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Cuevas-Reyes, Venancio; Rosales-Nieto, César
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Artículos Originales

Characterization of the dual-purpose bovine system in northwest Mexico: producers, resources and problematic

Caracterización del sistema bovino doble propósito en el noroeste de México: productores, recursos y problemática

Venancio Cuevas-Reyes
Instituto Nacional de Investigaciones Forestales, México
nieto_cesar@hotmail.com

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César Rosales-Nieto
Instituto Nacional de Investigaciones Forestales, México
nieto_cesar@hotmail.com

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Abstract:

Objective. The present study consisted in characterizing the dual-purpose cattle system and the factors that limit the productivity of this system in northern Sinaloa, Mexico. **Material and Methods.** We applied a survey to 214 producers and we analyzed the data with analyses of factors and conglomerate. **Results.** The analysis of factors identified five components: resources level, productivity, technological level, livestock management and socioeconomic aspects and these components explain 70.5% of the total cumulative variance. The conglomerate analysis identified three clusters: cluster 1 (52.5%, 105 producers) defined as a system focused on milk production. Cluster 2 (41.5%, 83 producers) defined as traditional farms of meat and milk production and Cluster 3 (6%; 12 producers) defined as farms focused on meat production. The three clusters present similar livestock management ($p>0.05$). The producers base their feeding strategies on grazing rangeland with seasonal supplementation of silage and commercial concentrate; however, each cluster differed ($p<0.05$) in the level of use of these resources. **Conclusion.** The present study identifies, in the dual-purpose cattle system in northern Sinaloa, low milk yield and limit forage resources as main problems that results in multiple strategies that the producers follow to solve it. The social aspects and the level of resources (land, animals, machinery and equipment and infrastructure) play an important role therefore they must be considered independently to help to define differentiated technological strategies.

Keywords: dry tropics, productive resources, problems, livestock grazing.

Resumen:

Objetivo. El estudio consistió en realizar una caracterización del sistema bovinos de doble propósito y los factores que limitan la productividad de este sistema en el norte de Sinaloa, México. **Materiales y Métodos.** Se aplicó una encuesta a 214 productores y la información se analizó mediante un análisis de factores y de conglomerados. **Resultados.** El análisis de factores identificó cinco componentes; nivel de recursos, productividad, nivel tecnológico, manejo del ganado y aspectos socioeconómicos. Estos cinco factores explican el 70.5% del total de la varianza acumulada. El análisis de conglomerados identificó tres clústers o grupos: Clúster 1 (105 productores, 52.5%) se definió como sistema enfocado a la producción de leche, Clúster 2 (83 productores, 41.5%) definido como explotaciones tradicionales productoras de carne y leche y Clúster 3 (12 productores, 6%) definido como explotaciones enfocadas la producción de carne. Los tres clústers presentan un manejo similar del ganado ($p>0.05$). Los productores de los clústers basan sus estrategias de alimentación del ganado en el pastoreo con suplementación estacional de ensilaje y concentrado comercial, no obstante, cada clúster tiene diferentes ($p<0.05$) niveles de uso de recursos. **Conclusiones.** El presente estudio identifico, en los sistemas bovino de doble propósito del norte de Sinaloa, como problemas principales una baja producción de leche y escasez de forraje que se manifiesta en múltiples estrategias que siguen los productores para resolverla. Los aspectos sociales y el nivel de recursos (tierra, animales, maquinaria, equipo e infraestructura) juegan un papel importante por lo que deben de ser considerados de manera independiente para la definición de estrategias tecnológicas diferenciadas.

Palabras clave: trópico seco, recursos productivos, problemática, pastoreo del ganado.

INTRODUCTION

Mixed farming systems, where crops and livestock are integrated into the same farm, are the base of smallholder production in developing countries (1). This system is also known as dual-purpose bovine system (DPBS) and in Latin America is one of the most relevant activity in rural areas (2). To address the food problems of this growing population, it would be necessary to increase food production by 70%, for which developing countries need to double up their production (3). The DPBS is characterized by having production units whose purpose is to produce and sell animal products: dairy products and/or meat (2). The producers of DPBS produce around 50% of cereals, 75% of dairy products (mainly milk), 65% of beef meat and 55% of lamb meat which turns out that this contributes with about half of the world's food (4).

In Mexico, the DPBS are associated with tropical vegetation that covers 26.4 million hectares. The distribution of the area related to this type of vegetation in the national territory is about 28.3%; which, 12.2% correspond to the humid tropic and 16.1% to the dry tropic (5). Recently, several authors have studied the DPBS in Mexico (6,7,8); however, most of the studies were done in conditions of humid tropical area. To our knowledge, there is limited information regarding studies that characterize the DPBS in the conditions of dry tropical area, which, reflects in its seasonal changes a difference between the wet season (vegetation with lush greenery) and the dry season (vegetation without foliage) in relation to the availability of humidity and moisture. In the north of Sinaloa, Mexico, this weather and vegetation conditions are present and sometimes the dry season can extent up to eight months (9).

The production units of the DPBS contribute up to 37% of the national production, which is up to 10.5 million liters of milk (10). However, the production potential of the producers from the DPBS could be increased if government generate differentiated policies and strategies if technological intervention. Therefore, it is important to identify differences and needs among the producers; thus, develop production strategies according to their needs, including resources and problems, in order to improve the efficiency of DPBS in this region. The objective of the present study is characterizing the DPBS and the factors that limit the productivity of this system in northern Sinaloa, Mexico.

MATERIAL AND METHODS

Study area. We did a survey on DPBS producers from three municipalities (Ahome [26°21'08" NL 109°24'20" WL], El Fuerte [26°26'45" NL and 108°37'17" WL] and Guasave [25°27'10" NL 108°48'05" WL]) of the North of Sinaloa. The weather in Sinaloa is considered dry, sub-humid and semi dry; however, in only 2% of the territory (highlands) the weather is considered sub-humid (5). In Sinaloa, there are 27,022 bovine (beef and dairy) production units and the north area has 38.7% of these production units (11). It is important to mention that the producers from Ahome and Guasave are located in the irrigation area; while the producers from El Fuerte are located in the area under rainfed conditions.

Producers and Surveys. In 2015, the Mexican government implemented a national rural extension program called "Proyectos Integrales de Extensión e Innovación". This program provided extension service to organized producers. In northern Sinaloa, producers from the DPBS in Guasave (n=40), Ahome (n=134) and El Fuerte (n=40) were identified and included in this program. Therefore, the sampling size of the data were of 214 surveys.

Due to the importance of cattle production in this region; we adequated and applied a structured survey to determine the diagnosis of the production units from the DPBS.

The survey contained information of the producers about general information, social and economic aspects, the type of property, inventories (animals, agricultural land, rangeland and water sources), facilities (infrastructure, machinery and equipment), animal reproduction, livestock feeding and supplementation, livestock health, milking and commercialization of livestock products.

Data collection. In July, six agricultural extension agents applied the survey to producers, in their production unit, from the municipalities considered. The database considered 214 applied surveys; however, we identified 14 surveys with atypical data; therefore, we do not consider those surveys in the analyses. Thus, we analyzed 200 surveys; which 17.5% are from El Fuerte, 20% are from Guasave and the rest (62.5%) from Ahome.

Variables. According to previous studies about the characterization of farm systems (7,12), sixteen quantitative variables were identified to characterize DPBS production in northern Sinaloa. The variables used were: 1) years of technical assistance, 2) age, 3) employees, 4) distance to the municipality, 5) number of sires, 6) number of cows, 7) number of animal units (UA), 8) total agricultural area, 9) infrastructure index, 10) machinery and equipment index, 11) weaning age, 12) weaning weight, 13) milk volume per day, 14) liters per cow per day, 15) liters per cow per hectare and, 16) income per sale of milk per day. The variable "index of machinery and equipment" was obtained from the analysis of 15 items that constituted it; plow, tractor, harrow, chopper, hammer mill, water pump, backpack pump, scale, artificial insemination thermos, mechanical milking machine, rennet tubs, cooler tank, skimmer, truck, trailer. The variable "infrastructure index" was composed of: management pen, milking parlor, milking pen, calving pen, chute, heifers, stalls, tick bath, feeders, drinking troughs, electric fence, warehouse, silos, workshop of dairy products, pasture area. Each item was categorized with 1 if the producer had it or 0 otherwise. The index was obtained by dividing the total number of items found in each variable by 15%. The typology of producers was obtained through the application of multivariate methods: principal component analysis (PCA) and cluster analysis (7, 13). The Kolmogorov-Smirnov test was applied to test the hypothesis of normality of the selected variables.

Principal component analysis (PCA). The main application of the PCA is focused on reducing the size of the data space, making synthetic descriptions and simplifying the problem that is studied (13). The sixteen variables were standardized to estimate the correlation matrix used in principal component analysis. The extraction method was the principal components with varimax rotation, which is an orthogonal rotation method that minimizes the number of variables with high saturations in each factor. Additionally, with the aid of the Kaiser-Meyer-Olkin (KMO) we evaluated the index by the sampling adequacy and, furthermore, the correlation matrix was identified with the aid of the Bartlett sphericity test. The principal components with own values above 1were used in the following cluster analysis.

Hierarchical analysis of clusters. The optimal cluster number was identified by hierarchical cluster analysis. To obtain the conglomerates the Ward method and the Euclidean distance squared were applied, which has been used before in typology studies of producers with homogeneous characteristics (14)

Statistical analysis. Once the production units were grouped, non-parametric test U of Kruskal-Wallis was used, analysis of variance for quantitative variables and tests of Chi square for qualitative variables to determine the differences ($p < 0.05$) among groups. Data analyses used the MINITAB and statistical package SPSS 15.0 (15)

RESULTADOS

Principal Component Analysis. According with the data analyzed; the Kaiser-Meyer-Olkin (KMO) statistic obtained showed a value of 0.699, which indicates a good sample adequacy to apply a factor analysis (16). The Barlett test of sphericity was significant (X2: 1832.48; $p<0.001$). Therefore, the analysis of main components of the retained variables proved to be an acceptable, reliable and appropriate model. In table 1, we present the matrix of the rotated factor (Varimax) of independent variables with factor loads for each variable. The commonality column shows the total amount of variance of each variable retained in the factors. In total, 16 variables were included in the principal component analysis, of which five main components with eigenvalues greater than one were conserved for a later analysis.

TABLA 1.
Tabla 1. Principal components from clusters identified in the DPBS of northern Sinaloa.

Variable	C1	C2	C3	C4	C5	Community
Technical assistance (years)	-.141	.142	.800	-.103	.374	.831
Age (years)	.138	-.116	-.026	.043	.620	.419
Employee (#)	.470	-.187	.405	-.082	-.247	.487
Distance municipality (km)	.079	-.292	.523	-.007	-.105	.375
Sires (#)	.803	.029	.075	.011	.051	.653
Cows (#)	.851	.123	.020	-.001	.315	.839
Animal unit (#)	.872	.097	.047	.024	.308	.867
Total area (ha)	.670	-.099	.144	.112	-.348	.613
Index of infrastructure (%)	.570	-.030	.488	.110	-.221	.625
Index of machinery and equipment (%)	.398	.055	.686	-.036	-.113	.646
Weaning age (mo)	.056	-.062	-.132	.909	-.056	.853
Weaning weight (kg)	.024	.029	.043	.918	.098	.856
Milk production (lt/day)	.211	.911	-.073	-.012	-.083	.887
Milk/cow/day (lt)	-.210	.800	-.085	-.004	-.259	.758
Milk/cow/ha (lt)	-.108	.776	-.015	.013	.273	.688
Daily income milk ($)	.185	.915	.016	-.046	-.075	.880
Eigenvalues	3.86	3.145	1.838	1.316	1.120	
Accumulative variance (%)	24.2	43.8	55.3	63.5	70.5	

Source: Own elaboration. Extraction method: principal component analysis. Rotation method: Kaiser with varimax. Rotation has converge in 11 interactions.

These five components explained 70.5% of the total variability in the data set. The first component explains 24.1% of the variation and correlates with the number of sires, the number of cows, the number of animal units (AU) and the total area. Therefore, the component represents the level of resources that the production unit has. The components 2, 3, 4 and 5 explain 19.6%, 11.5%, 8.2% and 7% of the variance respectively. Component 2 is correlated with the total milk volume of the herd, liters of milk per cow per day, liters of milk per cow per hectare and milk income obtained by selling milk per day, which represents the productivity in the DPBS. Component 3 is correlated with the number of years that the production unit has received technical assistance and the machinery and equipment index, which represents the production unit's technological level. Component 4 is correlated with variables of productive management (age and weaning weight of calves). Finally, component 5 is correlated with the age of the producer, thus, it represents social aspects of the person in charge of the production unit. Therefore, these five components could be named as "resources of the Production Unit" (C1), "livestock productivity" (C2), "technological level" (C3), "livestock management" (C4) and "social aspects" (C5).

Socioeconomic aspects of identified Clusters.

Cluster 1 is the most representative group (52.5%, 105 production units; G1) and was defined as DPBS with emphasis on milk production. Cluster 2 (41.5%, 83 production units; G2) was defined as traditional DPBS with milk and meat production. Cluster 3 (6%, 12 production units; G3) was defined as DPBS with an emphasis on meat production.

In table 2, we present the socioeconomic variables of the producers from the three clusters identified. Age of producers differed among clusters ($p<0.05$) with producers from G1 being the youngest and producers from G2 being the oldest. The number of familiar dependents differed among clusters and the income obtained from the sale of milk ($p<0.001$) with producers from G1 with more familiar dependents and with more income. The income obtained for the sale of calves differed among clusters ($p<0.05$) with producers from G3 with the highest income. Producers from all the clusters hire at least one employee along the year ($p<0.01$). The distance from the productive unit to the closest municipality differed among clusters ($p<0.01$); the producers from G2 are the closest to the municipality (Table 2).

TABLA 2.
Tabla 2. Socioeconomic characterization of from clusters identified in the DPBS of northern Sinaloa.

Variable	Clúster 1 (n=105)	Clúster 2 (n=83)	Clúster 3 (n=12)	p*
Familiar dependents (#)	2a±2	0b±1	0b±0	.000
Employee (#)	1a±1	1a±1	1.5b±1	.002
Distance municipality (km)	22a±24	20a±24	29.5b±19	.010
Milk income (US$/day)**	9.4a±12.7	6.2b±9.4	0b±4.9	.000
Meat income (US$/year)**	917a±2294	917a±1835	2753b±4244	.047
p* is probability obtained by Kruskal-Wallis test. **Exchange rate 19.18 pesos per dólar (nov 2017).				

Resources, productivity and technology variables. The number of sires, the number of cows, the number of animal units differ among clusters ($p<0.05$) favoring producers from G3. Milk production (per cow and per hectare) differed among clusters ($p<0.05$), favoring producers from G1. Total agricultural area differed among clusters ($p<0.05$) favoring producers from G3. Years receiving technical assistance, machinery and equipment index and infrastructure index differed among clusters ($p<0.05$), favoring producers from G3. Weight at weaning differed among clusters ($p<0.05$), but not age ($p>0.05$) (Table 3).

TABLA 3.
Tabla 3. Resources, production and technological variables from clusters identified in the DPBS of northern Sinaloa (mean ±RIC*).

Variable	Cluster 1 (n=105)	Cluster 2 (n=83)	Cluster 3 (n=12)	p**
Sires (#)	1a±1	1a±1	2b±3	.001
Total area (ha)	8a±10	8a±7	59.5b±47	.000
Employee (#)	1a±1	1a±1	1.5b±1	.002
Milk production (lt/day)	40a±50	25b±40	0b±19	.001
Milk/cow/day (lt)	2a±3	2a±4	0b±1	.001
Milk/cow/ha (lt)	3a±10	2b±6	0b±0	.000
Weaning age (mo)	8±5	8±4	9±2	.203
Weaning weight (kg)	180a±35	170b±30	185a±20	.001
Technical assistance (years)	0a±3	0a±2	2b±6	.018
Machinery and equipment (%)	7a±16	2a±8	25b±27	.001
Index of infrastructure (%)	3a±5	3a±3	15b±20	.000
*RIC: intercuartilico range p** Kruskal-Wallis test				

Grazing and livestock health. In north Sinaloa, producers form DPBS based their production on the grazing of different forage resources: grazing areas with crop residues (maize and sorghum), grazing on established pastures and grazing on rangeland areas with nutritional supplementation. In addition, the use of harvested forage and silage.

Availability of rangeland areas for grazing, the use of harvested forages, the use of silage and the use of concentrate differ among clusters ($p<0.05$). Grazing in rangeland with agricultural crops and harvested pastures does not differ among clusters ($p>0.05$). The use of artificial insemination did not differ among producers from the clusters ($p>0.05$)(Table 4).

TABLA 4.
Use of forage resources and livestock health from clusters identified in the DPBS of northern Sinaloa.

Variable	Cluster 1 (n=105)	Cluster 2 (n=83)	Cluster 3 (n=12)	p*
Grazing in crop residues (%)	90.5	96.4	91.7	.283
Grazing (%)	53.3	59	66.7	.563
Grazing in rangeland (%)	50.5a	42.2a	100b	.002
Use of harvested forage (%)	22.9a	18.1a	50 b	.046
Use of silaje (%)	15.2a	8.4a	50b	.001
Use of concentrate (%)	20a	21.7a	83.3b	.000
*Artificial insemination (%)	2.9	1.2	8.3	.317
Anaplamosis (%)	48.6a	51.8a	16.7b	.074
Diarrhea (%)	28.6	19.3	41.7	.145
Pneumonia (%)	21.9	13.3	25	.265
Mastitis (%)	23.8a	10.8b	25a	.063
p* Ji-square test. Values within columns with different superscript letters are different (p < 0.05). *AI was done only by 5 producers (C1:3; C2:1 and C3:1)				

The most frequent diseases were anaplasmosis, diarrhea, pneumonia and mastitis. The presence of diseases reported by the producers did not differ among clusters ($p>0.05$). However, the presence of anaplasmosis ($p=0.07$) and mastitis ($p=0.06$) tended to differ (Table 4).

DISCUSSION

Characterization of the producer and productive unit. The multivariate analysis has been used on countless occasions by several authors to identify homogenous groups within a production system and to classify and characterize production units in the agricultural field (17,18,19). Therefore, the present study through the multivariate analysis identified three groups or clusters of producers from the DPBS with similarities and differences in socioeconomic, productive and technological aspects. The characterization (producer´s profile and production unit characteristics) of the agricultural systems and animal production is essential for the success of development policies and technology transfer. With the appropriate information, support programs can be developed to increase the productive efficiency of DPBS production units. Unfortunately, in most cases, rural development policies are implemented without considering these aspects; thus limiting the possible impact on agriculture and animal production (8). It is of our knowledge that this type of studies have been replicated over time, however, the impact on productive systems is low or null. It is important to highlight that the age of producers from G1 compared to the age of producers from G2 and G3 may be an advantage for the adoption of innovations and new livestock knowledge; this is concur with another study that observed an inverse relationship between age and the adoption of technology (20).

The observed in the present study on the number of years with technical assistance that producers and production units have is consistent with previous studies in Mexico (19) and somewhere else, indicating a positive relationship in relation to this variable (21). However, when the analysis is done by cluster, the results with respect to these studies differ in the sense that at a lower distance from the production unit there will be greater adoption of technology and use of technical assistance.

The age of producers from G2 and G3 may be a limiting factor and it will require strategies for disseminate the technology appropriately to the cultural and socioeconomic conditions of this type of producer. If this is not the case, there is a risk of implement strategies of technological intervention focused on an average producer (22-23), which, as shown in the results, does not exist in reality, therefore, with the possibility of low impact on productivity of the DPBS. Besides characterizing the profile of the producers and the characteristics of the farm, in addition, it is necessary to explore deeper the characteristics of the productive system. The data will help us to elaborate and design strategies of technological intervention, which address the critical factors of each type of productive unit within achieving more efficiency in the use of natural, physical and human resources involved in production.

Analyses of the DPBS: grazing and livestock health. Overall, our results are in agreement with the previous study that indicate that the main problems of producers are related to shortage of forage during the dry period (24). This issue causes other problems related to undernutrition, such as low reproductive efficiency, low productivity and overuse of natural resources (soil, vegetation and water). A common feature of DPBS that often overlooked is the multifunctionality of the herds (25). The animals in this productive system are often, considered as a saving box and that can be used in times of need (family matter or animal management). Therefore, during the dry season producers sell young or mature animals in order to feed the most productive animals in the herd.

Most of the producers from the clusters (G1:50.5%, G2:42.2%, G3:100%) make use the rangeland during the wet season from one to three months to maintain the unproductive animals (heifers and dry cows). The results are consistent with a previous report, which indicated that the animals remained in the paddock for nine months and on the months of the dry season when shortage of forage occurs, the animals are retired from the paddock and fed with stubble and ground corn that were acquired at high prices (26). The use of grazing areas with crop residues (maize and sorghum), grazing on established pastures and grazing on rangeland areas represent an important variation in the quality and quantity of forage available (27). In the present study a higher percentage of producers from each cluster (G1:90.5%; G2:96.4%; G3:91.7%) reported grazing on areas with agriculture crop residues (sorghum or maize). Therefore, our observations concur to Valbuena et al (28), who indicated that grazing contributes between 10 and 90% of the diet of animals from the DPBS, depending on weather conditions and soil compaction.

The producers of the DPBS in the North of Sinaloa base their productivity on the intensive use of agricultural land available to them and the limited availability of machinery, equipment and infrastructure for livestock production. For example, on average, producers G1 and G2 have 8 hectares of land for crops that they use to feed between 21.6 and 24.4 animal units (this gives an stocking rate of 2.7 and 3.05 AU/ha for producers from G1 and G2, respectively). Therefore, producers need to follow different solution strategies for livestock feed. Therefore, 50% of producers with emphasis on meat production (G3) incorporate more resources and inputs for the feeding of the cattle (commercial concentrate, silage and harvested forage). On the other hand, the proportion of producers from G1 and G2 that use silage, buy commercial concentrate and use harvested forages is very limited. This can be explained because producers from G3 have more capital as reflected by their number of animals, agricultural and rangeland area.

Among the variables of management analyzed, we identified that the age at weaning was not similar among the producers of the different clusters and this could be explained by the objective of each of the clusters identified. Livestock health problems identified by the producers did not differ among clusters and our results concur with previous reports conducted in a region with similar environmental condition (7). An additional issue, in addition, to the natural resources, productivity and social analyzed in the DPBS is the low use of technology as reflected by the variable of artificial insemination. This technology is used for only three producers from G1, one from G2 and G3. This could be due to the nutritional issue of the animals that is not totally solved in the region of study.

The problem of lack of forage can be reflected in these multiple feeding strategies and in turn influences the low milk productivity presented by the production units of G1 and G2. The milk production reported by these clusters is lower than 6 lt per cow/day as reported by Loaiza et al (29). These authors indicated that with the use of technological components in the conservation and production of forages is possible improve the livestock productivity in the northern region of Sinaloa.

In conclusion, the main problem of SBDP in northern Sinaloa is the low milk production. This problem is a consequence of the of the lack of forage due to the limited use of technology for the production of fodder and feeding of livestock, in addition to high stocking rate (3.05 and 2.7 AU / ha) in clusters G1 and G2. In the medium and long term, this situation will result in an over-used of the natural resources (land, vegetation) of the region. Therefore, it is necessary that the definition of technological intervention strategies consider the social variables and the amount of resources that each producer has in order to improve the efficiency of natural resources and increase livestock production in the study area.

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