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Decisive factors for the adoption of silage in livestock production units in the dry tropics of northwestern Mexico

Factores que determinan la adopción del ensilaje en unidades de producción ganaderas en el trópico seco del noroeste de México

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Abstract

The aim of the study was to identify the factors that affect the probability of silage adoption in production units of northwestern Mexico. A sample focused on 171 farmers who participated in an agricultural extension program in northwestern Mexico was conducted. Then, by estimating a probit model, the decisive factors for the use of silage were obtained. The variables that were significant for the adoption of the silage were the level of schooling ($p < 0.05$) and the agricultural area ($p < 0.10$). The results show an average probability of 13.4% of silage adoption by farmers in the study region. Hence, the producers with larger agricultural surface and level of schooling are more prone to adopt the silage. Therefore, it is recommended that it is essential to seek other technological strategies in the study region that consider the differentiated level of agricultural surface and schooling of the producers to increase the adoption of this technology.

Keywords: animal feeding, drought, econometric models, innovation adoption, multipurpose breeds, technology transfer

Resumen

El objetivo del presente estudio fue identificar los factores que afectan la probabilidad de adopción del ensilaje en unidades de producción del noroeste de México. Se realizó una muestra dirigida a 171 ganaderos que participaron en un programa de extensión agrícola en el noroeste de México. Posteriormente, mediante la estimación de un modelo probit, se obtuvieron los factores que determinan el uso del ensilaje. Las variables que resultaron significativas para la adopción del ensilaje fueron el nivel de escolaridad ($p < 0,05$) y la superficie agrícola ($p < 0,10$). Los resultados muestran una probabilidad promedio de 13,4% de adopción del ensilaje por los ganaderos de la región de estudio. Los productores con mayor superficie agrícola y nivel de estudio son más propensos a adoptar el ensilaje. Por ello, se recomienda que, para aumentar la adopción de esta tecnología, se deberá buscar otro tipo de estrategias tecnológicas, considerando el nivel diferenciado de superficie agrícola y escolaridad de los ganaderos de la región de estudio.

Palabras clave: adopción de innovaciones, alimentación de los animales, modelos econométricos, razas mixtas, sequía, transferencia de tecnología

Introduction

In tropical areas, animal feeding is a critical factor in livestock production. However, during the dry season that occurs every year, there is a decrease in fodder that generates low productive and reproductive livestock rates (Castro-Rincón, Sierra-Alarcón, Mojica-Rodríguez, Carulla-Fornaguera, & Lascano-Aguilar, 2016; Katunga et al., 2014). The forage alternatives for silage are multiple, so it can be obtained from grasses, legumes, fodder crops (sorghum, corn), crop residues or other by-products (Mannetje, 2001a).

According to Campos (2015), silage is defined as "a conservation method for forage or agricultural by-products with high moisture content that is based on fermentation and that uses a small amount of energy for the production of volatile fatty acids in anaerobic conditions" (p. 1). Among the advantages of using silage is the fact that it is considered a food reserve for the dry season, which allows balancing the content of the diet and increasing animal productivity (Cowan, 2001).

Silage can be used to reduce the problems of feeding cattle and face shortage of fodder in the dry season (Castro et al., 2016; Reiber, Schultze-Kraft, Peters, Lenses & Hoffmann, 2010). The technology for silage production is recognized as an alternative to obtaining good quality forage for the dry season in the tropics, where there is a higher shortage of feed for livestock.

Besides, the use of silage can help solve animal feeding problems in both large and small production units; however, there are socioeconomic aspects that prevent the general adoption of this technology (Mannetje, 2001b). Hassan (2001) states that in Pakistan, the main causes that explain the failure to adopt silage innovation are represented by the high production cost, the small agricultural area and the small number of animals that the producer has. In this same line of work, a study conducted with small low-income producers in Honduras identified that the lack of equipment for silage was one of the most relevant variables for producers not to adopt this technology (Reiber, Schultze-Kraft, Peters, & Hoffmann, 2013).

Nonetheless, various efforts have been carried out to counteract the lack of adoption of silage technology. For example, studies have been performed for the preparation of silage based on grass and leguminous forage in plastic bags (Reiber, Schultze-Kraft, Peters, Lentes, & Hoffmann, 2009). Similarly, to counteract the problem of equipment and infrastructure, studies have been performed on the design of agricultural equipment for packing forage with corn silage (Herrera, Medina, & Quintero, 2008). Despite multiple research and development efforts, the use of silage by farmers to have food for livestock in tropical areas has been low (Mannetje, 2001b).

In the state of Sinaloa, located in northwestern Mexico, the main problem of farmers is the shortage of fodder in the dry season that lasts approximately six months, from January to June (Perales et al., 2000). For this reason, since 1996, in the study region, efforts have been made to solve this problem through various diffusion and transfer strategies for livestock innovations focused on forage production. The technologies that have been promoted are the following: the establishment of pastures with Mombasa (*Panicum maximum* Jacq. var. Mombasa), Tanzania (*P. maximun* var. Tanzania), Pretoria (*Dichanthium annulatum* (Forssk.) Stapf), Callie (*Cynodon dactylon* (L.) Pers.), Llanero (*Andropogon gayanus* Kunth) and buffel (*Cenchrus ciliaris* L.) grasses. The sowing of dual-purpose sorghum for silage has also been promoted. Further, the varieties used (i.e., Fortuna and Sorgo costeño 201) have been generated by local experimental stations, so they are well adapted to the region (Loaiza, 2011). Moreover, the varieties of sorghum disseminated are of free pollination, so producers can generate their own seed and, with this, reduce the production costs of crop establishment (Hernández, Moreno, Reyes, & Loaiza, 2011).

Other technologies that have been promoted at the state level are the establishment of forage legumes such as alfalfa (*Medicago sativa* L.) and velvet bean

(*Mucuna pruriens* (L.) DC.); forage conservation using the silage method; pasture treatment; elaboration of multi-nutritional blocks; and artificial insemination, among others (Loaiza, 2011).

According to the International Maize and Wheat Improvement Center (Cimmyt, 1993), technology adoption studies serve to improve generation efficiency and evaluate the effectiveness of technology transfer. It must be noted that the proposed technologies have more than 20 years of being disseminated. However, to date, the problem of low adoption of technologies, in general, continues to prevail and, in particular, the elements that favor or limit the use of silage are unknown, although these technologies have proven to be alternatives for good quality food availability for cattle during the dry season. Therefore, the aim of this study is to identify the factors that affect the probability of silage adoption in production units in northwestern Mexico.

Materials and methods

Location of the study site

The study was carried out in the northwestern area of the State of Sinaloa, Mexico. Surveys were applied to farmers in three municipalities in this region: Ahome, El Fuerte, and Guasave. Ahome is located at 25°47'00" N and 108°59'39" W, at an altitude of 9 m above the sea level; El Fuerte is located at 26°25'17" N and 108°37'11" W, at an altitude of 81 m above the sea level, and Guasave is located at 25°33'55" N and 108°28'18" W, at an altitude of 21 m above the sea level (Instituto Nacional de Estadística y Geografía. [INEGI], 2016). The climatic conditions in the study area are characterized by being very dry; the State of Sinaloa, in general, has warm subhumid, dry and semi-dry climates, and only 2 % of the State has a subhumid climate in the mountainous region (Instituto Nacional de Estadística y Geografía [INEGI], 2011).

Origin of the information

A survey was applied to 214 farmers (n = 214) who participated in an agricultural extension program in 2015 in Sinaloa, Mexico. The selection of the producers was carried out using the following criteria: 1) owns cattle, 2) was part of an annual extension program, and 3) the producer agreed to answer the initial diagnostic survey. The survey was divided into ten sections: 1) general information of the productive unit; 2) data related to the farmer; 3) land ownership; 4) scale of the productive unit (herd, surface for forage production, communal areas, water availability options); 5) infrastructure for production, machinery and equipment; 6) issues related to livestock reproduction; 7) type and characteristics of animal feeding and supplementation; 8) issues related to animal health; 9) aspects related to milking, and finally, 10) product market (milk and meat).

The interview was conducted in the productive unit of each producer in the three municipalities assessed at the end of 2015. The final research data comprised 171 interviews as the rest of the surveys showed erroneous information in the original data capture with the producer, so they were discarded. Data cleansing did not affect the representativeness of the study sample since the use of technological components is low for this type of producer in the area.

Econometric model

A binary discrete choice model (probit model) was used to identify the elements that affect the probability of silage adoption in production units in the northwestern region of Mexico. A binary model is recognized because the endogenous variable (y) shows two alternatives, zero (0) and one (1) (Aldrich & Nelson, 1984).

These values represent the only two feasible alternatives to be chosen by the producer. In this way, the variable related to the adoption of the silage practice (yi) of the cattle farmers in the study area will take two values: one (1), if the farmer adopted the silage practice, and zero (0), otherwise.

The probability (pi) of choosing any alternative or not choosing it can be expressed as presented in equation 1.

Equation 1

$$p_i = \text{prob}[Yi - 1|X] = \int_{-\infty}^{x'\beta} (2\pi)^{-1/2} \exp\left(\frac{-t^2}{2}\right) dt = \phi(x'\beta)$$

Where $\phi(x'\beta)$ represents the cumulative distribution of a standard normal variable (Greene, 2012).

McNamara, Wetzstein and Douce (1991) identified the following categories or groups of variables to establish the use or adoption of a technology: i) variables referring to the producer (age, schooling), ii) variables referring to the structure of the production unit (agricultural area, size of the herd measured in animal units), and iii) other institutional elements or factors (years of receiving technical assistance). On the other hand, variables related to institutional aspects, i.e., those related to the market (distance to market, percentage of the production sold, and access to market information, among others) were not included, because silage is an intermediate input for milk or meat production. Thus, the decision of the cattle farmer on the use of silage technology can be modeled empirically as expressed in equation 2.

Equation 2

$$y_i = \phi(x'\beta) + \mu = \delta Z_i + \mu_i$$

Where yi is the dichotomous dependent variable that reflects the difference between the use and the non-use of a technology (1, if the adoption of silage takes place, and 0, otherwise); δ is the vector of parameters to be estimated; Zi is the vector of exogenous variables that explains the adoption of silage; and μ_i is the error term of the normally distributed model.

For a non-dichotomous variable, the marginal probability is defined by the partial derivative of the probability that $y = 1$ compared to that variable. In this way, the marginal change is obtained from the product of the density function of the standard normal distribution, evaluated at a defined point and the parameter to be evaluated (Greene, 2012), as expressed in equation 3.

Equation 3

$$\frac{\partial p_i}{\partial X_{ki}} = \frac{\partial \phi(Xi\,\beta)}{\partial X_{ki}} = \phi(x_i'\beta)\beta_k$$

The evaluation of the marginal change is performed in the mean values of the regressors, so that a representative value of the marginal change is obtained. The maximum likelihood method was used to estimate the parameters of the proposed econometric model.

Statistical analysis

The Wald statistic or test was used to verify the significance of each model parameter. This test follows a typified normalized distribution. To carry out the global evaluation of the model, the McFadden R^2 and the LR statistic (or likelihood ratio) were used. The results of the econometric model were obtained using the Stata® package version 12. To estimate the model, the following commands were used: *dprobit*, *margins* and *marginsplot*.

Results and discussion

Variables used in the model

Table 1 shows the characteristics of the variables considered in the model evaluated; the age of producers is 51 years on average, although there are producers who have a minimum age of 21 and a maximum age of 85 years. The farmers interviewed have an average of seven years of schooling. However, it is important to point out that some are illiterate, and others have completed their studies at the bachelor level. Further, technical assistance refers to the number of years that the farmer has received the services of an extension worker; in this line, in the northern region of Sinaloa farmers have received on average, 1.47 years of this service.

The size of the ranch was measured considering the total agricultural area that the producer has in his productive unit. The average was 12.47 hectares, although there are producers who have up to 70 hectares. Finally, the size of the herd, measured in animal units, was also considered; on average, the producers interviewed have 24.27 animal units (table 1).

Table 1. Descriptive statistics of the variables used in the Probit model

Variable	Units	Mean	SD	CV	Min	Max
Age	Years	51,04	13,92	0,27	21	85
Scholarship	Years	7,27	4,61	0,63	0	16
Surface	Hectares	12,47	12,98	1,04	1	70
Herd	Animal unit	24,27	12,96	0,53	4	73
Technical assistance	Years	1,47	2,33	1,58	0	13

Source: Elaborated by the authors

Variables that have an impact on the probability of silage adoption

The Wald test (z-statistic) applied to the coefficients of the model evaluated shows that two variables were significant in explaining the adoption of silage practice among farmers in the study region. The first is the level of schooling, measured by the years of study undergone by the producer ($p < 0.05$), and the second is the agricultural area, measured in relation to the total area in hectares of the productive unit ($p < 0.10$). The results of the probit model are presented in table 2.

Most of the variables show a positive sign, but with very small marginal changes. The chi^2 test was used to contrast the overall significance of the model; the null hypothesis was that all the coefficients of the model, except for the constant term, are null. The number of correctly predicted cases was 95.32 %. The statistic LR Chi^2 (5) was 15.76, and the probability obtained was $p < 0.05$; therefore, the null hypothesis is rejected, and the proposed model is statistically significant.

The negative sign in the variable age suggests that silage practice is more likely to be adopted by young producers. In the same way, the positive sign in the variable technical assistance suggests that information on new technologies that producers can incorporate is relevant to their application. The positive sign in herd size suggests that producers with large herds can adopt the practice of silage on their ranch and, thereby, complement the feeding of cattle in the dry season.

Table 2. Coefficients of the variables that influence the probability of adopting silage

Variable	Coefficient	z	p > z	dy/dx
Age	-0,0123	-0,67	0,50	-0,0004
Scholarship	0,1469	2,20	0,02*	0,0050
Surface	0,0223	1,75	0,08**	0,0007
Herd	0,0002	0,02	0,98	0,0000
Technical assistance	0,0592	0,91	0,36	0,0020
Constant	-3,0200	-2,52	0,01	

dy/dx is the marginal effect of the variable *x* over the dependent variable *y*; the level of significance *dy/dx* is $p < 0.05$* and $p < 0.10$**; the number of observations (n): 171. LR $chi^2(5) = 15.76$; Prob > $chi^2 = 0.0076$; Pseudo $R^2 = 0.2439$; Correctly classified = 95.32 %.
Source: Elaborated by the authors

The schooling level of the producer was significant (p <0.05) for the adoption of silage technology. The relationship is positive so that for each year of schooling, the farmer increases the probability of adopting the silage practice by 0.5 %. That is, the probability that the producer decides to carry out the silage increases as the years of study increase, but decreases by 0.04 % as their age increases. On the other hand, the conditional marginal effect of the ranch size was positive ($p < 0.10$), a value that shows us that the probability of adoption of the silage practice increases 0.07 %, as the production unit has more agricultural land.

The results obtained from the evaluated model show an average probability of 13.4 % of adoption by farmers in northern Sinaloa. This level of adoption is low and is consistent with studies conducted on dual-purpose cattle production systems in Mexico, which have identified that only between 1 % (Vilaboa & Díaz, 2009) and 6 % (Chalate et al., 2010) of the producers carry out the silage practice. A recent study that analyzes information on 2,187 production units in the dry tropics of Mexico identified that only 17.7 % of the production units carry out silage practices. This same study analyzes the information by ranch size and identifies that the highest percentage of adoption (21.9 %) is found with medium-sized producers, who have between 20 and 50 breeding cows (Rangel et al., 2017b).

Various authors (Doss, 2006; Feder, Just, & Zilberman, 1985; McNamara et al., 1991; Teklewold, Kassie, & Shiferaw, 2013) have grouped the restrictions of technology adoption into three categories: 1) factors related to the characteristics of the producers; (2) factors related to the characteristics and relative performance of the technology, and (3) programmatic and institutional factors. The results obtained in the current study are discussed by the type the categories mentioned above.

Characteristics of the producer

The hypothesis is often raised regarding that a higher level of education or schooling contributes to increasing the probability of adopting new technologies (Daberkow & McBride, 2003). This situation was verified in the current study, since the years of schooling that the producer has, were significant and positive ($p < 0.05$) for the adoption of silage practices. The higher level of studies carried out by farmers in the study region helps to recognize the importance of carrying out the silage practice and having food for livestock during the dry season. In the current study, the negative coefficient obtained for the age variable can indicate that older producers are less likely to adopt the silage practice.

Characteristics of the productive unit

Specialized literature reports a positive relationship between the adoption of innovations and the size of the production units (Fernández-Cornejo, 1996; McNamara et al., 1991). In the study region, 91 % of small- and medium-sized producers have average herds that include between 21 and 55 animal units, 18 to 29 breeding cows and 32 to 44 ha of agricultural land, in average (Cuevas, Loaiza, Espinosa, Vélez, & Montoya, 2016).

The characteristics related to the structure of the production unit measured across the total agricultural area were significant ($p < 0.10$) and with a positive sign, which indicates that those farmers who are more likely to adopt the practice of silage are those that have more agricultural land. The previous could be explained to the extent that this type of producer, having a larger area, might also have higher economic resources and can allocate agricultural areas to cultivate crops for silage, so there is food for cattle consumption in the dry season.

On the other hand, small- and medium-sized producers could not allocate agricultural land to this type of crops and, therefore, have fewer technological innovations in the food area. These results are similar in a study carried out in Mexico by Rangel et al. (2017a). These authors found that the percentage of innovations in animal feeding used by producers was 28.3 %, with a coefficient of variation of 52.2 %, which shows a limited development of technology in the animal feed area, as well as a high heterogeneity between dual-purpose cattle farms in the tropical zone. On the other hand, the size of the herd had a positive coefficient, although this variable was not significant for the adoption of the silage practice.

Institutional factors

The technical assistance coefficient was positive, although, for this work, it was not significant. It is important to note that there are studies conducted in this same production system in Sinaloa, which found that the technical assistance service is significant ($p < 0.05$) in the medium term, that is, after five and a half years of being granted technical assistance to producers (Cuevas et al., 2013). In the case of silage technology in Honduras, Reiber et al. (2010) indicate that, under favorable conditions (i.e., presence of key innovators, motivated producer groups and a favorable dairy market), the adoption rate of this component reached 57 %.

The results found in this research show that despite being silage a food alternative for livestock in the dry season, this technological innovation has a low adoption probability (13.4 %). This may be due to the lack of technology to make more efficient use of the available agricultural land (Cuevas et al., 2018), but possibly also due to the lack of differentiated policies for dissemination and transfer of this technology, according to the schooling level and type of productive resources of the producers. Although in the state of Sinaloa, diffusion and transfer of technology actions have been carried out, the coverage of the technical assistance service and, therefore, the use of technological components (such as silage) in recent years barely reaches 3.05 % of the farmers of the state (Cuevas, Baca, & Sánchez, 2012).

In this way, support alternatives should be sought so that, through the organization of producers, small farmers can access resources for the acquisition of the machinery and equipment required to implement the practice of silage. Other alternatives may be through the adaptation of technology for small production units, such as silage in plastic bags (Reiber et al., 2009), as well as the creation of a silage market in which silage is offered directly on the farm, what in recent years happened in the study region. During the 2018 cycle, the producer organization that groups all the farmers in Sinaloa acquired machinery, equipment, and transport to carry out silage of corn and sorghum in irrigation areas, in order to bid at low prices (US$50 per ton) the silage to small and medium producers.

Conclusions

The probability of adoption of silage practices by the farmers interviewed was 13.4 %. The producers with the largest extension of agricultural land and the highest level of schooling were the most likely to adopt the practice of silage. Therefore, to increase the adoption of this technology with producers with fewer resources, other mechanisms should be sought, such as equipment rental or through the direct sale of silage obtained through producer organizations. Namely, differentiated strategies of support and transfer of technology for different types of producers must be generated, and thus, favor a greater adoption of the practice of silage and other technological innovations in the area of cattle feeding for the farmers of this study area, and for other producers in other areas of the dry tropics that have similar characteristics.

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