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Article

Native corn in Sinaloa: agroclimatic and sociocultural factors that limit its productivity

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Abstract

The state of Sinaloa is internationally recognized for its high production of corn from commercial hybrids and technified systems. Nevertheless, native corn is also grown by small producers, mainly in the mountain region. This practice has experienced a sharp reduction in its sowing area as well as variability in its production. The objective was i) to identify the main agroclimatic and sociocultural factors that have influenced the reduction of the area allocated to the cultivation of native corn varieties; and ii) to analyze the variability in the production volumes of these types of corn in the northern regions of the state of Sinaloa. The data were categorized into quantitative and qualitative; the former were analyzed using one-way Anova and Pearson's correlation, while the qualitative data were analyzed by content analysis. Analysis of historical data from 1980 to 2023 indicates a substantial 88.6% reduction in the planting area allocated to native corn cultivation, whereas production is highly variable between harvests. This is a result of the decrease in rainfall and the increase in temperatures. Likewise, the lack of public policies, insecurity, and the migration of young people to urban areas have led small producers to consider abandoning traditional corn practices, reducing the production of rainfed native corn, and putting at risk the genetic diversity of corn, compromising the food security of communities.

Keywords:

agribusiness, biomass, byproducts.

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Introduction

The state of Sinaloa is characterized as the national leader in commercial corn production, with more than 6.6 million tons during 2023, which represented 24.2% of the national production (SIAP, 2023). By 2023, in Sinaloa, 97.5% of the hectares were destined for the planting of irrigated hybrid corn and only 2.5% was used for the planting of native seeds, which are sown in the rainy season in the mountain areas due to the climatic and geographical conditions of the region (Siacon, 2023).

According to historical data reported by Siacon (2023), in the 1980s, native rainfed corn was planted on more hectares (156 015 ha of corn, with 76.3%) under rainfed conditions and only 36 901 ha under irrigation conditions. From 1991 onwards, this trend began to change. Most of the planted area was changed to an irrigation system with commercial hybrids (Siacon, 2023), primarily due to the technification and construction of dams (Mancera-Gonzáles, 2022). Since then, these increases have resulted in a considerable reduction in the area allocated to the cultivation of native rainfed corn of up to 88%, while production has been variable (with values from 11 057 t to 110 428.8 t) over the years (Siacon, 2023).

The main municipalities where native rainfed corn is grown in Sinaloa are Mocorito (3 130 ha), San Ignacio (2 236 ha), Badiraguato (2 180 ha), Cosalá (1 816 ha), Rosario (1 355 ha) and the municipality of Sinaloa (851 ha). The latter with significant losses in planting area compared to 2022 (Siacon, 2023).

Various studies Ureta *et al.* (2020); Zhang *et al*. (2022); Simanjuntak *et al*. (2023); Cruz-González *et al*. (2024); Zhao *et al*. (2025) mention that climatic aspects and socioeconomic characteristics influence the productivity of native corn crops, planted under rainy and irrigation conditions in the Sinaloa region.

Climate change has caused changes in temperature and rainfall patterns, negatively influencing grain yield in different regions of Mexico (Cruz-González *et al*., 2024); temperature is the most influential factor in yield under drought (rainfed) conditions, while precipitation has been the main factor in irrigated crops (Ureta *et al*., 2020).

In terms of socioeconomic aspects, it has been found that the lack of access to technology, financing and technical assistance in the mountain areas and the Yoreme-Mayo indigenous region reduces the capacity to respond to climate challenges, leaving the rural population vulnerable to the decrease in their production for self-consumption (Lara-Ponce *et al*., 2017), which contrasts with medium and large producers in the Valley area of the state, where their production is large-scale and commercialized, and they enjoy benefits from public policies and government support (Ibarrola-Rivas *et al*., 2020).

In Sinaloa, the importance of corn production (Zúñiga-Espinoza, 2023), its socioeconomic impact (Gerardo-Montoya and Armenta-Bojórquez, 2010), and the environmental implications of its production have been analyzed with a focus on hybrid corn (Cruz and Leos, 2019). For native corn varieties, genetic diversity has been studied, and they have been phenotypically and agronomically characterized (Pineda-Hidalgo *et al*., 2013; Linares-Olguín *et al*., 2019); however, regarding the cultivation of native corn in Sinaloa, very little is known about the main factors that impact its productivity.

In this context, the present research aimed: i) to identify the main agroclimatic and sociocultural factors that have influenced the reduction of the area allocated to the cultivation of native corn; and ii) to analyze the variability in the production volumes of this type of corn in the northern regions of the state of Sinaloa. It is hypothesized that the production of native rainfed corn in rural areas of northern Sinaloa has been affected by agricultural, economic, climatic and social factors, which result in a decrease in planting areas and endanger the agrodiversity of native corn in Sinaloa. The findings of this work could help to make visible the risk situation of the genetic diversity of native corn and clarify the factors that weaken the food security of local communities.

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Materials and methods

Historical records of native corn production (t), planting area (ha) and grain yield (t ha^{-1}) in the state of Sinaloa for the period 1980-2023 were accessed and downloaded (SIACON, 2023). Historical records of annual precipitation during the same period were also analyzed on the platform of the National Water Commission and the National Meteorological Service. Likewise, the database of INEGI (2019) was consulted to identify native corn planting areas.

As an exploratory tool, a semi-structured survey was designed, divided into three sections: agroeconomic, agroclimatic, and sociocultural factors. Data were obtained on the cultivation system, production and plot size, production costs, planting periods and types, tools and inclusion of technology, presence of rodents and diseases, harvest treatments, production destination, whether they will continue planting, how the weather has affected their harvests, as well as whether or not they have benefited from government programs.

The survey was conducted from November 2023 to July 2024, utilizing the snowball sampling technique. Respondents were chosen based on the following criteria: a) being a family member; b) living in rural and indigenous areas of the northern region of the state of Sinaloa; and c) planting native corn.

The results of the surveys were analyzed together with the data in section VII: agriculture, subsegments: agricultural production, cultivated crops, planted area, harvested area, production, production destination, use of fertilizers and manures, technology in agriculture, and environmental factors that affect the harvest of the National Agricultural Survey, applied in 2012, 2014, 2017, and 2019 (https://www.inegi.org.mx/programas/ena/2019/) of the same areas. The data were categorized into quantitative and qualitative data; the former were analyzed using one-way Anova and Pearson's correlation using the R statistical software (R Core Team, 2021), while the qualitative data were analyzed through content analysis (Vizcarra *et al*., 2015).

Results and discussion

Decrease in the planting area and variability of native rainfed corn production in Sinaloa.

In 1980, Sinaloa was barely listed as a corn-producing state, with just over 62 700 t in irrigated mode and 72 732 t in rainfed mode (SIACON, 2023). From 1991 onwards, most of the planting area transitioned to irrigation production due to increased infrastructure (dam construction), technological advances, adoption of improved varieties and economic incentives. By that year, more than 155 000 ha will already be planted under this modality, producing around 144 577 t, reaching more than 6 625 812 t in 2023 (SIACON, 2023).

The outlook for native corn was utterly different. Figure 1 shows production, area allocated to native rainfed corn, and grain yield from 1980 to 2023. A notable decrease in the sowing area can be observed (119 114 ha in 1980 to 13 547 ha in 2023). In other words, the area planted with native rainfed corn was reduced by more than 88%.

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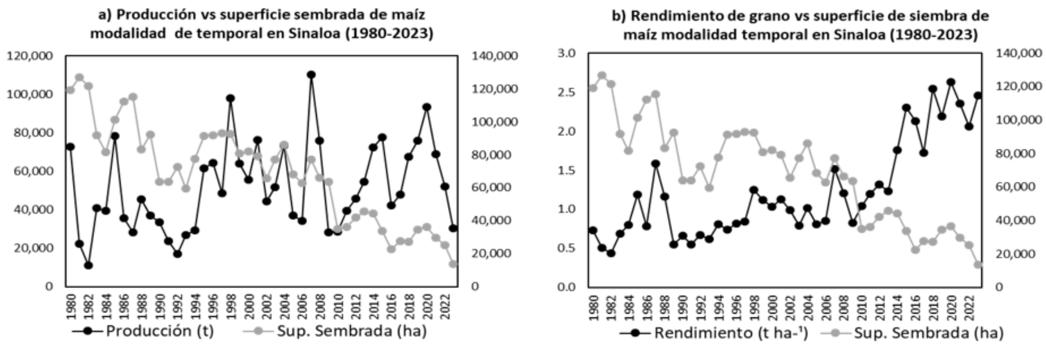
Figure 1. a) Production *vs* planted area (1980-2023); b) grain yield *vs* planted area (1980-2023). Production (t), planting area (ha), and yield (t ha^{-1}) of rainfed corn in Sinaloa during the period 1980-2023 (SIACON, 2023).



Interestingly, although the planted area had a constant reduction, production was variable (Figure 1a), with maximum production values in 2007 (110 428.8 t) and minimum values of 11 057 t in 1982. From 2020 onwards, production decreased to 30 518 t by 2023. As for the grain yield under rainfed conditions in 1980, a value of 0.72 t ha^{-1} was recorded, while for 2023, it increased to 2.46 t ha^{-1}, which contrasts with the large decrease in the sowing area (Figure 1b).

This gradual increase in yield reported in SIACON (2023) contrasts with what was declared by producers in the surveys carried out in 2024 (0.876 t ha^{-1}). The productive analysis of rainfed corn in Sinaloa highlights a considerable reduction in the planted area, prompting us to question what will happen to the conservation of native varieties, which are valuable to the local culture, in the following years. Discouraging scenarios are expected.

Various studies have reported fourteen corn breeds in Sinaloa, including Bofo, Blando de Sonora, Chapalote, Dulcillo del Noroeste, Elotero de Sinaloa, Jala, Onaveño, Reventador, Tabloncillo, Tabloncillo Perla, and Vandeño (Pineda-Hidalgo *et al*., 2013; Linares-Olguín *et al*., 2019), which represent 23% of the national racial genetic variation (Linares-Olguín *et al*., 2019).

Year after year, producers save their seeds in an artisanal way for the following season. If the reduction of the sowing area for these materials continues, it would result in a very significant loss. The primary source of food and livelihood for small producers is also at risk.

Only 22% of respondents record production costs, which range from \$5 000.00 to \$7 000.00 ha^{-1}. Rainfed corn producers who plant in the milpa system in Oaxaca, Puebla, and Veracruz reported production costs of \$6 748.00 to \$7 340.00 ha^{-1} (Sosa-Cabrera and González-Amaro, 2022). Regarding yield, producers responded that the average value was 876 kg ha^{-1}, very similar to what was obtained by Sosa-Cabrera and González-Amaro (2022), but in contrast to Lara-Ponce *et al*. (2017); Linares-Olguín *et al*. (2019); SIACON (2023), which report a production of 328 kg ha^{-1}, 2.3 t ha^{-1} and 2.46 t ha^{-1}, respectively for Sinaloa.

Among the corn varieties most commonly used in the study area are the following: Eight Carreras, Olote Colorado, Blando, Yellow Pinto, Breve San Juan, Cuarenteño, Yellow Corn, Black Corn, Chapalote and Surutato (Figure 2). The destination of their production is mainly for self-consumption and fodder (86.7%), while only 13.3% is destined for commercialization or used as an exchange with residents of nearby communities in community fairs, thus promoting a flow of plant material.

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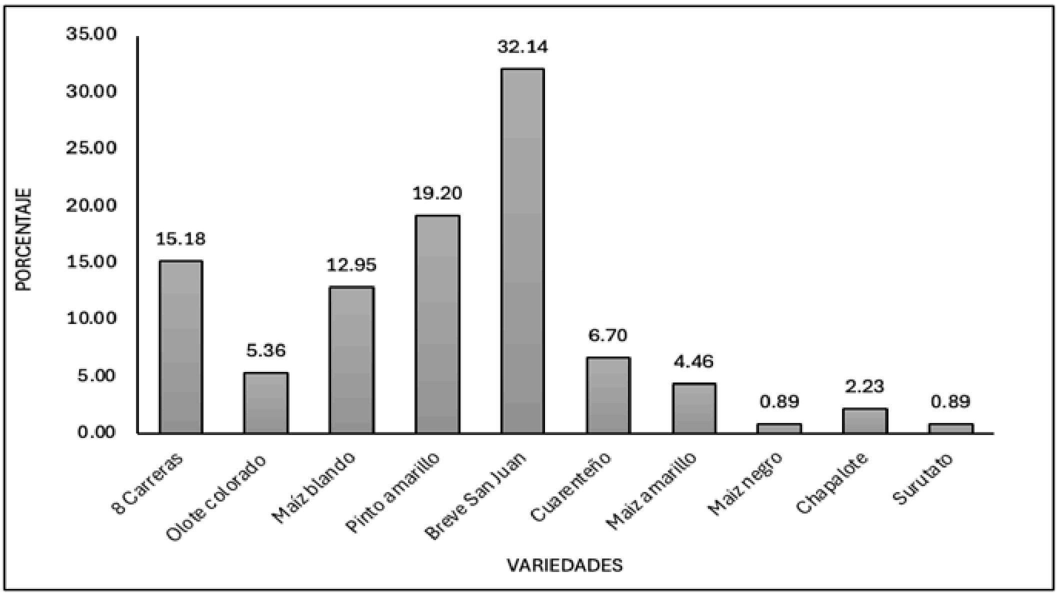
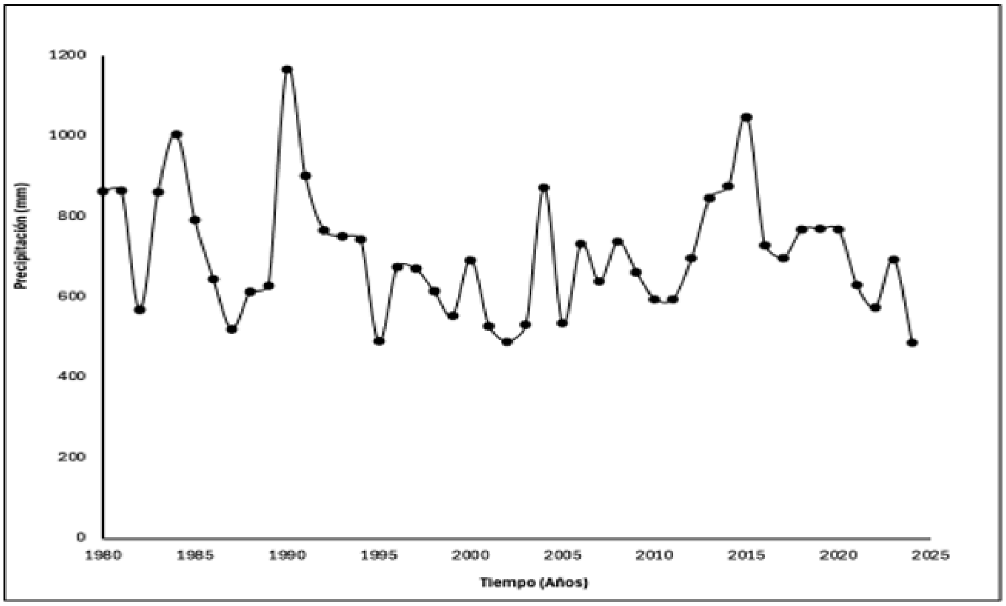
Figure 2. Varieties most commonly used for planting in rural regions of the state of Sinaloa.



Agroclimatic factors that limit production and planting area

Rainfall is key in rainfed corn production. For Sinaloa, from 1980 to 2024 (Figure 3), rainfall in the state fluctuated from 430 to 1 200 mm year^{-1}; however, since 2019 the reduction has been evident, coupled with the increase in temperatures that brings with it natural phenomena that occur in northwestern Mexico, such as 'El Niño' and anticyclonic events (CONAGUA, 2024).

Figure 3. Average annual rainfall in the state of Sinaloa from 1980 to 2024.



On the other hand, rainfall decreased from a cumulative total of 630 mm to 487 mm between 2021 and 2024. That is, 39% less than the average of the last 60 years (CONAGUA, 2024), which exacerbates conditions, particularly in these areas that depend 100% on rainfall. The aforementioned has also led to a reduction in seed conservation, causing partial to total crop losses.

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Ninety percent of producers surveyed agree that precipitation has been one of the most influential factors in the decrease in yield and corn planting area. Nevertheless, precipitation and yield are discretely correlated (R= 0.225), which may indicate that there are other relevant factors associated with rainfed corn yield. The study by Ureta *et al*. (2020) projected a discouraging scenario for Mexico by 2050, foreseeing drastic decreases in rainfall due to climate change, where the cultivation of corn under both rainfed and irrigated conditions will be severely affected. Rainfall is becoming less predictable, in terms of time and quantity, implying a great challenge for agriculture in general (Simanjuntak *et al*., 2023). Small-scale producers in the rainfed system of food production are the most vulnerable.

Sociocultural factors that limit production and planting area

Table 1 describes the producers surveyed as well as their agricultural practices. The average age of the respondents is 57 years, coinciding with what was reported by Uzcanga *et al*. (2017), who conducted an analysis of the milpa system in rural areas of the state of Yucatán. The areas surveyed in Sinaloa are characterized by the presence of the Yoreme-Mayo indigenous group, mainly concentrated in the municipalities of El Fuerte and Sinaloa de Leyva. Fifty-seven percent of the respondents identified with this group, while 10% with the Tarahumara group. Thirty-three percent did not define themselves by any ethnicity.

Table 1. Producers of native rainfed corn and agricultural practices implemented in rural mountain areas of the north of the state of Sinaloa.

Characteristics of native corn producers	
No. of producers interviewed	161
Percentage of male interviewees	62
Percentage of female interviewees	38
Average age of producers	57
Percentage of producers who speak an Indigenous language	67
Average planting area (ha)	4.95 ±0.73
Average years of planting and producing corn	20.3
Average corn production (t ha^{-1})	0.876 ±0.49
Native corn seed characteristics and exchange dynamics	
Percentage of producers using only one native corn variety	25.12
Percentage of producers alternating native corn varieties	74.88
Percentage of seed exchange practices with other communities	13.33
Percentage of producers who save their seed for the next planting cycle	86.3
Percentage of corn used for self-sustaining and fodder	86.67
Agricultural practices	
Percentage of corn planted in polyculture or “milpa” systems	87.3
Percentage of corn planted under monoculture systems	12.7
Percentage of producers using tractors for sowing	1.8
Percentage of producers who apply agrochemicals	3

These areas are characterized as low-resource areas (INEGI, 2019), where the primary activity is agriculture. One hundred percent of the respondents have an ejido land (4.95 ha on average) that they have inherited, of which they only plant 1 to 1.5 ha of corn. Most producers in the rainfed system in other rural areas of Mexico own plots of land no larger than 5 ha, which are also inherited, and only a part is allocated to planting corn in the milpa system (Cano-González and Cadena-Iñiguez, 2021).

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On the other hand, cultivation of native corn in these areas is practiced for self-sustenance, which is governed by customs that are transmitted from generation to generation. Ninety-seven percent mention not using fertilizer and pesticide inputs, mainly because their use is closely related to the purchasing power of each producer head of household. The use of these inputs results in an increase in the cost of production of at least 27% (González-Cruz *et al*., 2024).

Corn that is mainly grown in the milpa system is accompanied by beans and squash (Fonteyne *et al*., 2023). In contrast, in the surveyed area, 87.3% of producers mentioned combining native corn with beans, squash, peanuts, watermelons, or cucumbers, alternating combinations depending on their food needs and seed availability.

Finally, surveys indicate that the rural mountain areas of the state have experienced a 55% migration of their young inhabitants to the cities of the state in search of employment alternatives. This causes an erosion in the traditional knowledge and conservation of native corn. In addition, 70% of the producers surveyed mentioned that the lack of government support for inputs and fair prices has discouraged them, encouraging them to renounce their traditions and migrate in search of improving their quality of life.

One of the recurring requests (59.3%) in the surveys was for support in technification, since planting is carried out using rudimentary tools, which limits the planting area to be larger. Ibarrola-Rivas *et al*.(2020) noted that, after 2008, national government policies focused on supporting small rainfed corn producers in central and southern Mexico, leaving aside other regions with the same shortcomings and needs.

Conclusions

A significant trend of a more than 88% reduction in the planting area of rainfed corn in Sinaloa was found, contrasting with variable production and an increase in grain yield. The results position Sinaloa as a state where native corn is produced, grown in the mountain areas of the state for self-sustenance, mainly using the milpa system.

It is home to at least fourteen breeds, which are adapted to arid-dry climates, conserved and selected by small producers in the rainfed system of the rural mountain areas of the state, supporting a logic of language typical of the anthropology and culture of the region. The main factors that have triggered this scenario are the effects of climate change, mainly due to rainfall scarcity, the lack of government support, public policies, and access to technology that supports small producers, as well as the high rate of emigration of their inhabitants to urban areas.

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