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Article

Economic impact of the use of agroecological innovations by small corn farmers in Tlaxcala and Oaxaca

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Abstract

The agroecological transition of agricultural production is a medium-term process, so estimating the effect of using agroecological innovations through economic indicators can contribute to the identification of areas of opportunity and decision-making within the framework of this new paradigm. The objective was to estimate the economic effect of the use of agroecological innovations by small rainfed corn producers in Tlaxcala and Oaxaca, through economic indicators, during 2020 and 2021. The sample was non-probabilistic and aimed at 10 corn producers: five producers from Tlaxcala (G1) and five producers from Oaxaca (G2). The results showed that the groups are similar in their social and productive characteristics, they only differed (p< 0.05) in agricultural area. Three indicators that measure the economic effect of the use of technologies were obtained: change in production cost (CPC), change in yield (CY), and change in the cost of agrochemical use (CCAU). The CPC ranged from -3.1 to 14.6% for G1 and from -4.6 to 27.7% for G2; the CY was 12.8 and 6.8% for G1 and G2, respectively, and the CCAU from -15.6 to 2.2% for G1 and from -15.5 to 4.8% for G2. Obtaining the indicators can make it possible to identify producers with more sustainable food systems, analyze their components, and generate recommendations for replicating these systems.

Keywords:

bioinputs, corn, peasant agriculture.

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Introduction

The contribution of peasant agriculture to food security in the midst of climate change scenarios and economic and energy crises led to the concepts of food sovereignty and agroecologically based production systems gaining attention (Altieri *et al*., 2012). Thus, in Latin America, there has been a promotion of processes of transition and conversion from conventional agricultural production systems to agroecological production systems, which include agroecological practices and even, as stated by Cevallos *et al*. (2019), a model for the analysis of the complex relationships that occur between the ecosystem and cultures (socio-ecological system).

The sustainable management of agroecosystems from agroecology proposes the replacement of input technology with process technologies, in which locally adapted knowledge and various agronomic management practices play an interesting role (Bonaudo *et al*., 2014). Altieri and Nicholls (2007) point out that the conversion from conventional production systems, characterized by high-input managed monocultures, to diversified low-input systems is based on two agroecological pillars: improving soil quality and diversifying habitat. In this sense, agroecology incorporates the concepts of stability, resilience, and adaptability into agriculture in addition to those currently in force on productivity, efficiency, and effectiveness in production (Gutiérrez *et al*., 2008).

This approach has been taken up in Mexico because, since 2020, the 'production for well-being (PfW) program' was implemented under an agroecological approach (DOF, December 29, 2023). Food systems assessments use traditional economic indicators, such as benefit-cost ratio and project financial evaluation indicators (Silva-Cassani *et al*., 2022). A study on sustainability applied to coffee found that, despite their importance, socioeconomic indicators were reported less frequently (4.3%) than those of ecosystem services (57.2%) and biodiversity (35.6%) (Teixeira *et al*., 2022). The lack of studies assessing the impacts of diversification on input use, socioeconomic factors, and resilience is also observed in other types of agrifood systems (Heckwolf *et al*., 2021).

Thus, there is a limited existence of economic indicators to evaluate the changes caused by the use of agroecological technologies; that is, how to evaluate the economic impact of the use of agroecological technologies with small producers? Given this, the objective was to estimate the economic effect of the use of agroecological innovations by small rainfed corn producers in Tlaxcala and Oaxaca, through economic indicators, during 2020 and 2021.

Materials and methods

Location of the study area

The study was conducted in two municipalities in the state of Tlaxcala and Oaxaca. The municipality of Españita, Tlaxcala, has an altitude of 2 646 m and is located at the following geographical coordinates: latitude 19.4617, longitude-98.4239. North latitude 19° 27' 42" and west longitude 98° 25' 26" (INEGI, 2018). The municipality of San Juan Cotzocón is located in the Sierra Norte Region and in the Mixe District of Oaxaca located in the northeast of the state, its extreme geographical coordinates are 17° 01' - 17° 37' north latitude and 95° 07' - 95° 51' west longitude, and its altitude ranges from 0 to 1 200 m (INEGI, 2016).

Sample selection

The sample consisted of 10 small rainfed corn production units; five located in Tlaxcala in the municipality of Españita (G1) and five in Oaxaca, municipality of San Juan Cotzocón (G2). The selection was non-probabilistic and directed (Abascal and Grande, 2005). Producers who were beneficiaries of the PfW were selected using the following criteria: 1) that they participated in the PfW; 2) that they used at least one agroecological practice in the current cycle and 3) that they were willing to provide information on corn production costs.

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Instrument used and sources of information

The instrument used to collect the information was a questionnaire, which was applied in February 2022 for G1 and in April of the same year for G2. The questionnaire was structured in three sections: 1) identification of the producer (age and schooling); 2) corn production costs (costs in land preparation, sowing, fertilization, cultural work, pest and disease control, harvesting, and miscellaneous costs) for the current cycle (2021) and for the previous homologous cycle (2020) and 3) production data (sown area, yield, and sale price of the crop).

Estimation of variables and economic indicators

The indicators were obtained with information on three variables: total production costs, costs of agrochemical use, and yield per hectare for two corn production cycles (2020 and 2021). This makes it possible to estimate the indicators that measure the economic effects of the use of agroecological innovations by the producer: change in production cost (CPC), change in yield (CY), and change in cost of agrochemical use (CCAU). Production costs for 2020 and 2021 were updated with the national producer price index (INPP, for its initialism in Spanish) for grain corn (INEGI, 2023), so the results are expressed in 2022 Mexican pesos. The formula for obtaining each indicator is described below.

Change in production cost per hectare (CPC)

CPC= (CCC-CPHC) / CPHC)*100. Where: CCC= production cost of the current cycle per hectare with agroecological practice and CPHC= production cost of the previous homologous cycle per hectare.

Change in yield per hectare (CY)

CY= (YCC-YPHC) / YPHC)*100. Where: YCC= yield of the current cycle per hectare with agroecological practice and YPHC= yield of the previous homologous cycle per hectare.

Change in the cost of agrochemical use per hectare (CCAU)

CCAU= (PCCC-PCPHC)*100. Where: PCCC= percentage of the cost per hectare of the current cycle destined for the acquisition of agrochemicals and PCPHC= percentage of the cost of agrochemicals of the previous homologous cycle per hectare.

The information was captured in the Excel program (2016) and its statistical analysis was carried out with the Minitab® program version 16 (2021). Subsequently, the normality test was performed by establishing the following null hypothesis, Ho: the sample comes from a normal distribution *versus* H1: the sample does not come from a normal distribution. To carry out the test, the Kolmogorov-Smirnov (KS) test and the Ryan-Joiner (RJ) test similar to the Shapiro-Wilk test were applied (Porras, 2016). The p-value> 0.05; therefore, parametric statistics were used for the analysis of the data.

Results and discussion

Hypothesis tests were performed for the six variables analyzed. Where: p> 0.05 (age KS 0.198 and p> 0.15; area RJ 0.949 and p> 0.1; costs 2021 KS 0.173 and p> 0.15, costs 2020 KS 0.16 and p> 0.15, yield 2021 KS 0.235 and p> 0.117, yield 2020 KS 0.207 and p> 0.15). In this way, Ho is not rejected and it can be pointed out that the normal distribution fits the sample data well.

Sample characterization

The G1 producers had better levels of schooling: two of them have a technical bachelor's degree (one producer has completed it and the other has not completed it), one has studies at the high school level, one producer only has elementary education, and the other has no level of education at all. In contrast, the five producers of the G2 have studies at the elementary level.

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Both groups of producers are similar in terms of age (56.8 ±13.3 years for G1 and 58.8 ±4.4 for G2). The production costs of 2021 updated to 2022 values were 13 thousand pesos for both groups and the corn yields for this same year were 2.6 ±1.3 and 4.06 ±1.4 t ha^{-1} for G1 and G2, respectively. Corn production was carried out under rainfed conditions in small family farming production units of 3.6 ±1.8 and 1±0.6 ha of average area for G1 and G2, respectively (Table 1).

Table 1. Social and production variables and production costs.

Variable	G1 (Tlaxcala)	G2 (Oaxaca)	F	*p*-value
Age (years)	56.8 ±13.3	58.8 ±4.4	0.1	0.759
Area (ha)	3.6 ±1.8	1 ±0.6	9.2	0.016*
Costs 2021 ($)	13 082.00 ±3 927.00	13 687.00 ±5 053.00	0.05	0.833
Costs 2020 ($)	12 519.00 ±3 383.00	12 873.00 ±5 203.00	0.02	0.902
Yield (t ha^{-1}) 2021	2.6 ±1.3	4.06 ±1.4	2.53	0.15
Yield (t ha^{-1}) 2020	2.34 ±1.8	3.8 ±1.6	1.68	0.231

* = significant $p< 0.05$.

The producers of G1 and G2 are advanced in age and have low schooling, which can cause certain barriers to the adoption of new technologies since the older they are, the less likely they are to adopt innovations (Aguilar *et al*., 2013).

Use of agroecological innovations in corn

One way to start the agroecological transition processes is through the use of bioinputs that allow replacing the use of chemical fertilizers, and the agroecological management of pests. The producers of the G1 use native corn in monoculture, the preparation of the land is mechanized, and the cultural work is carried out with a team, the production of corn is under rainfed conditions on hilly lands in the spring-summer cycle. The innovations implemented in this group were: P1-Boashi, P2-Supermagro and mycorrhiza, P3 and P4-Supermagro, P5-Supermagro and *Beauveria bassiana*.

According to Duke (2018), bioinput is a product based on compounds or extracts of microorganisms, plants, or living microorganisms, capable of improving productivity, quality, and health when applied to vegetable crops, without generating negative impacts on the agroecosystem.

The preparation of biofertilizers included the use of local materials (cattle manure, piloncillo, whey, rock meal from the same plots, among others). The training meetings in the Tlaxcala region included: 'dialogues' between producers and technicians to learn what materials make up each of the biofertilizers and their function, mixing and at the end, clarifying that the fermentation processes require excellent sealing of the container and constant review of the gas escape valve.

Other technologies they used were mycorrhizal fungi (P1). Mycorrhizal plants are more resistant to infection by pathogens, tolerate stress better and also promote soil conservation (Carrillo-Saucedo *et al*., 2022) and *Beauveria bassiana* (Bals.) Vuill (Moniliales: Deuteromycetes), which was used by P5, these fungi are organisms that have the potential to infect insects as they can harm more than 200 species (Alean, 2004).

The G2 producers of San Juan Cotzocón use native corn in monoculture, the preparation of the land and the cultural work are carried out manually and with a team, the production of corn is under rainfed conditions in lands of the river plain and hills in the autumn-winter cycle. Producers focused on leachate-based agroecological technologies and fall armyworm agroecological management (FAAM): P1 and P2 leachate and FAAM, P3-leachate, P4-FAAM, and P5-Supermagro and leachate.

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The production of worm leachate was carried out in an organized manner; first, they selected and cleaned the place to install the geomembrane and leachate pile, made the pit, installed the irrigation system in the pile, placed manure and stubble and finally placed the box with worms. To produce Supermagro in San Juan Cotzocón, the following materials were used: cattle manure, ash, raw milk, molasses, water, tomato, banana, and egg.

The FAAM was based on the use of pheromone traps, elimination of larvae by the effect of rain, and biological control (López and Villa, 2021); they focused on this technology because the fall armyworm (*Spodoptera frugiperda*) is the main pest of corn crops in the Papaloapan region.

Estimating the change in production costs

In Table 2, it was observed that the P2 of the G1 obtained a total cost of 8 671.00 \$ ha^{-1}; this cost is very contrasting with that obtained by P5 (\$17 651.00). In both cases (P2 and P5), there was an increase of 2.7 and 3.8% in costs compared to the 2020 cycle. In contrast, the P3 of the G2 presented a minimum cost of \$6 291.00 and a maximum cost of \$19 641.00 (P5); these costs were also higher compared to the 2020 cycle.

Table 2. Change in the cost of corn production per hectare ($ 2022).

Producer	Group 1. Tlaxcala Region			Grupo 2. Oaxaca Region		
	Cycle 2021	Cycle 2020	CPC (%)	Cycle 2021	Cycle 2020	CPC (%)
1	12 709	12 552	1.3	15 772	16 527	-4.6
2	8 671**	8 441**	2.7	11 440	8 960	27.7
3	16 506	14 403	14.6	6 291**	5 776**	8.9
4	9 874	10 188	-3.1	15 289	15 499	-1.3
5	17 651***	17 008***	3.8	19 641**	17 601**	11.6

CPC= change in the production cost; **= minimum; ***= maximum.

In general, the increases in production costs were primarily due to the increase in the price of chemical fertilizers, which they continued to use (in smaller proportions), as well as to the purchase of materials for the production of bioinputs, the purchase of external inputs (*Beauveria bassiana*), among others. What is expected from this indicator in the medium term is that it will be negative (as was the case with the P4 of the G1 and producers 1 and 4 of the G2). Being negative, this indicator would imply that there is a decrease in the costs associated with the use of sustainable technologies. In this regard, Herrmann and Lesueur (2013) found that, in economic terms, it is less expensive to use bioinputs than chemical fertilizers.

The indicators show the changes in the costs obtained with the application of agroecological technologies evaluated under the environmental conditions and resources of the same producer in different production cycles and differ from the usual form of evaluation through the assignment of value to environmental parameters (Bathaei and Streimikiene, 2023) and traditional economic indicators (Silva-Cassani *et al*., 2022).

Estimating the change in yield

In Mexico, 73.9% of the sown area corresponds to rainfed conditions, with a low technological level and an average yield of 2.4 t ha^{-1} (Donnet *et al*., 2017). The results presented in Table 3 showed a positive change in the yield for both groups. The average yields of corn obtained in G2 exceed the national average yield whereas yields in G1 are similar.

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Table 3
Change in the yield of producer groups (t ha^{-1}).

Producer	Group 1. Tlaxcala Region			Group 2. Oaxaca Region		
	2021	2020	CY (%)	2021	2020	CY (%)
1	4	4	0	4	4	0
2	3.8	4	-5	3	2	50
3	1.5	0	-	3	3	0
4	0.9	3	-70	3.8	3.5	8.6
5	3	0.7	328.6	6.5	6.5	0
Mean	2.6	2.3	12.8	4.06	3.8	6.8

CY= change in yield.

The average increase in the yield of G1 (CY= 12.8%) was due to the presence of atypical data, extraordinary events (lack of rain during the grain maturity) that occurred to P3 and P5 in 2020 and to P4 in 2021, which caused crop loss and low yields, as a result of factors not controllable by the producer (precipitation). In contrast, the average increase in yield in G2 was not affected, with a CY= 6.8%, because they were in a region of high rainfall.

In this regard, an analysis of climatological and productive variables in the Toluca Valley found that variations in precipitation affected corn yield (Morales-Ruiz and Díaz-López, 2020). In Tlaxcala, when rainfall is regular and soil fertility is good, native corn can have yields of between 3 and 6 t ha^{-1}, with an average of 3.3 t ha^{-1} (Lazos, 2014). Meanwhile, in the Papaloapan Basin region, with high rainfall and moderate fertilizer application, yields of up to 10.7 t ha^{-1} can be obtained (López-Escudero *et al*., 2023).

Estimating the change in the cost of agrochemicals use

Table 4 shows that, in G1, there is a decrease in the percentage of economic resources allocated to the purchase of agrochemicals, except for P3 and P2, who did not apply. In G2, only P2 had an increase of 4.8% unlike the other producers, who decreased their percentage in investment.

Table 4. Change in the cost of agrochemical use (%).

Producer	Group 1. Tlaxcala Region			Grupo 2. Oaxaca Region		
	2021	2020	CCAU (%)	2021	2020	CCAU (%)
1	10.7	26.3	-15.6	0	15.5	-15.5
2	0	0	0	28.1	23.3	4.8
3	25.4	23.2	2.2	0	1.6	-1.6
4	12.7	24.6	-11.9	13.5	14.7	-1.2
5	9	11.1	-2.1	21.6	28.5	-7

CCAU= change in the cost of agrochemical use.

Agroecological practices can help achieve a transition to more sustainable food systems (Caron *et al*., 2014); however, this is not in the short term or through a linear approach, since, as Tittonell (2019) points out, agroecological transitions involve multiple scales, levels, and challenges over time. Thus, the P1 of the G2 (who used leachate and agroecological management of the fall armyworm), in 2020, had 15. 5% of the production cost related to the purchase of agrochemicals, in 2021, the producer stopped using this input. This agroecological transition allowed it to maintain the 4 t ha^{-1} yield in 2020 and 2021.

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Conclusions

The analysis of the three indicators showed that the use of agroecological technologies had increases in two of the three indicators of change analyzed: in costs (negative effect) and in yields (positive effect) for most of the two groups of producers analyzed. On the other hand, the indicator of percentage of expenditure on agrochemicals had a general decrease for both groups. The proposed indicators allow monitoring the impact of these interventions through individual management and the reduction or elimination of agrochemicals and their impact on production costs and yield.

The indicators measure the economic effects on corn production obtained as a result of the use of agroecological technologies with technical support, resources, and environmental conditions prevailing in the study areas and for the interviewed producers. Thus, obtaining the best indicators can make it possible to identify more sustainable food systems, analyze their components, and generate recommendations for other producers to replicate these systems.

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