Agricultura, Sociedad y Desarrollo

STRATEGIC COMPONENTS THAT BOOST THE AGROECOSYSTEM OF MILPA INTERCROPPED WITH FRUIT TREES (MIWF)

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ABSTRACT

The Programa Sembrando Vida (Sowing Life Program, SLP) promotes the Milpa Intercropped with Fruit Trees (MIWF) system, as a basis for improving the economic and dietary habits of beneficiaries, in addition to helping mitigate the effects of climate change. This research aimed to analyze three strategic components of the SLP that enhanced the benefits inherent to the MIWF agroecosystem: Peasant Learning Communities (PLC), community nurseries, and biofactories. A survey was conducted among a random sample of 55 SLP beneficiaries. The results show that PLCs represented a strategy for encouraging farmers to adopt agroecological innovations such as MIWF, while also improving the social and personal relationships of program beneficiaries. 69.2% considered the relationships between SLP members to be good or very good. However, the program fell short because technical advice was neither efficient nor well-timed in the SLP. The nurseries enabled access to fruit trees, helping to overcome the problem of producers' lack of resources for the initial investment required to establish the MIWF. The biofactories enabled the MIWF to become more agroecological, related to the Sustainable Hillside Management Project, thus eliminating dependence on agrochemicals. The problem with nurseries and biofactories was that they did not fulfill the beneficiaries' requirements. We conclude that these three analyzed components made a relevant contribution to improving knowledge and adoption of agroecological inputs and practices, among the program beneficiaries.

Keywords: biofactories, nurseries, peasant learning communities, training, vermicompost.

Citation: De la O-Romero CV, Valtierra-Pacheco E, Cortés-Flores JI, León-Merino A, Guarneros-Manoatl H. 2025. Strategic components that boost the agroecosystem of milpa intercropped with fruit trees (MIWF). Agricultura, Sociedad y Desarrollo https://doi.org/10.22231/asyd.v22i3.1727

ASyD(22): 417-438

Editor in Chief:
Dr. Benito Ramírez Valverde

Received: August 8, 2024.
Approved: October 15, 2024.

Estimated publication date:
June 18, 2025.

INTRODUCTION

Agriculture is one of the productive activities most affected by climate change and the deterioration of natural resources. Rainfall patterns have become more erratic, causing significant losses, whether due to flooding, drought, or variations in intensity and frequency of rainy seasons. Excessive exploitation and pollution of natural resources have seriously damaged the principal resources of agriculture: soil and water. This has significantly affected all agricultural producers, but especially small-scale producers with limited land and water resources.

Most agriculture in Mexico is carried out under a rainfed humid regime. According to CONAGUA (2021), 18.7 million hectares of land are harvested in Mexico, 75% of which are rainfed, and therefore exposed to extreme rainfall variations such as floods and droughts.

These environmental risks and other economic and social situations led the federal government to propose alternatives that would allow farmers to respond to these challenges through the implementation of Agroforestry Systems (AFS) on 1.0 ha and Milpa Intercalated with Fruit Trees (MIWF) on 1.5 ha of the beneficiaries' production units. The goal of the SLP was to establish the AFS and MIWF on 1,127,500 hectares (Secretaría de Bienestar, 2020). The objective of this research was to analyze the strategic components of the PLC (Peasant Learning Community, Community Nurseries, Biofactories) and assess how these enhance the benefits derived from MIWF to improve the production of the beneficiaries in the municipality of Españita, Tlaxcala.

The MIWF system, which emerged from the Sustainable Hillside Management Project, was the model that inspired the creators of the SLP to implement this model on a large scale, as demonstrated at a 2019 meeting attended by officials from the Ministry of Welfare and the Ministry of Agriculture and Rural Development with the creators of the MIWF of the SHMP (Secretariat of Welfare, 2019). Furthermore, prior to the SHMP, the technology of intercropping corn (maize) with other annual crops already existed, but it was not known as MIWF. What changed slightly with the SLP's MIWF is that it intended to promote an even more agroecological focus. The MIWF of the SHMP recommended using chemical fertilizers (Cortés *et al*., 2005), however the SLP founded the PLC biofactories to eliminate the use of chemical inputs, producing agroecological inputs such as composts, leachates, broths (sulfo, viso and Bordeaux), bioles (natural fertilizers), bocashi (fermented organic material), etc.

The environmental crisis and small-scale agriculture

Climate change has led to extreme weather events such as hurricanes and increasingly erratic rainfall, affecting large numbers of small-scale subsistence farmers living in fragile environments and putting their food security at risk (FAO, 2024). However, agricultural and forestry activities also contribute to climate change causing approximately 30% of annual greenhouse gas (GHG) emissions (deforestation and forest degradation 17% and agriculture 13%) (FAO, 2024).

Agroecosystems have been identified as having contributed the most to environmental degradation. Firstly, conventional agroindustrial or industrial agriculture systems have been a source of land degradation, greenhouse gases, water pollution, health problems, and soil and biodiversity loss (SEMARNAT, 2018). Likewise, traditional agrosystems, such as the slash-and-burn (SAB) system, practiced by millions of subsistence farmers, have also been identified as contributing significantly to GHG pollution and the deterioration of natural resources (Lora-Salcedo, 2012).

According to Lora-Salcedo (2012), there are 500 million farmers in the world who base their land cultivation on the SAB system. Mexico has 31 million hectares of arable land, of which 14 million hectares are hillsides, with moderate or steep slopes (Turrent-Fernández, 2018), where agriculture is largely developed under the SAB system. Cadena-Iñiguez *et al*., (2018) point out that in Chiapas, 60% of the corn area is planted (690,207.92 ha) on hillside lands under the SAB system. This suggests that in other states such as Oaxaca (514,551.62 ha) or Guerrero (506,629.14 ha) (SIAP, 2021), the proportion of corn planted on slopes is greater, because there is more subsistence production and less commercial corn production and the orography is even more rugged.

Adaptation to Climate Change and the Deterioration of Natural Resources

Therefore, it is essential to find alternatives for adapting to climate change in agriculture. FAO (2024) notes that agriculture can contribute to reducing GHG emissions through a series of measures, including the proper management of agroecosystems through conservation agriculture and agroforestry systems, which aid mitigation and adaptation, improving both local and global food security.

The IPCC (Intergovernmental Panel on Climate Change) pointed out that some adaptive solutions can build resilience to climate risks and provide broader sustainable development benefits. Adaptation based on redesigning agroecosystems can help smallholder farmers mitigate the impacts that already threaten their production methods, while also enabling biodiversity conservation, improving food security, enhancing carbon sequestration, and providing economic benefits (Boehm and Schumer, 2023).

Polyculture agricultural systems, such as associating trees with annual crops and crop diversification, are measures to improve climate resilience. Many traditional agroecological strategies that reduce the vulnerability of agriculture to climate change include crop diversification, maintaining local genetic diversity, adding organic matter to the soil, etc. (Nicholls and Altieri, 2019).

Sowing life program

The need to implement more resilient practices to mitigate climate change has led to public policies promoting more sustainable rural development. The

Sowing Life Program (SLP) was launched in early October 2018 to address the problems of environmental degradation and rural poverty. Its objectives were to reactivate the local economy, rescue the countryside, and regenerate the social fabric in communities by promoting food self-sufficiency and implementing plots with agroforestry production systems (Secretaría de Bienestar, 2022).

The SLP has been implemented in 21 states of the Mexican Republic, one of which is Tlaxcala, which was incorporated in 2020, with the aim of serving 5,000 peasants in the state, in 24 localities. To be included in SLP, the Program's Operating Rules (POR) establish that producers must have a production unit of 2.5 hectares, in conditions of abandonment, used as a cornfield, or be properties sustaining poor secondary vegetation such as pastures and they must not be subject to burning, logging, or other conflicts (Secretaría de Bienestar, 2020).

THEORETICAL FRAMEWORK

The traditional extension model or Rural Schools Approach

The origin of agricultural extension arose with the law known as *the Morrill Land Grant College Act* of 1862 in the United States, to create universities, known as Land Grant Colleges, and experimental stations, to promote "modern technology" (Thirty-Seventh United States Congress, 1862).

In the 20th century, many extension models emerged in different countries, some following the Land Grant College model; the predominant model of extensionism promoted by the so-called Green Revolution stands out, where technological research was carried out in experimental land areas and subsequently introduced to agricultural producers as extension agents.

In contrast to traditional extension approaches, the SLP adopted the Field School Approach (FSA), an alternative model introduced in 1991 by the Food and Agriculture Organization of the United Nations (FAO). Its purpose was to disseminate and exchange knowledge in agriculture using participatory methods that help farmers develop their analytical skills, critical thinking, and creativity (Ortiz *et al*., 2016). To disseminate information on agroforestry systems and ensure that beneficiaries implement the technologies to production units, the SLP is based on three strategic components:

- The Peasant Learning Communities (PLCs) are made up of approximately 25 beneficiaries and aim to generate knowledge through the exchange of experiences, that is to analyze productive conditions and design agroforestry systems; to promote and strengthen community organization, social finance, and a savings culture to regenerate the social fabric; and to foster cooperation that contributes to achieving food security, generating wealth, diversifying income, and restoring the environment (Secretaría de Bienestar, 2021).

- Community Nurseries: these are located in the beneficiaries' localities and related to each PLC and are used to produce the necessary plants for the beneficiaries' SAF and MIWF systems; they are responsible for the care and attention of the nursery, with technical support from the operational staff (Secretaría de Bienestar, 2021).
- Biofactories: facilities in which bioferments, biopreparations and other agroecological substances (broths, worm compost, bocashi, etc.) are produced, which are used by SLP beneficiaries to care for the production units (Secretariat of Welfare, 2021).

Agroforestry Systems

Agroforestry Systems (AFS) are based on the use and improvement of natural resources through association between woodland species (trees and shrubs), agricultural crops and livestock, under a topological or chronological arrangement. Moreno *et al*. (2020) establish that AFS consist of multiple implementation of biological and biocultural diversity that provide benefits, helping to mitigate the effects of erosion, because when various species interact, they provide shade and protection to each other, increasing soil fertility. These systems aim to diversify production, increase the level of organic matter, fix atmospheric nitrogen, modify the microclimate and optimize the production of the system, upholding the principle of a sustainable system (López-Tecpoyotl, 1992).

Milpa Intercropped with Fruit Trees (MIWF)

The Sowing Life Program, for the 2022 fiscal year, defines MIWF, in the POR, as an intercropping agroforestry system, made up of at least three species: fruit trees (epiculture), corn (mesoculture), and beans or other edible species, preferably legumes (subcrop). The production of corn and beans are strategic elements for the food security of rural families, improving net family income, increasing the organic matter content of the soil, controlling soil water erosion, and achieving more efficient use of rainwater. The spatial arrangement of the component species is designed to obtain high, good-quality yields of each species in the short, medium, and long term (Secretaría de Bienestar, 2021).

The founders of MIWF (Cortés *et al*., 2005) define this as a composite crop that includes corn, one or two edible legumes or other low-growing commercial annual species, and fruit trees, planted in intercropped furrows and rows. Corn stalk residues are placed transversely across the slope to act as a filter and retain sediment, where the stalks decompose and are incorporated into the soil as organic matter.

The MIWF technology generated in the Sustainable Hillside Management Project (SHMP) is derived from research into traditional agriculture with reference to that in the Huejotzingo area, Puebla, along with international scientific advances in sustainable hillside agricultural management (Turrent-Fernández, 2018). The SHMP operated between 1999 and 2005, through a collaborative process between the Colegio de Postgraduados and the National Institute of Forestry, Agricultural and Livestock Research (NIFALR), with funding from the World Bank. The SHMP was formed at the request of the World Bank's GEF (Global Environmental Facility) to identify a mechanism to improve carbon sequestration in agricultural areas on degraded land. The group of researchers in charge of the SHMP sought alternatives to this request, but at the same time they set themselves the task of ensuring that the project would improve production conditions and the well-being of producers; thus the MIWF was created.

Some of the benefits of MIWF are: it improves milpa yields (from corn and other annual crops combined in polyculture) in degraded soils, it provides income from the sale of the fruit harvest, it reduces erosion on sloping soils, it retains sediments carried by rainfall, it captures CO_2 from corn plant residues and others that are used as sediment filters, it improves the metabolic activity of microorganisms in the sediment reception and filter area, among others (Tapia-Hernández *et al*., 2024; Uribe *et al*., 2019; Arriaga-Vázquez, 2020).

Biopreparations

Application of nutrients and treatment of pests and diseases of plants and crops grown in the beneficiaries' production units are carried out, using organic agroecological inputs produced in biofactories. The Food and Agriculture Organization of the United Nations (FAO, 2010) establishes that biopreparations are substances or mixtures of plant or mineral origin that provide nutrients for plants and may have properties that repel or attract insects for the prevention of pests or diseases.

METHODOLOGY

The municipality of Españita, Tlaxcala, is located in the Mexican Central Highlands, at an average altitude of 2,640 meters above sea level. Its geographical position is 19° 27′ North latitude and 98° 25′ West longitude. It consists of an area of 140.18 km^2, representing 3.51% of the state (3,999.14 km^2) (Figure 1) (Españita Municipal Council, 2022).

The predominant soils in Españita consist of three types: cambisols, andosols, and fluvisols (Ayuntamiento Municipal de Españita, Tlaxcala, 2022).

The climate in Españita is temperate subhumid, with summer rains. The

Source: self-elaborated with data from the Paintmaps web (2023).
Figure 1. Location of study area.

average high temperature is 23 °C with a low of 7 °C. The warmest month is May, with an average high of 23 °C and a low of 10 °C (Weather Spark, 2022).

In 2020, Españita's population was 9,416, of which 51.3% were women. The predominant level of education was secondary (43.9%), followed by primary (28.2%). That same year, the illiteracy rate was 4.76% (Data México, 2020). The 2023 annual report on poverty and social backwardness shows that 69.4% of the municipality's population lives in poverty.

A quantitative survey research technique was used to collect field data from the research subjects. A pre-coded questionnaire was designed to enable efficient data collection and processing. The questionnaire was divided into six sections: 1) The respondent's personal characteristics, 2) Process of the beneficiary's incorporation into the SLP, 3) Knowledge of agroecological practices prior to the SLP, 4) Peasant Learning Communities, 5) Community nurseries, and 6) Biofactories.

The sampling framework consisted of 287 SLP beneficiaries in the municipality of Españita, Tlaxcala State. The sample size was calculated using a maximum variance formula, with a 90% confidence level and a 10% sampling error. Sample selection was entirely random.

$$n = \frac{NZ^2_{\alpha/2}pq}{Nd^2 + Z^2_{\alpha/2}pq}$$

Substitution:

$$n = \frac{(287)(1.645)^2(0.5)(0.5)}{(287)(0.1)^2 + (1.645)^2(0.5)(0.5)} = \frac{194.15729}{3.5465} = 54.74.616 \approx 55$$

A total of 55 questionnaires were applied to SLP beneficiaries in August 2023. A random sample selection was made from the complete list of SLP beneficiaries in the municipality of Españita. The randomly selected producers in the sample belonged to 13 PLC (Berlín, Cuextotitla, El Porvenir de San Agustín, El Renacer de San Agustín, Guerreros por la Naturaleza, La Costa, La Reforma de los Piñones, Labrando el Futuro, Los Epazotitos, Los Panchitos, Los Pipillolos, Ocelotzin, and Productores de Españita) in the municipality of Españita, Tlaxcala. Information was captured in Excel® in a straight forward manner because the questionnaires were pre-coded and statistical processing was performed in the SPSS® program. Most of the information was processed using descriptive statistics.

RESULTS

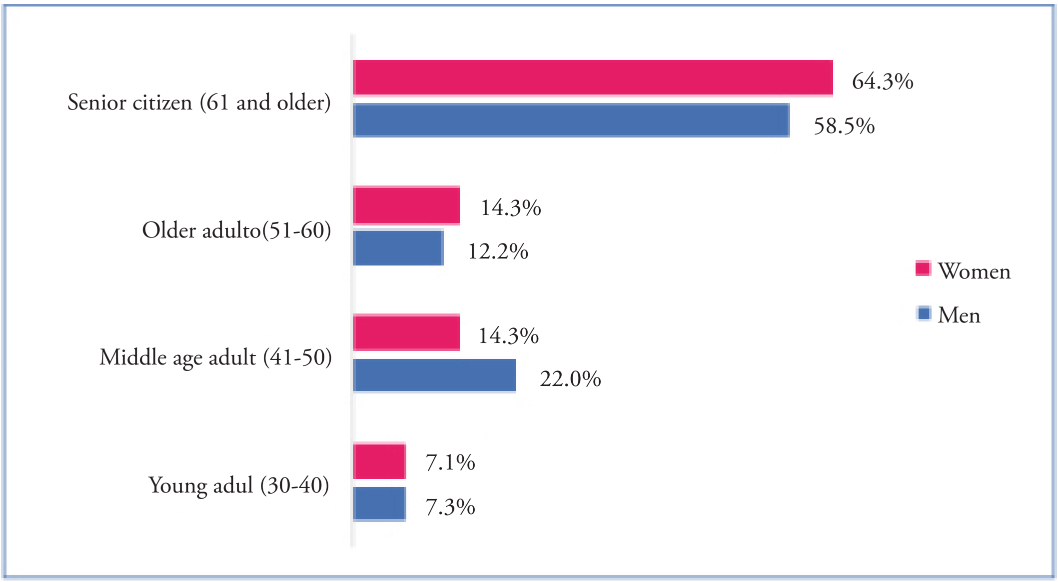
Socioeconomic Characteristics of the Population

The average age of beneficiaries is 62, and 25.5% are women. Most of the producers are older adults, who despite having numerous activities within the SLP, attempt to fulfill all these. Age distribution by gender shows a similar trend among older adults, both women and men (Figure 2).

For the most part, children support their parents, primarily in moving and planting trees, caring for nurseries, and attending meetings; some hire workers, when it comes to moving and planting trees. Activities in the Peasant Learning Communities relate to the training provided by technicians; both social and productive. In the community nurseries, substrate is prepared to fill bags and germinate seeds. The plants are then cared for and maintained, for which the farmers organize themselves into committees. Other activities carried out by the beneficiaries include tending to their production units, sowing annual crops, moving and planting trees, and monitoring them (irrigation, weeding, etc.).

Most beneficiaries (45.5%) completed at least one grade of primary or secondary school (32.7%). Only three beneficiaries are illiterate; some are supported by their children or grandchildren, who accompany them to meetings when necessary. To a much lesser extent, beneficiaries attended high school (12.7%), and only two have higher education.

Agriculture is the beneficiaries' primary source of income; however, in some cases, this income is not sufficient to meet their families' needs, so they have had to diversify their sources of income.



Source: self-elaborated with data from the interview, 2023.
Note: percentages were calculated for a sample of 41 men and 14 women.
Figure 2. Age distribution in relation to gender.

Inclusion of Beneficiaries in the SLP

In Tlaxcala, beneficiaries were required to have 2.5 ha available for the establishment of 1.0 ha of AFS and 1.5 ha of MIWF to comply with the POR of SLP. Beneficiaries allocated an average of 1.45 ha. This area may have consisted of a single plot (43.6%) or two polygons (49.1%), and the remainder consisted of three plots. In some cases, beneficiaries planted fruit trees on remote plots, due to a lack of knowledge, which has made their care difficult and led to losses in terms of planted fruit trees.

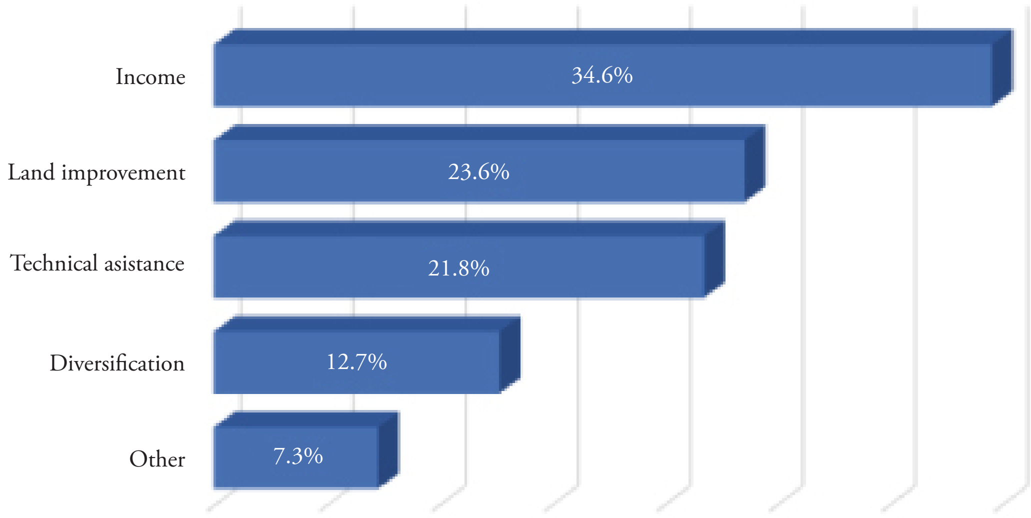
The process of incorporating producers into the SLP program began with the registration of beneficiaries at the beginning of 2020, with 50 of the 55 beneficiaries who were surveyed, later becoming members. The program was disseminated through various means; producers learned about it primarily from SLP staff (42.4%) and the ejido commissariat (22.0%). Most beneficiaries (50.9%) described the process of registering for the program as "easy," and 21.8% described it as "very easy." The process involved simply filing basic documents, and only required filling out one form. The operational staff were responsible for collecting these from their homes to incorporate them into the SLP. A notable aspect of this process was that some PLC were members of the same family.

Farmers had different reasons for joining SLP (Figure 3). The main ones were the monthly financial support provided for working on their plots, followed by the desire to improve their fields and production units, and the interest in receiving technical assistance and expanding their knowledge of farming. In some cases, beneficiaries were afraid to join the program because they were unsure of the activities they would be performing.

Characteristics of the Production Units

Most of the properties (71.4%) are on communal land; the same as that cultivated by the beneficiaries' parents and grandparents. Thus, 83.0% of the plots had established borders prior to the SLP; followed by smallholdings (27.0%); only one person was admitted with a plot subject to sharecropping. 94.5% of the properties are rainfed, which presented some problems for the producers when they planted fruit trees, due to losses resulting from the lack of water for their survival. This situation became more critical when their properties were divided into sections or far from their homes, due to difficulties in transporting water to the plots.

Before the SLP, most plots were used to cultivate traditional milpa (84.1%), that is corn was planted as the main crop, associated with other annual crops such as beans, tomatoes, broad beans, squash, etc. This meant that there was not a very strong productive reconversion, because they already cultivated milpa and one producer had also combined annual crops and fruit trees. Some properties were not used prior to the program (6.3%), because the beneficiaries were not involved in farming, some of whom did not even reside in the area.



Source: self-elaborated using data from the survey, 2023.
Figure 3. Types of investment in the SLP.

Prior knowledge concerning the MIWF system

The beneficiaries have worked in the fields for years, thus innovating and utilizing different practices to improve agricultural production. The majority of beneficiaries (94.5%) had implemented at least one agroecological practice in their production units before joining the program. 94.2% practiced crop rotation, and three-quarters of the farmers used native seeds. This factor is important because native seeds are adapted to the local natural environment, making them more resistant to pests and diseases and developing better, in line with the region's soil characteristics. Some beneficiaries (23.1%) prepared compost for the care and nutrition of their crops before joining the SLP. This situation has favored their production of compost, broths, fertilizers, etc., in the biofactories and for use on their plots.

However, the majority of beneficiaries (89.1%) were unfamiliar with the MIWF system prior to the SLP, so program staff had to start from scratch providing advice on this technology. In some cases, they were even unfamiliar with agriculture, as they were engaged in other activities. The greatest number of producers who identified with the MIWF technology form part of the Vicente Guerrero Group, which has been known in the state for promoting the use of agroecological practices for several decades.

As a result of this situation, during fieldwork, it was confirmed that the plots where the MIWF was established do not comply with the principles and guidelines established by the founders of the MIWF.

Strategic components of the SLP

PLCs were proposed as a strategic component from the moment SLP were created. PLC are organizational systems for beneficiaries based on the Farmer Field Schools Approach (Ortiz *et al*., 2016). These promote a process of exchange of ideas between producers and technicians, as well as providing advice and support to technicians in an orderly manner regarding the design, maintenance, and development of the MIWF and FFS (Farmer Field Schools) for producers' plots, as well as regarding other issues such as coexistence and savings promotion. They would also have administrative control functions for technicians and producers. Additionally, physical spaces were created to house the nurseries and biofactories where PLC members would work.

Community nurseries represent a strategic component of the SLP because one of the factors limiting the establishment of the MIWF is the cost of fruit trees and the availability of nurseries to supply these. From the outset, the SLP faced a lack of fruit trees for the establishment of the MIWF. The SLP supplied beneficiaries with trees from nearby nurseries that were sometimes certified and sometimes not, resulting in plant losses and mortality during the first year.

The biofactory component was proposed by the SLP because the MIWF was intended to be a system based solely on agroecological practices, rejecting the use of agrochemicals (fertilizers, pesticides, and others). This was in contrast to the original MIWF design, which emerged from the Sustainable Hillside Management Project (SHMP) (1999 to 2005), which did not have a fully agroecological approach because it used chemical fertilizers. Virtually all of the original MIWF components can be considered agroecological practices (polyculture; combining fruit trees with traditional annual milpa crops, contour crops following the contour lines, manual weeding, use of native seeds, use of legumes to capture nitrogen in the soil, incorporation of corn residues to perform sediment filtering and carbon sequestration functions, along with other practices).

For this reason, the SLP proposed the inclusion of some inputs and practices that would make the MIWF "more agroecological" than the MIWF of the SHMP. Biofactories were created in the PLC for the production of bio-inputs or organic inputs such as vermicompost (a product of the decomposition of organic matter by worms), bioles (liquid biopreparations with microorganisms), bocashi (solid organic fertilizer, the product of an aerobic fermentation process), and various organic broths such as Bordeaux (a pathogen protectant resulting from the combination of copper sulfate and slaked lime or hydrated lime). Notably, not all Biofactories produced the full range of organic inputs.

Peasant Learning Communities

The 2020 POR of the SLP indicate that Peasant Learning Communities (PLC) constitute the collective aspect of the program, whose main objectives are: to analyze productive conditions and design agroforestry systems; to promote and strengthen community organization, social finance, and a culture of savings to regenerate the social fabric; and to foster cooperation that contributes to achieving food security, generating wealth, diversifying income, and restoring the environment (Secretaría de Bienestar, 2020). In Españita, the 13 PLC are made up of an average of 23 beneficiaries; the smallest consisting of 15 and the largest 30 farmers. Each PLC is managed by a technical team (a social technician and a production technician). In Españita, there are two teams, and they are in charge of half of the PLC (one team manages 7 and the other the remaining 6). At the start of the program, the production technicians were not present due to hiring issues. As a result, the social technicians took on the responsibility of fulfilling both roles.

Most PLC (70.9%) meet once a week, while 25.5% meet twice a week. It is important to mention that producers meet in the PLC without the need for technicians to be present. Beneficiaries must comply with meeting attendance, as failure to attend may result in sanctions, according to the internal regulations agreed upon by each PLC.

Beneficiaries meet with their technicians at the PLC, on average every two weeks to review various social (savings, participation in committees, work plans, etc.) and productive (production projects, pests, diseases, plot care, nursery management, etc.) aspects. However, on occasion these meetings are less frequent due to the activities of the operational staff.

In the Community-Based Agricultural Development (PLC) programs, beneficiaries form committees to oversee and supervise the program's various tasks. 49.1% participate in one or more of these committees. The most representative (16.4%) is the community nursery committee, which oversees plant production process, followed by the savings committee (12.7%), which collects funds for necessary purchases and manages loans and grants. 9.1% belong to the plot review committee, in which those responsible visit farmers' plots and count the established plant numbers. Other committees include health, education, food, and community contributions.

Most people consider that coexistence in the PLC is good (52.7%) or very good (16.45%), because everyone participates and support is mutual; there is respect and good communication between the beneficiaries, so they coordinate and support each other to achieve the SLP activities, however, 29.1% rate it as regular, due to the fact that some beneficiaries show no interest in the activities, which affects the communication and organization of the entire group.

The PLC have fostered relationships, coexistence, and beneficiaries' interest in different aspects of the program. Therefore, beneficiaries indicated different reasons for their participation, such as coexistence and improving relationships (27.9%) and training and learning (19.7%), with the rest being less important. Figure 4 shows the aims of PLC as expressed by beneficiaries. Font size indicates importance. The members of the PLC already knew each other; several were even family members, but it was observed that in the meetings and activities carried out within the PLC, the relationships between members made it possible to improve previously established relationships. An example of the improvement in social relations is that PLC members organize to prepare breakfast at each meeting, with or without the technicians. On occasion, they may prepare breakfast together at the PLC facilities, or each person will bring something to share. During the meetings, it was observed that there was great camaraderie and kindness between PLC members; however, we cannot be sure, whether this is how they live together on a daily basis or whether this is how they behave due to the presence of the researchers.

Source: self-elaborated using data from the survey, 2023.
Figure 4. Mental map of PLC objectives according to beneficiaries.

However, farmers require ongoing training, tailored to the needs and growth stages of their crops, and therefore need training on various topics of interest (Table 1). The most important topics of interest are those related to fruit trees, as not all producers have worked with perennial plants prior to the MIWF. However, the advisory services have not been effective because, three years after the implementation of the MIWF system, beneficiaries still have knowledge gaps in topological design and the implementation of the most important fruit tree practices, such as grafting and pruning.

Community Nurseries

Establishing the MIWF system requires fruit trees, which represent a significant investment, both in terms of purchasing plants and for their planting. If purchased from a commercial nursery, the cost for a density of 650 trees per hectare could range from $40,000.00 pesos to over $130,000.00 pesos, depending on the size, variety, and condition of the trees. Fruit trees serve as the economic engine of MIWF technology, so the initial investment can be recovered in just a few years.

The SLP established nurseries in the localities to supply plants to the beneficiaries. The quantity and types of plants produced in the nurseries are defined based on the agroforestry system and the farmers' work plans, as

Table 1. Training requirements of beneficiaries.

Aspects	Beneficiaries	Percentage
Grafting of fruit trees	30	55.6
Pruning of fruit trees	24	44.4
MIWF care system	21	38.9
Design of MIWF system	20	37.0
Species selection	18	33.3
Corn stubble use	18	33.3
Regional soil type	18	33.3
Benefits of MIWF	13	24.1
Necessary inputs for MIWF	12	22.2
Crop rotation	11	20.4
Tracing of contour levels	10	18.5
Others	10	18.5

Source: self-elaborated using survey data, 2023.

well as the planting periods. For establishing the nurseries, beneficiaries were aided in a variety of ways, including irrigation systems (79.2%), shade netting (71.7%), germination bags (58.5%), and seeds (30.2%). However, in some cases, the inputs arrived late and were insufficient, so the beneficiaries purchased the materials with their own resources.

Production began the year the nurseries were established (2020), and the majority of forest species were germinated because these seeds are easier to obtain; most of the seed (83.6%) is purchased or collected locally (61.8%).

The technical staff has trained the beneficiaries in various contexts: substrate preparation (94.5%), nursery plant care (78.2%), grafting (76.4%), seed collection and selection (40.0%), among others. However, producers believe they need more training and follow-up, because they have encountered diseases in the nursery, and sometimes the seeds have not germinated or have died in the early stages. Unfortunately, the technical support does not arrive quickly enough to solve these problems.

Most beneficiaries (90.9%) are responsible for the care and maintenance of the nurseries. They organize themselves to water the plants, weed, prepare the substrate, etc. They normally meet twice a week to monitor plant production under the direction of the committee in charge of the nursery.

Work in the nurseries has motivated the beneficiaries because they identify several advantages, for example, the production of saplings to plant on their plots. However, they have had to purchase trees with their own resources because nursery production is not sufficient to meet the program's goal of 1,000 plants per hectare. Various situations have arisen, such as losses during germination or while transporting the trees to the plot.

Biofactories

The Ministry of Welfare (2021) establishes that the SLP may provide part or all of the materials necessary to produce bio-inputs such as composts, bio-fermented products, bio-preparations and other agro-ecological inputs that promote organic agriculture, taking advantage of any material found on production unit land.

The biofactories produce compost and biopreparations that are used in the nurseries and on the beneficiaries' plots. The frequency of meetings at these locations depends on the needs of the plots and nurseries, and on the workshops or activities they hold with technicians. Sometimes, the technical teams are unable to attend training sessions due to their bureaucratic workload, which has left farmers without the necessary knowledge to address the problems of nutrition, pests, and diseases affecting their crops and trees.

Some of the products produced in the biofactories are compost (94.4%), bioles (90.7%), bocashi (88.9%), vermicompost (75.9%), and broths (sulfo, viso, and Bordeaux) (51.9%). These inputs are used to nourish plants and crops and combat diseases and pests. A large portion of the beneficiaries (78.2%) have noticed improved results in crop production and reduced costs compared to when they only used chemical inputs (49.1%). They have also understood the importance of producing safe food based on the application of these organic inputs that they produce themselves.

DISCUSSION

Most beneficiaries (91.7%) receive assistance with activities on their plots, especially with moving and transplanting trees. The study on the aging of the rural population in Mexico (SAGARPA and FAO, 2014) mentions that the increased presence of older rural producers has implications for the production, management, and administration of natural resources in agriculture, due to the decline in physical capacities that occur at this age. Therefore, it is understood that these producers need assistance to carry out the activities of the Sembrando Vida (Sowing Life) Program.

The most prevalent level of education in the area is primary school, due to the fact that beneficiaries began working in the fields with their parents or on farms from a young age. There are cases in which producers worked outside their communities, and some dropped out due to poor performance. Similarly, most older adults, who, according to CONEVAL (National Council for the Evaluation of Social Development Policy) (2020), in 2018, 54.4% of the older adult population in Mexico had a poor education level, causing this group to experience social and economic inequalities. 69.1% of beneficiaries only have one source of income. In this sense, Arteaga-Domínguez *et al*. (2021) point out that age has a negative relationship with income diversification; that is, the older they are, the less likely they are to be employed in other activities.

Characteristics of Production Units

Most of the plots (84.1%) included in the SLP had polyculture cultivation, which according to Roland *et al*. (2017), has been shown in various studies to have multiple benefits such as providing resilience, when facing external disturbances, adaptation to climate change and increased production. In this sense, Tamayo and Alegre (2022) point out that the association of crops with trees (Agroforestry Systems) promotes the diversification of the agroecosystem, controls erosion, improves soil fertility, captures and stores carbon and improves family income.

In contrast, a small proportion of plots (7.9%) were cultivated under the monoculture system, with corn or maguey. According to CIMMYT (2020), monocultures are more prone to pests and weeds, reducing producers' profits due to the inputs they need to control them. They can also present loss of soil and biodiversity. Carbon sequestration in monocultures is much lower than in forests and polyculture systems, and they reduce organic matter, resulting in diminishing returns on plots due to loss of fertility.

Previous knowledge of the MIWF system

Most farmers (94.5%) had implemented at least one agroecological practice, which has facilitated their adaptation to SLP activities; they approve and are interested in the MIWF activities carried out on their plots and in the strategic components (nurseries, PLC, and biofactories) of the program. According to Martínez-Castro *et al*. (2020), there is a direct relationship between experience and level of technological adoption. The problem arises when a new system like the MIWF is introduced, which slightly modifies the practices traditional producers have practiced since ancient times. The plots where the MIWF was established in the municipality of Españita did not follow the principles recommended by the creators of the MIWF, Cortés-Flores *et al*. (2012), in the SHMP. This situation is not specific to the MIWF promoted by the SLP in Tlaxcala; Tapia-Hernández *et al*. (2024) found that something similar has occurred in the Usumacinta Canyon region, Tabasco.

One of the main practices used in the study area is the use of native seeds. In the state of Tlaxcala, particularly in the municipality of Españita, community seed banks have been created. These have promoted sustainable agricultural practices and the conservation of native seeds, strengthening the capacity of communities to preserve and share traditional varieties. These seeds were created by the Vicente Guerrero Group, several decades prior to the SLP (Vicente Guerrero Group, 2024).

Peasant Learning Communities

The Peasant Learning Communities, implemented within the Sowing Life Program, were designed to provide technical assistance and allow beneficiaries to carry out activities together, for example establishing and working in nurseries and biofactories. However, an additional benefit observed and reflected in the farmers' opinions was the improvement of social relationships within and outside the PLC. These results are consistent with those reported by Ortiz *et al*. (2016), who indicate that Peasant Learning Communities improve relationships between farmers, foster increasingly stronger commitments and relationships, and encourage the adoption of new knowledge.

Within the PLC, committees have been formed to subdivide specific activities within the SLP. These committees have fostered beneficiaries' interest in the targeted activities. Ortiz *et al*. (2016) mention that farmers' schools emphasize the pursuit of common interests and collective action, increasing producer relationships and improving levels of cooperation. Producers who participate in farmers' schools improve their relationships and acquire new knowledge.

Community nurseries

The primary source of fruit trees for the Program has been community nurseries, due to the multiple advantages they offer to beneficiaries. Cortés-Flores *et al*. (2012) note that one option for obtaining fruit trees is to establish local nurseries managed by the farmers themselves, with prior training and ongoing professional advice, aimed at teaching them fruit tree propagation practices and obtaining quality trees at a lower cost. However, even with the production of this component beneficiary demand has not been met.

Biofactories

Despite the benefits that producers have experienced from using biopreparations or bioinputs, the quantities produced have not always been sufficient or in time. However, they have discovered various advantages, such as ease of use and preparation and reduced toxicity compared to chemicals. In this regard, Gómez-Tovar and Rodríguez-Hernández (2013) point out that biopreparations avoid the risks posed by chemical pesticides; the residual effects are minimal because the molecules are disintegrated by weathering processes; they are easy to produce and significantly reduce costs.

CONCLUSIONS

Some beneficiaries had experience with agroecological practices, which has allowed them to easily adapt to the activities of the Sowing Life Program and has fostered producers' interest in the Milpa Intercropped with Fruit Trees (MIWF) system and agroecological practices. They received advice from technical staff, but it was insufficient, which is why the MIWF design on the beneficiaries' plots in the municipality of Españita, in most cases, does not resemble the original MIWF design of traditional producers in Puebla, much less the one designed by researchers at the SHMP.

The Peasant Learning Communities (PLCs) provided a space for training and technology transfer activities. Unfortunately, in the opinion of the producers, these knowledge transfer processes have not been timely or efficient in ensuring that producers have adequate knowledge of the Milpa Intercropped with Fruit Tree system. However, the work environment of the PLC brought another benefit: improved social relations between members, both within and outside the PLC. This is corroborated by the authors' perceptions during fieldwork and the responses provided by those surveyed.

Community nurseries have provided farmers with fruit trees for the establishment of the Milpa Intercropped with Fruit Trees system, which has reduced establishment costs because the trees represent a significant investment, if purchased from a commercial nursery. The problem is that plant production has not been sufficient to supply all beneficiaries' plots.

The products produced in the biofactories have reduced the use of chemical inputs in production units, resulting in safer food. The work in the biofactories has fostered farmers' awareness and interest in agroecological practices; however, organic inputs have not been produced in sufficient quantities or in time to meet the needs of the beneficiaries of the Sowing Life Program.

Despite the program's operational deficiencies, the implementation of the three strategic components has one thing in common: they improved knowledge of agroecological inputs and practices through the training provided by technicians for biofactories, nurseries, and the establishment of MIWF on producers' properties. Despite the deficiencies noted in the training, it will certainly be useful to producers should the Sowing Life Program cease to exist after the current six-year term.

Future research on the SLP's MIWF should produce data once the fruit trees planted with support from the SLP are in full production to determine how much of the MIWF's benefits are being observed in the beneficiaries' plots and in terms of their well-being.

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