

## SOCIAL AND SOLIDARITY ECONOMY MODEL FOR THE PRODUCTION, PROCESSING, AND MARKETING OF NOPAL IN THE DESERT AREAS OF CIUDAD JUÁREZ, CHIHUAHUA

## SOCIAL AND SOLIDARITY ECONOMY MODEL FOR THE PRODUCTION, INDUSTRIALIZATION, AND MARKETING OF NOPAL IN THE DESERT AREAS OF CIUDAD JUÁREZ, CHIHUAHUA

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**Abstract--** The principles of the Social and Solidarity Economy (SSE) form the basis of the model presented in this study. This perspective aims to promote sustainability, social justice, collaboration, and democratic governance as fundamental elements for restructuring the prickly pear production chain in the desert areas of Ciudad Juárez, Chihuahua. This vision seeks to integrate key variables of production, industrialization, and marketing to generate a positive impact on the quality of life of producers and their environment.

The SSE methodology is implemented through a comprehensive assessment that examines commercial, technological, and agroecological factors, followed by a collaborative co-creation process in which producers, technical experts, and local stakeholders work together to establish the model. The implementation of a pilot project makes it possible to assess its effectiveness from social, environmental, and economic perspectives. To this end, a mixed methodology is used that encompasses qualitative and quantitative methods (workshops, surveys, physical-chemical analyses, and interviews) and ensures rigor through the use of thematic and statistical analyses.

The purpose of the model is to improve participants' technical and organizational capacities, increase the added value of nopal, and facilitate access to solidarity markets. It also aims to coordinate the entire production chain under sustainable and solidarity-based principles, thereby contributing to territorial development that is inclusive and replicable. This type of development promotes equity, productivity, and sustainability in nopal-growing communities in semi-arid areas.

**Keywords**—Community cooperation, Social and Solidarity Economy (SSE), Democratic management, Solidarity markets, Participatory model.

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The SSE methodology is implemented through a comprehensive assessment that examines commercial, technological, and agroecological factors, followed by a collaborative co-creation process in which producers, technicians, and local stakeholders work together to define the model. The implementation of a pilot project enables the evaluation of its effectiveness from social, environmental, and economic perspectives. To this end, a mixed methodology is used, encompassing qualitative and quantitative methods (workshops, surveys, physicochemical analyses, and interviews), ensuring rigor through thematic and statistical analyses.

The purpose of the model is to enhance the technical and organizational capacities of participants, increase the added value of nopal, and facilitate access to solidarity markets. Likewise, it aims to coordinate the entire production chain under sustainable and solidarity principles, thereby contributing to inclusive and replicable territorial development. This type of development promotes equity, productivity, and sustainability in nopal-producing communities in semi-arid areas.

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## Introduction

This research proposes a model for the production, industrialization, and sale of nopal-derived products in desert areas of Ciudad Juárez, Chihuahua, grounded in the Social and Solidarity Economy (SSE) methodology. The SSE provides a theoretical framework based on social justice,

sustainability, democratic management, and collaborative work, which makes it possible to reconfigure and strengthen the nopal production chain.

The main objective is to combine key variables of production, technology, and marketing to optimize conditions for local producers and foster balanced progress in economic, social, and environmental terms. To this end, a comprehensive assessment is conducted that includes agroecological, commercial, and technological elements. This participatory process involves the collaboration of technicians, producers, and community members in the development of the model.

Furthermore, to determine its effectiveness and adaptability at the local level, the pilot implementation of the model employs a combined approach that integrates qualitative and quantitative tools. The expected outcome is a replicable model that improves organizational and technical skills, increases the added value of nopal, and facilitates access to fair-trade markets, thereby contributing to sustainable and inclusive territorial development in semi-arid regions.

## **Development**

### **Study Design and Methodological Framework**

The model is based on a mixed participatory methodology grounded in the principles of the social and solidarity economy (SSE), such as autonomy, accountability, sustainability, transparency, and solidarity. This approach combines qualitative techniques (focus groups, workshops, interviews) and quantitative techniques (physical-chemical analyses, surveys, inferential and descriptive statistics) with the aim of determining, co-constructing, and verifying the model within the nopal production chain (production, processing, and marketing) in desert areas of Ciudad Juárez, Chihuahua.

The study consists of four consecutive stages: (1) participatory diagnosis, (2) co-creation of the model, (3) pilot-scale implementation, and (4) evaluation of the effects. Key stakeholders were included: 50 nopal producers (selected through purposive sampling), 10 agroecology experts, 5 SSE organizations (cooperatives), researchers from the academic community, and representatives of the public sector at the municipal level. To ensure representativeness, a total of 80 participants were used as the sample. Inclusion criteria (living in desert areas and having experience in nopal production) and exclusion criteria (conflicts of interest) were applied for this purpose.

## Phase 1: Participatory Diagnosis

A comprehensive assessment was conducted to identify limiting factors in terms of agroecology (droughts, desertification), technology (lack of industrialization), and commerce (market access, intermediaries).

- Quantitative instruments: Structured questionnaires (n=60, 1–5 Likert scale) and production data (post-harvest losses, yield per hectare). The market study covered local prices and volumes sold. Descriptive statistics (standard deviations, means) and inferential statistics (ANOVA for variations by area;  $\alpha=0.05$ , Student's t-tests to compare yields) were used.
- Qualitative instruments: Focus groups (n=4, each with 8–10 participants) and semi-structured interviews (n=20, lasting between 45 and 60 minutes). To identify patterns such as “low valuation of mucilage” or “exclusion from fair-trade markets,” thematic coding (NVivo software) was used for analysis.

Initial triangulation incorporated the data and showed that 72% of producers report losses exceeding 30% due to a lack of technology, in addition to recurring issues such as “chronic drought” (85% frequency).

## Phase 2: Participatory Co-creation of the Model

Based on the diagnosis, the model was developed in participatory workshops (n=6, with 20 to 30 participants). The stakeholders established governance structures: thematic committees (on finance, agroecology, and marketing), spaces for ongoing dialogue (monthly assemblies), and a pluralistic council (with equitable representation).

The model integrates:

- Production: Agroecological techniques (such as crop rotation with legumes or drip irrigation) to reduce desertification.
- Industrialization: Methods for derivatives (flours, mucilage, cosmetics), validated through physicochemical analyses (pH, viscosity, protein content; AOAC methods).
- Marketing: Solidarity networks (ethical digital platforms, local fairs) for direct access that increases added value by 40–50%.

Democratic management was prioritized through training (n=4 workshops, 40 hours) in organizational skills and collective voting.

### Phase 3: Pilot Implementation

The pilot was carried out on a 1-hectare plot in desert areas (approximate coordinates: 31.7°N, 106.4°W), with a 12-month timeline (see Table 1). It included:

**Table 1.** 12-month timeline.

No.	Activity	Deliverables	Period	Amount (MXN)
1	Site Demarcation	Location, characteristics	2 months	5,000
2	Staff training	Trained team	1 month	3,500
3	Materials (lime, odometer)	Inventory obtained	1 month	7,500
4	Irrigation system	Materials purchased	1 month	5,500
5	Irrigation training	Trained staff	1 month	3,500
6	Soil preparation and planting	Plowed furrows	6 months	5,000
Total			12 months	30,000

**Source:** Prepared by the author.

500 prickly pear plants (*Opuntia ficus-indica* variety) were planted using efficient irrigation (60% reduction in water consumption). A pilot industrialization process processed 200 kg (mucilage extraction: 15% yield).

### Phase 4: Impact Assessment and Validation

Impacts were measured using agreed-upon indicators:

- Economic: Revenue per kg (pre/post pilot), value added (linear regression:  $y = \beta_0 + \beta_1 x + \epsilon$ , where  $y$  = revenue,  $x$  = processed volume).
- Social: Organizational skills (pre/post surveys, 35% improvement), empowerment (thematic analysis).
- Environmental: Soil (moisture, erosion; ANOVA), water saved (volumetric measurement).

The model was validated through a final triangulation (qualitative and quantitative) with feedback (n=25 key stakeholders): 88% acceptance, minor modifications (e.g., monitoring application). Ethics: informed consent, anonymity, diversity and inclusion.

By connecting academia, the productive sector (including cooperatives and IPNs), and public policies for inclusive territorial development, this approach ensures that it is replicable.

## **Discussion and Analysis of Results**

The results confirm that the model based on the Social and Solidarity Economy (SSE) effectively restructures the prickly pear production chain in the desert areas of Ciudad Juárez, Chihuahua, through the implementation of participatory assessments and pilot projects that optimize sales, production, and industrialization processes. The co-creation process increases added value when adaptive technologies and solidarity markets are implemented, which is in line with the principles of social justice and sustainability. This has a positive effect on community cohesion and income, which is expected to grow by 25% to 30%. This approach addresses the constraints identified in the problem formulation, such as agroecological underutilization and ineffective intermediaries, by moving beyond traditional extractive perspectives through democratic governance.

By applying the model to the desert nopal cactus through physicochemical analyses and mixed triangulation, innovations are incorporated. It aligns with previous research on SSE in semi-arid agricultural supply chains, such as that by Rosas Heimpel (2018) and Bonilla (2020), which emphasize cooperation to reduce post-harvest losses. This proposal focuses on environmental resilience in arid environments, unlike experiences that have taken place in Brazil (Singer) or Europe (Monzón and Chaves), which focus on urban cooperatives. Furthermore, it confirms the feasibility of replicating the results through pilot projects with local participants. Minor differences, such as the stronger emphasis on ICTs for solidarity markets, stem from the unique geographical context of Ciudad Juárez. In theory, by demonstrating its role as a catalyst for inclusive territorial development, this approach strengthens the interdisciplinary framework of the SSE. It proposes a perspective that can be applied in semi-arid zones and integrates agroecology with democratic governance. In addition to environmental benefits, such as reducing desertification through drip irrigation, it helps empower nopal-growing communities by improving organizational skills and providing access to fair trade channels. It promotes public policies

for the SSE, such as tax incentives for cooperatives, which enables its impact to extend beyond Juárez. Although the pilot confirms that it is viable on a small scale (15–30 participants), there are limitations, such as dependence on initial budgets (approximately 30,000 Mexican pesos) and potential cultural resistance to self-management. Future research should incorporate econometric modeling for long-term forecasts, scale up to different communities, and examine climate adaptation capacity in the face of extreme droughts. If these extensions are implemented, the model would become a benchmark for the ESS in arid Latin America.

## Conclusion

The study shows that, in desert areas of Ciudad Juárez, Chihuahua, the model based on the Social and Solidarity Economy (SSE) effectively improves the prickly pear production chain. This is achieved through the implementation of participatory assessments, collaboration with local stakeholders, and pilot projects that enhance organizational capacities, increase value added, and make solidarity markets more accessible.

The model promotes social justice, sustainability, and democratic management to achieve inclusive territorial progress that can be replicated in semi-arid regions; at the same time, it addresses the agricultural, technological, and commercial challenges that have been identified. The following results are anticipated: increased profits (from 30% to 25%), reduced post-harvest losses, and community strengthening through pluralistic governance and a mixed methodological approach.

The local productive sector is strengthened through adapted technological innovation (such as drip irrigation and mucilage extraction), cooperatives, and alignment with public policies, which generates contextualized knowledge to increase the ESS in Mexico. It contributes to equality and food sovereignty in vulnerable communities.

Implement the pilot project on a large scale with higher budgets (an initial MXN 30,000), continuously monitor environmental impacts, and foster inter-institutional cooperation. Future extensions should assess whether the model can be replicated in other arid zones, including econometric modeling for long-term projections.

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