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Exploring Agroecological Impacts on Rural Farming Systems in Southern Mexico

Explorando los impactos agroecológicos en los sistemas agrícolas rurales del sur de México.

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Abstract

Agroecology offers a sustainable solution to the growing demand for food by mitigating environmental degradation caused by conventional agricultural practices. However, evidence on the impacts of public policies promoting agroecology remains limited. This study provides a comparative analysis of differences associated with the Estrategia de Acompañamiento Técnico (EAT), part of the Producción para el Bienestar (PpB) program, on the agroecological transition of producers in two municipalities in Mexico. The EAT promotes this transition through training and technical assistance, while PpB provides direct financial support. The analysis compared three groups of production units (EAT and PpB, only PpB, and without support), using soil quality indicators (pH, compaction, electrical conductivity, redox potential, and organic matter) and an assessment of agroecological status. The comparative analysis indicates that production units participating in the EAT tend to exhibit higher values in some of the agroecological transition indicators analyzed. Implementation challenges were identified, including labor shortages, logistical difficulties, limited understanding of agroecological benefits, and parallel policies promoting chemical fertilizers that counteract EAT's objectives. The study is relevant because it expands the evidence on the effects of public policies in agroecology, providing recommendations to enhance EAT, guide large-scale evaluations, and support the implementation of similar initiatives in other contexts.

Keywords: Agroecology; Public policy; Soil quality; Smallholder farming; Mexico

JEL Classification: Q01, Q18, Q24

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 Resumen

La agroecología ofrece una solución sostenible ante la creciente demanda de alimentos al mitigar la degradación ambiental generada por las prácticas agrícolas convencionales. Sin embargo, la evidencia sobre los impactos de las políticas públicas que promueven la agroecología sigue siendo limitada. Este estudio presenta un análisis comparativo de las diferencias asociadas a la implementación de la Estrategia de Acompañamiento Técnico (EAT), parte del programa Producción para el Bienestar (PpB), en la transición agroecológica de productores en dos municipios de México. La EAT impulsa dicha transición mediante capacitación y asistencia técnica, mientras que PpB proporciona apoyo financiero directo. El análisis comparó tres grupos de unidades de producción (EAT y PpB, solo PpB y sin apoyo), utilizando indicadores de calidad del suelo (pH, compactación, conductividad eléctrica, potencial redox y materia orgánica) y una evaluación del estatus agroecológico. Los resultados sugieren que las unidades de producción beneficiarias de la EAT presentan mayores valores en algunos de los indicadores de transición agroecológica analizados. Se identificaron diversos retos de implementación, entre ellos la escasez de mano de obra, dificultades logísticas, un entendimiento limitado de los beneficios de la agroecología y políticas paralelas que promueven fertilizantes químicos y contrarrestan los objetivos de la EAT. Este estudio es relevante porque amplía la evidencia sobre los efectos de las políticas públicas en agroecología, y ofrece recomendaciones para fortalecer la EAT, orientar evaluaciones a gran escala y apoyar la implementación de iniciativas similares en otros contextos.

Palabras clave: Agroecología; Política pública; Calidad del suelo; Agricultura campesina; México

Clasificación JEL: Q01, Q18, Q24

1. Introduction

Global food demand is projected to soar as the world population approaches 9.7 billion by 2050 (United Nations, 2022). This demographic growth will place unprecedented pressure on agricultural systems, necessitating a 35% to 56% increase in global food production to satisfy rising needs (Van Dijk *et al.*, 2021). Historically, agricultural expansion has focused on boosting crop yields, often through widespread seed replacement, monocropping, and excessive reliance on agrochemicals. While these methods have delivered short-term productivity gains, they have also triggered severe environmental degradation, including soil erosion, water contamination, and loss of biodiversity. Moreover, they have marginalized smallholder farmers and eroded traditional agricultural knowledge, undermining rural resilience (Sarandón and Flores, 2014).

This increasing pressure on agricultural production systems, coupled with the looming impacts of climate change, underscores the urgent need to transition towards more sustainable models (Piñeiro *et al.*, 2020). Agroecology has emerged as a promising alternative—providing a holistic framework that integrates ecological, social, economic, and cultural dimensions to promote sustainability (Darmaun *et al.*, 2023). Unlike conventional methods, agroecological practices leverage local knowledge and available resources, making them particularly suitable for smallholder farmers who often lack access to costly external inputs (Gutiérrez Cedillo *et al.*, 2008).

In this context, this article examines the possible effects of a public policy designed to promote the adoption of agroecological practices in Mexico — the Estrategia de

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Acompañamiento Técnico (EAT), implemented within the Producción para el Bienestar (PpB) program. PpB is a government initiative that supports small- and medium-scale farmers through direct cash transfers and agroecological training aimed at enhancing the productivity of key crops. The EAT delivers technical support and training through Escuelas de Campo (ECAs), focusing on the use of bio-inputs, soil conservation, and other agroecological techniques, benefiting a subset of producers who receive direct cash transfers through the PpB program.

Specifically, this study examines whether participation in the EAT is associated with changes in agroecological transition and soil health in participating production units (UP, the acronym of Unidades de Producción), offering preliminary insights based on the cases analyzed. To achieve this, data collection involved two complementary approaches. First, soil technical parameters were measured to assess soil health. Second, the Agroecological Status Assessment Survey, developed by Nicholls *et al.* (2020), was applied. This survey evaluates the alignment of producers' practices with the ten agroecological principles established by the FAO (2018), providing a comprehensive measure of agroecological adoption.

The analysis focused on a set of maize-producing units located in two municipalities in Oaxaca, Mexico. These agricultural UP were categorized into three mutually exclusive groups of production: (1) those receiving cash transfers from the PpB and participating in the EAT, (2) those receiving only cash transfers from the PpB, and (3) those neither receiving cash transfers from the PpB nor participating in the EAT. This classification enables a comparative analysis, highlighting how full PpB+EAT beneficiaries differ from those who only receive cash transfers and those who do not participate in the program at all.

The results indicate that UPs participating in both PpB and EAT exhibit a more advanced transition toward agroecology. Additionally, in terms of soil quality, these units show higher pH levels, which may enhance nutrient availability for crops. However, no significant differences were observed in other soil quality indicators, such as compaction, electrical conductivity, redox potential, and organic matter content. Interviews and existing literature suggest that the apparent success of the EAT can be partially attributed to the role of ECAs, which foster community bonds through collective labor (*mano vuelta*) and facilitate knowledge exchange. Nevertheless, the study also identifies significant barriers to adopting agroecological practices, including limited labor availability and logistical challenges in transporting bio-inputs to remote areas.

There is a growing body of literature exploring the various effects of adopting agroecological practices. Much of the existing evidence comes from case studies and qualitative analyses based on interviews or focus groups. At the country level, most empirical studies have been conducted in Italy, Brazil and France. Evidence seems to suggest that agroecological practices positively impact environmental sustainability (Alletto *et al.*, 2022), contribute to food sovereignty (Hernández *et al.*, 2017), enhance financial capital (D'Annolfo *et al.*, 2017), and can even promote climate change mitigation and adaptation (Dittmer *et al.*, 2023).

Nevertheless, around the world, “agroecological practices and action plans at national level are still marginal and varied” (Gargano *et al.*, 2021: 4). There are some experiences of governments promoting agroecological transition by using incentives such as subsidies, price premiums, technical support, and regulatory frameworks (Ogotu *et al.*, 2025). France and Nicaragua, for instance, have gone a step further by formally integrating agroecology into their national legislation. This institutionalization provides a legal foundation for the promotion and

implementation of agroecological principles at a national scale (Schiller *et al.*, 2020; Wezel and David, 2020). However, evidence on the outcomes and effectiveness of such policy initiatives remains limited and fragmented. While national governments possess the institutional capacity, financial resources, and infrastructure to support research, disseminate knowledge, and coordinate diverse stakeholders, the inherently bottom-up nature may represent a challenge for its implementation.

Latin American agroecology emerged as a social movement in response to economic exclusion (Sanderson Bellamy and Ioris, 2017). Nevertheless, according to some scholars agricultural policies in the region are primarily oriented toward promoting agribusiness and exports (Jean-Francois *et al.*, 2020). Consequently, it remains unclear to what extent top-down, government-led initiatives can effectively align with or support the deeply participatory, decentralized, and place-based ethos of agroecology. In this regard, some authors argue that the state can help create the conditions for agroecology to flourish, but it also tends to establish enduring pathways that reinforce or restore existing structures of economic power (Giraldo and McCune, 2019).

Some studies have focused on identifying the conditions that enable agroecological transitions, suggesting that the role of government may be secondary to more localized, intrinsic drivers of change. Farmers' internal motivations, as well as the type of agroecological innovations, seem to be more relevant. Some personal characteristics, like gender, age, education, income and social awareness; and some external conditions, such as weather and market access, may seem to be relevant too (Manyanga *et al.*, 2023; Polonio Punzano *et al.*, 2021). In contrast, top-down conditions, such as organic certification schemes, legal mandates, or requirements imposed by buyers, appear to have a more limited impact (Garini *et al.*, 2017; Ghali *et al.*, 2022). Moreover, evidence suggests that many farmers inadvertently operate according to agroecological principles, even if they do not explicitly identify their practices, which may make it difficult to identify the conditions that foster their adoption (Reza *et al.*, 2025).

This article makes three significant contributions to the literature on this subject. First, it adds to the limited body of research evaluating public policies that promote agroecology by identifying both biological and production organization effects, using two innovative tools to assess policy impacts: a set of soil quality indicators and the Nicholls *et al.* (2020) methodology. Second, it provides evidence on the challenges and opportunities faced by developing countries in adopting agroecology. Finally, it offers actionable recommendations to improve the analyzed program, guide broader-scale assessments, and support the implementation of similar initiatives in other contexts.

It is important to note that the empirical strategy adopted in this study is exploratory and comparative in nature. Given the non-random selection of UP and the absence of baseline data, the results do not allow for causal inference. Instead, the analysis identifies patterns and differences across groups that are consistent with expected outcomes of the intervention, without attributing these differences directly to the program.

The paper is organized as follows. Section 2 describes the institutional context of the PpB program and the EAT, the study area, the characteristics of the production units analyzed, and the data collection instruments used. Section 3 presents the results, beginning with a characterization of the agroecosystems, followed by an analysis of production practices, inputs, and labor demands, and concluding with the soil quality measurements and the evaluation of

agroecological transition indicators. Section 4 discusses the main findings, identifies implementation challenges, and offers recommendations to strengthen the EAT and guide future evaluations.

2. Material and Methods

2.1. Producción para el Bienestar (PpB) and Estrategia de Acompañamiento Técnico (EAT)

Launched in 2019, the PpB program is one of the Mexican government's flagship initiatives to support small- and medium-scale farmers. Eligibility is primarily determined by landholding size and crop type: small-scale producers are typically defined as those cultivating up to five hectares of staple crops (such as maize), while medium-scale producers may cultivate larger areas under specific eligibility thresholds established by the program's operating rules.

Its central objective is to boost the productivity of key crops—such as maize, the milpa system, and beans—through direct cash transfers (Apoyos Productivos Directos). Transfers are granted on a per-hectare basis, with annual payments ranging from approximately 6,000 to 24,000 pesos per year depending on farm size and crop type. These transfers are not strictly conditional on specific input use; rather, they are designed as income support to strengthen productive capacity. While beneficiaries are expected to be engaged in agricultural production, the program does not impose strict monitoring of how funds are allocated within the household or farm.

In addition to these transfers, the program incorporated the EAT early, a technical assistance component aimed at promoting agroecological practices. The EAT is implemented through ECA (farmer field schools), which are organized as group-based, participatory learning spaces where producers meet regularly. These schools are facilitated by trained agroecological technicians who guide farmers through experiential, “learning-by-doing” processes rather than conventional top-down extension methods.

The pedagogical approach of the EAT emphasizes horizontal knowledge exchange, collective experimentation, and adaptation to local agroecological conditions. Training focuses on sustainable practices, including the use of bio-inputs, composting, biological pest control, and soil restoration (SADER, 2022). In many cases, demonstration plots are used to test and compare practices, allowing producers to directly observe results and adapt innovations to their own production systems.

A distinctive feature of the EAT is its emphasis on social organization and collective action. ECA often function not only as training platforms but also as spaces for strengthening community ties, facilitating labor-sharing arrangements, and reinforcing local knowledge systems. This approach is particularly relevant in smallholder contexts, where the adoption of agroecological practices may be constrained by labor requirements, risk aversion, or limited access to external inputs.

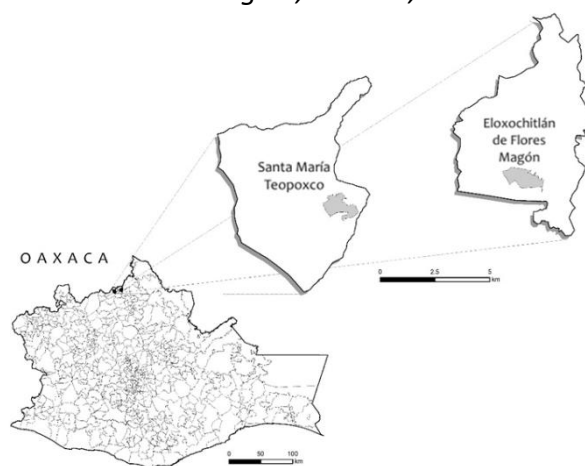
The selection and geographic distribution of ECA are determined by institutional and territorial criteria, including the concentration of eligible producers, agroecological conditions, and logistical feasibility. Participation in ECA is generally targeted toward PpB beneficiaries; however, in practice, some non-beneficiary producers may also attend, depending on local implementation dynamics and community openness.

In 2024, the PpB program provided monetary support to approximately 2 million beneficiaries.¹ However, its agroecological component remained more limited in scope: around 4,826 ECA had been established across 28 states, reaching an estimated 172,524 producers (Gobierno de México, 2024). Given its relatively small scale compared to the Direct Support component and its potential for expansion, the EAT would greatly benefit from stronger evidence on its potential impacts and implementation challenges. In this regard, the findings presented in this study —on both the effects and limitations of the strategy— can inform improvements in its design and support future scaling efforts for this program, as well as among other interventions promoting agroecological alternatives in developing countries.

2.2. Study Area

In the original research design, the study aimed to include communities with EAT presence in northern, central, and southern Mexico in order to capture regional heterogeneity in agricultural practices and production contexts. However, due to budgetary and safety constraints, this component of the evaluation was ultimately limited to a single state, Oaxaca, which was selected because of its high concentration of PpB beneficiaries and its relatively safe conditions for fieldwork. Within Oaxaca, fieldwork was conducted in two municipalities: Eloxochitlán de Flores Magon and Santa María Teopoxco, both located in the Mazateca region of the State of Oaxaca, Mexico (Figure 1).

Figure 1. *Study Area: Municipalities of Eloxochitlán de Flores Magón and Santa María Teopoxco in the Mazateca Region, Oaxaca, Mexico.*



Source: Authors

The municipalities and communities included in the study were selected based on three criteria: (1) the presence of the EAT since the beginning of the program, such that at least one

¹ <https://programasparaelbienestar.gob.mx/en-2024-aumentara-apoyo-de-produccion-para-el-bienestar-beneficiarios-recibiran-entre-6-mil-200-y-24-mil-pesos-anuales/>

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ECA had been in operation for two or more years; (2) the absence of recent reports of violence or criminal activity either within the municipality or along the route to it; and (3) reported maize production during the previous year. The first criterion was adopted because the EAT had been implemented only recently and its expected effects require time to materialize; therefore, selecting municipalities in which field schools had been operating for at least two years increased the likelihood of identifying producers who had already begun to apply agroecological practices in their crops. The second criterion was intended to ensure that the communities could be reached safely and that fieldwork could be conducted without risk to the interviewers. Finally, in light of the drought conditions experienced in Mexico in previous years, the third criterion excluded communities in which no agricultural production had taken place during the previous agricultural cycle. Given the limitations of the sample, the findings should be interpreted as exploratory evidence on the potential effects of the agroecological transition rather than as causal estimates.

While both municipalities are located in the Sierra Madre del Sur, they exhibit some environmental differences. Eloxochitlan is situated at an elevation of 1,350 meters above sea level (m asl), with an annual rainfall range of 2,000 to 2,500 mm, and a predominantly humid tropical climate. In contrast, Santa María Teopoxco is located at an average altitude of 1,820 m asl, with annual rainfall ranging from 1,000 to 2,500 mm, and a predominantly humid temperate climate. These differences in elevation and precipitation contribute to varying ecological conditions and agricultural practices in each municipality.

Both municipalities are enrolled in the two main components of the PpB program—direct cash transfers and the EAT—and also benefit from the federal Fertilizantes para el Bienestar (FPB) program. FPB is a national initiative aimed at increasing the yields of priority crops—such as maize, beans, rice, and wheat—by providing small- and medium-scale farmers with free fertilizers distributed directly and without intermediaries (SADER, 2023).

2.3. Characteristics of the Production Units (UP)

The unit of analysis for this study was the agricultural UP, which, according to the National Institute of Statistics and Geography (INEGI) of Mexico, is defined as an economic unit made up of one or more plots of land located within the same municipality, managed by a single producer, where agricultural activities are carried out using shared production resources such as equipment, machinery, vehicles, and labor (INEGI, 2022). This unit of analysis was selected because both the PpB and the EAT programs are granted at the producer level rather than at the individual plot level.

In each municipality, three types of UP can be identified based on their participation in the PpB program (through direct cash transfers) and the EAT:

1. Case A: Participants in both the PPB and EAT.
2. Case B: Participants only in the PPB.
3. Case C: Non-participants in both the PPB and EAT.

This distinction between the three cases enables a comparative analysis of the impact of full participation in both the PpB and EAT (Case A) against the effects of receiving only cash transfers from the PpB (Case B) or neither intervention (Case C). Comparing Cases A and B provides evidence on the potential effects of the EAT among those already receiving cash

transfers, while the comparison between Cases A and C reveals the combined impact of both interventions.

2.4. Data Collection

A total of 18 UP were interviewed in 2024 for this exploratory analysis—9 in each municipality. These included six case A units (participating in both PpB and the EAT), two Case B units (participating only in PpB), and one Case C unit (not participating in either component). The analysis focused on maize-producing units, given the crop's central role in the Mexican food system and its relevance as a target of both PpB and the EAT interventions.

Given the qualitative nature of the study, sample size was determined not on the basis of statistical representativeness but to enable in-depth analysis of each production unit. The sample was originally defined for the broader qualitative evaluation of the program with the aim of reaching analytical saturation in both EAT and non-EAT units (EQUIDE, 2024), and the same set of production units was used in the present study to examine agroecological transition. The findings should therefore be interpreted as exploratory and analytically informative, rather than statistically generalizable.

UP were selected using a non-random, purposive sampling strategy based on accessibility, willingness to participate, and the need to capture variation in program participation. Consequently, the sample is not statistically representative and is unbalanced across groups, with a higher proportion of Case A units. While this design reflects the exploratory nature of the study and fieldwork constraints in remote areas, it limits comparability across groups and precludes causal inference.

As shown in Table 1, the socio-demographic characteristics of producers managing the UP are relatively homogeneous across municipalities, with some differences by case. In Teopoxco, the average age ranges from 39.5 to 44.5 years in Cases A and B, while in Case C the single producer is 41 years old. In Eloxochitlán, producers in Case A are older on average (53 years), followed by Case B (42 years), and a considerably younger producer in Case C (24 years).

The gender distribution is balanced in Cases A and B across both municipalities (50% male), while Case C consists of a female producer in Teopoxco and a male producer in Eloxochitlán. Household size is relatively homogeneous across all groups, averaging around 4.5 members. Additionally, all producers in San Antonio Eloxochitlan report speaking an Indigenous language, whereas none do so in Santa María Teopoxco.

In terms of education, secondary and upper secondary levels predominate. In Teopoxco, Case A combines secondary education (50%) and upper secondary education (33%), with a smaller share of producers with no formal education (17%). Case B is evenly split between secondary and upper secondary education (50% each), while the producer in Case C has upper secondary education. In Eloxochitlan, Case A is equally divided between secondary and upper secondary education (50% each), Case B consists exclusively of producers with upper secondary education (100%), and Case C corresponds to a single producer with university education (100%), representing the only instance of this level in the sample.

Table 1. *Socio-demographic Characteristics of Agricultural Workers at the Selected Municipalities and the Study Sample*

Characteristic	Santa María Teopoxco				Eloxochitlán de Flores Magón			
	All agricultural workers	Selected UP's			All agricultural workers	Selected UP's		
		Case A	Case B	Case C		Case A	Case B	Case C
Age (years)	44	45	40	41	45	53	42	24
% Male	94	50	50	0	75	50	50	100
Education								
% No formal education	18	17	0	0	25	0	0	0
% Secondary	22	50	50	0	15	50	0	0
% Upper secondary	5	33	50	100	4	50	100	0
% College or higher	0	0	0	0	0	0	0	100
Household size	4	5	5	4	4	5	5	4
Observations	756	6	2	1	1,002	6	2	1

Source: Authors' calculations based on the 2020 Census and field data collected by the authors

Within each unit, the analysis focused on the main maize plot, defined as the plot where the largest area of maize is cultivated. Among the sampled producers, white maize was the dominant crop, shaping the structure and dynamics of agricultural activities across the study regions.

Three instruments were developed to assess the extent to which the EAT has contributed to the adoption of agroecological practices and their effects at the plot level among its beneficiaries.

1. **UP diagnosis questionnaire:** This instrument aimed to collect comprehensive data on the characteristics and management practices of the UP. Data were gathered on the size and number of plots, land tenure, genetic diversity and species cultivated in time and space, soil and pest management practices, labor, post-harvest handling, and the final destination of the production. Additionally, observations were made regarding the landscape matrix surrounding the primary plot of the interviewed families.
2. **Collection of soil technical parameters:** To assess soil health, key technical parameters were directly measured in the field, including soil compaction, pH, electrical conductivity, redox potential, and organic matter content. These measurements provided essential data on the soil's physical and chemical properties.
3. **Agroecological Status Assessment Survey:** The evaluation survey and methodology developed by Nicholls *et al.* (2020) were used to assess the extent to which UP were adopting agroecological principles. This approach involves scoring eight indicators that align farm practices with the ten agroecological principles proposed by the FAO (2019). These indicators include: landscape diversity, crop diversity, genetic diversity, soil quality and management, plant health and pest management, dependence on external inputs,



interactions and synergies, and productivity. It provides a structured and practical framework for evaluating the implementation of agroecological practices at the farm level.

These instruments provided a comprehensive approach to understanding the practices and conditions within the UP and allowed for a detailed analysis of the adoption of agroecological principles.

2.4.1. Collection of soil technical parameters

Technical soil data were collected from the most important plot within each production unit (UP), through field visits where *in situ* measurements were conducted. As previously mentioned, information was gathered for five key indicators: soil compaction, pH (acidity), electrical conductivity (EC), oxidation-reduction potential (ORP), and organic matter (OM). In addition, surface area measurements of each plot were obtained using geographic positioning. The instruments used and the reference values for each measurement are presented in Table 2.

Table 2. *Instruments and Techniques Used for Measuring Technical Parameters of the Plot*

Technical Parameter	Instrument/Technique	Reference
Soil Compaction (Psi)	Penetrometer	< 200: Good conditions 200 – 300: Fair conditions > 300: Poor conditions
Acidity pH (0 to 14)	pH Meter (Peachimeter)	< 5.5: Very acidic 5.5 – 6.5: Acidic 6.5 – 7.5: Neutral 7.5 – 8.5: Alkaline > 8.5: Very alkaline
EC (dS/m)	EC Meter (Conductivity Meter)	< 1: Salt-free soil 2 to 4: Moderately saline soil 4 to 8: Saline soil 8 to 16: Highly saline soil
ORP (mV)	ORP Meter	+800 mV: Strong oxidation 0 mV: Equilibrium -300 mV: Strong reduction
OM	Estimated by hydrogen peroxide technique	Minimal effervescence = Poor in OM Low effervescence = Moderate in OM High effervescence = High in OM
Surface Measurement (Ha.)	Mapit GIS. A tool that allows precise measurement of polygon surfaces. It is especially useful when plots have irregular shapes.	

Source: Authors

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The topographical characteristics of the plots, such as difficult access, steep slopes, stony soils (few), irregular shapes, and, in some cases, plowed (bare) soils, posed constraints for conducting full in situ measurements at multiple locations within each plot. Therefore, it was decided to perform the measurements on a composite soil sample from each plot.

Soil samples were therefore collected from five sampling points per plot using the "Five of Gold" technique. Subsamples from these points were combined to form a composite sample for each plot, on which organic matter, pH, electrical conductivity, and redox potential were measured. Soil compaction, however, was measured directly at each sampling point, and average values were subsequently calculated at the plot level.

Once the technical parameter measurements were completed, the Agroecological Status Assessment Survey was administered.

2.5. Data Processing

The information collected in the field was entered into an Excel database, followed by a data cleaning process to correct any possible entry errors or outliers. The data were then divided by municipality and case (A, B, and C). Averages were calculated, which were subsequently graphed and interpreted. It is important to note that a key component of the analysis is the information derived from observations made during the fieldwork.

3. Results

3.1. Characterization of the Agroecosystem of the UP

The UPs vary in terms of the number and size of plots. Of the 18 UP visited, half of them (nine) consist of 2 plots, four have three plots, two have one plot each, and the remaining three units have 4, 5, and 6 plots, respectively, totaling 47 plots. The size of the plots ranges from 0.03 to 1.32 hectares, with an average size of 0.26 hectares. Each production unit covers an average area of 0.66 hectares, with 100% of the land being used for annual crops. Of the 46 plots, 37 are owned, 8 are rented, and only one is borrowed from a relative.

The UPs are fully dedicated to crop production, with no plots used for livestock. The plots are scattered across the region, some near the home while others are located far away and are difficult to access. In some cases, access requires walking over narrow trails for more than an hour, making it impossible to transport goods with pack animals. This situation has significant implications for the implementation of agroecological practices, especially those that involve moving large volumes of products.

3.2. Production and Management of the Most Important Plot

To gain a deeper understanding of the agricultural production processes and how they are transitioning toward agroecological practices, we examined in detail the products, inputs, labor, and key activities carried out on the plot that the farmer considers most important.

3.2.1. Main Activities of the Agroecosystem

Maize is the primary crop that dictates agricultural activities. This means that every activity on the plot is conditioned by the maize production cycle, which in turn influences the planting and management of other crops, most of which are part of the milpa system. Figure 2 illustrates the key stages in the maize production process, along with the activities performed at each stage. The numbers in parentheses refer to the UPs that carry out each activity.

The differences observed in some stages, such as soil preparation, are due to the customs and traditions of the municipalities, as the characteristics of the plots are very similar. In Eloxochitlan, soil preparation is done manually, while in Teopoxco, most of the work is done with oxen; similarly, planting is done with a hoe in Teopoxco and with a *barreton* (digging bar) in Eloxochitlan. The rest of the activities are carried out in a similar manner, except for planting in some households in Eloxochitlan, where the practice of communal labor (*mano vuelta*) still prevails.

Three key practices are implemented during crop development:

a) **Chemical fertilization** (16 out of 18 families), primarily using urea and diammonium phosphate (DAP) from the FPB program;

b) **Weed control**, which is entirely done manually (no herbicides are reported) in two stages. The first weeding occurs when the plant reaches 50 to 70 cm in height, and the second is done before the maize flowers. Both practices are combined with fertilization, during which the fertilizer is covered.

c) **Pest control**, which is present but not typically treated with chemical applications. However, some agroecological inputs, such as calcium sulfate, have begun to be implemented.

The maize harvest, whether with or without husk, depends on the size of the ear, the amount harvested, the intended use of the production, and the weather conditions. Small ears are harvested without the husk and are consumed first, while larger ears are harvested with the husk, as they are kept for household consumption throughout the year and for seed for the next cycle. If it rains at the time of harvest, regardless of the ear size, the maize is harvested with the husk to protect it from the rain.

Maize production is primarily for household consumption, as output is insufficient for sale. Given the region's high relative humidity, most production units store maize cobs by hanging them from household roofs and shell kernels as needed. This practice is universal for seed maize and used by approximately 70% of units for consumption of maize. In contrast, only a minority (30%) shell and store maize in containers such as bottles, barrels, or metal silos, the latter reported by a single producer.

Figure 2. Key Activities Associated with Maize and Other Crops in the Most Significant Plot

Soil Preparation	Sowing	Vegetative Growth	Harvest	Post-Harvest
Clearing with Machete and Hoe (17)	Hoe (10)	Fertilization (11): Urea (6); Phosphate (8); Sulfate (4)	Double picking ² (5)	Hanging Corn Cobs (13)
Chopping (3)	Digging Bar (<i>Barreton</i>) (8)	Fertilization before Flowering (6): Urea, Phosphate	Harvest Without Husk (1)	Shelling in Airtight Containers (6)
Burning (2)	Fertilization (3) - Poultry Manure + Manure ¹	First Weeding with Hoe (18)	Harvest With Husk (11)	Shelling in Sacks (6), with Folidol (2), with Bitter Herbs (1)
Plowing with Yoke (10)		Second Weeding and Soil Mounding with Hoe (8)	Harvest Half With Husk, Half Without Husk (6)	Cobs in enclosures or granary (3)
Preparation with Hoe (9)		Agroecological Pest Control (6)		
		No Control (12)		
		Chemical (0)		

Notes:

¹ “Poultry manure” refers to *pollinaza*, an externally sourced organic fertilizer derived from chicken excreta, while “Manure” refers to organic fertilizer obtained from the producers’ own domestic animals (e.g., horses, goats, and chickens). In both cases, these inputs are applied directly without prior processing.

² Double picking is a regional practice that involves harvesting the *jilote*—a secondary maize ear that does not fully develop—which is primarily consumed boiled as a traditional food.

Source: Authors

3.2.2. Genetic and Species Diversity

Maize and beans, the two principal crops cultivated in the region, exhibit remarkable genetic diversity, a cornerstone of agroecological systems. On the most important plot for each household, we identified four maize varieties—White Maize, Yellow Maize, Red Maize, and Speckled Maize—and four bean varieties: Ayocote Bean, Bush Bean, Cimatl Bean, and Pinto Bean. In terms of distribution, white and yellow maize are each cultivated in 40% of the production units on their main plot, while red and speckled maize are each present in 10% of the units.

Polyculture is a prevalent practice in both municipalities studied. Plots often include additional vegetables and legumes, such as squash, *chilacayote* (fig-leaf gourd), *haba* (broad bean), peas, and *quelites* (edible greens), but also crops like bananas, citrus fruits, *chile* (pepper),

and potatoes. Furthermore, the traditional *milpa* system incorporates a wide variety of species grown alongside maize, contributing to both ecological resilience and food security. Thus, it is likely that even greater genetic and species diversity can be found in other plots, backyard gardens, or during the Autumn-Winter (AW) cropping cycle. Across all surveyed UP, this system is consistently practiced.

Notably, only two out of the 18 participating families reported cultivating crops during the previous AW cycle (2022–2023), reflecting potential limitations or shifts in agricultural practices during that period.

3.2.3. Yield per Hectare of Major Crops by Type of UP

Table 3 presents the yield per hectare for each crop species. One notable finding is that, in Case A in both municipalities, maize diversification is significantly higher compared to Cases B and C. Additionally, the yield of major crops (maize and beans) is higher in Case A than in Case C, with a particularly notable increase in white maize yield in Eloxochitlán, which includes the plot with the highest organic matter (OM) content. There are some exceptions, such as with squash and chilacayote, where Case B in both municipalities had the highest yields, which is offset by the lower maize yields in this group.

Table 3. *Yield per Hectare of the Different Crops Grown in the Most Important Plot*

Crop	Municipality	Case A (PpB and EAT)*	Case B (Only PpB)*	Case C (None)*
White Maize	Eloxochitlan	6,250	714	694
	Teopoxco	1,293	1,121	1,204
Yellow Maize	Eloxochitlan	1,797	1,250	416
	Teopoxco	3,500	-	-
Red Maize	Eloxochitlan	714	-	-
	Teopoxco	-	-	-
Speckled Maize	Eloxochitlan	-	-	-
	Teopoxco	1,867	-	-
Ayocote Bean	Eloxochitlan	56	13	-
	Teopoxco	55	151	15
Cimatl Bean	Eloxochitlan	-	-	-
	Teopoxco	192	-	-
Pinto Bean	Eloxochitlan	-	-	-
	Teopoxco	19	-	-
Bush Bean	Eloxochitlan	152	-	11
	Teopoxco	-	-	-
Squash	Eloxochitlan	903	-	111
	Teopoxco	54	455	417
Chilacayote	Eloxochitlan	433	555	-
	Teopoxco	582	727	278
Chayote	Eloxochitlan	2,000	-	-
	Teopoxco	181	-	-

Crop	Municipality	Case A (PpB and EAT)*	Case B (Only PpB)*	Case C (None)*
Quelites (Edible Greens)	Eloxochitlan	195	5	-
	Teopoxco	127	-	28

Notes: *(kg/Ha). Source: Authors

Many of the plots are very small and located close to the household, which allows for more appropriate management of the crops in terms of timing and execution. This proximity facilitates achieving favorable results, which, when converted to per-hectare yields, reflect good production under the region's conditions.

3.2.4. Inputs Used in Agroecosystems by Type of UP

Table 4 shows the inputs used by the UP, along with the percentage of units utilizing them on the most important plot, and the quantity used per hectare. Urea and DAP (diammonium phosphate) are used by the majority of the UP. Nevertheless, in Eloxochitlan, large quantities of these fertilizers are being applied per hectare, which does not correspond to the crop yields. It is likely that the fertilizers are oxidizing or being immobilized due to the high soil acidity (pH below 5.5) before the plants can utilize them.

Table 4. *Use and Intensity of Agricultural Inputs on the Main Plot*

Agricultural inputs or practices		% of UPs Using	Quantity per hectare (ha)	
			Eloxochitlan	Teopoxco
Chemical Fertilizers	Urea*	83%	698	145
	Diammonium Phosphate*	83%	870	172
	Ammonium Sulfate*	22%	556	159
Organic fertilizers	Compost*	11%	0	101
	Vermicompost*	17%	1134	24
	Bocashi*	17%	1000	4375
	Poultry Manure*	11%	0	506
	Organic Fertilizer (animal/vegetal)*	17%	167	264
	Leachate**	17%	0	93
	Biol**	33%	33	74
Microorganisms	Mycorrhizae**	17%	0	9
Chemical insecticides		0%	0	0

Organic Insecticides	Ash Broth**	6%	0	21
	Butterfly Traps (units/ha)	17%	12	0
Chemical fungicides		0%	0	0
Organic Fungicides	Sulfocalcic**	28%	7	13
Chemical herbicides		0%	0	0
Organic herbicides		0%	0	0

Notes: *(kg/ha) ** (lt/ha)

Compost refers to an organic fertilizer obtained from the anaerobic decomposition of organic matter derived from crop residues, animal manure, kitchen organic waste, and leaf litter. **Vermicompost** is an organic fertilizer produced through the transformation of organic matter by earthworms. **Bocashi** refers to an organic fertilizer produced through the anaerobic fermentation of organic matter, supplemented with whey, yeast, and molasses. **Leachate** is a liquid organic fertilizer obtained from the washing process of vermicompost during its decomposition. **Biol** refers to a liquid organic fertilizer that may originate from compost tea or activated microorganisms produced through anaerobic fermentation or aerobic oxidation processes. Source: Authors

Both municipalities are using agroecological inputs or practices, although Teopoxco shows a greater diversity of these practices. Conventional practices such as the use of chemical insecticides, fungicides, and herbicides are not common in these communities.

All UPs in Case A across both municipalities have implemented all agroecological practices (Table 5). Notably, there is a clear preference for processing organic fertilizers into vermicompost or bokashi, rather than applying them directly to crops. In contrast, direct application is more common in Cases B and C, though this approach is less efficient for plant uptake due to the slow decomposition rate of compost.

Table 5. *Types and Quantities of Inputs Used in Each Case*

Inputs	Municipality	Case "A" (PpB and EAT)	Case "B" (Only PpB)	Case "C" (None)
Chemical Fertilizers				
Urea*	Eloxochitlan	725	615	0
	Teopoxco	156	152	78
Diammonium Phosphate*	Eloxochitlan	798	615	0
	Teopoxco	192	152	78
Ammonium Sulfate*	Eloxochitlan	0	0	556
	Teopoxco	167	167	0
Natural Fertilizers				
Compost*	Eloxochitlan	0	0	0
	Teopoxco	51	0	0
Vermicompost*	Eloxochitlan	1,134	0	0
	Teopoxco	24	0	0
Bocashi*	Eloxochitlan	1,000	0	0
	Teopoxco	4,375	0	0
Poultry Manure*	Eloxochitlan	0	0	0

Inputs	Municipality	Case "A" (PpB and EAT)	Case "B" (Only PpB)	Case "C" (None)
	Teopoxco	0	91	926
Organic Fertilizer (animal/vegetal)*	Eloxochitlan	167	0	0
	Teopoxco	0	64	463
Leachate**	Eloxochitlan	0	0	0
	Teopoxco	93	0	0
Biol**	Eloxochitlan	33	0	0
	Teopoxco	37	0	0
Microorganisms				
Mycorrhizae**	Eloxochitlan	0	0	0
	Teopoxco	9	0	0
Organic Insecticides				
Ash Broth**	Eloxochitlan	0	0	0
	Teopoxco	21	0	0
Butterfly Traps (pieces/ha)	Eloxochitlan	12	0	0
	Teopoxco	0	0	0
Organic Fungicides				
Sulfocalcic**	Eloxochitlan	7	0	0
	Teopoxco	21	0	0

*(kg/ha) ** (lt/ha). No reports on the use of chemical insecticides, chemical fungicides, chemical herbicides, or organic herbicides were found. Source: Authors

Cases A and B are the primary users of urea and DAP, fertilizers obtained through the FPB program. Ammonium sulfate is mostly used by the UPs in Case C, as well as by some in Cases A and B, particularly in Teopoxco. Unlike urea and DAP, ammonium sulfate is purchased, and it is preferred due to its lower cost. However, as an acidic fertilizer, it tends to worsen soil acidity.

Approximately 50% of the total parcels in the UPs incorporate some agroecological practices. However, these practices are often applied only to specific sections of a parcel. This is due to several factors, such as testing the effectiveness of the practices, limited availability of the products, accessibility issues (e.g., the parcel is divided by a path, and the practices are applied to the more accessible section), or targeting areas where a specific species or variety has been planted. Many of the agroecological products are produced collectively within the ECAs and then distributed equally among participants. Nonetheless, some individuals have begun producing these products independently within their own UPs (Table 6).

**Table 6.** *Producers Preparing Agroecological Products Independently*

Product	Producers
Compost	2
Vermicompost	3
Bocashi	3
Leachate	3
Biol	4
Total	15

Source: Authors

3.2.5. Labor for Maize and Associated Crop Production

One of the distinctive features of agroecology is the higher demand for labor compared to conventional systems, especially because most practices are carried out manually. This is particularly true in areas where agriculture remains entirely manual, as in the Mazateca region where this study was conducted. The size of the parcels is very small, especially in Eloxochitlán, and when converted to hectares, labor requirements increase significantly (Figure 3).

To better understand the reasons behind the observed differences, comparisons are first made between municipalities and then between cases. In Eloxochitlán, the two activities that demand the most labor are soil preparation and first weeding. In contrast, in Teopoxco, the most labor-intensive activities are planting, first weeding, and harvesting. Soil preparation requires less labor in Teopoxco than in Eloxochitlán, as the former relies on yokes while the latter performs this task manually. Moreover, in both cases, fertilizers are applied during planting and first weeding, further increasing labor demands.

When comparing Case A with Case C, a considerable increase in workdays is observed in both municipalities. This increase is three times greater than the difference observed when comparing Case A with Case B in Eloxochitlán. Some explanations for these increases are described below:

Mano vuelta (Community Work): This agricultural practice is more common in Eloxochitlán, particularly during planting, as observed in all three cases from this municipality. One of the core principles of agroecology is the recovery of local knowledge and traditional practices—an objective that is being successfully advanced. In both municipalities, the practice of *mano vuelta* is more prevalent in Case A compared to the other cases, which helps explain the considerable increase in labor days. In this social practice, community interaction is prioritized over the agricultural task itself. As a result, up to 20 people may participate in an activity that typically would be done by two or three individuals in a standard eight-hour workday.

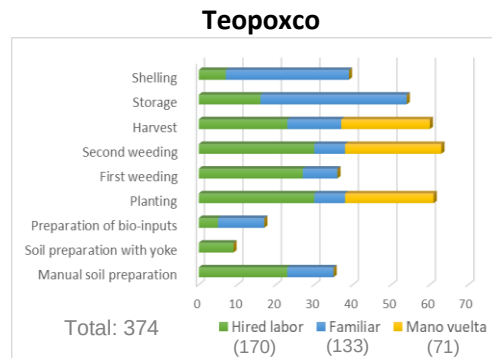
Use of Organic Fertilizers and Agroecological Practices: The preparation and application of inputs, such as bocashi and chicken manure, require significant labor during planting and the first weeding, as these are the two key moments when these inputs are applied.

Parcel Conditions: The higher labor demand also reflects the difficult access to parcels (distance, narrow paths) and the challenging conditions such as steep slopes, rocky terrain, and the type of vegetation that predominates after harvest. These factors require additional time and, consequently, more labor to manage the parcels effectively.

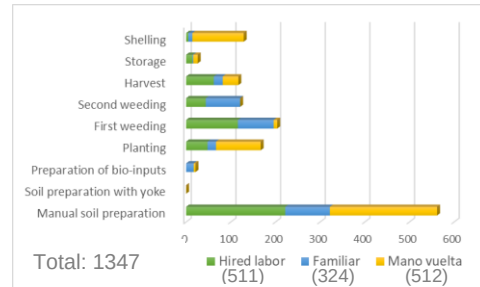
Use of Synthetic Chemical Fertilizers: Case A and Case B in both municipalities share the common use of fertilizers provided by the government program. The first and second weeding activities, which are linked to the application of these fertilizers, result in the highest labor demands compared to Case C, where no fertilizer is applied.

Figure 3. *Workdays per hectare by activity and type of labor*

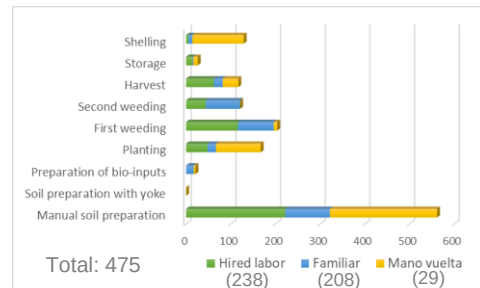
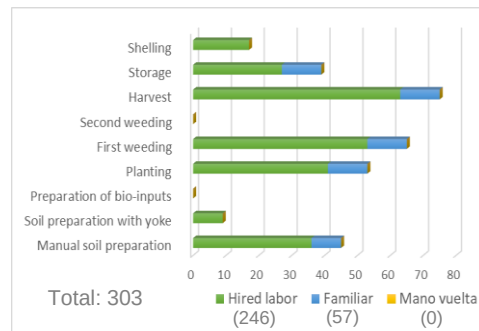
**A (PpB
and EAT)**



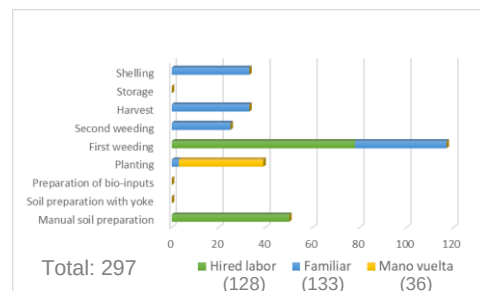
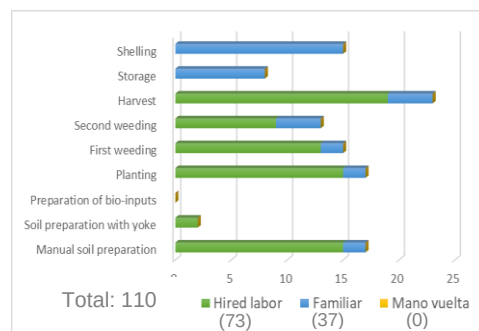
Eloxochitlan



**B (PpB
only)**



**C (neither
PpB nor
EAT)**



Note: The total number of workdays required by type of labor is indicated in parentheses. Source: Author's own elaboration.

3.3. Physical and Chemical Soil Properties by Parcel Management

The way plots are managed has both positive and negative effects on the physical and chemical properties of the soil. The following section presents and discusses key technical parameters measured in the field, considering the three types of management analyzed in this study: Case A (PpB and EAT), Case B (PpB only), and Case C (neither PpB nor EAT).

pH: On average, the sampled plots have a pH below 5.5, indicating that the soils are highly acidic (Table 7). This level of acidity has important implications for nutrient availability: macronutrients become less accessible to plants, while the concentration of micronutrients in the soil solution increases, potentially reaching toxic levels. The implementation of agroecological practices, even over a relatively short period of two years, is associated with higher soil pH levels in the observed UP (Table 7). In both municipalities, Case A exhibits higher pH levels compared to Cases B and C, where such practices are not implemented. The more acidic pH observed in Case C may be related to the use of ammonium sulfate as a fertilizer.

Table 7. *Mean pH Levels by Type of Plot*

Municipality	Case A (PpB and EAT)	Case B (PpB only)	Case C (neither PpB nor EAT)
Eloxochitlán	5.4	4.7	4.7
Teopoxco	4.7	4.4	4.2

Notes: pH References: < 5.5: Very acidic; 5.5–6.5: Acidic; 6.5–7.5: Neutral*; 7.5–8.5: Basic; > 8.5: Very basic. *Range in which most plants grow well. Source: Author's own elaboration

Soil Compaction: The soil management practices (using oxen teams or manual labor) in combination with the hillside conditions have positively influenced the soil's physical properties. The soil is not compacted in any of the cases, which facilitates proper root development and good water infiltration.

Organic matter (OM): The analysis reveals no consistent trend in OM content across the studied parcels in the different cases. In both municipalities, Case A parcels predominantly exhibit moderate OM levels, though some parcels also show low or high OM content. Parcels with higher OM are often associated with the abundant application of bocashi, less acidic soil pH, and higher crop yields. Conversely, parcels with low OM content tend to have a history of burning crop residues, prolonged sugarcane cultivation, or are recently rented or newly acquired.

In Eloxochitlán, Case B encompasses two starkly contrasting parcels. One has very low OM, is flat, located in a river valley, and serves as part of the household's backyard. This parcel benefits from convenient access, being near the town center. In contrast, the other parcel is rich in OM, recently cleared for agriculture, situated on extreme slopes near the mountain top, and requires over an hour's walk via steep and narrow paths for access.

In Teopoxco, Case B parcels are located on the town's outskirts, close to residential areas. These parcels lack soil cover, and their poor health and fertility are evident, as indicated by the absence of wild weeds.

Case C parcels in both municipalities implement practices that leave crop residues and weeds as soil cover. In Teopoxco, these parcels are further enriched by their proximity to forests and the substantial application of animal manure and chicken litter.

Electrical Conductivity: In both municipalities and across all cases, the soils are currently free of salinity issues. While significant quantities of fertilizers have been applied, this practice is relatively recent, initiated under the FPB program. However, continued fertilizer use at current rates could lead to the accumulation of salts in the soil over time. This buildup may adversely affect the soil's physical and chemical structure, ultimately compromising its productivity.

Oxidation-Reduction Potential (ORP): The ORP reflects the soil's chemical properties. In highly oxidized soils, nutrients lose electrons and bind tightly to negatively charged clay particles, making them unavailable to plants. In Teopoxco and Eloxochitlan, the soils exhibit oxidation, which is likely driving increased acidity. This acidity negatively impacts nutrient availability and soil health, reducing agricultural productivity.

3.4. Evaluation of the Level of Application of Agroecological Principles

An effective way to evaluate the progress of UPs toward an agroecological system is by examining whether the design and management of a farm align with agroecological principles. For this purpose, we employed a simple and rapid assessment survey originally proposed by Nicholls *et al.* (2020). This survey is structured around eight indicators designed to evaluate whether farmers' practices align with the ten agroecological principles established by the FAO. According to the methodology, each indicator is assessed individually and scored on a scale from 1 to 5, where 1 represents the lowest performance, 2.5 indicates moderate performance, and 5 reflects strong performance. A detailed description of each indicator, along with the criteria for low, moderate, and high scores, is presented in Table 8.

Table 8. *Indicators and Evaluation Scale for Assessing Alignment with Agroecological Principles*

Indicator	Established value	Characteristics/attributes
Landscape diversity Presence of hedgerows, vegetation strips, forest or natural vegetation remnants, etc. Efforts to isolate themselves (barrier of some kind?) Neighboring farms are conventional? Organic? Mosaic?	1	Less than 20% of the perimeter of the farm surrounded by diverse natural vegetation (consider if the surrounding vegetation is composed of various plant species, if surrounded by monospecific vegetation receives a lower value)
	2.5	20–50% is surrounded by a diverse community of natural vegetation
	5	> than 60% farm is surrounded by a diverse community of natural plants
Crop diversity: Various crop species and varieties grown in temporal and spatial designs assessed at the time of the farm visit	1	Monoculture: only one crop species grown (give higher values if 2 crop species are grown as monocultures in separate plots)
	2.5	Between 3–4 crop species grown intercropped or in rotation (Lower value if 3–4 crop species are grown as monocultures in separate plots)



	5	More than 5 crop species grown intercropped or in rotation (Lower value if more than 5 crop species are grown as monocultures in separate plots)
Genetic diversity	1	Monoculture: only one variety of each crop species (higher value if local varieties)
	2.5	3–4 varieties of each crop
	5	More than 5 varieties of each crop
Soil Quality and management	1	< 1% organic matter content, 100% soil uncovered, no recycling and incorporation of biomass. No cover crops or green manures used
	2.5	Between 2–3 % organic matter, 30–50% soil covered. Some level of recycling and incorporation of biomass and limited use of cover cropping or green manuring (Lower value if use plastic mulch)
	5	More than 4 to 5% organic matter, more than 50-70% soil covered
	5	High level of recycling and incorporation of biomass and use of cover cropping or green manuring. No plastic mulch
Plant health and pest management Use of biological and cultural pest control methods (release of beneficial insects, habitats, antagonists, organic weed control methods, etc.)	1	Farmers use pesticides and no practices of biological and cultural control of pests, diseases and weeds
	2.5	Farmers use input substitution practices (microbial, botanical or other pesticides) to control pests, diseases and weed. Limited use of practices that enhance beneficial insects and antagonists
	5	Farmers rely on soil and plant management practices to enhance biological control processes that help them to avoid, withstand and/or recover from pests, diseases and weeds
Dependency on external inputs	1	High dependency on external inputs, more than 80% of inputs purchased outside the farm
	2.5	Medium dependency on external inputs, 30–70% of inputs purchased off farm
	5	Low use of external inputs, less than 20% of inputs purchased off-farm
Interactions and synergies*	1	No observed interactions between agrobiodiversity components
	2.5	One or two interactions observed
	5	More than three interactions observed
Productivity*	1	Low total productivity
	2.5	Medium total productivity
	5	Higher total productivity

Notes: * Interactions and synergies refer to crop associations that generate mutual benefits, such as maize supporting beans, beans contributing nitrogen, or intercropping combinations that enhance pest control and soil health. Total productivity is assessed based on two variables: crop diversity and output per hectare. Source: Nicholls *et al.* (2020)

Table 9 presents the average scores for the eight agroecological indicators, disaggregated by production unit case and municipality. While the general conclusion is that Case A units tend to outperform the others, a closer examination by municipality reveals meaningful contextual differences.

In Teopoxco, Case A units show, on average, higher performance than Cases B and C across nearly all indicators. They stand out particularly in crop diversity (2.92) and reduced dependence on external inputs (3.42). However, there is one exception: in landscape diversity, Case C achieves the highest score (4.50).

In Eloxochitlan, the results are more mixed. Case A scores higher than Case B in crop diversity, plant health and pest management, and dependence on external inputs; shows similar values in landscape diversity and interactions and synergies; and scores lower in genetic diversity, soil quality and management, and productivity. Compared to Case C, Case A performs better overall: it scores higher in five indicators, matches it in one (interactions and synergies), and scores lower in two (genetic diversity and plant health and pest management).

Table 9. *Average Scores of Agroecological Indicators by Type of Production Unit and Municipality*

	UP type	Landscape diversity	Crop diversity	Genetic diversity	Soil quality and management	Plant health and pest management	Dependence on external inputs	Interactions and synergies	Productivity
Teopoxco	Case A	2.83	2.92	2.25	2.42	2.67	3.42	2.50	2.83
	Case B	2.00	2.00	1.50	1.50	2.00	2.50	2.00	1.50
	Case C	4.50	2.50	1.00	1.00	2.00	2.00	2.00	2.00
Eloxochitlan	Case A	3.25	2.67	1.58	2.75	2.25	3.17	2.00	2.58
	Case B	3.25	2.25	1.75	3.25	2.00	2.25	2.00	2.75
	Case C	2.50	2.50	2.00	2.00	3.00	2.00	2.00	2.50

Source: Author's own elaboration.

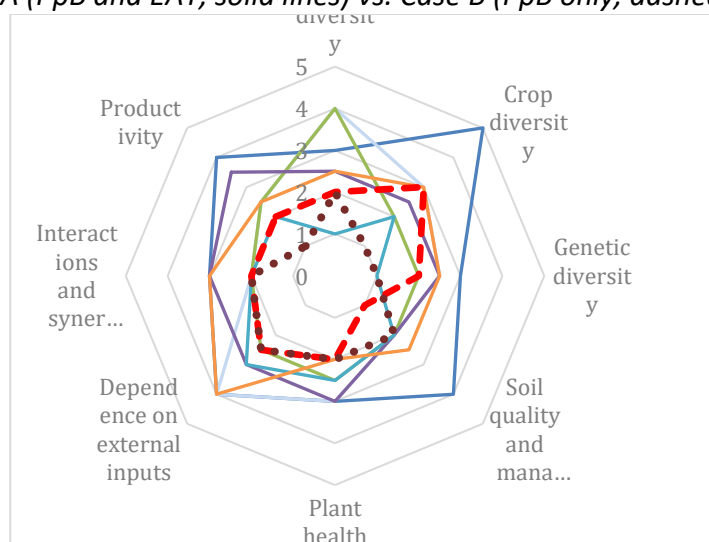
Following (Nicholls *et al.*, 2020), Figures 4 and 5 present amoeba diagrams that illustrate the agroecological performance of each production unit across eight evaluated indicators. Each axis represents one indicator, with values ranging from 1 (center) to 5 (outer edge), indicating the degree of alignment with agroecological principles. The shape and area covered by each amoeba reflect the overall level of agroecological transition: broader and more outward-reaching figures suggest greater progress, while smaller, inward-concentrated shapes indicate more limited adoption.

Consistent with previous findings, Figure 4 shows that agroecological transition levels in Teopoxco are generally higher among Case A units, as their amoeba diagrams extend further from the center compared to those of Cases B and C. However, the evidence of a stronger agroecological transition among Case A units in Eloxochitlan is relatively weak. It is found that each Case B unit has a Case A counterpart with stronger overall performance, and that no Case B

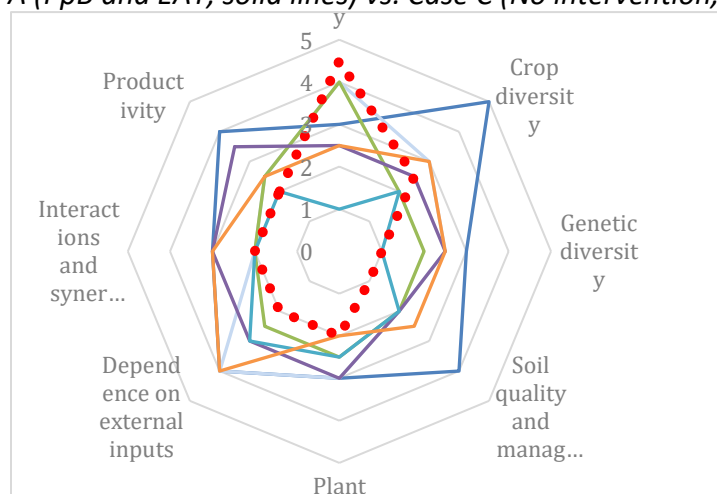
unit exhibits a higher agroecological transition than the Case A units. The comparison between Cases A and C shows that the sole Case C unit records the highest score in the Plant health and pest management indicator, which prevents any Case A unit from demonstrating a clearly superior agroecological transition. However, when this indicator is excluded, two Case A units outperform the Case C unit in overall performance. Also, the Case C unit does not surpass any of the Case A units across the eight set of agroecological transition indicators.

Figure 4. *Agroecological Indicator Scores by Production Unit Type in Teopoxco*

Case A (PpB and EAT, solid lines) vs. Case B (PpB only, dashed lines)



Case A (PpB and EAT, solid lines) vs. Case C (No intervention, dashed lines)

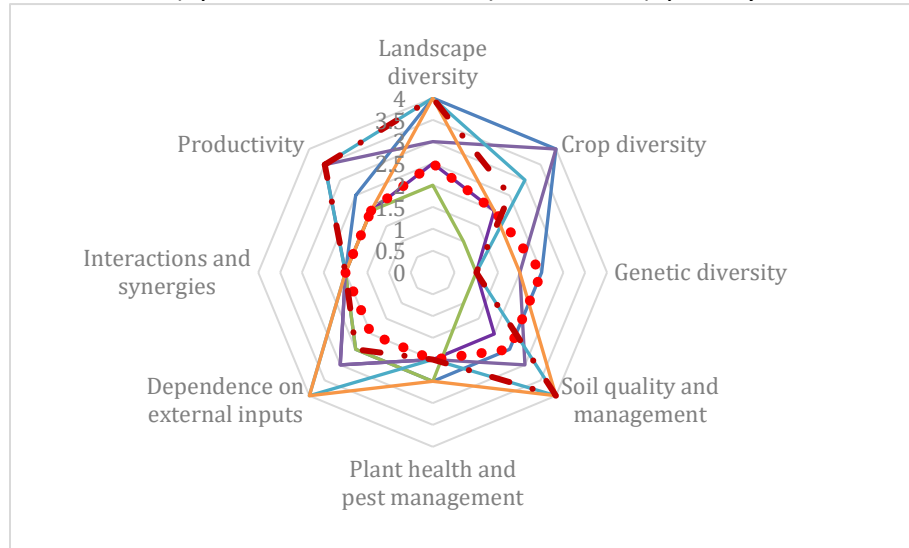


Source: Author's own elaboration

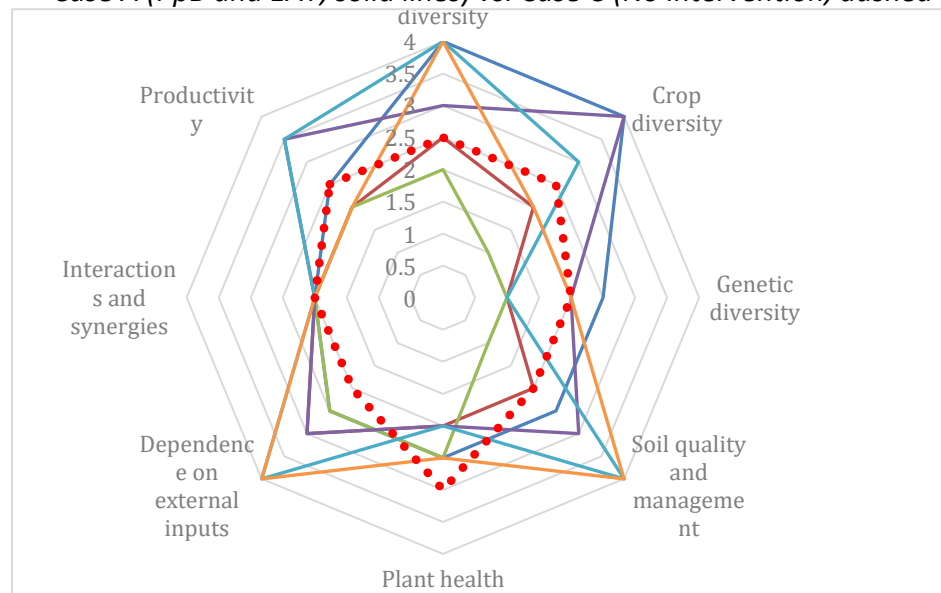
Note: The top figure compares Type B UP (dashed lines) with Type A UP (solid lines), while the bottom figure compares Type C UP (dashed lines) with Type A units (solid lines).

Figure 5. Agroecological Indicator Scores by Production Unit Type in Eloxochitlan

Case A (PpB and EAT, solid lines) vs. Case B (PpB only, dashed lines)



Case A (PpB and EAT, solid lines) vs. Case C (No intervention, dashed lines)



Note: The top figure compares Type B UP (dashed lines) with Type A UP (solid lines), while the bottom figure compares Type C UP (dashed lines) with Type A UP (solid lines). Source: Author's own elaboration

4. Discussion and Conclusions

Agroecology presents a sustainable alternative to the challenges faced by conventional agriculture. However, its implementation in communities is not an easy task, due to various factors, particularly social, economic, and climatic issues. It is crucial to analyze the implemented cases to draw from the successes and, most importantly, to redirect aspects that may not be functioning effectively.

Since 2019, Mexico has implemented a strategy aimed at promoting agroecology among small and medium-scale agricultural producers: the EAT, a component of the PpB program. The EAT provides agroecological training to a subset of PpB beneficiaries—a program that grants direct monetary support—promoting sustainable practices such as soil conservation, integrated pest management, and biodiversity, while fostering the exchange of traditional and scientific knowledge among producers.

Despite six years of implementation, evidence of the Program's impact on agroecological transition remains limited. This article aims to address this gap through an exploratory analysis of the potential effects of the EAT on agroecological transition levels among participating UP, as well as on five soil quality indicators. The study was conducted in two municipalities of Oaxaca, Mexico—Eloxochitlán de Flores Magon and Santa Maria Teopoxco—by comparing three groups of UP: those receiving support from the PpB program and participating in the EAT (Case A), those receiving only financial support from PpB (Case B), and those not participating in either modality (Case C).

While the results should be interpreted as descriptive and comparative rather than causal, they show that UP involved in both the PpB and the EAT outperform those in the other two categories (Cases B and C) across eight key indicators, which reflect how closely their agricultural practices align with the agroecological principles established by the FAO (FAO, 2018). This suggests a more advanced transition toward agroecology. It is important to note that the strength of this pattern varies between municipalities, with stronger evidence observed in Teopoxco compared to Eloxochitlán.

The results related to soil quality suggest that the EAT may be beginning to have a positive impact. Although no significant differences were observed in terms of soil compaction, electrical conductivity, redox potential, or organic matter content among the three categories of units, those that participated in the EAT showed higher pH levels. This translates into greater availability of essential nutrients for crops, which may enhance their growth and productivity.

According to the literature, the greater progress in agroecological transition associated with receiving EAT can be attributed to the capacity of ECAs to strengthen community bonds. ECAs foster communal labor practices, known as *mano vuelta*, where farmers work together and exchange experiences. This collaborative approach has proven effective in promoting the adoption of agroecological practices, particularly among producers with limited access to capital (De La Cruz and Dessein, 2021).

A limitation of the results of this study is that the observed effects cannot be considered causal, as they may be influenced by differences between the comparison groups, such as soil conditions, previous farming practices, producers' skills, and other factors (selection bias). Therefore, our results should be interpreted as descriptive and comparative rather than causal.

Additionally, the sample size is small, which limits the ability to draw robust and generalizable conclusions. Moreover, the distribution of UP across groups is unbalanced, with a predominance of units participating in both PpB and EAT (12 out of 18), compared to those receiving only PpB support or no intervention. Consequently, the results should be interpreted as indicative patterns rather than evidence of causal effects. Nevertheless, the findings provide a basis for making recommendations for the program, conducting larger-scale evaluations, and implementing similar initiatives in other countries.

In this context, one aspect that program designers like those of the EAT initiative should consider is the increased labor demand associated with the implementation of agroecological practices, as documented in this study. Given that rural areas are experiencing a decline in labor availability (Charlton and Taylor, 2016), this situation could hinder the widespread adoption of such practices as the program expands, especially among producers with limited access to labor.

Another key finding of this study, consistent with the results of Kirui *et al.* (2025) and Nikiema *et al.* (2024), is the importance of promoting agroecological practices tailored to the specific conditions of each region, rather than applying uniform solutions. Specifically, the study found that the EAT must account for the fact that—like in many other regions of the country—several beneficiary UPs are located in forested areas with difficult access and steep slopes. These conditions not only limit mobility but also complicate the transportation of bio-inputs produced in the ECA, which, according to interviewed producers, can become a substantial barrier to adopting the agroecological practices promoted by the EAT.

The interviews also revealed the need to strengthen awareness-raising activities to help producers better understand the benefits of agroecology. Although most of the interviewees attending the ECA are familiar with the agroecological practices they implement—they know what compost, bocashi, biofertilizers, and calcium sulfate are, and they know how to prepare them—they lack a clear understanding of their purpose and benefits. This lack of understanding could limit their adoption and sustainability once the program ends (Tankoano and Sawadogo, 2023).

Moreover, it is essential to highlight the importance of policy coherence to ensure the effectiveness of initiatives such as the EAT in advancing the agroecological transition (Schiller *et al.*, 2020; Wienhold and Goulao, 2023). Our study identified a significant risk associated with the Fertilizantes para el Bienestar (FPB) program, which distributes chemical fertilizers—even to beneficiaries of the EAT—leading to a substantial increase in their use. This trend has raised labor demands and may generate short-term negative impacts, such as soil salinization, while also hindering the agroecological transition by reinforcing conventional farming practices at the expense of sustainable approaches.

Beyond their technical function, ECAs appear to play a broader social role in facilitating agroecological transitions. Evidence from fieldwork suggests that these spaces strengthen community ties, enable collective labor arrangements (e.g., *mano vuelta*), and promote horizontal knowledge exchange among producers. This social dimension may be particularly relevant in contexts where individual adoption of agroecological practices is constrained by labor requirements or risk perceptions. From a policy perspective, this implies that ECAs should not be understood solely as training platforms, but as institutional mechanisms that foster collective action and reduce barriers to adoption. Strengthening these social dynamics—through continuity

of technical support, group stability, and local leadership—could enhance the effectiveness of agroecological policies.

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