https://doi.org/10.22319/rmcp.v15i3.6529

Article

Producer typology and indirect effects of climate change on cattle ranching in Sinaloa

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Abstract:

The objective of the work was to typify dual-purpose production units and characterize the resources for fodder production and the issues affecting livestock production in Sinaloa, Mexico. Through non-probabilistic sampling, 61 ranches were selected from eight municipalities in the state of Sinaloa, and four groups of producers were identified through factor analysis and cluster analysis: E1, E2, E3, and E4. Producers have diverse land uses for fodder production: planting of annual crops, pastures, grazing on fallow land, and use of pasture lands. Drought is the main issue for 52.5 % of the producers. Producers with larger herd sizes (E3 and E4) have more agricultural and grazing land; however, their production systems are more vulnerable and, therefore, they have to resort to the purchase of forage. 86.7 % of the producers pointed out that the herd has decreased due to the problem of drought, which requires the development of technological strategies and policies to improve forage production within the context of climate change, and thus reduce the pressure and potential deterioration of agricultural and pasture land in the study region.

Keywords: Pasture land, Pastures and forage, Cattle, Drought, Tropic.

Received: 13/07/2023

Accepted: 11/10/2023

Introduction

The main threats to the production sector relate not only to climate change trends, but also, and more importantly, to climate variability and extreme weather events such as heat waves, droughts, floods, cyclones, and forest fires(1). These weather events affect livestock health through heat stress, metabolic disturbance, oxidative stress, and immune suppression, resulting in increased susceptibility to disease incidence and death(2). In general, it has been identified that a drought event reduces the average agricultural gross domestic product by 0.8 % worldwide(3). Direct effects of climate change on livestock include affecting livestock growth rates, milk and egg production, reproductive performance, as well as morbidity and mortality, along with feed supply(4), while indirect effects relate to the impact of climate change on pastures, forage crops, and feed productivity(5).

In Mexico, there are recent studies on the management, recovery, conservation of vegetation cover, and sustainable use of pasture land in livestock farming(6,7,8). However, they do not refer to the relationship between these and the level of agricultural resources for forage production available to producers in a drought context. At the producer level, the main perceived climatic changes include erratic and reduced rainfall, increased temperature, and prolonged and frequent periods of drought, which have had negative impacts on livestock production, namely forage and water shortages, leading to starvation, malnutrition, and mortality of livestock, reduced productivity, and low market prices(9).

At the producer level, the main perceived climatic changes include erratic and reduced rainfall, increased temperature and prolonged and frequent periods of drought, which have had negative impacts on livestock production; forage and water shortages, leading to starvation, malnutrition and mortality of livestock, decreased productivity and low market prices. At the national level, livestock production is associated with an area with natural vegetation of 26.4 million hectares in forests (28.3 %), of which 12.2 % correspond to the humid tropics and 16.1 % to the dry tropics, respectively[10]. Livestock production in Sinaloa is mainly located in the dry tropics, where a diversity of land and pasture uses converge in the region, with specific problems and management from the producer's perspective. In addition, under the current context, there is very little information on the direct and indirect effects of climate change on livestock production.

This study describes the agricultural and pasture land utilized for forage production, pinpoints the main issues in livestock production, and identifies drought as a consequence of climate change from the perspective and opinion of different groups of producers. The objective of the work was to typify dual-purpose production units and characterize the resources for forage production and the problems affecting livestock production in Sinaloa, Mexico. The hypothesis is that environmental vulnerability in the livestock production system has a direct relationship with the level of productive resources that the producer has; thus, the larger the herd size, the greater the purchase of forage and pasture land and the greater the perception of drought as a serious problem that affects the production system.

Material and methods

Location of the study area

The study area is located in the northwest of the country, in the state of Sinaloa, at the following extreme coordinates: 27°02'32" N to the north, 22°28'02" N to the south; east 105°23'32" W to the east, and 109°26'52" W to the west. The state represents 2.9 % of the country's surface and is bordered to the north by the state of Sonora and Chihuahua; to the east, by Durango and Nayarit; to the south, by Nayarit and the Pacific Ocean, and to the west, by the Gulf of California[11]. Sinaloa is made up of 18 municipalities; this study was carried out in eight municipalities, which represent 44.44 % and are located in three geographical regions: Southern area (Rosario, Mazatlán, Concordia, San Ignacio); Central area (Elota), and Northern area (Guasave, Mocorito, El Fuerte). These municipalities were selected in order to have information from the three geographic zones of the state.

Climate conditions in Sinaloa are very dry; in general, it has a warm sub-humid, dry, and semi-dry climate, and only 2 % of the state has a temperate sub-humid climate in the highlands[12]. Precipitation occurs irregularly, with average precipitation values increasing from north to south and as one moves up from the coast to the high mountains. In the coastal plain, they range from 200 to 700 mm, and in the southeastern portion, they exceed 1,000 mm. In the northwest, rainfall is 600 mm, and in the southeast, it varies from 800 to more than 1,500 mm[13].

Vegetation types and livestock management

A total of 45.1 % of Sinaloa's surface area is covered by natural vegetation (jungle, forest, hydrophilic vegetation, scrubland, other types of vegetation, and pastureland), i.e., it has not been altered by man or natural events. While 54.9 % corresponds to agricultural land, cultivated pastures, urban areas, areas with no apparent vegetation, water bodies, and secondary vegetation[10]. The natural vegetation existing in the pasturelands of Sinaloa corresponds mainly to the so-called "tropical deciduous forest"[14], also known as "dry forests"[15]. Livestock management in Sinaloa uses pasture land; this resource is fundamental for the provision of forage for livestock feeding during the rainy season, in addition to the use of grazing annual crops (sorghum, corn) in the traditional way[16], and the rainy and dry season use of perennial grasslands established as a result of technology transfer by local research centers.

Sample selection and applied instrument

The study used information obtained through producer surveys. The sample was obtained through the use of non-probabilistic purposive sampling[17]. Purposive sampling prioritizes the selection of cases that provide quality information on a specific topic for in-depth analysis and is carried out through the definition of criteria defined by the researcher[18,19]. The survey was conducted by six livestock extensionists located in the study area and hired by the Directorate of Livestock of the Sinaloa State Government; they selected the municipalities and producers to be interviewed based on ease of access and security; the interviewees must: 1) be dual-purpose cattle producers (representative system of Sinaloa), and 2) agree to answer the survey.

A total of 61 surveys were conducted in three different areas: North (10), Central (7), and South (44). This survey was conducted in the first quarter of 2022. It was designed to obtain information related to the age of the producer, the total area used for livestock production, sowing areas, grazing areas, including information on whether or not they have pasture, months of use and total pasture area, the livestock inventory of each production unit, the perception of the dates related to the beginning and end of the rainy season (when did the rainy season begin and when did it end?), the behavior of the herd size in the last ten years (Do you consider that the number of cattle had increased, decreased or remained the same in the last ten years? What was the reason for the decrease?). In order to identify the issues, the farmer was asked to select, in order of importance from most to least important, the problems that, in his perception, most affected livestock production. The issues raised were: high forage costs, high fuel costs, low milk prices, low price per kilo of calves, lack of government support, and drought.

Information analysis

Factor analysis (FA) was used to reduce the dimension of the data and explain a phenomenon from a smaller number of variables called factors(20). The main purpose of a FA is "to try to establish an underlying structure between the variables of the analysis, based on the correlation structures between them, i.e., it seeks to define groups of variables (better known as factors) that are highly correlated with each other"(21). In order to determine the number of factors to be extracted, the criterion of the percentage of explained variance was considered, which for social sciences can be set at a minimum of 60 %(22). The factor matrix was estimated using the Varimax rotation method with Kaiser normalization; the rotated solution stops when the weights at the factor level are maximized. In other words, each item or variable is expected to be representative in only one of them, to minimize the number of variables within each factor as much as possible; the factor matrix was thus obtained, which contains the weights (loadings or weights) of each variable, so that a variable is contained in a factor when its contribution is above 0.5(23).

The FA used 10 quantitative variables, which have been used in other studies for producer typologies(24,25,26): number of animal units and herd size, planted area, pasture area, number of offspring working on the ranch, total number of offspring, producer's age, pasture area, fallow area, and number of months with forage shortage. To verify the usefulness of factor analysis, the Kaiser-Meyer-Olkin (KMO) sample adequacy measure was obtained: values of this statistic below 0.5 would indicate that FA would not be a useful technique, and values between 0.5 and 0.6, that the degree of intercorrelation is medium, but applicable, while a KMO with values above 0.7 would indicate a high intercorrelation between the variables(27). In addition, Bartlett's test of sphericity was utilized to test the null hypothesis that the variables are intercorrelated, that is, to evaluate whether the correlation matrix is not an identity matrix, that is, one in which there is no relationship between the variables; this test is accepted as valid if the significance level is less than 5%(28).

In order to identify the different groups of producers, a cluster analysis (CA) was performed, which allowed clustering producers with similar characteristics within the group and with a wide variability among them. According to Rao and Srinivas[29] in CA the groups are formed in such a way that each object is similar to those within the cluster. Hierarchical cluster analysis with Ward's method and the squared Euclidean distance were utilized to identify the groups[30]. An analysis between groups was performed using the Kruskal-Wallis test and Chi-square tests for qualitative variables to determine differences (P<0.05) between groups. A Spearman correlation analysis was performed to verify whether there is a relationship between pasture area, number of months of purchased fodder, and number of heads in the herd, given that the normality of the data was not fulfilled. Statistical analyses were carried out with SPSS software[31].

Results and discussion

Factor analysis

The FA identified four factors that explain 68.79 % of the variance of the data (Table 1). The components obtained were denominated as follows: agricultural resources (C1), forage resources (C2), family resources (C3), and additional forage resources (C4); the variables were positive in each component. The sample adequacy measure KMO presented a value of 0.61 and Bartlett's test of sphericity showed a Chi-square (X^2) value of 444.73 and a significance of P<0.0001, so it can be affirmed that the PA was a suitable and appropriate model for the reduction of variables. The cluster analysis identified four groups: group 1 (G1) represented 27.80 % of the sample, G2 represented 49.20 % and had the highest percentage of producers interviewed, G3 represented 9.80 % and finally, G4 represented 13.10 % of the total producers.

Table 1: Matrix of rotated components and percentage of explained variance

Variable	C1	C2	C3	C4	Communality
Herd size	.964	.053	-.068	-.089	.945
Animal units	.964	.053	-.065	-.093	.945
Planted surface area, ha	.754	.261	-.008	.233	.691
Surface area of pasture lands, ha	.529	-.400	.114	-.177	.484
No. of children working on the ranch, #	-.011	-.062	.873	-.082	.774
Total number of children	-.052	.344	.783	.177	.766
Producer's age	-.068	.559	.220	.109	.378
Surface area with meadows, ha	.207	.621	.181	-.047	.464
Fallow surface area, ha	-.040	-.034	.039	.958	.922
Months with fodder shortage	.062	.694	-.130	-.090	.511
Inherent value	2.813	1.861	1.185	1.021	
% of the variance	28.132	18.606	11.845	10.214	
% cummulative	28.132	46.738	58.583	68.797	

Family resources

The age of the producers was similar among the four groups (*P*>0.05), ranging between 50 and 57 years; G4 producers were the youngest with a median age of 50 yr. The four groups have 2 or 3 children on average. In general, there is very little participation by the offspring in the productive activities of the ranches (Table 2). These results coincide with Cuevas *et al*[32] who point out that the socioeconomic characteristics of the producer in Sinaloa are homogeneous.

Table 2: Family resources of producer groups (median±IQR*)

Variable	G1	G2	G3	G4	*P***
Age	56.00±26.00	57.50±21.25	56.00±23.25	50.00±17.00	0.338
Total number of children, #	3.00±3.50	2.00±3.20	2.00±3.20	3.00±3.50	0.544
Number of working children, #	0±1.00	0±1.00	0±1.00	0.50±1.00	0.657

*IQR= interquartile range, ** Kruskal-Wallis test.

Farming resources

Herd size was similar between G1and G2 (36 and 42.5 head of cattle per group), but different (P<0.05) between the rest of the groups (180 for G3 and 110.5 in G4); this behavior was similar for the animal unit (AU) variable. There were no differences (*P*>0.05) between groups G1, G2, and G4 in the planted area (*P*>0.05), unlike in the area of pasture land owned by farmers, which exhibited differences (*P*<0.05) between groups G1, G2, and G3 (Table 3).

Table 3: Agricultural resources of the producer groups (median±IQR*)

Variable	G1	G2	G3	G4	*P***
Herd, No. of heads	36.00±28.50[a]	42.50±27.25[a]	180.00±69.50[b]	110.50±21.25[c]	0.001
AU	32.75±26.00[a]	37.25±25.61[a]	154.50±61.70[b]	95.20±13.42[c]	0.001
Planted area, ha	20.00±21.50[a]	12.00±12.18[a]	50.00±62.50[b]	13.00±15.25[a]	0.027
Pasture land, ha	38.00±40.50[a]	3.50±90.00[b]	65.00±126.00[c]	15.00±80.80[a]	0.001

*IQR=interquartile range, ***P* is the probability obtained by the Kruskal-Wallis test.

[abc] Values with distinct literal are different (*P*<0.05).

The use of agricultural resources (sown area and pasture) for forage production depends on the rainy season. Producers reported a three-month rainy season (63.90 % mentioned that the rainy season starts in July, while 41% said it ends in September). Thus, the rainy season would correspond to a period of three months, July through September, while the rainy season could be up to nine months a year: October to June.

The pasture land ("agostadero") is used during the rainy season when the tropical deciduous forest is renewed; previous studies indicate that, during the rainy season, unproductive cattle, calves, and weaned calves are sent to the "pasture land" to graze grasses and trees[(33)], these same authors describe the main species that exist in the pasture land; the vertical structure is made up of dominant trees with heights of 10 to 15 m, the upper floor is made up of species such as *Lysilpma divaricata*, *Caesalpinia sclerocarpa*, *Pithecellobium mangense*, and *Conzattia serícea*. During the summer, the undergrowth is covered by a dense carpet of herbaceous species, which are highly preferred by cattle: *Carlowrightia costarina*, *Henrya imbricans*, *Henrya scorpioides*, *Ruellia donnell-smithii*, and *Siphonoglossa sessilis*. This resource is used by producers and is one of the most threatened plant resources in Mexico; a study conducted on this type of vegetation found an annual deforestation rate of 1.4 %, as well as fragmented and disturbed areas[(34)].

Finally, during the "dry season, the land planted with annual crops is used as "paddocks", that is, after harvesting the corn or sorghum, the rest of the plant (stubble) serves as feed for livestock. At this time, all cattle are concentrated in these paddocks, which are fenced with barbed wire and regional wood posts obtained from the pasture, and feeding is complemented with the purchase of forage and the use of the state's irrigated areas. These results are consistent with a study of the dual-purpose bovine system (DPBS) carried out in northern Sinaloa[35] which indicates that the DPBS is based on the grazing of different forage resources: grazing on residues in cultivated areas (corn and sorghum crops), on established pastures, and on the grazing of areas of common use called *agostadero*, combined with feed supplementation.

Livestock forage resources

The use of grasslands and "savannas" was similar in the four producer groups (P>0.05). There is a small amount of grasslands and fallow land: only 45.90 % of the producers reported the use of grassland, and 21.30 % allowed land to lie fallow. However, all groups have purchased fodder, but those with the largest number of animals (G3 and G4) do so for a larger number of months, namely, 5 to 6.6 mo per year (Table 4).

Table 4: Fodder resources of the producer groups (median±IQR*)

Variable (ha)	G1	G2	G3	G4	*P***
Meadows	0±12.50	0.50±3.00	0±16.00	0±12.75	0.927
Purchase of forage, months	3.00±2.50	3.00±3.00	5.00±4.50	6.50±90	0.057
Fallow surface area, ha	0±10.00	0±0	0±2.00	0±0	0.107

*IQR=interquartile range, **Kruskal-Wallis test.

Cattle management in regard to this type of resource is as follows: at the beginning of the rainy season, lactating cows remain in the fallow areas or "savannas" (agricultural areas open to cultivation that are not sown and, therefore, allow this type of cattle to continue grazing on natural vegetation or native grasses). The use of savannas is a necessity for maintaining livestock, even though crop residues are often low quality.

Producers who have pastures use forage during the dry season, as, during the wet season, the savannas provide enough forage for the cows. In this regard, a study on small producers conducted in Sinaloa[36] shows that "producers who have perennial pastures use them as reserve lots in the dry months i.e., January through June; the animals graze continuously until they totally consume the pastures, which then are allowed to lie fallow and recover during the wet period (July to December), a situation that goes against pasture management, but the producer's decisions in this regard are conditioned by the rainy period during which the pastures are utilized as a source of food".

The results of the correlation between herd size (HS) and the purchase of fodder was significant (*P*<0.05), with a value of rho59=.255, *P*=.047, and the correlation between HS and the number of hectares of pasture was moderate (*P*<0.05), with a value of rho59=.305, *P*=.017. This seems to indicate that, for the sample analyzed, producers with a larger HS have a larger surface area of pastureland and a greater need to purchase fodder, which may lead to a loss of productivity of this resource. As Enríquez *et al*[37] point out, in at least 24 states of the country, the number of head of cattle exceeds the carrying capacity based on forage production. This situation results in the gradual degradation of grasslands and, consequently, in a reduction of their productivity.

Issues in the livestock system

The first and second issues for livestock production in the study region were drought and the high cost of fodder; there were no differences (*P*>0.05) between the four groups analyzed; the only problem that differed among the groups was the low price of the calves (*P*<0.05), between G1 and G4 (Table 5). These results agree with Habte *et al*[9] in the sense that drought is one of the most important indirect effects of climate change on livestock production, given that 52.50% of the interviewed producers indicated that the main issue has to do rather with the intense droughts that limit the production of fodder for livestock feed.

Table 5: Main cattle raising problems in the study region (%)

Issue	*G1 (17)	G2 (30)	G3 (6)	G4 (4)	Average	X^2
Droughts	64.70	43.30	50.00	62.50	52.50	0.691
High cost of fodder	29.40	26.70	33.30	12.50	26.20	0.687
Low price per kilo of calves	35.30[a]	13.30[b]	0.0	37.50a	21.30	0.005
Lack of government support	17.60	16.70	16.70	12.50	16.40	0.173
Low milk prices	23.50	13.30	0.0	12.50	14.80	0.188
High fuel costs	0	6.7	0.0	0.0	3.30	0.748

X^2= Xi-square test, * The total number of producers in the group is shown in parentheses.
[ab] Values with distinct literal are different (*P*<0.05).

Through the drought monitoring carried out by the National Water Commission[38] at the national level and in Sinaloa, this institution has identified several years with critical drought periods; in its report for the year 2021, it identified in the study region five municipalities (Concordia, Elota, Mazatlán, Mocorito and San Ignacio) with extreme drought conditions, while the other three municipalities (El Fuerte, Guasave, and Rosario) exhibited severe drought in the year 2021.

86.70 % of the producers pointed out that the livestock inventory has decreased in the last ten years, and 67.30 % mentioned frequent periods of drought as the main reason. Given that periods of intense drought reduce the availability of forage, extreme events such as hot spells, intense droughts, and floods will also have adverse effects on the agricultural sector and livestock productivity, as well as affecting the producer inventory(8,9). It is worth mentioning that the months and mechanisms to provide water to the animals were not directly researched; however, water management for the animals is provided by wells, streams near the corrals, and dams. Producers in the north of the state (El Fuerte, Guasave) have their land close to irrigation canals and also "haul" water in pickup trucks. Drought and water management for livestock is a topic that should be further explored in future studies on livestock production in the tropics.

Conclusions and implications

The drought period in the analyzed sample was nine months; the shortage of forage during this period forces producers to buy pasture and other feed for up to six months of the year. In this sense, the hypothesis was corroborated by the fact that producers with larger herds are more vulnerable in the production of fodder for livestock feed, so they have to resort to the purchase of fodder and the use of a larger agricultural and pasture area. As for vulnerability to drought as a climate change issue, producers with larger herd sizes indicated drought as the main problem; however, the percentage of producers who pointed at drought as the main problem was higher among producers with small herds. These results apply to the interviewed producers; however, they could be used for regions with similar geographic conditions. Technological strategies and policies differentiated by types of producers according to their resources must be developed to improve fodder production within the context of drought and thereby reduce the pressure on and potential deterioration of agricultural and pasture lands in the state of Sinaloa.

Acknowledgments

The authors are grateful to the agricultural extensionists who applied the survey; to the interviewed producers, and to INIFAP for financing the *SIGI* project No. 14235135370: *“Producción sustentable de forraje bajo un contexto de cambio climático y degradación de*

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