

# Determinants of artificial insemination use in cattle in northern Sinaloa, Mexico

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## ABSTRACT

**Objective:** To identify the factors that determine the use of artificial insemination by cattle producers in northern Sinaloa.

**Design/methodology/approach:** We used a discrete-choice logit model for 200 cattle producers from northern Sinaloa.

**Results:** Four variables were significant ( $p \leq 0.05$ ): two of them reduce the probability that the farmer will adopt the artificial insemination technology (age and distance from the ranch to the municipality), while the other two increase the probability of adoption (income from the sale of calves and machinery and equipment index).

**Limitations/implications:** The results only apply to the sample from three municipalities in northern Sinaloa, although they may be useful for other regions with similar characteristics.

**Findings/conclusions:** Farmers with a higher rate of machinery and equipment have a 36.43% probability of adoption.

**Keywords:** dry tropics, genetic improvement, technological adoption.

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## INTRODUCTION

Animal production systems in tropical areas can contribute to a greater demand for food of animal origin; these systems have the best conditions to increase food production, based on their ability to generate biomass (Chará *et al.*, 2015). In tropical areas, livestock is characterized by the production of milk or cheese and animals for slaughter (Urdaneta, 2019); consequently, this dual-purpose cattle production system is called “Sistemas Bovinos de Doble Propósito (SBDP)”. In Mexico, SBDPs are associated with a tropical vegetation



area of 28.3 million hectares (INEGI, 2019) and a 13% contribution to the national milk production (SIAP, 2020).

The productivity of tropical livestock herds in Mexico is below 50% of their biological capacity (REDGATRO, 2018). In other words, this type of livestock—due to its current conditions—has a high productive potential. Therefore, the improvement of reproductive efficiency is an important step to achieve this potential and to maximize the profitability of the said system (Horrach *et al.*, 2020).

Artificial insemination (IA) is an assisted reproductive technology that generates an accelerated genetic gain that affects the productive, reproductive, and collective performance of the cattle herd, potentially increasing the beef and dairy production (Kubkomawa, 2018; Baruselli *et al.*, 2018). Despite these benefits, few farmers have used and adopted this technology.

In Mexico and other countries, 4-15% of the farmers use this technology (Kubkomawa, 2018; Baruselli *et al.*, 2019; Lassala *et al.*, 2020). In the state of Sinaloa, “livestock is based on undefined crossbreds and it is not focused on productive improvement, which results in low-weight calves at birth, low fattening performance, and low-quality carcasses” (Casillas, 2012, p. 8). Faced with this problem, for more than 20 years, local research centers have implemented projects to promote the use of various technologies (including IA), in the dual-purpose cattle system prevalent in the state of Sinaloa (Loaiza, 2011).

Some studies have used diagnoses to identify the percentage of producers that use IA in the tropical regions of Mexico (Basurto *et al.*, 1997; Cuevas *et al.*, 2013; Rangel *et al.*, 2017, 2020). However, in general there have not been many studies that identify the factors that determine the use of IA; specifically, there are no studies of this type in northern Sinaloa. Perhaps the low use of this technology in the study region can be explained by the excessive (economic, technical, and human) requirements and inputs (such as nitrogen). The objective of this work is to identify the factors that determine the use of artificial insemination by cattle producers in northern Sinaloa.

## **MATERIALS AND METHODS**

### **Location of the study area**

The study was carried out in the state of Sinaloa in northwestern Mexico. Sinaloa is located between the following geographic coordinates: 27° 02' 32" N, 22° 28' 02" S, 105° 23' 32" E, and 109° 26' 52" W. The weather in the state is divided as follows: 37.14% has a warm sub-humid climate with rainfall in summer A(w); 21.27% has a semi-arid climate that is very hot and hot BS1 (h'); and 18.56% has an arid climate that is very hot and hot BS0 (h'). In the upper parts of the Sierra Madre Occidental (2.26%), Sinaloa has a temperate sub-humid climate with rainfall in summer (INEGI, 2017).

### **Instrument used**

The information was obtained through a survey aimed at the producers who participated in the Proyecto Integral de Innovación y Extensionismo Rural (PIIEX): “Bovinos doble propósito”. The project was financed by the Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA). The survey was carried out from

September to November 2015. Nevertheless, the analysis of the variables that determine the use of IA in dual-purpose cattle is still valid, because there is no information on the subject for the region.

A sample of n=200 producers was obtained through non-probabilistic sampling in three municipalities in the north of Sinaloa (Ahome, El Fuerte, and Guasave). The following criteria were used to select the producers: 1) the producer owned cattle; 2) the producer had not been a beneficiary of government programs in previous years; and 3) the producer agreed to answer the survey. The information we obtained included the age, educational level, and number of children of the producer, as well as farm-related aspects (cattle herd and constructions, as well as machines and equipment). The information also covered commercialization, context variables, rural extension services, and distance from the productive unit to the municipality, among others. Cuevas-Reyes and Rosales-Nieto (2018) further described the calculation of the infrastructure, machinery and equipment index.

### Econometric model and variables

A discrete-choice logit model was used to estimate the factors that determine the use of IA. These models use a binary categorical variable with two mutually exclusive categories — which can be expressed by numerical values of 1 and 0 (Greene, 2003). The model assumes that there is a  $Y_i$  variable that measures the use of the IA by the  $i$ -th farmer expressed in the following formula:  $Y_i = X_i'\theta + U_i$ . Where  $X_i'$  is a vector of the explanatory variables,  $\theta$  is an unknown parameter that must be estimated, and  $U_i$  is the stochastic term. In this model, the  $Y_i$  dependent variable is binary and has two values:  $Y_i=1$  (if the farmer uses IA) and  $Y_i=0$  (otherwise). Therefore, the binary logistic regression model is given by the following equation (Cameron *et al.*, 2005):

$$p_i = Pr[y_i = 1 | x_i] = \frac{\exp(x_i\beta_i)}{1 + \exp(x_i\beta_i)} \quad (1)$$

This ensures that the probability is between 0 and 1. The logit model marginal effects are given by the following equation, that is commonly known as the probability density function of the logistic distribution, multiplied by the coefficient of the explanatory variable under consideration (Cameron *et al.*, 2005):

$$\frac{dp_i}{dx_i} = \frac{\exp(x_i\beta_i)}{(1 + \exp(x_i\beta_i))^2} \beta_i \quad (2)$$

The explanatory variables used for the empirical analysis included information regarding four levels that are recognized in literature as determinants for the adoption of technology: producer, ranch, market, and context variables (Teakleworld *et al.*, 2013; Cuevas *et al.*, 2013; Zuwarimwe and Mbaai, 2015). Two variables are associated with

the producer: age (EDAD) and schooling (ESCOLARIDAD). The variables related to the ranch were: productivity measured in liters per cow per day (LITROS/VACA), number of animal units (UA), infrastructure (INFRAE), and machinery and equipment (MAQ). Economic or market variables such as income obtained from the sale of milk (LECHE) and income from the sale of calves (CARNE) were also included. In addition, context variables such as the distance from the ranch to the municipality (DIST) and the number of years with technical assistance (AT) that the producer has had were included. Therefore, the estimated empirical model was the following:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + u_i \tag{3}$$

Where:  $Y$ =binary variable for the use of IA,  $\beta_i$ =coefficients to be estimated,  $X_1$ =EDAD;  $X_2$ =ESCOL;  $X_3$ =LITROS/VACA;  $X_4$ =UA;  $X_5$ =INFRAE;  $X_6$ =MAQ;  $X_7$ =LECHE;  $X_8$ =CARNE;  $X_9$ =DIST;  $X_{10}$ =AT, and  $u_i$ =stochastic error.

The information was captured in Excel spreadsheets; subsequently, the information was subject to a statistical analysis using the STATA program (StataCorp, 2015).

## RESULTS

### Production units and significance of the model

We interviewed producers that had an interest in the extension program: producers with extensive livestock production experience (the oldest producer interviewed was 85 years old), as well as young producers (21 years old) participated in the survey. In general, having a wide variability of participating producers is reflected in the descriptive statistics of the sample (Table 1).

In the producer-related variables, the average age identified was  $50.94 \pm 13.84$  years, while the average schooling was  $6.63 \pm 5.10$  years. It is important to point out that the

**Table 1.** Characterization of the production units analyzed.

Variable	Mean ± SD	Minimum	Maximum
Average age of Producers (years)	50.94 ± 13.84	21	85
Producer schooling years	6.63 ± 5.10	0	16
Average milk per cow	2.63 ± 2.07	0	11.5
Animal units (AU) per ranch	25.87 ± 20.98	4	194.3
Infrastructure index (%)	0.05 ± 0.06	0	0.36
Machinery and equipment index (%)	0.09 ± 0.11	0	0.54
Sale of milk per week (\$)	167.50 ± 179.80	0	1250
Sale of calves per year (\$)	28468.00 ± 34042.00	0	176000
Distance from the ranch to the municipality (km)	3.06 ± 5.12	0	40
Number of years with technical assistance	1.44 ± 2.33	0	13

participants included producers with undergraduate and even postgraduate studies, as well as producers who did not have any schooling. In the characteristics related to the production unit or ranches, a low average milk production ( $2.63 \pm 2.07$ ) was identified, as well as an average womb inventory level ( $25.87 \pm 20.98$ ) of animal units per ranch. With regard to the variables indirectly related to the capitalization level, very low infrastructure ( $0.05 \pm 0.06$ ) and machinery and equipment ( $0.09 \pm 0.11$ ) indexes were detected. In market-related variables, the income obtained from the sale of milk per week ( $\$167.50 \pm \$179.80$  MXN) was analyzed, as well as the income obtained from the sale of calves per year, which amounts to  $\$28,468.00 \pm \$34,042.00$  MXN. This seems to indicate that selling calves has preference over the production of milk. With regard to the context variables—those that do not depend on the production unit—, we recorded the distance in kilometers between the ranch and the municipal seat, as well as the years the producers had received technical assistance. Regarding this variable, is important to point out that the minimum value was 0 years and the maximum value was 13 years. On average, the distance from the ranches is  $3.06 \pm 5.12$  km, while producers have had  $1.44 \pm 2.33$  years of technical assistance (Table 1).

In the sample that we analyzed, only 4% of the farmers used IA technology. The  $X^2$  test was used to evaluate the global significance of the model; the null hypothesis was that all the coefficients of the equation (except for the constant) are null. The number of correctly predicted cases was 97.46%, the LR  $\chi^2$  (10) statistic was 46.87, and the associated probability was  $<0.000$ ; consequently, the null hypothesis is rejected and the global model is proved to be significant. The statistical significance of the estimated parameters was obtained through the Wald test (z-statistic). In the study, the IA was independent ( $p > 0.05$ ) of the schooling level and milk production per cow variables, as well of the income from milk sales and the average number of years that the producer had received technical assistance. In contrast, four variables were found to be significant ( $p \leq 0.05$ ): age and distance from the ranch to the municipality have a negative influence in the decision to use IA, while the machinery and equipment index, as well as the sale of calves, have a positive influence in the decision of farmers to use this technology (Table 2).

The adoption of IA in the study region is negatively influenced by the age of the producer: older producers are 0.29% less likely to use IA technology. Meanwhile, the machinery index had a significant and positive conditional marginal effect ( $p \leq 0.05$ ); this result indicates that producers who had a higher level of machinery and equipment have a probability of adopting the IA of up to 36.43%. In the same sense, the sale of calves was also significant and positive ( $p \leq 0.05$ ), which showed that producers who sell calves are 0.00007% likely to adopt IA.

The coefficient of the distance variable was negative and significant ( $p \leq 0.05$ ). Consequently, ranches located at a greater distance from the municipality are 2.3% less likely to adopt artificial insemination.

The objective of this work was to identify factors associated with the producer, production unit, income from product sales, and other context variables that determine the use of IA by cattle producers in northern Sinaloa. The results indicate that the IA was independent of variables related to the level of education, milk production per cow, income from milk



**Table 2.** Coefficients of the variables that influence the probability of using artificial insemination.

Variable	Coefficient	z	P>z	dy/dx
Age	-0.192	-2.04	0.042*	-0.0029
Producer schooling years	-0.281	-0.18	0.853	-0.0005
Average milk per cow	0.373	1.43	0.153	0.005
Animal units (AU) per ranch	0.020	0.84	0.402	.0003
Infrastructure index (%)	-5.842	-0.58	0.564	-0.089
Machinery and equipment index (%)	23.886	2.41	0.016*	0.3643
Sale of milk per week (\$)	-0.0007	-0.31	0.756	-0.00001
Sale of calves per year (\$)	0.00004	0.043	0.043*	0.00000007
Distance from the ranch to the municipality (km)	-1.553	2.03	0.023*	-0.023
Number of years with technical assistance	-0.407	-0.85	0.396	-0.0005
Constant	-0.281	-0.18	0.816	

dy/dx is the marginal effect of the X variable on the dependent Y variable; dy/dx significance level:  $p < 0.05$   
 \*. Number of observations (n): 200. LR  $\chi^2(10) = 46.87$ ; Prob >  $\chi^2 = 0.0000$ ; Pseudo  $R^2 = 0.7003$ , correctly classified = 97.46%.

sales, and the average number of years that the producer has had technical assistance. However, the age of the producer and the distance from the ranch to the municipality had a negative impact on the decision to use IA, while the machinery and equipment index and the sale of calves positively influenced the decision of farmers to use this technology. These results are discussed below.

The results obtained indicate that the distance from the production unit or the ranch is a determining factor for the use of IA and, the further away the production unit is from the municipality, the producer is less likely to adopt IA technology. Our results match the findings of Sirajuddin *et al.* (2018), who determined that location is important in the IA process, since the closer the ranch is to the inseminator, the greater the adoption of this practice. Not only are technical personnel more readily available when the producers are closer to the municipal seats, it is also possible to get supplies more quickly (pipettes, gloves, nitrogen, etc.). In other words, it seems that the use of IA is indeed related to a greater availability of the resources that can meet the requirements of this technology.

Additionally, the results indicate that the machinery and equipment index and the sale of calves are preponderant factors that contribute significantly to the adoption of IA. The use and adoption of IA has indeed many requirements, particularly knowledge/experience, personnel, and financial resources for the acquisition of inputs. Our results agree with reports that have indicated that the economic or purchasing factor plays a crucial role in the producer's decision to whether or not use IA (Howley *et al.*, 2012; Cortés-Mora *et al.*, 2014, Rathod *et al.*, 2017; Lassala *et al.*, 2020). It is also evident that age plays an important role in the adoption of technology; since older producers showed little interest in using or learning about IA technology. Therefore; the probability of adopting IA decreases inversely with the age of the producer.

The successful use of the IA technique requires that several factors occur simultaneously. Our results identify factors related to the producer and the productive unit (age, availability

of machinery, sale of calves, distance from the ranch to the municipality) as determining factors in the use of this technology. These results complement previous reports that indicate that environmental factors, climate change, inadequate extension services, training, and limited financing reduce the use of IA in production units (Baruselli *et al.*, 2019; Moreki *et al.*, 2019). Taking into consideration the physiology of cows and the insemination technique is also necessary. Therefore, a successful heat detection, the technique used at the time of insemination, semen management (thaw and apply), the metabolic status, and the well-being of the cow are factors that can limit the success of IA (Yehalaw *et al.*, 2018).

The animal units (UA) median for the interviewed producers was 21.6, which indicates—according to Cuevas *et al.* (2016)—that most of the producers analyzed belong to the small-scale producer stratum. This type of producer has a low level of resources, which undoubtedly limits the use of artificial insemination. The results match the findings of Cortés-Mora *et al.* (2012), Cuevas *et al.* (2013), Rangel *et al.* (2017, 2020) who indicate that there is a low technological level in the use of reproduction methods—such as artificial insemination or embryo transfer—in Latin America and that producers with greater purchasing or economic power are more likely to use IA, as reported in Latin America and Mexico by us and other authors (González-Quintero *et al.*, 2020; Lassala *et al.*, 2020).

Sectoral agricultural policies must be aligned with the needs of producers, in order to make production more efficient and to meet the demands for agricultural food production.

## CONCLUSIONS

The age of the producer and the distance from the ranch to the municipal seat are variables that have a negative impact on the use of artificial insemination technology; in contrast, income from the sale of calves and the machinery and equipment index have a positive impact on the adoption of artificial insemination by producers from northern Sinaloa. Consequently, producers with a higher level of machinery and equipment have a probability of adopting IA of up to 36.43%. Artificial insemination in the study region requires the definition of a technology diffusion and transfer policy that provides the different producers with permanent information about this technology, availability of inputs, and development of capacities. Only in this sense, the gaps in the use of this technology between small and large producers could be closed, thereby contributing to the improvement of livestock among the producers from northern Sinaloa.

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