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Adaptive practices to reduce environmental vulnerability due to drought in livestock production

Cuevas-Reyes, Venancio[1]; Rosales-Nieto, Cesar[2]; Jiménez-Muñoz, Edith[1]; Loaiza-Meza, Alfredo[3]; Sánchez-Toledano, Blanca Isabel[4*]

[1] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental Valle de México. km. 13.5 Carr. Los Reyes-Texcoco, Coatlinchán. Texcoco Edo de México. C.P. 56250.
[2] Universidad Autónoma San Luis Potosí, Facultad de Agronomía y Veterinaria, San Luis Potosí 78321, Mexico.
[3] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental Valle de Culiacán.
[4] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental Zacatecas, Km. 24.5 Carretera Zacatecas-Fresnillo, C.P. 98500.
* Correspondence: sanchez.blanca@inifap.gob.mx

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ABSTRACT

Objective: To analyze the use of different adaptive practices that cattle producers carry out in Concordia, Sinaloa, located on the dry tropics of Mexico, to reduce the environmental vulnerability caused by drought.
Design/methodology/approach: Intentional sampling was used to interview n=40 cattle producers from Concordia, Sinaloa, during the year 2023. Through percentile analysis, four types of producers were characterized. The non-parametric Kruskal-Wallis and Chi-squared tests for qualitative variables were used, in order to determine the differences between groups.
Results: There are adaptive practices for drought, which are poorly understood (22.4% of livestock producers know them) and of low use (under 26%). The producers who use this type of practices more are those who have greater environmental vulnerability to drought (less surface, fewer heads of livestock, and in general insufficient productive resources). The most widely used practice was the availability of shade in paddocks and the use of conservation methods for fodders.
Limitations on study/implications: The results were applied to a sample selected and a region in particular.
Findings/conclusions: Contrary to the hypothesis set out, small-scale producers are the ones that make greater use of adaptive practices and technologies for livestock production. The percentage of livestock producers who use these practices is less than 26%, despite there being local institutions that promote their use.

Keywords: climate change, livestock technologies, dry tropics.

INTRODUCTION

Climate change is the alteration of climate patterns that change the distribution of key climate variables such as temperature, precipitation, moisture, wind speed, duration of sunlight, and evaporation (Peng *et al.*, 2017). Climate change (CC) and variability have generated great uncertainties in agricultural production, particularly at a small scale

(Zougmoré *et al.*, 2018). These uncertainties are characterized by erratic rain patterns and higher temperatures, with prolonged dry periods that cause moisture scarcity in the soil during the growing season of crops. Therefore, cultivation systems that are more resistant to these adverse conditions are necessary (Mhlanga and Thierfelder, 2021).

The increase in temperature, reduction in precipitation, and irregular patterns of rainfaill reduce crop yield and livestock production, which expose the impact of climate change on food security of developing countries (Abebaw, 2025). In the presence of effects from CC, strategies are required to strengthen the resilience of agricultural and livestock systems with the aim of reducing the risk of food insecurity both now and in the future (Smith and Frankenberger, 2018).

The impacts of drought, for example, in the rural communities of Mexico can increase by 5% the probability of becoming poor and reduce by 3% female employment and male school attendance (Arceo-Gómez *et al.*, 2020). Climate change in Mexico has led to an increase in the temperature; thus, the mean temperature at national scale has increased by +0.71 °C between 1951 and 2017 (moving average at 10 years, $p<0.001$), or else by +0.96 °C if it is calculated by ten-year periods ($p<0.001$); however, the region around the Gulf of California (northwestern states) showed the greatest rise in temperature, increasing up to +2.7 °C, and a decrease of 20% in annual precipitations in the last 67 years (Murray-Tortarolo, 2021).

In Mexico, during the fourth trimester of 2024, livestock production showed a fall in every region, except the south. In the north and center-north of the country, the formation of cattle inventories decreased as consequence of drought, which affected various stages of development in the herd, particularly in previous trimesters, and which, in the case of the northwestern zone of the country, persisted until the beginning of 2025 (Banxico, 2025). In a study conducted about drought in years 2011-2021, Murray-Tortarolo and Jaramillo (2019) found that the existence of cattle and goat livestock decreased around 3% in response to the drought throughout the country. These same authors point out that under the scenario of severe climate change, a higher frequency of extremely dry years (once every three years) would have negative impacts on the livestock production at the regional level in Mexico.

Climate change is the greatest environmental danger intimidating the whole global population; the average global temperature is increasing, the sea level is rising, the glaciers are melting, and the rain patterns are changing in an unpredictable manner. Consequently, strategies for adaptation and confrontation from small-scale producers are essential to mitigate these impacts of climate change (Okolie *et al.*, 2024).

In Mexico, 70% of agriculture is carried out in non-irrigated or rainfed areas (SIAP, 2022), which makes this sector especially vulnerable to climate change. It is important to increase the resilience of small-scale agriculture in developing countries; although studies have focused on the impacts of climate on crops and the decisions for adaptation, obstacles to adopt adaptive measure by small-scale farmers continue to be largely unexplored (Lamichhane *et al.*, 2022).

Although there are many political and economic barriers that hinder the development of adaptation initiatives, detailed and geographically explicit information is still needed about who and where the most vulnerable small-scale farmers are. This, with the aim of generating recommendations based on evidence about adaptation strategies and practices (or possible new strategies for adaptation), for small-scale farmers who work in different production systems (Donatti *et al.*, 2018). In this sense, the objective of this study was to analyze the use of different adaptive practices that cattle producers perform in the municipality of Concordia, Sinaloa, located in the dry tropics of Mexico, to reduce the environmental vulnerability caused by drought. The research hypothesis was based on the idea that the use of technology and the implementation of adaptive practices for the drought problem has a direct relationship with the scale and availability of resources from the livestock producer; with higher level of productive resources, there will be greater use of adaptive practices.

MATERIALS AND METHODS

Study zone

The municipality of Concordia (23° 04' and 23° 47' LN, 105° 41' and 106° 15' LW), with altitude from 100 to 2300 m, presents subhumid warm climate with summer rains of lower moisture (44.11%), warm subhumid with summer rains of average moisture (23.99%), semiwarm subhumid with summer rains of higher moisture (15.03%), warm subhumid with summer rains of higher moisture (13.20%), and temperate subhumid with summer rains of higher moisture (3.67%) (INEGI, 2010).

Selection of the sample and instrument used

The livestock producers interviewed were selected through non-probabilistic and intentional sampling (Hernández, 2021). The survey was applied in the year 2023 and was obtained this way to decrease the risks from the insecurity prevalent in the study zone. To obtain the information, a structured questionnaire was used, which was made up of four sections: 1) identification of the producer, 2) characterization of the production unit (crops and size of the herd), 3) impact of climate on livestock production, and 4) knowledge and use of adaptive practices and technologies for the drought problem. In total, n=40 livestock producers were interviewed as key agents.

Information analysis

To identify the types of adaptive practices that the livestock producers know and use, the production units were grouped based on the productive scale related to the number of cows that they have. According to Cuevas-Reyes *et al.* (2013), a classification of livestock production units was carried out through the use of percentiles.

The classification obtained was the following: group 1 (Q2≤11 cows, small-scale livestock producers - SLP), group 2 (Q3> than 11 and ≤21 cows, medium-scale livestock producers - MLP), and group 3 (Q4>21 cows, large-scale livestock producers - LLP). A percentile is a value under which a specific proportion of observations are found; percentiles offer an alternative to quotients based on the average (Bornmann *et al.*, 2013). In general, percentiles are not as strongly influenced by extreme values of the distribution as the mean value (Waltman *et al.*, 2011), and they do not depend on the selection of a function of specific probability density compared with the arithmetic mean, which requires a normal distribution (Bornmann *et al.*, 2013). The analysis of quantitative variables was carried out through the Kruskal-Wallis non-parametric and Chi-squared tests for qualitative variables, to determine the differences ($P<0.05$) between the groups.

RESULTS AND DISCUSSION

Socioeconomic characterization

Results showed that the three groups of producers have a similar age ($p<0.05$), from 51 to 59 years of age; they are mature producers that have a median of three children and in terms of education they only have between two and three years of study. The distance between the ranches and the municipal township did not have differences, although the medium-scale producers have their ranches farther from the municipal township (13 kilometers), compared to the medium-scale and small-scale livestock producers (Table 1). The proximity of production units to municipal townships facilitates the economic dynamics through efficient commercialization of products and with cost reduction (Espinoza *et al.*, 2024).

Characterization of the productive unit

The productive resources for fodder production (land and pastureland) had significant differences ($p>0.05$ and $p<0.10$), favoring the group of large-scale livestock producers. The total agricultural surface ranged between 19 hectares (MLP) and 80 ha in the LLP; this ratio is kept both for the surface planted and for the total hectares that livestock producers have. That is, the small-scale and medium-scale livestock producers are similar in the variables of agricultural surface and pastureland, but different compared to the LLP in the amount of land for fodder production (Table 2).

Small-scale and medium-scale livestock producers showed a similarity in terms of number of bulls, male calves and female calves produced, but there were differences ($p<0.05$) compared to the group of large-scale livestock producers. The variable number of adult cows presented statistical differences ($p<0.05$) between the three groups analyzed. Small-scale and medium-scale livestock producers had one bull compared to those in the LLP which have two, higher number of adult cows, as well as a larger number of male and female calves produced per year (median of seven) (Table 3).

Table 1. Characterization of the producer (median±RIC*).

Variables	SLP (n=20)	MLP (n=11)	LLP (n=9)	p**
Age (years)	59±16.2[a]	55±9.0[a]	51±15.5[a]	0.47
Years of schooling	2±3[a]	2±3[a]	3±2[a]	0.40
Number of children	3±1[a]	3±2[a]	3±2.5[a]	0.41
Distance from the ranch (km)	6.5±23.7[a]	13±35[a]	8.5±18.7	0.20

Source: Prepared by the authors. *RIC=inter-quartile range, p**=Kruskal-Wallis test.
SLP: small-scale livestock producers; MLP: medium-scale livestock producers; LLP: large-scale livestock producers.

Table 2. Agricultural surface for fodder growing (median±RIC*).

Variables	SLP	MLP	LLP	p**
Total area	20±26[a]	19±39 [a]	80±94.5 [b]	0.01***
Sown area	10±12 [a]	12±111.2 [a]	20±31 [b]	0.04***
Rangeland	9±22[a]	6±35 [a]	24±63 [b]	0.09****

Source: Prepared by the authors. *RIC=inter-quartile range, p**=Kruskal-Wallis test. ***Significative at 95 %, ****Significative at 90%.
SLP: small-scale livestock producers; MLP: medium-scale livestock producers; LLP: large-scale livestock producers

Table 3. Number of heads of livestock (median±RIC*).

Variables	SLP	MLP	LLP	p**
Bulls	1±1[a]	1±1[a]	2±2 [b]	0.001***
Adult cows	8±3.7 [a]	14±6 [b]	30±22 [c]	0.001***
Calves	2.5±3.7 [a]	4±3 [a]	7±10 [b]	0.003***
Calves	2±2[a]	4±3 [a]	7±5 [b]	0.001***

Source: Prepared by the authors. *RIC=inter-quartile range, p**=Kruskal-Wallis test. ***Significative at 95%.
SLP: small-scale livestock producers; MLP: medium-scale livestock producers; LLP: large-scale livestock producers.

Main problems caused by drought

The three groups of producers pointed out that the main problem for livestock production was drought which lasts on average six months in the study zone, so that during this period the lack of food for the livestock (fodder) becomes accentuated. The results agreed with what was described by Perales *et al.* (2000), who point out that in the state of Sinaloa, the scarcity of fodder for livestock feed is the main problem of livestock producers during six months of the year (January to June).

In this regard, the livestock producers agreed ($p>0.05$) in mentioning the existence of four main problems derived from the recurring droughts in recent years: the lack of fodder (84.7%), followed by the lack of water for the livestock (57.7%), and the lack of water for production of fodder crops (33.8%). The problem related to the death of livestock was mentioned in fourth place, although it is more evident in the stratum of large-scale livestock producers (11%), in addition to 5% of small-scale producers mentioning that they have this type of problem (Table 4).

Table 4. Problems related to drought (%).

Variables	SLP	MLP	LLP	Average	X^2
Lack of water for livestock	60	45.5	67	57.7	0.602
Lack of water for forage production	50	18.2	33.3	33.8	0.207
Lack of forage	85	91	78	84.7	0.716
Livestock deaths	5	0	11	5.3	0.526

Source: Prepared by the authors. SLP: small-scale livestock producers; MLP: medium-scale livestock producers; LLP: large-scale livestock producers

Our results converge with what was found by Harvey *et al.* (2018), who revealed that small-scale farmers in Central America have observed climate change, and that most of them are already experiencing the impacts of the increase in temperatures, unpredictable rains, and extreme meteorological phenomena in crop yield and livestock productivity, higher incidence of pests and diseases, as well as the generation of impacts on families' income and, in some cases, food security.

The National Water Commission has identified many years with critical drought periods; in its report from the year 2021, the agency identified that the municipality of Concordia presented conditions of extreme drought (CONAGUA, 2021), which according to the same author, were related to higher losses in crops and grasses.

Adaptive practices and technologies, knowledge and use

In the state of Sinaloa, there have been efforts to solve the problems related to the lack of fodder since 1996, through different strategies for dissemination and transference of livestock innovations carried out by state research centers. Since that period, diverse species of grasses have been generated and validated for the implementation of pasturelands, liberation of fodder sorghum, use of legumes, and methods for fodder ensilage and conservation (Loaiza, 2011; Hernández *et al.*, 2011).

However, despite these efforts, there is still poor knowledge of adaptive practices for the drought problem among the producers interviewed; only 22.4% of the total producers interviewed know the six practices promoted to improve the production of fodders and the wellbeing of livestock. The practices that they least know about are those of adjusting the animal load and the existence of fodder species adapted to the drought conditions (both with 7.5%). The most well-known practices were availability of shade in the paddock and conservation of fodders (37.5 %) (Table 5).

Regarding the application of these adaptive practices in livestock production by the farmers interviewed, no significant differences were found ($p>0.05$). However, there are indications that small-scale livestock producers are the most prone to use practices that mitigate the vulnerability of the drought problem (on average, this type of producers use 29.2% of the adaptive practices and technologies).

Table 5. Knowledge of adaptive practices and technologies (%).

Practices	SLP	MLP	LLP	Total	X^2
Shade availability in pastures	45	36.4	22.2	37.5	0.501
Adjust stocking rate	5	9.1	11.1	7.5	0.823
Conserve forage (silage, hay)	35	54.5	22.2	37.5	0.315
Implement silvopastoral systems	25	27.3	11.1	22.5	0.642
Forage species adapted to drought	15	0	0	7.5	0.98
Conserve soil and water	25	18.2	22.2	22.5	0.910
Average	25	27.3	14.8	22.4	

Source: Prepared by the authors. SLP: small-scale livestock producers; MLP: medium-scale livestock producers; LLP: large-scale livestock producers.

In general, the adaptive practice of greatest use by the livestock producers interviewed was to provide availability of shade in the paddocks (57.5%). In the case of the tropics, it is known that the effect of thermal stress tends to accentuate during the warmest hours of the day (between 11:00 and 15:00 hrs), and it is higher during the dry season and at the beginning of the rainy season (García, 2010). Tree shade in livestock productin systems stands out as a component that improves productivity in the herd. On the one side, it decreases the caloric stress of the livestock and, in addition, shade improves the quality of the pastureland through positive changes in protein contents and a decrease in fiber structures, which consequently improve the digestibility, finally translating into better weight gain of the animals (Obispo *et al.*, 2013).

On the other hand, the practice of fodder conservation through ensilage is recognized as an alternative to obtain good quality feed for the dry season in the tropics, where there is greater scarcity of feed for the livestock (Cuevas, 2019). This is the second practice in importance that livestock producers interviewed have used (55%), which is necessary to decrease the environmental vulnerability related to the lack of feed and quality fodders caused by drought in the study zone (Table 6).

The use of adaptive practices for the problem of lack of fodder caused by long periods of drought in the study zone requires joint efforts from various stakeholders in the sector, in order for more livestock producers to know the alternatives to face the environmental vulnerability in fodder production. However, the adaptation of these technological innovations depends on the producer perceiving the impact of climate change as a risk to be able to implement adaptations, technologies and socially solid policies that mitigate the adverse effects of climate change (Whitmarsh and Capstick 2018; Adger *et al.*, 2009). Viguera *et al.* (2019) described that perceiving the effects of climate change is a necessary condition to implement adaptation strategies by producers and institutions.

Our results showed that it is not enough to have technological alternatives that may be used as adaptive practices, but rather that there are other elements that impact the use or adoption of these alternatives. In this regard, in a study of the agricultural community in Bangladesh, Islam *et al.* (2014) found that there are limitations for the adoption of adaptive measures to climate change in terms of natural, technological, social, economic

Table 6. Use of adaptive practices and technologies (%).

Practices	SLP	MLP	LLP	Total	X^2
Shade availability in pastures	55	54.5	66.7	57.5	0.819
Adjust stocking rate	20	18.2	0	15.0	0.356
Conserve forage (silage, hay)	60	36.4	66.7	55.0	0.326
Implement silvopastoral systems	15	18.2	11.1	15.0	0.908
Forage species adapted to drought	0	18.2	0	5.0	0.068
Conserve soil and water	25	0	0	12.5	0.057
Average	29.2	24.3	24.2	25.9	

Source: Prepared by the authors. SLP: small-scale livestock producers; MLP: medium-scale livestock producers; LLP: large-scale livestock producers.

and institutional processes that are mostly interrelated and collectively influence decisions of adaptation.

The results from this study specify that small-scale livestock producers who have more vulnerability and fewer economic resources are the ones who carry out more adaptive practices, which contrasts to what was found by Schmidt *et al.* (2012), who mentioned that small-scale producers have been the most affected by these changes in climate patterns but do not know how to adapt to these changes to protect their production unit, their family, and guarantee their food security. Harvey *et al.* (2018) mentioned that small-scale farmers are one of the most vulberable groups to climate change; however, efforts to support the adaptation of farmers are obstructed by the lack of information about how they are experiencing and responding to climate change.

CONCLUSIONS

Problems related to drought in Mexico are increasingly recurrent, so it is necessary to identify, design and implement adaptive practices to reduce the environmental vulnerability caused by this climate phenomenon. The study demonstrates that, contrary to the hypothesis set out, small-scale producers are the ones who use more adaptive practices and technologies for livestock production. However, the percentage of livestock producers who use them is under 26%, even when there are local institutions that promote the use of said technologies. An integral strategy to mitigate the effects of climate change is required, although differentiated according to the characteristics of each group of livestock producers. This would have the aim of including their existing level of adaptation, resources, perceptions, opinions and experiences to strengthen their capacities and tools at the local level.

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