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Profitability of Corn (*Zea mays* L.) Grown in *Milpa* Production Systems in Oaxaca, Puebla, and Veracruz, Mexico

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ABSTRACT

Objective: To compare the profitability of corn cultivation under the *milpa* production system in Oaxaca, Puebla, and Veracruz.

Methodology: Ninety-one producers, from Villa de Zaachila, Oaxaca, Chalchicomula de Sesma, Puebla, and Tequila, Veracruz, Mexico, were interviewed about corn production in *milpa* production systems. Average yield per hectare, costs, selling price, and total income were compared and the Cost Benefit Ratio (CBR) of the *milpas* of each municipality was analyzed.

Results: In Villa de Zaachila, corn production is carried out in a modern agriculture system with a $13,650 ha^{-1} total production costs, a 2,257 kg ha^{-1} yield, a $23,429.27 ha^{-1} total income, and a 1.72 CBR. The producers of Chalchicomula de Sesma use a traditional agriculture system and the production is sold to intermediaries, with a $12,380 ha^{-1} total cost, a 2,456 kg ha^{-1} yield, a $12,280.00 ha^{-1} total income, and a 0.99 CBR. In Tequila, a subsistence agriculture is used, with a $7,350 ha^{-1} total production cost, a 964 kg ha^{-1} yield, a $6,748.00 ha^{-1} total income, and a 0.92 CBR.

Study Limitations: The data were taken from an exploratory sample, limited in time and space. Non-sampled versions or productive practices could have been omitted, when technical-economic specificities are different from those shown in this study.

Conclusions: The contrasting modifications in the structure, function, and logic of the *milpa* (2020-2021 cycle) resulted in a profitable agroecosystem in Villa de Zaachila; however, Chalchicomula de Sesma and Tequila had a non-profitable cycle.

Keywords: Traditional agriculture, Rural development, Agricultural Economics, Farming.

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INTRODUCTION

In Mexico, corn (*Zea mays* L.) is fundamental to the culinary and cultural traditions of the rural society (Leyva *et al.*, 2020; Novotny *et al.*, 2021). The acceptance and reproduction of this crop is based on the diversification of its use and the adaptation of the 68 races to their

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uses and the different weather conditions (Caballero, Córdova, and López, 2019). Only 22% of the arable land in Mexico can be considered as high-quality land with irrigation, while 78% of the arable land is used for rainfed agriculture. In the latter area, corn crops are grown under *milpa* production systems. Corn is the main product of traditional agriculture (Turrent *et al*., 2014; Rodríguez *et al*., 2020; López *et al*., 2021).

The *milpa* is a complex system with synergies between its plants and weeds, such as tolerance, protection, nutrient fixation, and pest management, among others (Caballero and Cortés, 2001; Eyzaguirre and Linares, 2004). In practice, these agroecosystems are dynamic and adaptable to such an extent that they have currently diversified from polycultures to monocultures to satisfy the soil, market, or destination of the production requirements (Guzmán, 2016; Sosa and González, 2021).

In this scenario, analyzing the different productive aspects of the said agroecosystem's regional adaptations is fundamental. This analysis compares those regional adaptations with the adaptations, improvement points, and agronomic optimization required to increase the agricultural yields, according to the requirements of the farmers and their ethno-biological uses.

Consequently, the objective of this study was to compare the yield of corn crops grown under *milpa* production systems, in three different scenarios. The productive versions of this agroecosystem were compared based on the data from the Valles Centrales in Oaxaca, Valle de Serdán in Puebla, and Zongolica, in Veracruz. The hypothesis was that —according to the dynamism of the *milpa* as an adapted agricultural practice-contrasting modifications would be found in the structure, function, and logic of the most profitable production model for each context.

MATERIALS AND METHODS

This research was developed within the framework of the Proyecto Nacional de Investigación e Incidencia "Estudio agroecológico del sistema *milpa* en Veracruz, Oaxaca y Puebla" organized by the Consejo Nacional de Ciencia y Tecnología (CONACyT). As contrasting measure, the study area included municipalities with different degrees of technology innovation in the *milpa* and contradictory environmental conditions, as well as recent adaptations of the agroecosystem (INEGI, 1995; INEGI, 1997; INEGI, 2009; SEDESOL, 2012; SEGOB Veracruz, 2019). The municipalities of Villa de Zaachila, Chalchicomula de Sesma, and Tequila were chosen based on these criteria (Table 1).

An exploratory interview tool was designed. This tool included specific data of the *milpa* production system, such as: a) size and ownership of the plot; b) sowing and crop association data; c) tools and inclusion of technology; d) pests and diseases; e) harvest, treatment, and destination of the production.

From december 2020 to april 2021, producers linked to *milpa* production systems were interviewed about their productive characteristics. The interviewees were divided as follows: 25 from the Villa de Zaachila municipality, in the Valles Centrales region, Oaxaca; 25 from the Chalchicomula de Sesma municipality, Puebla, in Región III Valle de Serdán (Ciudad Serdán); and 41 from the Tequila municipality in the Las Montañas

Table 1. Comparison of the study areas: Villa de Zaachila, Chalchicomula de Sesma, and Tequila.

	Villa de Zaachila, Valles Centrales, Oaxaca	**Chalchicomula de Sesma, Valle de Serdán, Puebla**	**Tequila, Las Montañas, Veracruz**
Physiographic province	Southern Sierra Madre, sierras, and valleys of Oaxaca sub province	Neovolcanix Axis, lakes and volcanos of Anáhuac sub province	Southern Sierra Madre, Eastern sierras sub province
Weather	BS1h'(h)w(w)i'gw"	Cb(W0) i'g	(A)C(W2) ig
Soils	Vertosols, regosols, and leptosols	Regosols	Luvisols
Type of agriculture	Modern	Traditional	Subsistence

region (Zongolica), Veracruz. The participants were chosen based on the following factors: a) being a member of a farmer family, b) living in the chosen communities, and c) growing native corn crops in monoculture or association.

The data from the interviews were analyzed as a whole, in order to create a hypothetic plot per each group of producers. The values of costs and benefits were analyzed in Mexican pesos (MXN). Each analyzed municipality produced 1 ha of corn during the 2020-2021 period. To calculate the yield, the following basic economic variables were determined:

a) Total costs (TC). The productive costs were estimated according to the work stage: 1) land preparation, 2) sowing, 3) fertilization, 4) pest and disease control, 5) weed control, 6) support labors, and 7) harvest. The following formula was used to calculate the TC calculus:

$$TC = FC + VC$$

b) Fixed costs (FC). Constant costs that do not change in relation with the production volume.
c) Variable costs (VC). Costs that are modified in relation with production volume.
d) Total income (TI). Income that could be obtained when the whole harvest is sold (Q) at the average price of the region (P).

$$TI = P * Q$$

e) Sales revenue (SR). The TI formula was considered, but it was adjusted to the mean proportion of the harvest that is sold in each study area.
f) Self-consumption opportunity cost (OC). The SR and Self-Consumption Revenue were established, and the Significant Difference Method was used to determine the Opportunity Cost.

$$Opportunity\ Cost = Total\ income - Self - Consumption\ Revenue$$

g) Cost-Benefit Ratio (CBR). This value is obtained dividing the Net Present Benefit Values (NPBV) by the Total Cost Present Value (TCPV). A positive yield factor (higher than 1) result in a profitable CBR.

$$CBR = \frac{NPBV}{TCPV}$$

RESULTS AND DISCUSSION

Villa de Zaachila, Oaxaca

According to the survey conducted in this research, the total average size of the production units in Villa de Zaachila is 2.16 ha and 65% of the interviewees owned their production unit. Fourteen different crops or soil uses were mentioned and corn production accounts for 68.1% of the arable land. For the purposes of this research, corn production in Villa de Zaachila is considered as a modern agricultural system.

The farmers in the region that have irrigation and consequently can produce two cycles per year amount to 58.3% of the local producers. The crops sown were improved corn (53.8%) and bolita corn, associated to the following crops: crookneck squash (*Cucurbita moschata*), acorn squash (*Cucurbita pepo*), silver-seed gourd (*Cucubita argyrosperma*), and bean (*Phaseolus vulgaris*). Eighty-one percent of the interviewees use a tractor; 80.7% use chemical fertilization methods; 57.7% use chemical products to control pests and diseases; and 38.46% use mainly yokes to control the weed. Table 2 shows that the total cost of corn production for the 2020-2021 cycle in Villa de Zaachila amounted to $13,650.00 ha^{-1}.

The average harvest (Q) reached 2,257 kg ha^{-1} and the production is mainly destined for sales, forage, and family consumption. The selling price (P) amounted to $35.00 per bushel (approximately 3.5 kg), which means that the price was $10.00 kg^{-1}. The TI was $23,429.27 ha^{-1}; however, only a fraction of the harvest is sold. In average, this fraction amounted to 1,896 kg ha^{-1}, which means that the SR of the 2020-2021 cycle was just $18,963.64 ha^{-1}. Table 3 shows that the OC reached $4,465.63 ha^{-1}.

Table 2. Total cost of the corn production in Villa de Zaachila, for the 2020-2021 cycle.

Activity	Fixed Costs	Variable Costs	Cost per Activity
Land preparation ($ ha^{-1})	1,050.00	2,700.00	3,750.00
Sowing ($ ha^{-1})	1,700.00	2,200.00	3,900.00
Fertilization ($ ha^{-1})	0.00	1,420.00	1,420.00
Pest and disease control ($ ha^{-1})	400.00	380.00	780.00
Weed control ($ ha^{-1})	800.00	0.00	800.00
Support labor ($ ha^{-1})	0.00	0.00	0.00
Harvest ($ ha^{-1})	3,000.00	0.00	3,000.00
TOTAL ($ ha^{-1})	6,950.00	6,700.00	13,650.00

Table 3. Corn production Income in Villa de Zaachila for the 2020-2021 cycle.

Harvested Corn (Q)	Selling Price (P)	Total Income (TI)	Average Amount of Sold Corn	Sale Revenue (SR)	Self-Consumption Opportunity Cost (OC)
2,343 kg ha^{-1}	10.00 $ kg^{-1}	23,429.27 $ ha^{-1}	1,896 kg ha^{-1}	18,963.64 $ ha^{-1}	4,465.63 $ ha^{-1}

Chalchicomula de Sesma, Puebla

In the communities of San Francisco Cuautlancingo and Santa Cruz Veladero, Chalchicomula de Sesma municipality, Región Valle de Serdán, the total average size of the production units is 4.98 ha and 78% of the interviewees own their production units. Nine different crops were mentioned; corn is sown in 52.37% of the arable land. For the purposes of this research, corn production in Chalchicomula de Serma is considered as traditional agriculture.

All the interviewees produce only one crop cycle per year. The corn varieties grown in this area belong to the Chalqueño race. This corn is grown in association with broad bean (*Vicia faba*), bean, runner bean (*Phaseolus coccineus*), and pea (*Pisum sativum*). Eighty percent of the interviewees use a tractor; 96% use one or several chemical fertilization methods; and 56% use chemical products to control pests and diseases. Sixty percent of the interviewees control weeds mainly by hand and all producers harvest using handpicking methods. Table 4 shows that the total cost of corn production in Chalchicomula de Sesma for the 2020-2021 cycle amounted to \$12,380.00 ha^{-1}.

The average harvest (Q) reached 2,456 kg ha^{-1} and 92% of the harvest is mainly sold to intermediaries. The selling price (P) is \$5.00 kg^{-1}. The TI amounted to \$12,280.00 ha^{-1}; however, only a fraction of the harvest is sold. In average, this fraction amounted to 2,128 kg ha^{-1}, which means that the SR of the 2020-2021 cycle was just \$10,640.00 ha^{-1}. Consequently, the OC for that period only amounted to \$1,640.00 ha^{-1} (Table 5).

Table 4. Total cost of corn production in Chalchicomula de Sesma, for the 2020-2021 cycle.

Activity (\$ ha^{-1})	Fixed Costs	Variable Costs	Cost per Activity
Land preparation	1,200.00	0.00	1,200.00
Sowing	2,450.00	0.00	2,450.00
Fertilization	900.00	1,260.00	2,160.00
Pest and disease control	900.00	970.00	1,870.00
Weed control	450.00	0.00	450.00
Support labor	1,800.00	0.00	1,800.00
Harvest	2,450.00	0.00	2,450.00
TOTAL	10,150.00	2,230.00	12,380.00

Table 5. Corn production income in Chalchicomula de Sesma for the 2020-2021 cycle.

Harvested Corn (Q)	Selling Price (P)	Total Income (TI)	Average Amount of Sold Corn	Sales Revenue (SR)	Self-consumption Opportunity Cost (OC)
2,456 kg ha^{-1}	5.00 \$ kg^{-1}	12,280.00 \$ ha^{-1}	2,128 kg ha^{-1}	10,640.00 \$ ha^{-1}	1,640.00 \$ ha^{-1}

Tequila, Veracruz

According to this research, the total average size of the production units in the municipality of Tequila, Veracruz is 0.56 ha and 64% of the interviewees own the plot of the *milpa*. However, in many cases, the plot used for the *milpa* is rented. Only 6 crops were mentioned by the interviewees and corn represented 55.2% of the arable land. For the purposes of this research, corn production in Tequila is considered as subsistence agriculture.

The corn grown in this area belongs to the Coscomatepec race and it grows in association with bean, runner bean, squash, *cempasúchil* (*Tagetes erecta*), and smooth pigweed (*Amaranthus hybridus*) (grown). Chemical fertilization methods are used by 58.5% of the interviewees; most of them do not control pest or weeds. All of them harvest using handpicking methods. Table 6 shows that the total cost of corn production in Tequila for the 2020-2021 cycle amounted to \$7,350.00 ha^{-1}.

The average harvest (Q) reached 964 kg ha^{-1}; 100% of the harvest is used for self-consumption. The estimated selling price (P) in this study is \$7.00 kg^{-1}. The estimated TI is \$6,748.00 ha^{-1}; however, the harvest is not sold, which means that the sales revenue (SR) for the 2020-2021 cycle was \$0.00, leaving the OC at only \$6,748.00 ha^{-1} (Table 7).

Table 6. Total cost of the corn production in Tequila for the 2020-2021 cycle.

Activity (\$ ha^{-1})	Fixed Costs	Variable Costs	Cost per Activity
Land preparation	2,390.00	0.00	2,390.00
Sowing	880.00	0.00	880.00
Fertilization	520.00	980.00	1,500.00
Pest and disease control	130.00	0.00	130.00
Weed control	650.00	0.00	650.00
Support labor	780.00	0.00	780.00
Harvest	1,020.00	0.00	1,020.00
TOTAL	6,370.00	2,230.00	7,350.00

Table 7. Corn production income in Tequila for the 2020-2021 cycle.

Harvested Corn (Q)	Selling Price (P)	Total Income (TI)	Average Amount of Sold Corn	Sales Revenue (SR)	Self-Consumption Opportunity Cost (OC)
964 kg ha^{-1}	7.00 \$ kg^{-1}	6,748.00 \$ ha^{-1}	0 kg ha^{-1}	0.00 \$ ha^{-1}	6,748.00 \$ ha^{-1}

Profitability Analysis

Considering the productive data of corn grown under *milpa* production systems in each study area, an important difference in the CBR obtained was recoded. This difference matches the productive, technological, investment, and priority capacities of each farmer group that develops every version of the agroecosystem in question (Table 8).

For example, the modern agriculture production system used in Villa de Zaachila, Oaxaca had the highest material and labor investment (\$13,650.00 ha^{-1}); nevertheless, the said expenditure was compensated by the economic benefits (\$23,429.27 ha^{-1}). This amount doubles the initial investment.

Meanwhile, in the scenarios with highest limitations regarding investment, installed capacities, and availability of materials, the productive results were not favorable. Regarding traditional agriculture in Chalchicomula, the total cost of investment (\$12,380.00 ha^{-1}) was similar to the investment of the modern agriculture system, as a result of the use of machinery, labor, and even a minimum amount of agricultural material. Consequently, a considerable production volume was obtained (2,456 kg ha^{-1}). However, the uneven commercial relations with the intermediaries favored low selling prices, reducing their incomes (\$12,280.00 ha^{-1}).

Finally, the case of the subsistence agriculture in Tequila shows a completely different view, as a consequence of the importance given to coffee as main source of income, replacing the *milpa* production system which becomes a complementary and specific self-consumption activity. Therefore, the *milpa* is only an afterthought, taking up "spare" materials and labor from the coffee crops. This situation accounts for the small areas used (0.56 ha) and the low investment spent (\$7,350.00 ha^{-1}) in the *milpa*.

In synthesis, analyzing the productive nuances of the production systems is fundamental. However, this analysis must simultaneously take into account the agricultural, ecological, social, cultural, political, and economy aspects of the regional adaptations. Subsequently, these adaptations must be compared in order to determine their optimal modifications, aimed to the economic benefit of farmer families. These adaptations must also enable the growth of corn crops within an economic model, despite harsh conditions —such as production costs, uneven commercial relations, and low installed capacity, among others.

Table 8. Investment and profit of 1 ha of corn in Villa de Zaachila, Chalchicomula de Sesma, and Tequila for the 2020-2021 cycle.

Concept (\$ ha^{-1})	Villa de Zaachila	Chalchicomula de Sesma	Tequila
Total Production Cost	13,650.00	12,380.0	7,350.00
Yield	2,257	2,456	964
Selling Price	10.00	5.00	7.00
Total Income	23,429.27	12,280.00	6,748.00
Gross Profit	9,779.27	−100.00	−602.00
CBR	1.72	0.99	0.92

The scenarios described above show the diversity of the ecosystems, weather, human resources, capital availability, social relationships, and exploitation logics, regarding corn grown in Mexico, whether in association or as monoculture. Unsurprisingly, models with highest investment, labor availability, and technologies also achieve the highest harvest profits, while the traditional systems which operate in uneven contexts do not only fail to obtain profits, but also compromise food safety.

The *milpa* production system is the guiding principle of the farming agriculture production systems. It is based on the pluriactivity and the multiple use of natural resources, in order to benefit the families and the communities. To unite the said factors, the *milpa* constantly undergoes adaptations, modifications, and substitution of its constituting elements, with the aim to provide the highest possible benefits, even under low or null profit scenarios of its main crop (corn).

CONCLUSIONS

The contrasting modifications in the structure, function, and logic of the *milpa* for the 2020-2021 cycle resulted in a profitable agroecosystem in Villa de Zaachila; however, this system was not profitable in Chalchicomula de Sesma and Tequila. The socioecological factors surrounding the *milpa* are determinant to identify modifications in structure (size, density, crop association), function (the relationship of corn with other associated crops, weeds, and insects) and logic (trade or self-consumption). Nevertheless, these modifications in the *milpa* did not necessarily result in the highest profitability model for an exclusive corn production model for each context.

The result of this study back up the claim that farmers' logic is the basis of corn cultivation, including work, mutual help, experience, deep-rooted connection with the land, food, traditions, family organization, daily life, conservation practices, agricultural lore, and customs. Therefore, rather than provide a monetized economic benefit, corn production meets daily consumption needs. The *milpa* must be understood beyond the plot concept. The *milpa* is a paradigm of the farmers' life and organization, which involves technological learning and innovation, and it goes against the capital tide: *milpa* is community.

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