Aspects, strategies and challenges for banana producers in Mexico towards sustainable cultivation

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ABSTRACT

Objective: to analyze the strategies and challenges faced by banana producers in southern Mexico, from the key aspects that contribute to the achievement of the Sustainable Development Goals (SDGs).

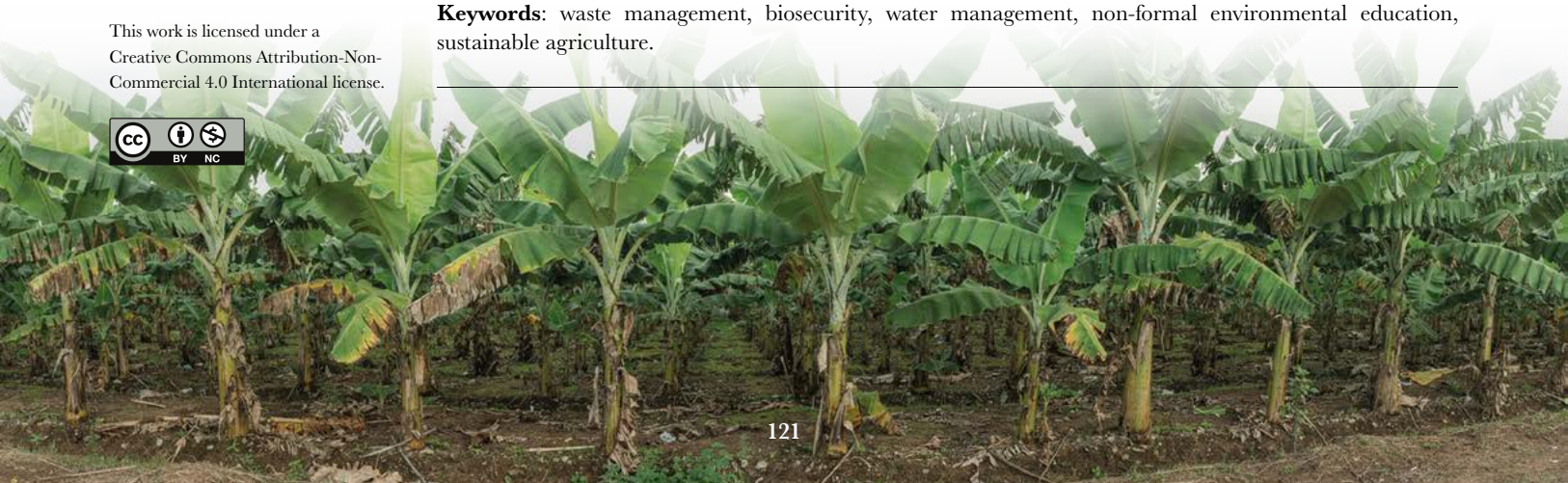
Design/Methodology/Approach: from a cross-sectional descriptive design, a survey was applied, with five sections and 40 items, to 42 banana producers. As well as in-depth interviews (according to the snowball technique) with key informants from three localities in the municipality of Tecpan de Galeana, in the state of Guerrero, Mexico.

Results: most producers operate in small family units and only 33% have some formal training, the rest learn empirically and develop productive activities by trial-and-error. A wide gap was identified between sustainable practices (best management) and practices applied in the field, which were related to the key aspects analyzed. These are training, biosecurity measures, waste management, use of traditional cultivation techniques, and water management for irrigation activities. With the information collected and these determinants, differences in the agricultural practices of the producers interviewed were identified in the three localities.

Limitations/implications of the study: the size of the interviewed population was small due to the restrictions of the CovID-19 pandemic, during the period in which the study was conducted. In addition, it was identified that the state does not have an official registry of banana producers; although its annual production is estimated at the state scale.

Findings/Conclusions: hereby the proposed strategies we highlight are the promotion of composting practices, use of organic fertilizers and improvements in irrigation infrastructure. As well as the intervention with a non-formal environmental education program to raise awareness and transfer knowledge that promotes more sustainable agricultural practices.

Keywords: waste management, biosecurity, water management, non-formal environmental education, sustainable agriculture.



INTRODUCTION

The agricultural sector worldwide is of great relevance for socioeconomic development, because it contributes directly to two of the Sustainable Development Goals (SDGs): no poverty and zero hunger, towards ensuring food safety (Gumbi *et al.*, 2023). The United Nations (UN) recognizes that agricultural activity is crucial to achieving the SDGs, especially when it has a sustainable approach (Cao & Solangi, 2023). Sustainable agriculture arises to reduce environmental impacts related to the leaching of chemicals into water, and the loss of soil quality (He *et al.*, 2023); as well as those related to traditional irrigation systems and the use of agrochemicals.

Several studies have shown success in the adoption of sustainable practices in agriculture; one province in Ecuador carried out the implementation of agroecological practices with producers formed in groups or organizations. Mature organizations have more experience and have presented better results that are reflected in more sustainable production and improved living conditions in rural communities (Alava *et al.*, 2020).

In Australia, the transition from capitalist to sustainable agriculture has generated a peasant social movement that demonstrates an interest in the environment, food sovereignty and public policies (Jonas & Gressier, 2025). On the other hand, there have been cases that link health to traditional agricultural practices; for instance, in Mexico, the presence of organochlorine pesticides was found in blood samples from pregnant women, agricultural soils, and surficial bodies of water (Arce-Estrada *et al.*, 2025).

The transition of agriculture in Mexico towards healthy food production with sustainable practices focuses on strategies to counteract environmental deterioration and its adaptation to climate change (Castellanos-Gutiérrez *et al.*, 2021, Vázquez *et al.*, 2021). Therefore, the objective of this study was to analyze the strategies and challenges faced by banana producers in southern Mexico, from the key aspects that contribute to the achievement of the Sustainable Development Goals (SDGs).

METHODOLOGY

Study design

The study was based on the analysis of information with a cross-sectional descriptive design, because its application was in a certain timeline under complex circumstances due to restrictions of the CovID-19 pandemic, between December 2020 and January 2021. However, the interaction period with the producers was larger; as it began before the study to build bonds of trust, and the interaction continued after the study was conducted.

Participants

The study involved 42 banana growers from three localities in Tecpan de Galeana (Guerrero), Mexico including key informants. The selection of participants was done through convenience sampling (Kleeberg & Ramos, 2009), for reasons of accessibility and availability of producers during the period of restrictions. To minimize selection bias, producers from the three localities with diversity in age, experience and educational level were included.

In addition, the sample was complemented with the 'snowball' technique to include producers recommended by the key informants, thus enriching the representativeness of the sample. It was noteworthy that producers expressed their agreement to participate in the survey and interviews, as well as giving their consent to share their agricultural ideas, experiences, and practices (Table 1).

Survey design

A questionnaire was designed to collect specific information, the construction of the items was guided by the themes and the objective of the research (Borromeo-García, 2023). Once the questionnaire was formulated, it was reviewed by a committee of five environmental experts and a pilot test was applied to three producers to calculate the time of application, as well as to verify the understanding and relevance of the questions. Afterwards, adjustments were made to the questions for a second review, and finally the questionnaire was applied to the selected interviewees.

The questionnaire was divided into five dimensions to address 40 items related to the factors identified as the main challenges that slow down socioeconomic development in the

Table 1. Sociodemographic characteristics of banana producers in three localities of Tecpan de Galeana (Guerrero), Mexico.

Data record description	Number of producers	%
Localities		
El Súchil	20	47.6
Tenexpa	15	35.7
Tetitlán	7	16.7
Gender		
Male	41	97.6
Female	1	2.40
Age (years)		
18-40	3	7.10
41-60	20	47.6
Older than 60	19	45.2
Level of Education		
No schooling	7	16.7
Primary (Elementary)	17	40.5
Secondary (Junior High School)	8	19.0
Senior High School	7	16.7
College (undergraduate)	3	7.10
Cultivation experience (years)		
5-10	9	21.4
11-20	8	19.0
21-30	18	42.9
More than 30	7	16.7

agricultural sector (Gambart *et al.*, 2020; Gumbi *et al.*, 2023). In this context, those factors also affect banana cultivation (Table 2).

The interviews were applied to key informants from the three locations under study, using the participant observation technique with in-depth interviews (Vázquez-López *et al.*, 2018). They addressed questions focused on land use, cultivation practices and security measures. Each interview was conducted on the plantations, a space where producers felt more comfortable sharing their experiences and perceptions.

Data collection and analysis

For the application of the questionnaire in the cultivation plots, individual technical visits were scheduled. Research in the field made it possible to verify the crop production system, waste management, both agrochemical containers and green waste, as well as water use and the type of irrigation. The data obtained were systematized and analyzed in Excel® Microsoft™ 2019 version. Due to the sample size (n=42) and the design of the study, descriptive statistics were chosen to analyze the patterns of responses in the practices and perceptions of the producers. No inferential tests were performed; a qualitative analysis was complementary to the interviews and allowed triangulation to deepen the quantitative findings and increase the internal validity of the study.

Interviews were scheduled through socialization with key informants, intentionally selected for their greater experience in banana cultivation. This intervention allowed us to delve into the relevant and determining aspects of the study. The interview was analyzed from an interpretive paradigm approach, which is based on the subjectivities of the participant. This allowed us to understand a vision of the world through the perspective of each person individually (Miranda & Ortiz, 2020).

Table 2. Structure of the questionnaire applied to 42 banana producers interviewed in Tecpan de Galeana (Guerrero), Mexico.

Dimension	Description	Items	Response type
Sociodemographic	It addresses issues such as age, gender, schooling and trade of the participants.	5	Open and multiple selection
Training	Collect participation by courses, the number of courses taken, and their level of importance to the participant.	5	Open and dichotomous (Yes/No)
Biosecurity and sanitary measures	It focuses on questions about the use of personal protective equipment (PPE) during and after agriculture activities, as well as an exploration of health status.	10	Binary numerical response (0 & 1)
Solid waste management	It investigates the treatment of that waste generated in the plot, from plastic agrochemical containers to the green waste generated during planting (harvest and post-harvest).	10	Open and binary numerical response (0 & 1)
Agricultural techniques, technologies and water use	It collects information on planting techniques that contribute to sustainable development, including the use of water for crop irrigation.	10	Open and binary numerical response (0 y 1)

In each interview, photos and videos were taken, as well as notes, a qualitative ethnographic research technique. Some notes were made privately during the intervention, with a thoughtful composition of the content that revealed information on land use and management, safety measures and environmentally friendly practices in banana cultivation. Then, the main arguments that best explained the context and environmental behavior were extracted to validate the findings, detect patterns or discrepancies.

Study area

The three localities under study are in the municipality of Tecpan de Galeana, in the Costa Grande geo-economic region of the state of Guerrero (Mexico) at coordinates 17° 13′21" N and 100° 37′57" W (INEGI, 2020). According to the Ministry of Economy (SE, 2020) in Mexico, Tecpan de Galeana has a population of 65 237 inhabitants (Figure 1).

In addition to agriculture, most of the population is engaged in retail, temporary accommodation services, and food and beverage preparation, as well as manufacturing (SE, 2020). These particularities allowed this study to be conducted during the CovID-19 pandemic (2020-2021). The number of producers interviewed was reduced due to limited interaction between people, due to the sanitary restrictions imposed by the Federal Government. However, the intervention with the 42 banana producers identified important points for future comparative studies. In Mexico, there is no updated record of the number of banana producers at the state level. This is due to the lack of organization in formal farmer associations, since most are small producers organized by independent family groups.

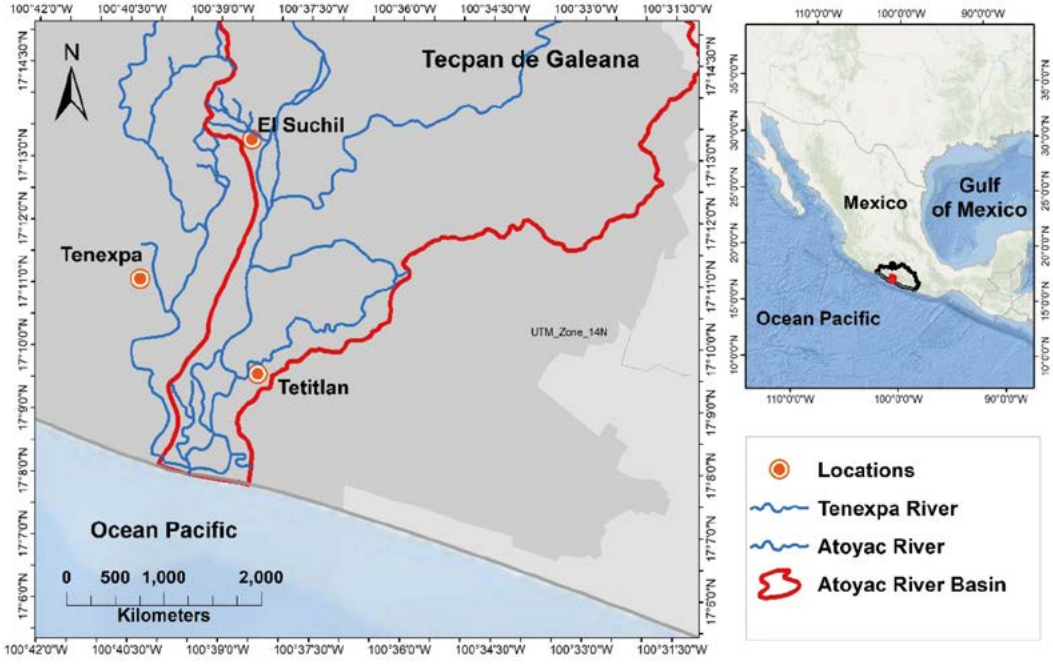


Figure 1. Banana producing localities (El Súchil, Tenexpa and Tetitlán) in Tecpan de Galeana (Guerrero), Mexico and their water supply network.

RESULTS AND DISCUSSION

Overall, the findings showed a wide gap between sustainable practices and actual field practices related to key aspects of sustainable banana cultivation in three locations in southern Mexico.

Key aspects for sustainable cultivation

Farmer training

Most farmers implement weeding, fertilization and application of herbicides, fungicides and other agrochemicals with insufficient training. It is worth mentioning that doing this type of activity with limited knowledge is a health risk and a threat to the environment. For this reason, training through talks and courses is a key aspect in the agricultural sector, and in this case farmers in the three localities under study received training. Regarding the training, annual talks were identified in which most farmers acquired knowledge about vermicompost, the use of herbicides and the management of post-harvest residues (Figure 2A).

Figure 2B shows evidence of training received through courses that addressed various topics such as fertilizers, herbicides, fungicides, safety measures, and final disposal of wastes. Data showed a minimum participation in the courses of no more than 38%, since, of 42 producers, only 14 confirmed having attended at least one course. While the rest of the participants have acquired their learning through the experience of family or friends, through verbal exchange of knowledge. Other producers stated that they used the trial-and-error method in the application of fertilizers and agrochemicals on their plots.

These findings coincide with studies such as those by Sánchez-Gervacio *et al.* (2021) and Mukta *et al.* (2022), who stressed that the mere transfer of knowledge is insufficient if it is not complemented by economic incentives, continuous technical support, and non-formal environmental education strategies. Likewise, Xian-Kang & Hong-Song (2024) reported that training from a technical perspective can encourage the adoption of technologies, especially those related to the efficient use of water in agriculture.

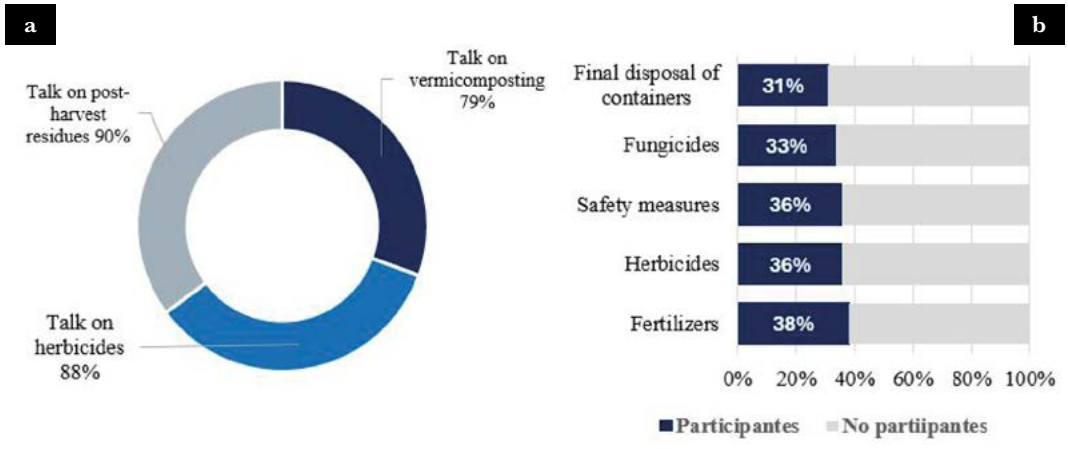


Figure 2. Participation of banana growers in a: talks on environmental issues and agricultural practices, and b: training courses on Agriculture in El Súchil, Tenexpa and Tetitlán, localities of Tecpan de Galeana (Guerrero), Mexico.

Biosecurity and sanitary practices

The first three items made a greater contribution (62%) from producers in biosecurity actions, although they partially complied with protocols, prioritizing health protection with the use of gloves, boots and masks. The rest of the participants (38%) stated that they did not use any type of safety equipment to carry out their activities in the field, they only practiced hand washing and changing clothes (Table 3).

Safety habits were confirmed during field trips and interviews. In fact, one of the producers commented "*I like to give conditions to my workers; but they argue that they do not like to feel uncomfortable, and that they would only accept a suit that clears their view, like a windshield*." Of their own volition, these workers managed their activities with minimal protection in a high-risk context. When discussing contamination problems with producers in the three localities of Tecpan de Galeana, only a minority (14.3%) acknowledged they have presented health problems such as skin irritation and headaches after applying agrochemicals (Figure 3). However, solving this situation is complex; *i.e.*, one of the banana producers argued that they acted like this "*because they had no other option, they live off the work of the land*".

Another important aspect is health and biosecurity measures. Responses showed that the use of personal protective equipment in the field is considered uncomfortable; and some use it inappropriately or incompletely. In this regard, Sánchez-Gervacio *et al.* (2021) noted that farmers should be trained in the correct use of personal protective equipment (PPE)

Table 3. Safety actions and hygiene measures of banana producers in the localities of Tecpan de Galeana (Guerrero), Mexico.

Biosecurity actions	%
Use of gloves, boots, masks, hand washing and changing clothes	28.6
Use of gloves, boots, masks and hand washing	21.4
Use of boots, masks and hand washing	12.0
Hand washing and changing clothes	19.0
Only hand washing	19.0

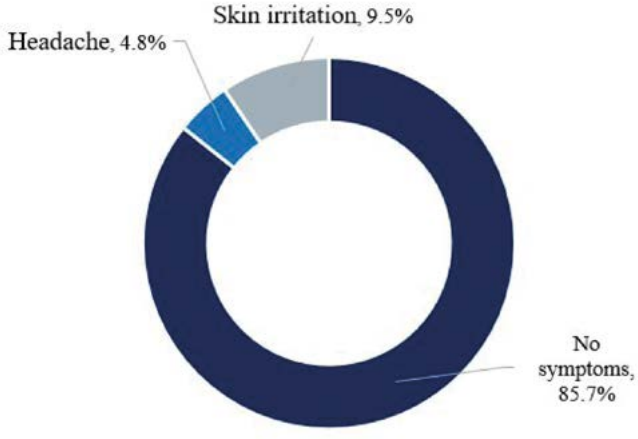


Figure 3. Health effects of banana producers generated by the application of agrochemicals in Tecpan de Galeana (Guerrero), Mexico.

and stressed the importance of using it despite the discomfort it causes in hot climates. The real impact is that direct contact with agrochemicals can cause from just discomfort such as vomiting, headache or drowsiness, to seizures, congenital malformations, and chronic health problems such as cancer or peripheral neuropathies that can lead to death. Hence the importance of adopting biosecurity measures, mainly in the management of fertilizers and agrochemicals, due to their high-risk effects on human health (Harizanova-Bartos & Stoyanova, 2018; Sharifzadeh *et al*., 2019).

Agriculture waste management

Banana crop residues are generated in different stages: planting, harvesting and post-harvest. Organic waste is often placed in the soil to be disintegrated as organic matter. In the post-harvest stage, the residues of the cut (banana stem or rachis and banana waste) are handled. In this last stage, producers obtain economic income from the sale of the fruit, and the waste generated in the previous stages is considered of minor importance, therefore, they do not keep track of it.

In all three localities, the main practice observed in agricultural waste management is composting (70.6%); another common practice is the burning of agricultural waste. The use of this waste to prepare feed for livestock also occurs; this use in Tetitlán represents 14%, and in Tenexpa it is done by 7% of the interviewed producers (Table 4).

Another way to take advantage of the agricultural waste generated by the cuttings or shoots of the banana plant is to distribute them throughout the plantations. So that through its natural degradation a compost is generated useful for the recovery of nutrients in the soils thus fertilized. Even depositing them in the soil as ridges has been observed to help reduce erosion in banana orchards. And another type of waste that is generated in banana cultivation is agrochemical packaging, which generates a problem of contamination in soils and bodies of water when disposed of improperly. In this case, the town of El Súchil showed an outstanding participation, as 50% of the interviewees reported that they participate in an efficient control of agrochemical containers, by returning them to the distributor or supplier (Figure 4).

It is important to note that the favorable response in the town of El Súchil is due to a direct interaction with the agrochemical supplier and their business location close to the town. In addition, there is a collection center for these by-products, supported by dissemination through packaging collection campaigns and an agreement with other civil associations; that is, there is citizen participation for this collection.

Table 4. Management of agriculture residues by banana producers in three localities of the municipality of Tecpan de Galeana (Guerrero), Mexico.

Actions in waste management	El Súchil (%)	Tenexpa (%)	Tetitlán (%)
Composting	80	60	72
Burning	20	27	14
Preparing livestock feed	0	7	14
Transport of harvest	0	6	0
Totals	100	100	100

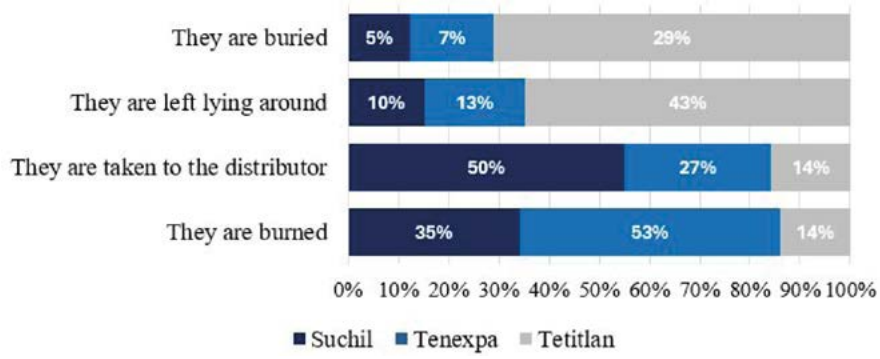


Figure 4. Disposal of agrochemical containers used by banana producers in three localities, in Tecpan de Galeana (Guerrero), Mexico.

In contrast to the other localities, 53% of the producers in Tenexpa burn the containers, which generates air pollution. In Tetitlán, 43% throw them away and accumulate them in an area of their orchards, with the risk of contaminating the soil and groundwater. Therefore, there is a need to raise awareness among banana producers to implement correct management of agrochemical containers in the locality.

In regard to the management of agricultural waste, burning is an activity that if not controlled can cause serious fires, and even authorities try to impose sanctions on this common practice. However, Luna-Celino & Kainer (2024) suggested that local governments provide technical assistance and training to apply controlled burns, which also incorporate the knowledge and experience of farmers on fire and wind management as factors. Likewise, Kouman *et al.* (2009) shared another use of the waste, in this case the covers of the banana pseudostems, as these can be used to transport the banana from the orchard to the ripening facilities, or to treatment and packaging points.

Strategies and challenges for environmental-friendly cultivation

Traditional farming techniques

In agricultural techniques, some traditional aspects are outstanding, such as family influence on production decisions, the way in which cultural practices are made, and the exchange of knowledge. All this influences the adoption of good practices, which come from the transmission of intergenerational experience from parents to children or from exchange with other producers. For example, cultural practices are of great importance in the elimination of tissues that limit the productive potential and quality of bananas, through the removal of leaves and the removal of some sprouts. The latter involves leaving the plant (offshoot) with greater vigor, so that it develops better and eliminating the others that compete for nutrients and space. Another example is the taping that serves to identify the degree of ripeness, as well as the practice of bagging the bunches to avoid damage caused by harmful fauna and placing a wooden pitchfork (in the form of a slingshot, with the double point-ends at the top) to support the plant so that it does not bend.

In the three localities, most decisions in the countryside are preferably made through family, ejido or communal agreements and exchanges. Similarly, land loans and transactions

are generated and validated more by family or neighborhood exchanges and agreements than by the participation of banks or the free competition of capital in the land market. This can be exemplified by the opinion of one of the producers who commented "*to make agreements for the purchase and sale of land, you negotiate first with relatives, then with neighbors, and finally with foreigners.*" Mukta *et al.* (2022) stated that culture changes continuously, as well as the members of the group to which they belong. For example, younger generations among producers tend to be more sensitive to environmental issues.

Water technologies and use

The problems faced by banana producers in the municipality of Tecpan are diverse, but one of the main difficulties is the large volume of water demanded by the production of bananas and other fruits. In terms of their irrigation practices, 18% of the producers surveyed indicated that they use sprinkler and drip irrigation, while 82% prefer flood systems despite water scarcity in some areas. Only in times of low water supply (dry season) do they try drip and sprinkler irrigation techniques, or a combination of both (Figure 5).

In Tecpan de Galeana, banana production takes place in an area irrigated by the Tecpan River (Figure 1). The water collection from the river is distributed through an infrastructure, such as an irrigation canal, which benefits the towns of El Súchil and Tenexpa. During the dry season, both localities supplement their irrigation needs with water extracted from artesian wells with connection to drip and sprinkler irrigation systems. While in Tetitlán, farmers rely exclusively on groundwater, extracted from deep wells, and try to use water efficiently through drip and sprinkler irrigation systems.

The maintenance of water infrastructure depends largely on public investment and community work. According to one of the producers, "*the last investment with Government support was in 2012 when a one-kilometer pipeline was dredged and rehabilitated in the town of El Súchil. Every year, we make the desilting work and installation of a stone-dam that distributes water to the canals in the months of June-July and November-December.*" The implementation of best management practices for banana cultivation in Tecpan de

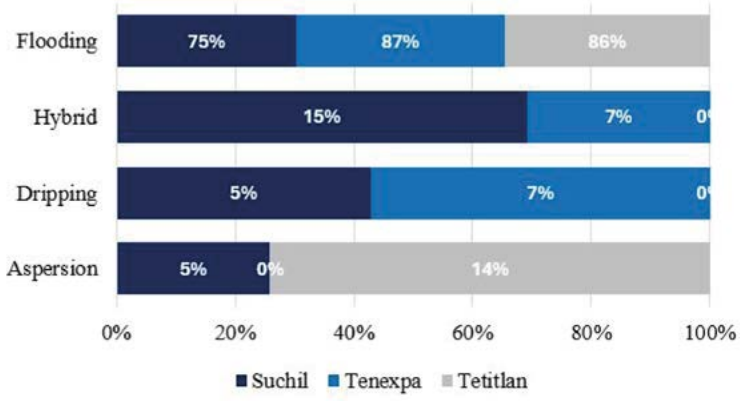


Figure 5. Types of irrigation systems for the cultivation of bananas and other crops in the localities of El Súchil, Tenexpa and Tetitlán, in Tecpan de Galeana (Guerrero), Mexico.

Galeana is a challenge for many producers, since many of them demand investment, technology and knowledge to guarantee effectiveness, since the application requires specialized soil and hydrology studies, as well as previous experience for pest control and water use.

Although the study reveals some good practices with the use of water, these represent a challenge for small farmers due to the cost and the specialized personnel required for their installation. The use of modern agricultural technologies, such as drip or sprinkler irrigation systems, can effectively alleviate the problem of water resource scarcity (Xian-Kang & Hong-Song, 2024). To achieve this, the United Nations Food and Agriculture Organization (FAO) (2020) recommended investing in irrigation systems or modernizing and rehabilitating existing ones to use water in agriculture more efficiently.

Consensus on environmentally friendly agricultural strategies

During the study, several talks were held with producers where they shared experiences aimed at environmental-friendly practices, such as the use of agricultural waste, the production of organic fertilizers and biosecurity measures that include water conservation. The proposals that resulted from this consensus are described (Table 5).

Table 5. Consensual proposals with banana producers in the municipality of Tecpan de Galeana (Guerrero), Mexico.

Challenges	Strategies	Intervention	Themes for EE
Soil degradation from intensive use of agrochemicals	Studies that consider the degree of soil fertility and the use of organic fertilizers at affordable prices.	Analysis of soil fertility and development of a plan that includes the use of waste.	• Importance of soil fertility studies. • Use of waste for soil recovery.
Use of PPE	Adjust protective equipment to make it more comfortable. Campaigns for rising awareness on the use of PPE in farmlands.	Health brigades from research institutions.	• PPE for farmers. • Proper use of PPE. • Risks and consequences for farmer health.
Agriculture Waste Management	Use of organic waste to produce vermicomposting and leachates.	Studies of leachate components demonstrate usefulness.	• Waste use. • Adding value to crop residues.
Proper handling/ disposing of agrochemical containers	Training in triple washing. Reporting on the packaging management chain with suppliers.	Implementation of a Non-Formal Environmental Education Program (NFEEP)	• Hazardous waste. Health effects, soil and water pollution.
Water management for irrigation	Awareness campaigns, state support for the acquisition and training of new technology for efficient use of water.	Implementation of a Non-Formal Environmental Education Program (NFEEP).	• Development of contents on the water cycle and environmental care to avoid water pollution.

EE: environmental education; PPE: personal protective equipment; NFEEP: non-formal environmental education program.

The results showed that in localities with strong solidarity, farmers tend to share knowledge, forming a broad local network committed to minimizing pesticide use. Building consensus on sustainable agricultural practices through the exchange of experiences can be complex, although the results are often favorable and conducive to the common good. According to Kumar *et al.* (2023) Each region has a particular method to implement various activities, which involves cropping systems and the management of their residues; as well as the use of available local resources and the socioeconomic conditions of farmers. For example, Mukta *et al.* (2022) pointed to an experience with farmers in Bangladesh, who solved their problems related to pest management in their crops by using community knowledge from nearby sources, such as neighbors, friends, farmer family, local suppliers, and officials visiting the community.

Although this study was limited in scope, with a focus on banana crop producers, some of their socio-environmental dynamics were identified. Therefore, for a deeper understanding regarding the adoption of sustainable practices for the crop studied, it is convenient to extend the evaluation to other types of crops. To obtain information on other good practices in aspects of training, biosecurity measures and use of agricultural residues. Also, to analyze other key aspects that serve as support for the formulation of agricultural programs, from a scientific context for decision-makers.

A larger study could reveal more information if the implementation of a non-formal environmental education program is added to raise awareness and enhance the knowledge acquired from the experiences of producers. This would encourage and promote a change towards safer and more environmentally friendly agricultural practices in the medium term, and experiment subsequently with the appropriation of new practices or technologies aimed at sustainable agriculture.

Findings brought evidence of a wide gap between sustainable practices and practices applied in the field, in aspects such as training, biosecurity measures, and agricultural waste management, which includes agrochemical packaging, in which inadequate practices persist. Among the suggested strategies, we highlighted the promotion of composting practices, the use of organic fertilizers, which are essential to move towards a more sustainable agriculture. Challenges were observed in the use of personal protective equipment and the improvement of irrigation infrastructure, since both require campaigns to raise awareness to generate changes in overall attitudes. Although the changes imply an economic investment that most of small producers are not yet willing to make.

CONCLUSIONS

Although banana producers present challenges in implementing sustainable cultivation, they also present opportunities if they organize themselves into groups or guilds. Consensus among producers identified viable practices for sustainable agriculture. However, Government involvement is key to driving these advances and positioning the region as a leader in banana production. It is important to note that an investment in non-formal environmental education programs (NFEEP) can encourage the use of environmental-friendly practices. This is not only for banana cultivation, but also for other types of

crops. An environmental education program can be a driver that attracts investment and economic development to the region.

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