Agricultural structure and municipal resilience in the Northern region of Sinaloa

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ABSTRACT

Objective. To characterize the agricultural specialization of the municipalities that compose the northern region of Sinaloa, based on their patterns of specialization and diversification in the production of crops.

Design/Methodology/Approach. The agricultural structure of the five municipalities that compose the northern region of Sinaloa was evaluated based on the specialization indices of the planted area and the value of the production of the crops registered in 2023. With these indicators, four classes were constructed that combine patterns of concentration and diversification.

Results. The analysis showed three categories of agricultural structure, resilience-oriented, moderately resilience, and vulnerable or at risk. Each one reflects different capacities to face adverse situations and sustain productive stability over time.

Limitations/ Implications of the study. The study was limited to an agricultural cycle and did not incorporate external factors such as public policies or technological changes, which constrain the construction of future scenarios.

Findings/Conclusions. The geographical concentration of production of a small number of crops generates comparative advantages and greater market share but also implies structural risks. The identification of agricultural resilience categories provides a basis for the design of differentiated strategies that strengthen regional sustainability.

Keywords: specialization index, agricultural resilience, agricultural diversification.

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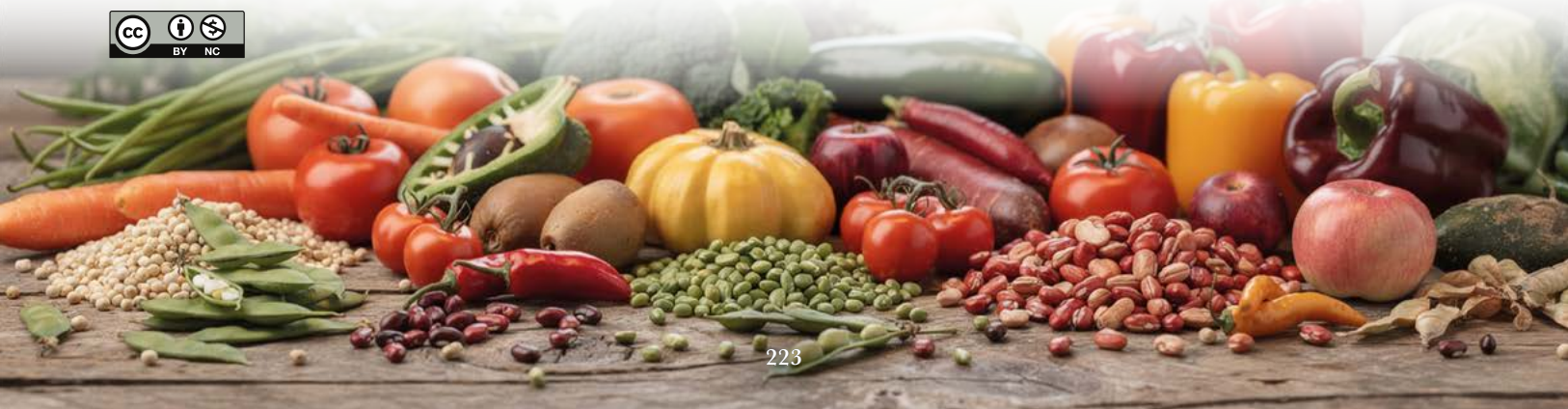
INTRODUCTION

In the current globalized and interconnected context, productive specialization is a frequent strategy for countries and regions to insert effectively into international markets (Johansson & Olaberría, 2014). Krugman (1991) explained that the geographical concentration of goods and services is the result of economies of scale, which allow companies to reduce costs and increase their efficiency.

In agriculture and agribusiness, specialization is understood as the significant production of a limited number of crops in a region. This model offers comparative advantages, since



quality improvements, as well as higher productivity and yields are achieved through technological innovation and efficient use of inputs. This allows producers to integrate into international markets (Zayas, 2018; Herment & Mignemi, 2021).

However, low agricultural diversification carries risks such as dependence on external markets and vulnerability to price fluctuations, trade policies, and tariff barriers. It also generates difficulties in adapting to changing conditions such as climate variability or reduced demand for certain products (Abson, 2019). Added to these factors are environmental impacts, including loss of biodiversity, soil degradation, pests spreading and intensive use of chemicals (Perfecto & Vandermeer, 2010; Cuadras *et al.*, 2021; Kaur *et al.*, 2024).

Studies reports also warn that excessive specialization and monocultures can lead to regional food insecurity and inequalities (FAO, 2018). Because they marginalize small producers, low-profitability crops, and other sectors, with negative effects on employment and opportunities (Campi *et al.*, 2021). Therefore, the need is posed to monitor levels of agricultural specialization in order to establish adequate limits of concentration, that at the same time promote diversified portfolios of products as a basic strategy for resilience (Klasen *et al.*, 2016).

In Mexico, agriculture is a pillar for economic development, food security, environmental conservation, and rural sustainability (Ayala *et al.*, 2012). The country ranks thirteenth in the world in food production and fifth in Latin America, but it is also the main food importer in the region (FAO & IFPRI, 2023), thus reflecting tensions between specialization and self-sufficiency.

The state of Sinaloa, in the northwest of the country, is established as one of the most productive agricultural areas, due to its level of contribution to national and international markets (SIAP, 2023). Sinaloa's leadership has been built around irrigated agriculture that has ensured high levels of productivity since the mid-20th century. This strategic role has led to this Mexican state being recognized as "the grain storehouse of Mexico" (Román & Carrillo, 2021).

Sinaloa's horticulture is characterized by its export orientation, mainly to the United States. Factors such as geographic location, climatic conditions, technological innovation, infrastructure, and trade agreements such as the North American Free Trade Agreement (NAFTA) have driven agricultural specialization (Fiscal *et al.*, 2017).

Despite this, studies on agricultural specialization in Mexico are limited and tend to focus on national or regional scales. Some analyze the production of a small group of fruits and vegetables (Cruz-Delgado *et al.*, 2013), while others focus on specific crops such as strawberries, asparagus, blueberries, green peppers or maize (Bustamante *et al.*, 2019, 2020; Portillo *et al.*, 2023; Pacheco *et al.*, 2024; Rodríguez *et al.*, 2025).

Although these studies made valuable contributions, there is still a lack of research focused on the productive structure of Sinaloa, and particularly on the northern region that is the most dynamic and productive in the state. In 2023, this area planted 72% of the 53 products grown in Sinaloa (SIAP, 2023), which confirms its strategic importance.

Hence, this analysis seeks to identify the productive profiles of Ahome, El Fuerte, Choix, Guasave and Sinaloa, the five municipalities that compose Sinaloa's northern region,

based on four classes that combine the degree of specialization, estimated as the planted area, and the value of production of crops as it was recorded in 2023. The objective of this study was to characterize the agricultural specialization of the municipalities that compose the northern region of Sinaloa, based on their patterns of specialization and diversification in the production of crops.

MATERIALS AND METHODS

For the analysis of the agricultural structure of the northern region of Sinaloa, the location index (or quotient) was used as a relative measure of the level of specialization shown by each municipality in regard to a specific crop (Castro & Fuentes, 2017). The index was calculated for both the planted area and the value of production in 2023, based on data obtained from Mexico's Agri-Food and Fisheries Information Service (SIAP, 2023).

The specialization index compares the share of crop *i* in municipality *j* with the share of the same crop in the entire state. It is obtained with the formula:

$$IEA_{ij} = \frac{C_{ij} / C_j}{C_{iE} / C_E}$$

IEA_{ij}: agricultural specialization index of *i*-crop in *j*-municipality; C_{ij}: area or value of production of the *i*-crop in the *j*-municipality; C_j: area or total value of production in the municipality. C_{iE}: area or value of production of the *i*-crop in the $_E$-state. C_E: area or total value of production in the state.

Values obtained as indicators are interpreted as follows: If IEA>1 it is understood that the municipality is overrepresented or specialized in a particular crop; If IEA<1 the municipality is underrepresented or not specialized in that crop; If IEA=1 the crop is considered as represented but the municipality is not specialized in it. The combination of the indices obtained by planted area (IEAs) and by production value (IEAv), allows us to classify the crops into four classes or types (Table 1).

Table 1. Classes of crops according to agricultural specialization indices.

Type	IEAs	IEAv	Description
I	>1	>1	Specialization in both cultivated area and production value
II	>1	<1	Specialization in cultivated area but not in production value (extensive, inefficient, or damaged crop)
III	<1	>1	Specialization in production value but not in cultivated area (intensive, efficient, or high-value crop)
IV	<1	<1	Not specialized in either aspect

IEAs: Agricultural specialization index by cultivated area. IEAv: Agricultural specialization index by production value.

RESULTS AND DISCUSSION

In 2023, the northern region of Sinaloa specialized in more than half of the crops planted (66% by planted area and 74% by value of production). In this way, it showed different patterns of agricultural activity in the five municipalities that compose the region (Table 2).

In Ahome, 87% of the crops in the region were planted (33/38). This municipality is characterized by its specialization in more than half of its crops, both in planted area (58%) and in production value (61%). In addition to presenting a diversified and specialized agricultural structure, Ahome has nine crops that exceed four or five times the state value, which indicates a high degree of agricultural specialization. However, it combines with this high specialization a diversified agricultural structure that provides the municipality with more secure economic conditions. Consequently, its agricultural structure, in addition to being competitive, implies a low level of risk when facing adverse situations such as abrupt changes in the market or other eventualities.

The opposite case to the previous one is Choix, where only 13% of the products of the northern region were planted (7/38). In addition, this municipality specialized in most of them, in terms of planted area (71%) and in more than half of crops in terms of production value (57%). Therefore, this municipality is characterized by little agricultural diversification and a very high specialization in more than half of its crops, which exceed the state value by more than 10 times. Both conditions together imply a risky situation in the face of market variations and other eventualities. This fact characterizes Choix as a vulnerable profile.

The rest of the municipalities in the region presented similar proportions in regard to the crops planted (El Fuerte, 43%; Guasave, 45% and Sinaloa, 42%). However, regarding specialization by planted area, or production value, Sinaloa (50% and 55%) and El Fuerte (52% and 48%) showed similar percentages in the two indicators. On the other hand, Guasave presented a notable difference between the two indicators, with 38% in planted area and 58% in production value, which indicates a more marked specialization in crops of high economic value.

An additional difference is that Sinaloa and El Fuerte have high and very high specialization in some crops, with values that exceed the state proportion by more than

Table 2. Agricultural specialization in municipalities according to crop number and type, planted area, and value of production in the northern region of Sinaloa (Mexico).

Municipality	Crops	Specialization		Type			
		Area	Value	I	II	III	IV
Ahome	33	19	20	19	0	1	13
Choix	7	5	4	4	1	0	2
El Fuerte	23	12	11	10	2	1	10
Guasave	24	9	14	10	0	1	13
Sinaloa	22	11	12	10	1	2	9
Northern region	38	25	28	22	2	7	7

five or 10 times. On the other hand, Guasave shows high specialization in a single crop. Therefore, although these municipalities can be considered semi-diversified and with a certain degree of specialization, they do not reach the same level of competitiveness as Ahome does.

As for the typology of municipal specialization, Ahome has more than half of the crops in type I (specialization both in area and in value), among which oats, chia, coriander, sunflower, vegetables, potato seed, wheat seed and marigolds are notable for their high specialization (Table 2). However, more than a third of the products sown are underrepresented (type IV) and sorghum is only overrepresented in its value of production (type III). This product can be intensive or have a certain efficiency in terms of the relationship between the area and the value of production shown in the different municipalities (Table 3).

The municipality of Choix has more than half of its crops in type I (sesame, peanut, watermelon, grassland and rangeland plants), although with very high specialization, since they exceed by more than 15 times the state proportion in planted area, and by more than 50 times the value of production, especially the cultivation of grassland and rangeland plants. These products can exhibit high efficiency depending on the surface-to-value ratio. The rest of the crops were classified as types II and IV, but two of those (maize and sorghum) presented total losses due unforseen contingencies. Choix's production was concentrated on efficient crops that gave this municipality a competitive advantage and a good position in the market. However, its poorly diversified agricultural structure exposes Choix to risks in the face of economic fluctuations or environmental contingencies. In addition to threatening the sustainability of the agricultural sector due to the agroecological deterioration that low diversification generates.

The municipality of Sinaloa has 45% of the products in type I: safflower, green peas, beans, chickpeas, potatoes, fodder sorghum, sorghum grain and wheat grain, chickpea seed and cauliflower. Among which the last two are outstanding for the high specialization in surface area, and very high in value of production. Due to the relationship between both variables, those latter could be considered efficient crops, along with fodder sorghum. The municipality has nine products in type IV (non-specialized), as well as peanuts and green tomatoes in type III. In addition to sesame seeds (type II) with a very low index in production value compared to that of the planted area, perhaps due to some eventuality, since this behavior is atypical in the region.

El Fuerte has 42% of its products in type I (sesame, peanut, pumpkin, green peas, green beans, maize ear —sweet corn—, beans, potatoes, sorghum grain, grassland and rangeland plants). Among these, green peas are outstanding for their very high specialization, both in surface area and in production value. Pumpkin and green beans also are outstanding, with an atypical relationship between the indicators (5.17 *vs.* 2.91 and 4.40 *vs.* 1.20, respectively). This suggests inefficient crops or the possible existence of losses; a situation similar to that observed in green pepper and zucchini, both classified as type II. The municipality has 46% of its crops in type IV (non-specialized), whereas safflower is classified in type III, as a crop with a certain degree of efficiency.

The municipality of Guasave concentrates more than half of the crops in type IV (non-specialized), in addition to 38% of its products classified as type I (green peas, cabbage,

Table 3. Agricultural specialization of municipalities in the northern region of Sinaloa (Mexico) based on the indices estimated per crop.

Crop	Ahome		Choix		El Fuerte		Guasave		Sinaloa	
	IEAs	IEAv	IEAs	IEAv	IEAs	IEAv	IEAs	IEAv	IEAs	IEAv
Sesame	1.94	1.96	15.86	57.20	1.57	1.70	0.00	0.00	2.14	0.24
Oat grain	4.58	5.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eggplant	0.13	0.03	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00
Peanut	0.28	0.16	20.74	242.21	1.52	1.87	0.00	0.00	0.78	1.09
Zucchini	0.92	0.91	0.00	0.00	0.16	0.06	0.95	0.85	0.37	0.43
Pumpkin	2.43	3.51	0.00	0.00	5.17	2.92	0.59	0.61	0.00	0.00
Safflower	0.35	0.45	0.00	0.00	0.61	1.09	0.34	0.52	2.49	3.78
Onion	0.22	0.16	0.00	0.00	0.80	0.16	0.51	0.64	0.60	0.43
Chia	4.58	5.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green peas	0.00	0.00	0.00	0.00	14.03	15.76	1.94	2.29	1.15	1.66
Green pepper	0.29	0.60	0.00	0.00	1.22	0.73	0.28	0.40	0.48	0.42
Coriander	4.58	5.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cabbage	0.00	0.00	0.00	0.00	0.00	0.00	2.32	4.65	0.00	0.00
Cauliflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.36	12.84
Green bean	0.17	0.06	0.00	0.00	4.40	1.20	1.90	1.94	0.45	0.46
Maize ear (sweet corn)	3.36	4.05	0.00	0.00	3.70	3.42	0.39	0.35	0.20	0.23
Strawberry	4.14	2.99	0.00	0.00	0.00	0.00	0.51	2.43	0.00	0.00
Bean	1.50	1.66	0.07	0.14	1.48	1.75	1.83	1.98	1.40	1.85
Chickpea grain	0.14	0.19	0.00	0.00	0.04	0.06	1.40	1.71	2.53	3.14
Sunflower	4.58	5.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vegetables	4.58	5.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maize grain	0.80	0.94	0.04	0.00	0.84	0.99	1.04	1.18	0.71	0.97
Potato	2.42	2.64	0.00	0.00	1.83	2.26	1.27	1.47	1.54	2.12
Grassland and rangeland plants	0.00	0.00	50.83	236.35	2.79	2.12	0.00	0.00	0.00	0.00
Cucumber	0.38	0.13	0.00	0.00	0.14	0.04	0.31	0.30	0.21	0.15
Watermelon	1.55	1.38	21.52	52.54	0.47	0.40	0.28	0.34	0.08	0.09
Bean seed	1.35	1.03	0.00	0.00	0.00	0.00	3.69	4.65	0.00	0.00
Chickpea seed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.36	12.84
Maize seed	2.40	2.28	0.00	0.00	0.11	0.15	0.06	0.10	0.00	0.00
Potato seed	4.58	5.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wheat seed	4.58	5.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green fodder sorghum	0.08	0.14	0.00	0.00	0.30	0.51	0.00	0.00	3.89	6.23
Sorghum grain	0.84	1.44	1.61	0.00	1.88	2.25	0.96	1.54	1.41	1.43
Soy bean	2.73	2.97	0.00	0.00	0.00	0.00	0.31	0.30	0.00	0.00
Red tomato	0.07	0.04	0.00	0.00	2.55	0.94	0.51	0.37	0.73	0.38
Green tomato (tomatillo)	0.79	0.53	0.00	0.00	0.81	0.65	1.06	1.31	0.92	1.51
Wheat grain	3.16	3.57	0.00	0.00	0.62	0.54	0.45	0.51	1.11	1.45
MX marigold (cempasuchil)	4.58	5.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

IEAs: agricultural specialization index by cultivated area. IEAv: agricultural specialization index by production value. Mexican marigold is the native species *Tagetes erecta* or Cempohualxochitl (Nahuatl) that means "20-flowers flower"; It is called cempasuchil in Mexico.

green beans, beans, chickpeas, maize, potatoes, beans and green tomatoes). Of these, cabbage and beans are outstanding in the value of production (4.65). Cabbage also presents a relationship between the indicators that shows a certain efficiency in cultivation; similar to strawberries and sorghum, both classified in type III.

These latter three municipalities have few products that are efficient in terms of production value, and are highly specialized in a small number of products. For this reason, these municipalities do not reach the level of positioning presented by the other two profiles; however, their semi-diversified structure gives them relative security in the face of disruptive events. Therefore, these municipalities are defined by the pattern we called moderate resilience.

This analytical exercise corroborates the prominence of the northern region of the state of Sinaloa and characterizes their production profiles or patterns. This study not only allowed us to assess the current agricultural condition in the region, but it is also useful to establish strategies towards sustainability, conservation and food security.

CONCLUSIONS

The combination of the agricultural specialization indices, by planted area and value of production, allowed us the identification of three municipal patterns or profiles of production in Sinaloa that represent different opportunities and risks. The resilient pattern corresponds to Ahome, which is specialized in a wide variety of crops that provides security in the face of market changes. The vulnerable pattern is characteristic of Choix, with few types of crops and very high specialization in high-value production. The third profile, moderate resilience, corresponds to the municipalities of Sinaloa, El Fuerte and Guasave, which allocate a significant area to few crops, and also maintain a certain variety in types of crops and are specialized in a number of them.

The analysis of agricultural specialization corroborated the prominence of the northern region of Sinaloa, as well as the existence of different patterns or profiles of production within that region. This implies specific conditions of advantage or disadvantage per municipality in the face of possible contingencies or uncertain scenarios. This study not only allows us to know the current situation but is also useful to establish strategies aimed at strengthening the resilience and sustainability of the regional agricultural sector, towards the conservation of natural resources and food security in the long term.

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