception that the plot of land is affected by environmental factors. Tadesse and Belay (2004) agree that the awareness of the farmers regarding the soil erosion problem and the location of the agricultural land within the watershed influence positively the probability of adoption of soil conservation technologies.

The results of the econometric model regarding the willingness of producers to learn techniques that mitigate erosion are justified by the fact that the cost of these conservation practices surpasses the short term benefits; the benefits of soil conservation practices are gained over a longer term, while the costs of conservation practices occur in the short term (Calatrava *et al.*, 2007).

Regarding the willingness to invest a minimum in the development and adoption of technologies that mitigate the negative effect of soil erosion affecting productivity, a positive response by 74.13% of those surveyed was found, while 25.86% responded as unwilling.

Table 1. Estimated parameters for different variables related to the willingness to adopt soil erosion mitigation technologies.

Parameter	FG	Estimator	Standard error	Chi-squared of Wald	Pr>ChiSq
Intercept	1	−8.7013	3.0226	8.2870	0.0040
Location of watershed	1	2.9734	0.9650	9.4932	0.0021
Availability of acceptance	1	1.2724	0.6132	4.3061	0.0380

Marginal effects. The main variable that affected the decision to pay for technology adoption was the producer's awareness of the existence of soil dragging due to wind or rain. The probability of paying to implement soil improvement techniques increased by 45.03% when farmers are aware of the problem on their lands, while the decision to adopt increases by 41.57% when the production unit is located in the middle watershed (Table 2). This indicates that soil erosion is perceived more in the middle watershed and less in the lower watershed, given that the second is where soil deposition takes place.

The willingness to pay that was observed in this study is consistent with evidence reported by other authors (Tadesse and Belay 2004, Mekuriaw *et al.*, 2018), who affirm that the awareness of the farmers about the soil erosion problem, its costs and benefits, is key to determine the adoption of soil conservation practices.

Finally, the economic activity or, ultimately, the profitability of the production unit also influenced the model positively. The producers that combine activities (agriculture and livestock production) have a 17.78% greater probability of implementing erosion mitigation technologies compared to those who only carry out one activity in their plots. If we assume that the farmer's profits increase when their costs decrease by producing their own forage for the livestock, then the additional income can be invested in soil improvement.

Amarasekara *et al.* (2009) point out that producers tend to invest more in soil conservation measures when there is an increase in farming income; however, farming income is determined by many other technical and socioeconomic factors such as type of crop, education level, size of the unit, among others. Soule *et al.* (2000) mention that farmers consider economic factors in order to decide whether or not to adopt specific conservation practices. These factors include short term profitability, as well as the long term value of the assets.

CONCLUSIONS

Understanding and accepting technology is important even when the financial yields are reflected in the mid-term, since eventually the investments will generate a sustained profit, thus compensating for the short-term increase in production costs. Any program used to mitigate the impact of soil erosion must take into account the socioeconomic characteristics, the location of the plots of land, the perception of the problem, and above all, the technology must be suitable to the context of the producers. Training in the methods of soil degradation management is necessary for a successful intervention.

Table 2. Estimated marginal effects according to the variable analyzed.

Variable	Marginal effect
Location of watershed	0.41571
Technology acceptance	0.17789
Erosion perception	0.45032

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