Certification of Fertilizers and Pesticides as a Strategy for Sustainable Development: The Case of Agricultural Trading Companies in Sinaloa

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Abstract. The certification of fertilizers and pesticides is vital for promoting ecological agriculture and safeguarding soil and food production. A major challenge for global agriculture is ensuring future food supply by increasing yields per cultivated area. To achieve this, best practices, particularly in fertilizer and pesticide use, are essential. This study examines how input certification supports agricultural trading companies and contributes to Sustainable Development Goal 12 of the United Nations 2030 Agenda, focusing on sustainable consumption and production patterns. Using a qualitative methodology, the study involved surveys with agricultural-input suppliers from Sinaloa State-Mexico, and interviews with company executives and government officials. Data analysis was conducted using SPSS and ATLAS.ti. Results from 48 surveys and 5 interviews reveal a positive link between organic certification and increased profits, as well as growing interest in sustainability among farm managers. However, bureaucratic delays and lack of institutional support hinder certification efforts. Given that Sinaloa is a major agricultural region, these findings can be applied to other parts of Mexico, particularly where agriculture is central to the economy. The insights offer valuable implications for states looking to adopt sustainable practices and could guide policymakers in simplifying certification processes to support the sector nationwide.

1 Introduction

'Earth Overshoot Day' relates to the production of renewable resources and services that the planet can generate in a year with the average global consumption, estimating a date from which it is considered that we are using resources from future generations. As shown in Figure 1, this analysis indicates that by 2024, the production of 1.75 planets will be required to meet global demand [1]. Furthermore, according to the United Nations (UN), if the world population reaches the estimated 9.7 billion by 2050, an equivalent of three planets would be needed to satisfy humanity's needs, based on the current lifestyle [2].

Among the proposals set forth by the UN in its 2030 Agenda, with 17 Sustainable Development Goals (SDG), Goal 12, "Ensure sustainable consumption and production patterns", outlines some targets to address this issue [3]. Currently, the adoption of good agricultural practices to improve crop management is increasingly necessary. These practices emphasize soil care by providing the appropriate doses of nutrients through various types of fertilizers [4].

Through the evolution of the agricultural process, the significant socio-economic and developmental benefits brought using fertilizers and pesticides can be inferred, especially in terms of productivity. Despite this, there are also some disadvantages. For example, not all the nutrients applied are fully absorbed by the soil, and this excess generates environmental pollution, causing imbalances in ecosystems and thus affecting biodiversity [5].

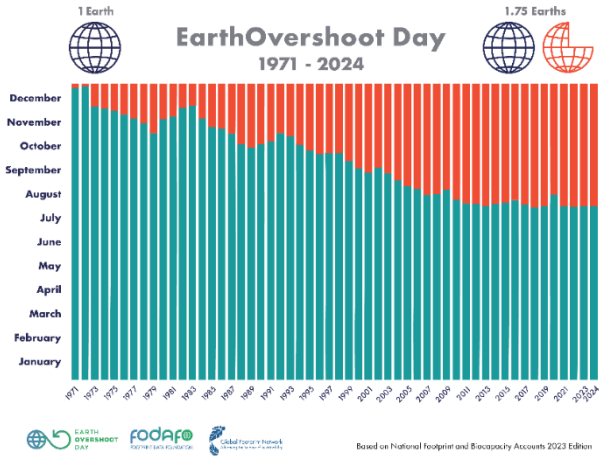

Fig. 1. Earth Overshoot Day 1970-2024 [1]

The overall objective of this research is to analyze the impact of the certification process of fertilizers and pesticides on the development of agricultural-input trading companies and to assess how these certifications contribute to achieving SDG 12 of the UN 2030 Agenda, which pursues to promote sustainable consumption and production patterns. To achieve this goal, a structured

survey was conducted targeting the agricultural-input trading subsector in Sinaloa State-Mexico.

2 Problem Statement and Literature Discussion

2.1 Problem

Currently, one of the greatest challenges facing the global agricultural sector is ensuring the food supply for future generations. According to the United Nations, the world population is projected to reach 8.5 billion by 2030, 9.7 billion by 2050, and 10.3 billion by 2100, according to the UN's medium fertility scenario. The United Nations Food and Agriculture Organization (FAO) estimates that a nearly 50% increase in food production will be needed to meet the expected global demand by 2050. Achieving this goal requires transforming food systems to be more efficient, inclusive, and resilient, while ensuring coherence between national and international governance systems. The goal is to balance increasing food production with reducing environmental impact [2,6].

In Mexico, the Agri-food and Fishery Information Service (SIAP) indicates that food supply is also a significant challenge, despite 24.6 million hectares of arable land in 2020 [7]. Given the projected population growth in the coming decades, this area could shrink considerably as land is repurposed for housing.

To ensure food supply, more must be done with less, meaning increased yield per unit of cultivated land. To achieve this, sustainable agricultural practices must be implemented. According to the Secretary of Agriculture and Rural Development (SADER), conservation agriculture is a key tool for soil health and sustainable yield gains [8], requiring greater knowledge of soil, water, the processes for the use, storage, and disposal of agrochemicals, and the appropriate use of fertilizers.

Both fertilizers and pesticides help improve crop yield and, in turn, induce agricultural productivity. In theory, that should reduce costs for the final consumers and improve food access for the global population [9]. However, excessive use of these agricultural inputs can lead to severe soil contamination, from nitrogen deposits to water system damage. Although nitrogen is a crucial nutrient for agricultural production, its mismanagement can have environmental consequences. New technologies, such as Nitrogen Use Efficient (NUE) crops, are being developed to better control this element [10]. In the short term, more efficient use can be achieved by applying slow-release nitrogen fertilizers, precision nitrogen application tools, or fertigation through micro-irrigation [11].

It is also necessary to ensure that Good Agricultural Practices (GAP) and Good Manufacturing Practices (GMP) being promoted and implemented throughout the agri-food chain. Organizations exist to promote their application, both nationally and internationally, through certifications and initiatives aimed at improving food safety under standards of health, quality, social well-being, and environmental care.

Based on the above parameters, the crucial role that fertilizers and pesticides play in agricultural production can be distinguished in terms of productivity, and environmental sustainability. This highlights the importance of ensuring that the substances used throughout the production chain comply with established organic and quality standards.

Furthermore, the certification of fertilizers and pesticides can be considered as strategic for business improvement, allowing organizations to raise revenues and market share by offering certified organic products to their customers. Altogether contributes to meeting SDG 12, "Ensure sustainable consumption and production patterns".

2.2 Literature Review

To analyze the beginnings of fertilizer and pesticide certification, it is necessary to address the phenomenon of the Green Revolution, which developed in the early 20th century. This movement saw an expansion in agricultural production through changes in innovative methods; monoculture was also used, dedicating a hectare to the production of a single type of crop, where greater quantities of fertilizers, pesticides, and water were applied [12].

However, the Green Revolution not only brought benefits to the agri-food subsector but had social and environmental consequences, too. The quality of arable land deteriorated, and the health of both producers and consumers was, eventually, affected due to the excessive use of chemicals in food production.

Given the challenges faced, it has become crucial to generate more sustainable alternatives for the production and consumption of goods and services, which include standardization in terms of food safety and quality, while also addressing environmental care, such as through the certification of fertilizers and pesticides.

The research of this topic has taken the last 30 years through various research efforts, both in academic studies and business. For example, Vázquez and Labarca [13] from the University of Zulia in Maracaibo, Venezuela, analyzed quality and standardization as competitive strategies in the agri-food sector through a documentary study. They concluded that these strategies play a decisive role in business success, as they can provide a competitive advantage, especially in the agri-food sector, by promoting productivity, yield, and crop safety. Within this standardization framework, the certification is a strategy to achieve organizational differentiation [14].

Regarding SDG 12, "Ensure sustainable consumption and production patterns", the importance of sustainability studies has been growing since the 1987 Brundtland Report. For instance, the statistical analysis conducted by Héctor-Ardisana, Torres-García, Fosado-Téllez, Peñarrieta-Bravo, Solórzano-Bravo, Jarre-Mendoza, Medranda-Vera, and Montoya-Bazán [15], titled "Influence of Bio-stimulants on the Growth and Yield of Short-Cycle Crops in Manabí, Ecuador," intends to address the current need to improve agri-food systems by exploring alternative ways to increase

productivity and yield while maintaining environmental sustainability.

This research is supported by three theories, as shown in Table 1.

Table 1. Theory of Sustainable Development, Asymmetric Information, and Competitive Advantage.

Theory	Connection with research
Sustainable Development	It analyzes the impact of fertilizer and pesticide certifications on agricultural companies, focusing on three dimensions: environmental (sustainable practices), social (consumption and production patterns), and economic (financial growth).
Asymmetric Information	It emphasizes the role of certifications in solving adverse selection, meeting international standards, and building customer trust, thus promoting sustainable practices aligned with SDG 12.
Competitive Advantage	It embraces the hypothesis that certifications strengthen the development of agricultural companies in Sinaloa State by adding value through safety and quality standards.

3 Methodology and Estimation Results

3.1 Methodology

This research employed a qualitative approach, aiming to provide an in-depth analysis with a descriptive and explanatory scope. The qualitative component focused on interpreting insights from a structured survey, academic articles, reports, and graduate theses relevant to agricultural input trading, complemented by semi-structured interviews with key stakeholders.

To calculate the statistical sample for the fertilizer and pesticide trading company subsector in Sinaloa, the population of agricultural-input trading companies in the state entity was surveyed. According to the National Statistical Directory of Economic Units (DENUE) data from the National Institute of Statistics, Geography and Technological Information (INEGI) in Sinaloa State, there are 540 economic units dedicated to the wholesale trade of fertilizers, pesticides, and seeds. Of this total, 188 companies have current certification as agricultural pesticide traders [16]. However, this count includes each branch of the trading companies; when duplicate companies are removed, the total comes to 96 economic units. From this population, the sample of agricultural-input trading companies is designed using the following formula [17]:

$$n = \frac{N * Z^2 * p * q}{(N-1) * e^2 + Z^2 * p * q}$$

Where:

n = sample size to be estimated
N = population size
Z = standard deviation of the mean value accepted for the desired confidence level
e = margin of error
p = positive variability
q = negative variability, 1-p

Given that the population of certified agricultural input trading companies in Sinaloa State is composed of 96 companies, and assuming a 95% confidence level, a 10% margin of error, and a variability of 0.5, it was determined that the sample size should be 48 economic units.

The structured survey contains 23 items, each aligned with at least one of the 8 research indicators. A Likert scale was used to collect statistical information. The survey was conducted both in person and virtually using the *Google Forms* tool.

The semi-structured interview for company directors/owners consisted of 13 questions and was conducted in person with three directors from agricultural input trading companies in Sinaloa. A second semi-structured interview, designed for the government sector, included six questions and was also conducted in person with two officials: one from SENASICA and one from the state government.

A methodological model for data processing was designed according to the action plan. It is subdivided into three phases (see Table 2).

Table 2. Methodological Procedure for Data Processing.

Phases	Description
1. Data Collection	- A structured (closed) survey for fertilizer and pesticide trading companies in Sinaloa. - Semi-structured interviews with company directors/owners. - Semi-structured interviews with government sector officials. - Some documents (academic articles, reports, graduate theses)
2. Data Processing	- Entering collected information into SPSS and ATLAS.ti software packages. - Refining relevant information obtained from the survey and other documents. - Elaboration of research notes. - Organization of information by variable, dimension, objective, and indicator criteria.
3. Data Analysis	- Classification of information sets by variables and dimensions. - Comparisons between findings and research hypothesis. - Drawing of conclusions and policy options.

3.2 Results Obtained

3.2.1 Survey

In this section, the most relevant questions from the survey were selected to provide brief and concrete interpretations for each one.

The first question concerns the proportion of products that have a registration issued by the Federal Commission for the Protection against Sanitary Risks (COFEPRIS) at the time they are marketed by the companies. The resulting data can be seen in Figure 2.

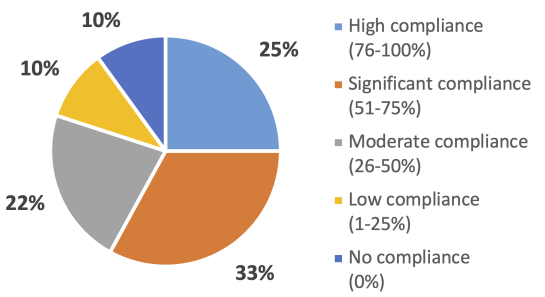

Fig. 2. Proportion of products with COFEPRIS registration at the time of being marketed by companies.

This situation allows for the assessment of regulatory compliance and the quality of products offered by companies. The results reveal different levels of compliance: 25% (12) have a high compliance level (76% - 100%), 33% (15) show a significant level (51% - 75%), 22% (11) have a moderate compliance level (26% - 50%), while 10% (5) show low compliance (1% - 25%). Surprisingly, another 10% (5) do not comply with any regulation. These companies must take immediate action to ensure the legality and quality of their products.

In the same context of regulatory compliance and product quality offered by companies, a question was included regarding the percentage of products that have some organic certification at the time of being marketed.

By including this question, the aim is to evaluate whether companies are aligned with current trends and the growing demand for organic products, generating trust and value-added products and services for consumers concerned about their health and the environment. Figure 3 shows the results to this question.

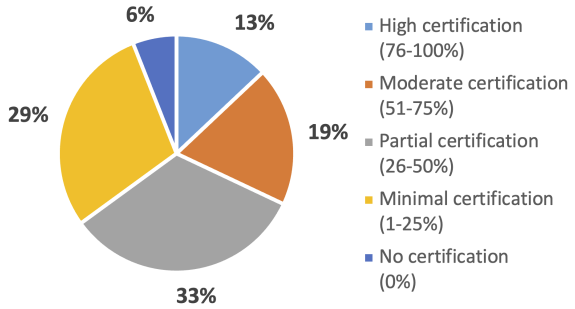

Fig. 3. Percentage of products that are marketed with any organic certification.

The results shown in Figure 3 reveal varying levels of commitment and adoption of certified organic production practices by companies. Thirteen percent (6) have certification for between 76% and 100% of their products, demonstrating a strong pledge allegiance to sustainable practices. Nineteen percent (9) have certification for 51% to 75% of their products, indicating progress towards more sustainable practices. Thirty-three percent (16) have certification for 26% to 50%, while twenty-nine percent (14) have certification for 1% to 25% of their products. Six percent (3) have not yet ventured into organic certification but may consider this option to meet the market demand for organic products and demonstrate they are committed to health and the environment.

Now, to delve into the effects obtained through the organic certification of their products, companies were asked if they noticed any change in the sales of those products after acquiring any of these certificates compared to before obtaining them. The results are depicted in Figure 4.

The data presented in Figure 4 shows a generally positive impact of certification on the sales of the companies surveyed. Twenty-one percent (10) experienced a very positive effect, with an increase of more than 50% in sales after obtaining certification. Sixty percent (29) reported a positive impact, with an increase ranging from 1% to 50%, reflecting a favorable response from consumers towards certified products. Nineteen percent (9) indicated a neutral effect on sales, suggesting the need to consider additional strategies to maximize the benefits of certification.

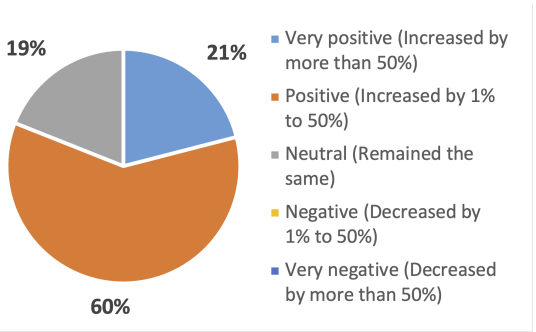

Fig. 4. Effect of obtaining organic certification on product sales compared to before certification.

Continuing with the effects of organic certification on the organization, they were also asked whether obtaining such certifications generated any changes regarding their market share. The results are shown in Figure 5.

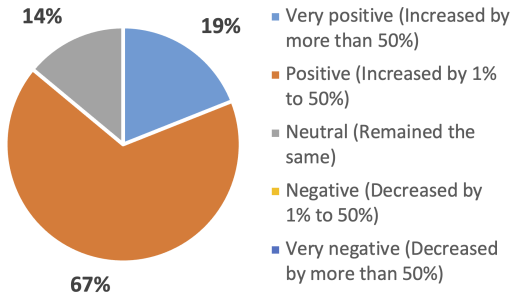

Fig. 5. Effects of organic certification on market share as a company overall.

The analysis of the data in Figure 5 reveals that certification has had a largely positive impact on the companies' market position. 19% (9) experienced a very positive effect, with an increase of more than 50% in their market share, suggesting a strong competitive position and consumer preference. 67% (32) reported a positive effect with a span from 1% to 50%, improving their competitive position and consumer confidence. 14% (7) indicated a neutral effect, which could be

attributed to economic competition or lack of dissemination. These companies might consider additional strategies to maximize the benefits of certification and increase their market share.

One of the key measures to contribute to SDG 12 "Ensure sustainable consumption and production patterns" in the business sector, is the training and education of employees, suppliers, and other relevant actors about sustainable production and consumption practices and guidelines. The inclusion of this question in the survey aims to understand how frequently companies are carrying out these training activities and how they are contributing to sensibility and adoption of sustainable practices accordingly, i.e. in their business environment. The results of this inquiry are illustrated in Figure 6.

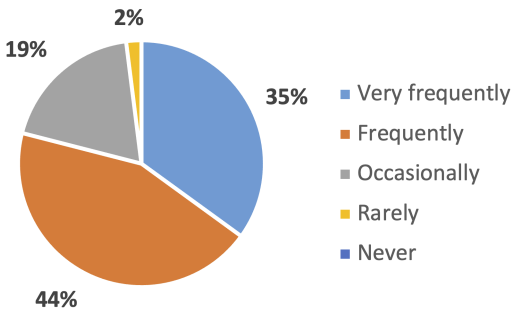

Fig. 6. Training of employees, suppliers, and the entire value chain in sustainable production and consumption practices and guidelines.

The figure 6 shows that most of the surveyed companies have a significant commitment to sustainability training. The 35% (17) do so very frequently, and 44% (21) do so frequently, reflecting a proactive approach to informing and training employees and suppliers. However, 19% (9) do so occasionally, and 2% (1) do so rarely, suggesting there is room for improvement in the frequency of these activities. It is essential for companies to continue prioritizing sustainability training to promote responsible practices and contribute to sustainable development in their sectors.

Another crucial point considered in this research is the degree of governmental information dissemination regarding the importance of having organic certifications. These certifications represent a fundamental element for ensuring responsible and environmentally friendly production practices.

Therefore, including the question about the perception upon the level of official dissemination of information allows to take pulse about companies' awareness regarding the promotion and encouragement of sustainable practices. Additionally, it reveals the influence and effectiveness of governmental policies and actions in raising consciousness of the value over adopting organic certifications by companies. The results can be seen in figure 7.

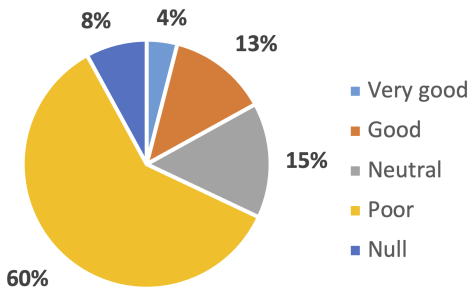

Fig. 7. Perception of the level of government dissemination regarding the importance of having organic certifications for achieving sustainable development.

Figure 7 reveals a predominantly negative perception among the companies surveyed regarding governmental promotion related to the relevance of organic certifications for promoting sustainable practices. Thus, sixty percent (29) consider that the level of dissemination is deficient, and 8% (4) perceive it as nonexistent in practice. Fifteen percent (7) have a neutral perception, while a small percentage (4% and 13%) believe the level of information dissemination is good or very good.

Another question included to gain deeper insight into the current state of organic certification in the subsector of companies marketing agricultural inputs relates to the main obstacles confronted by companies in obtaining such certifications, which is relevant for understanding the challenges and difficulties they encounter on their path to certification. The results for this question are graphically represented in figure 8.

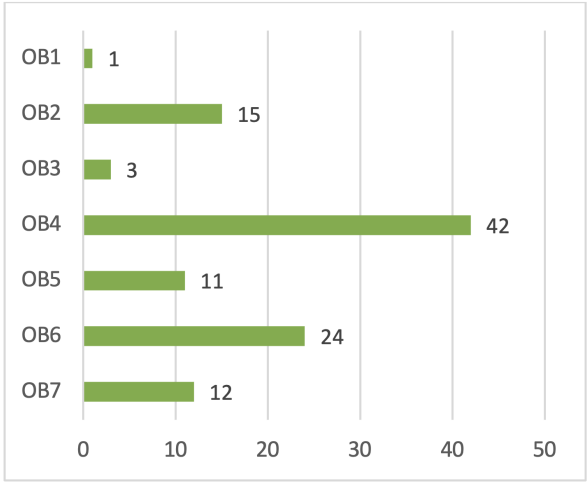

Fig. 8. Main obstacles confronted in obtaining these types of certifications.

Where:

OB1 = Formulation of products to qualify as organic
OB2 = Lack of mandatory requirements
OB3 = Unawareness of options
OB4 = Lengthy bureaucratic processes
OB5 = Applicable legal framework
OB6 = Complexity of the process
OB7 = High costs

Figure 8 highlights that the main obstacle to obtaining organic certifications is the "lengthy

bureaucratic process" (OB4), which is acknowledged by 42% of the companies surveyed. This is followed by OB6 "complexity of the process" (24%) and OB2 "lack of mandatory requirements" (15%). In general, obstacles may vary according to the context and structural characteristics of each company but, in turn, judging them is an essential decision criterion for assuming effective strategies and providing support in overcoming these barriers. Furthermore, understanding the specific obstacles encountered by the companies, it provides valuable information for identifying areas of opportunity to improve the organic certification processes and fostering a more conducive environment for the adoption of sustainable practices.

3.2.2 Interviews

For the analysis of the interviews with directors of agricultural input trading companies and government officials, the software ATLAS.ti 23 was used. This software enabled the establishment of relationships between the responses of the interviewees, creating connections between the research variables.

From the network generated in ATLAS.ti, figures 9 and 10 were created, which highlight the significant convergence of codes between the dependent and independent variables. This convergence reveals a substantial interconnection between the perceptions and effects of certification within the agricultural input industry and the achievement of sustainable development goals, specifically SDG 12 for this research.

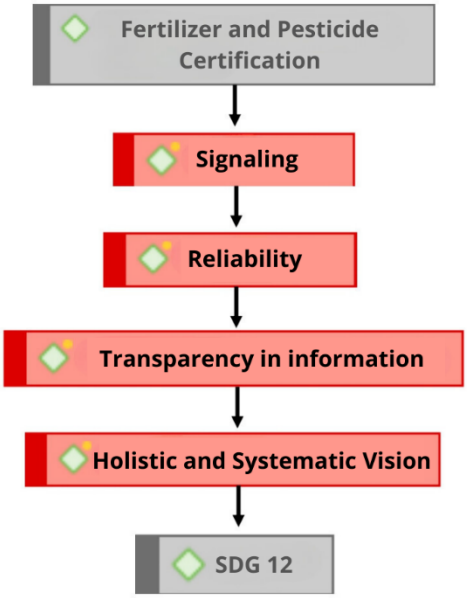

Fig. 9. Quality and Transparency Pathway in Sustainable Agriculture.

In figure 9 (red path), a chain of relationships unfolds, illustrating how the certification of fertilizers and pesticides serves as a quality signaling mechanism. This signaling is closely linked to the 'reliability' code, as reliability is a fundamental characteristic of any effective signaling system. By ensuring compliance with established standards, certification fosters trust and confidence, which in turn enhances the reliability of the agricultural products involved. This reliability naturally leads to greater transparency in information, a key component in the holistic and systematic approach to sustainable practices. Transparency ensures that all stakeholders have access to clear and accurate information about production processes, positioning it as a cornerstone of sustainability. Ultimately, this path culminates in a direct connection with SDG 12, 'Ensure sustainable consumption and production patterns,' highlighting how certification contributes to achieving sustainable development goals by promoting responsible production and consumption practices.

On the other hand, figure 10 (blue path) shifts the focus to the relationship between agricultural production and the certification of fertilizers and pesticides. This connection leads to the 'food security' code, which is fundamental to agricultural production, as ensuring the safety and quality of food is essential for its success. The certification of agricultural inputs, such as fertilizers and pesticides, directly supports food security by guaranteeing the safety of the crops and products being cultivated. Moreover, food security is framed within the broader context of the Circular Economy, which aims to minimize waste and optimize resource use—principles that align with sustainable development. Ultimately, this path culminates in the SDG 12 variable, underscoring how the certification of agricultural inputs plays a critical role in achieving broader sustainability goals, particularly by promoting responsible practices that contribute to a circular and sustainable agricultural system.

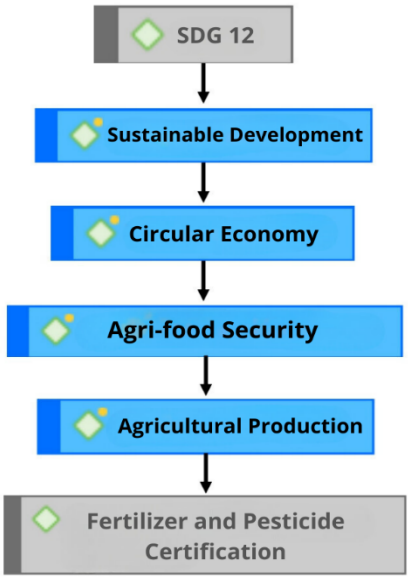

Fig. 10. Food Security and Circular Economy Pathway.

4 Conclusions and Recommendations

4.1 Conclusions

The certification of fertilizers and pesticides positively impacts the development of companies marketing

agricultural inputs in Sinaloa, as these certifications contribute to generating added value in the products and services offered, enhancing competitiveness and strengthening their market position. Moreover, it supports the achievement of Sustainable Development Goal 12 of the 2030 Agenda by promoting sustainable production and consumption practices, thereby contributing to environmental preservation and social well-being in the community.

The obstacles to obtaining certification include lengthy bureaucratic processes, the complexity of the certification process, and the lack of mandatory requirements for certification. These challenges can hinder companies' access to certifications and require special attention to promote sustainable practices among a larger number of organizations.

Given that Sinaloa is a primarily agricultural region, these findings may be generalized to a broader Mexican context, particularly in regions where agriculture is a central economic activity. The insights gained from this study provide valuable implications for other Mexican states aiming to implement sustainable agricultural practices and could guide policymakers in developing more accessible certification processes to benefit the sector nationwide.

4.2 Recommendations

1. To promote governmental information dissemination on the importance of holding organic certifications and their impact on sustainable profitability. Likewise, installing and enhancing communication channels between government and agricultural-inputs companies, let alone the setting of schemes, both technical and financial, are envisaged as key factors first, to retain existing firms on business and encourage new ones to get entry into this specialized market segment and, second, on administrative grounds, to simplify the issuance of certification capacity.

2. To encourage the training in operative skills and in sustainability principles within employees, suppliers, and key stakeholders, is also crucial in elevating social responsibility and in embedding sustainable practices throughout the value chain.

3. To establish incentives and recognition for companies that obtain certifications and excel in sustainable practices. Recognizing and rewarding companies' efforts stimulates the widespread adoption of sustainable practices in the subsector.

4. To agree with the public and private sectors that the adoption of best practices through collaboration and partnership schemes are urgently needed given current climate change effects for underplaying them. Close cooperation among incumbent stakeholders as on the agricultural-input sellers and manufacturing providers' side, as on the clients' side, it is expected to bring forward the implementation of sustainable production and consumption practices likewise their spreading out of a sustainability culture in the Sinaloa State and elsewhere in the Northwest region and Mexico as a whole.

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