

IDENTIFICATION OF ASPECTS AFFECTING RESILIENCE IN THE TOMATO SUPPLY CHAIN IN AND AROUND SUTAMARCHÁN

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Abstract

The study assesses the subjective resilience of tomato producers in the municipalities of Sutamarchán, Santa Sofía, and Villa de Leyva. Surveys are applied to examine factors such as climate shocks, market uncertainty, labor shortages, and limited access to financial services. The objectives of this study are threefold: (1) to conduct a literature review of previous data and studies related to resilience in supply chains, focusing specifically on the tomato sector; (2) to collect information from primary sources on aspects influencing the resilience of tomato supply chains; and (3) to analyze survey results, identify trends and areas for improvement, and determine the strengths impacting the resilience of the tomato supply chain. The findings indicated a degree of resilience, as evidenced by farmers' adoption of various strategies, including soil maintenance and financing from non-bank entities, as well as crop diversification, in response to crises. The study's findings indicate the presence of a fundamental resilience within the system. However, it is determined that this resilience is inadequate to ensure the system's sustainability over an extended period. The necessity for interventions that focus on enhancing producers' collective, financial, and organizational capacities is therefore emphasized.

Keywords: Agricultural resilience, supply chain, agricultural production systems, market.

INTRODUCTION

In recent years, the tomato supply chain in Colombia has confronted a series of challenges, including climate change, the volatility of international currency prices, political conflicts within the country and globally, the emergence of the novel Coronavirus (SARS-CoV-2), and other factors. Despite the growth in rural GDP, the available data suggest that the social crisis in rural areas has worsened during the pandemic. This is evidenced by the challenges that rural inhabitants face in accessing essential services such as healthcare, education, telecommunications, and public goods. These challenges are further compounded by the persistent structural impediments affecting the marketing of their agricultural products, exacerbated by the impact of natural phenomena, including the recent winter season, which has impacted certain regions of the country. Extreme climatic variations, including droughts and floods, have a direct impact on tomato production because this crop requires substantial amounts of water for cultivation. Abrupt changes in the prices of international currencies have the potential to affect the prices of necessary inputs. Political conflicts, both internal and external, can cause variations in the logistics and management of each of the stages of tomato production [1].

Among the essential nutritious foods, fresh fruits and vegetables, such as tomatoes, are produced to meet local demand, but also to be traded internationally. Tomatoes are high-

value products that represent a significant source of income for their producers. However, the production of these water-demanding crops is subject to vulnerability to climatic disturbances, such as drought or torrential rains, which threaten the livelihoods of their producers. Among the various forms of care required for the cultivation of tomatoes, one of the most critical pertains to the management of water, given the plant's substantial water requirements. The accessibility and availability of water are not only influenced by human interventions but also by climatic patterns, thereby necessitating a comprehensive understanding of these factors to ensure the optimal growth and productivity of these crops [2]. On farms, a range of soil and water-related practices contribute to the maintenance of soil and agroecosystem quality, thereby helping farmers to cope with climate shocks. Horticultural crops are distinguished by their relatively brief vegetative period, a characteristic that engenders greater flexibility in planting patterns and practices [3].

In the context of tomato production and distribution in Colombia, resilience has been identified as a critical factor for ensuring operational continuity and meeting market demands. "Resilience is predicated on the provision of alternative pathways and the expeditious response to disruptive situations. Adaptability is a critical factor in enhancing resilience, thereby contributing to the strengthening of supply chains." By identifying the various disruptions that may occur in the tomato supply chain within the country, it becomes possible to enhance its adaptive capacity by increasing its resilience[4].

The agricultural supply chain is subject to the various actors involved in its operation, including producers, transporters, traders, suppliers, and others. Enhancing the collaboration among these actors to facilitate more efficient and timely interactions could contribute to enhancing the supply chain's resilience. According to [5], the term "collaborative supply chain" signifies the integration of efforts, techniques, tactics, and strategies among the various actors involved in the supply chain, both vertically and horizontally, with the objective of enhancing efficiency and speed. The study presents various models that facilitate the implementation of this collaborative chain. However, it is emphasized that the viability of these models hinges on the absence of certain characteristics present in existing models, which precludes their development within the agricultural industry.

The following objectives were presented to determine the factors that affect the resilience of the supply chain:

- I. Conduct a literature review on previous data and studies related to resilience in supply chains with a specific focus on the tomato sector.
- II. Collect information from primary sources on the aspects that influence the resilience of tomato supply chains.
- III. Analyze the results obtained through the survey, identifying trends, areas for improvement, and strengths that impact the resilience of the tomato supply chain.

The implementation of specific tools, such as surveys, will facilitate the accurate assessment of current perceptions and practices in the supply chain, thereby providing quantifiable data to inform the development of improved strategies. The results obtained from this study will provide practical and actionable information that can be used by farmers, distributors, and other participants in the chain to strengthen their operations and prepare for adverse situations.

METHODS

Survey methodology and data collection

This study is founded on the overall methodology and structure of the work conducted by Benabderrazik, who examined how smallholder farmers in Ghana cope with climate change using structured surveys. With the authorization of the study's principal author, the data collection instrument was adapted to align with the agricultural context of Colombia, particularly the tomato-producing region of Boyacá. Furthermore, a congruent methodology is employed in the structuring and processing of data, with requisite modifications implemented in accordance with local conditions [3, 6].

The objective of the study was to assess farmers' subjective resilience in the face of the various challenges associated with managing tomato crops. The study was grounded in a survey that sought to measure farmers' perceived resilience in the face of these challenges. This survey enables the analysis of farmers' strategies for addressing challenges throughout the tomato production cycle. These challenges may include weather events such as rainfall and droughts, fluctuations in market prices, and limitations in resource availability, including inputs and labor. The survey was administered to 31 households by university students who were informed in a timely manner of the purpose and structure of the survey. Through this survey, the students identified the households to be interviewed in order to obtain quantitative information [7].

The interviews were conducted using Google Forms, a digital tool that facilitates remote interviews. The data was collected in person. The survey contained six sections, each comprising a distinct set of inquiries. These inquiries encompassed a wide array of topics, including demographic information, the nature of the cultivated crops, the requisite inputs, the various climatic disturbances to which the respondents have been exposed, the management strategies employed in regard to production, and inquiries concerning technology and sustainability. The survey was administered for a duration of approximately 15 to 20 minutes, and respondents were informed of the purpose of the survey, the handling of their data, and the privacy of their data, in accordance with the ethical principles of similar studies in Latin America[8] [9] [10].

Operationalizing resilience

In recent years, considerable attention has been directed toward the potential of agricultural systems to withstand and adapt to climate change. It is acknowledged that resilience is imperative for sustaining food production and environmental stewardship. Nevertheless, considerable discourse persists regarding the precise conceptualization of resilience and the development of effective measurement instruments. According to the theoretical framework employed in numerous studies, three fundamental aspects have been identified for comprehending and implementing this concept: robustness, defined as the capacity to sustain favorable outcomes despite the presence of challenges or alterations; adaptability, denoting the capacity to modify practices and strategies when circumstances necessitate it; and transformability, signifying the potential for comprehensive system modification or even complete abandonment in pursuit of a more robust system in the face of adversity. The aforementioned concepts were initially proposed by several authors in previous research. In recent studies, these concepts have been methodically organized and revised to facilitate their comprehension and implementation in the agricultural sector.

Study Area

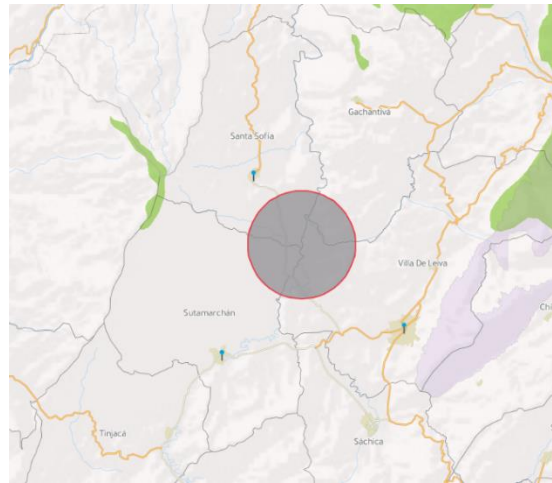


Figure 1. Area map of the surveyed regions

Figure 1 shows the map of the three municipalities taken into account for the interviews carried out and their respective boundaries[11]:

"Sutamarchán is located on a branch of the eastern mountain range of the Andes, to the west of the department of Boyacá, forming several abutments and buttresses. The municipality is located in the province of Alto Ricaurte at an altitude of 2,095 meters above sea level. Research on tomato supply chain resilience in and around Sutamarchán is critical to addressing the specific challenges faced by this farming community. In an environment where tomato production and distribution play a crucial role in the local economy, it is vital to ensure their resilience. A significant proportion of national tomato production is concentrated in a limited number of departments within the Andean region. Specifically, Boyacá stands out as a leading producer, achieving an impressive yield of up to 100 tons per hectare. This is followed by Caldas, Risaralda, and Cundinamarca, which also demonstrate notable productivity levels.

The following text is intended to provide a comprehensive overview of the subject matter. First, the necessity to adapt strategies to the particular conditions of the community and its tomato supply chain is recognized by focusing specifically on Sutamarchán. According to recent data, 77% of the population is engaged in agricultural activity. The primary agricultural products are greenhouse tomatoes, Curubo, corn, potatoes, beans, paprika, tree tomatoes, and onions. These products are produced with minimal technological sophistication. In contrast, the lower regions are dedicated to the cultivation of grapes, which are processed to produce wine for export. Furthermore, the identification of pivotal factors to enhance such resilience will facilitate the assurance of long-term sustainable production and distribution, thereby benefiting local actors and promoting economic stability [12] [13] [14].

"Santa Sofía is located on the western flank of the Cordillera Oriental. The geographical location of the region is characterized by cold thermal floors. The region's physical and climatic characteristics are conducive to agricultural and livestock production. The primary watercourse is the Moniquirá, which supplies water to the Sutamarchán River [15].

The Municipality of Villa de Leyva is situated at an altitude ranging from 2,000 to 3,200 meters above sea level. It is located within the geographical boundaries of the Eastern Mountain Range in Colombia. The month of October is characterized as the rainiest, while the initial months of the year are noted for their aridity. Villa de Leyva is supplied with water by means of three rivers that collect the waters from the moors of Gachaneque, Merchán - El Águila, Morro Negro and Iguaque. The three river axes are the Sutamarchán River, the Sáchica River, and the Cane River, with a wide network of minor tributaries. These rivers join together to form the Moniquira River, through which they discharge their waters to the Suárez River. In terms of its climatic characteristics, the region is divided into three distinct zones. Dry, Sub-Humid, and Humid." [16].

RESULTS

Characteristics of homes

Of the three regions selected: Sutamarchán, Villa de Leyva and Santa Sofía, 74.2% were men and 25.8% were women, as shown in Figure 2; and among them, 54.8% are tenants of the land and 45.2% are owners, mostly from Sutamarchán, followed by Santa Sofía and in last place Villa de Leyva.

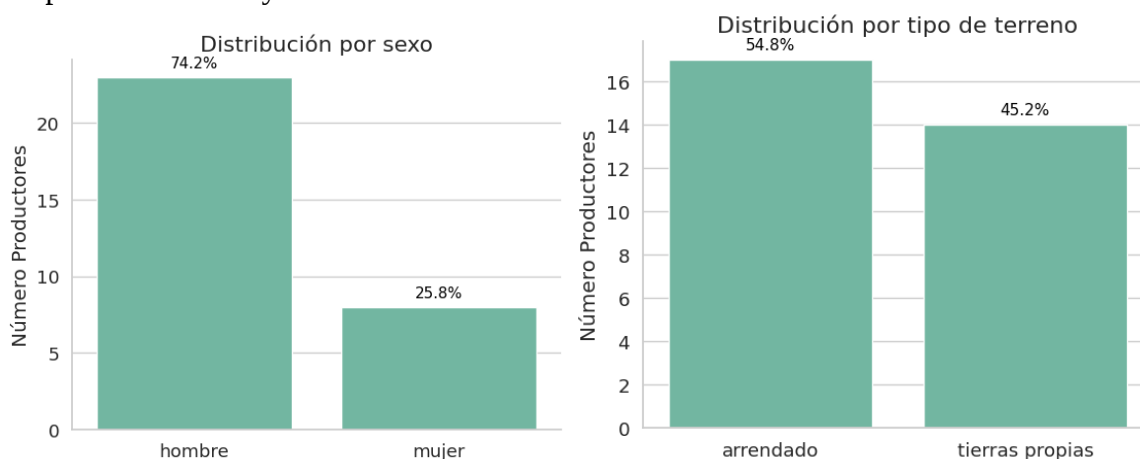


Figure 2. Distribution by sex of the producers (own elaboration).

The majority of the land (58.1%) is characterized by an annual yield of 1 to 3 bushels, with the entire yield being allocated to the cultivation of tomatoes for commercial purposes. The implementation of irrigation systems is a universal practice among all farmers. The majority of survey respondents indicated that they possessed over a decade of experience in the field (65%), while 25% reported between five and ten years of experience and 10% indicated that they had less than five years of experience. This distribution corresponds to the age demographic of the respondents, who primarily comprise individuals over 40 years of age. In all of the households surveyed, tomato production is conducted biannually. The most prevalent types of tomato utilized in this process are the chonto tomato, followed by the long-life tomato and other varieties. The chonto tomato is a firm fruit variety with a vegetative period of 90–110 days, as illustrated in Figure 3 [17].

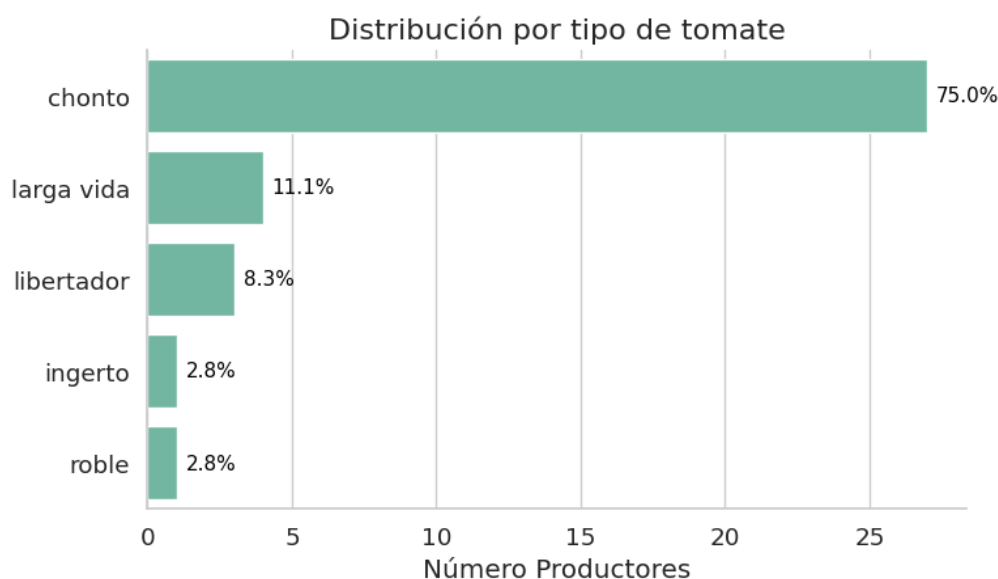


Figure 3. Distribution by type of tomato (own elaboration).

Conversely, 84% of producers have observed a decline in production over the past five years, while the remaining 16% have noted no change. A substantial proportion of these households, specifically 88%, derive their primary income from agricultural pursuits. The remaining households, however, utilize diverse sources of income, such as rental income, livestock rearing, and various forms of employment. The acquired income is predominantly allocated toward the procurement of essential inputs and agricultural implements necessary for subsequent production activities and the settlement of associated expenses. A significant proportion of the surveyed population, specifically 84%, have encountered difficulties in maintaining financial stability following the disbursement of these expenses. This has compelled a considerable number of households to seek external economic assistance, including bank loans and loans from relatives or merchants. The high level of competition in the region and the consequent price volatility have further exacerbated the situation, prompting some households to adopt income-generating activities as a means of coping with these challenges. Regarding access to information, households possess devices such as cell phones, televisions, and radios. However, 97% of households are unaware of government policies or programs concerning climate change and/or sustainable agriculture. All the households surveyed utilize the greenhouse as a cultivation method. Recent studies on tomato production in greenhouses in Boyacá and Santander highlight the heterogeneity in structures and microclimates, coinciding with the majority use of metal structures (87%) and, to a lesser extent, wood (13%) in the farms surveyed[18].

Exposures faced by the crop

Soil Care

Weeds in the fields typically have a negative impact on crops, which is the rationale behind our inquiry of producers. A significant proportion of respondents, specifically 94%, have attested to having observed weeds. To address this issue, various control measures have been implemented, including the utilization of herbicides (the dosage of herbicides utilized varies contingent upon the cultivated area) and manual extraction techniques, among others. Moreover, 94% of respondents reported experiencing pest or disease problems in

their greenhouses. As illustrated in Figure 4, these respondents employed a variety of pest management strategies, including natural pesticides, biological control methods, and most commonly, fumigation.

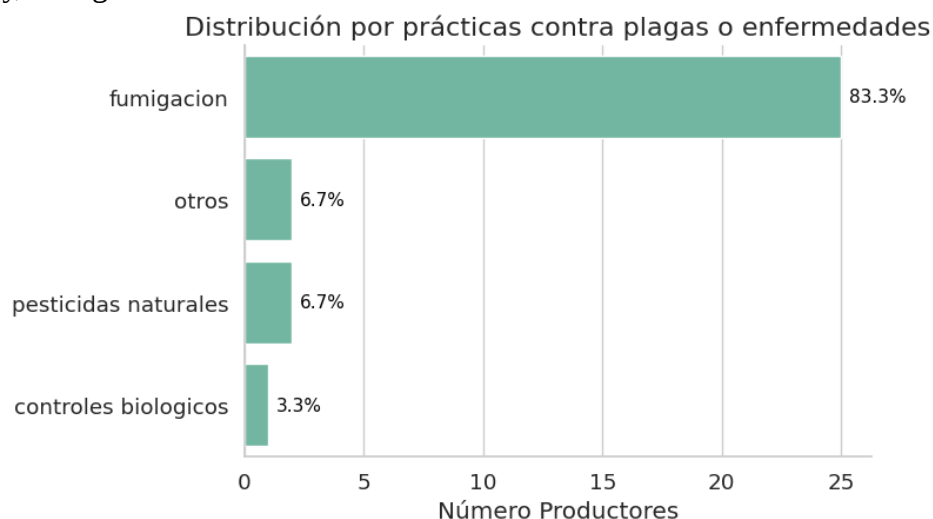


Figure 4. Distribution of practices against pests or diseases (own elaboration).

In order to maintain the integrity of the soil, the vast majority of producers have implemented measures such as liming, rotational grazing, and composting. Furthermore, they supplement these practices with the addition of self-produced nutrients. The utilization of herbicides and pesticides in tomato cultivation systems in Colombia has been thoroughly documented by scientific research. Analysis of tomato fruits from open fields and greenhouses has revealed up to 17 different residues, indicating the implementation of frequent fumigation and pest management practices. These practices frequently occur without adhering to the recommended pre-harvest intervals, potentially compromising the safety and quality of the produce [19].

Given the substantial water requirements of these crops, farmers typically have access to one or more water sources for production. Among this group, only 29% have two water sources: wells on the farm (which are filled with rainwater or tankers) or rivers for those in close proximity. It is noteworthy that all respondents indicated that the travel time to these sources does not exceed 30 minutes. With regard to the availability of resources, Colombia experiences both rainy and dry seasons. However, approximately 97% of farmers have reported a decline in water availability over the past three years.

Responding to a climate shock

The vast majority of respondents have reported experiencing various challenges due to climate change, including droughts, floods, heat waves, and strong winds. In some cases, these occurrences have been reported to occur more than four times a year, with durations sometimes exceeding three months. As illustrated in Figure 5, the distribution for each type of climate disturbance is depicted.

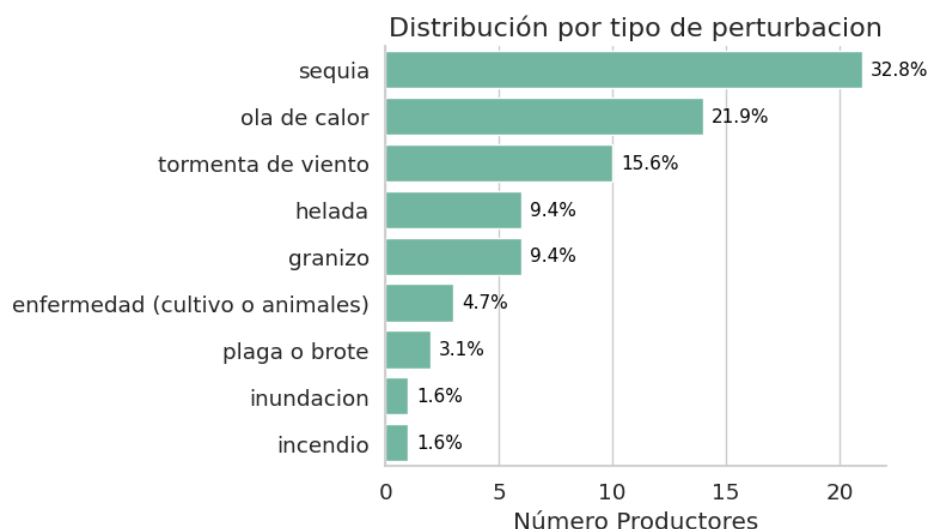


Figure 5. Distribution of climatic disturbances (own elaboration).

These disturbances have been shown to have significant ramifications for crop productivity, water scarcity, and tomato revenues. Furthermore, the disturbances have been demonstrated to cause damage to infrastructure and result in the loss of assets throughout the year. In response to the prevailing circumstances, agricultural producers have been compelled to explore alternative employment opportunities, seek financial assistance, and conserve their assets. This strategic response, however, has often resulted in substantial economic setbacks, including the forfeiture of land for agricultural use. In instances of extreme aridity, preventing the replenishment of wells, tank trucks are contracted to ensure the uninterrupted irrigation and maintenance of crops. Farmers have reported an increase in temperatures and a continuous reduction in rainfall and water availability. The confluence of extreme temperatures, delayed onset of the rainy season, and increasing climate variability has precipitated rapid shifts in crop management practices, necessitating constant adaptations to avert losses. A study of farmers reveals that 10% of them have suffered total losses attributed to climate change.

Furthermore, a significant proportion of the population, specifically 87%, lacks access to information regarding adaptation practices. Only a minority of 13% has access to such information, and of this group, only 33% has successfully implemented any adaptation measures, yielding limited results. These perceptions and strategies are consistent with findings in analogous Andean regions, where farmers have reported increases in temperature, decreases in rainfall, and partial adoption of adaptive mitigation and adaptation practices [20].

Market Exposure

Market pressures

The distribution of the production is facilitated by transporters from supply centers in Bucaramanga and, to a lesser extent, Bogotá, and to a lesser extent, merchants in the area. The majority of tomato cultivators are able to sell their produce in its entirety, and are compelled to sell at the price indicated for these plants. Given the challenges associated with deriving an aggregate value of seedlings utilized during a given season, a significant

proportion of producers rely on nurseries for the provision of seedlings, which are responsible for the initial phases of production.

Competition between farmers and price management by supply centers engenders a situation in which farmers are subjected to prices that lack a clear origin or rationale. They are unable to risk waiting for a more favorable price since the same production has a short duration. If they wait for better prices, they run the risk of losing part or all of what is produced. This issue has been thoroughly examined in recent studies, which demonstrate how small-scale producers in Colombia encounter constrained access to price information, resulting in a competitive disadvantage when compared to intermediaries within supply chains[21].

Inputs

The Boyacá region is a prominent contributor to Colombia's tomato production, supplying predominantly to central markets. This assertion is corroborated by respondents who attest to the presence of essential inputs within the primary tomato-producing areas. According to farmers in the region, the following items are readily available: seedlings, fertilizers, agricultural equipment, machinery, and pesticides. This accessibility facilitates the presence of multiple providers of these essential resources, thereby enhancing the region's agricultural efficiency and resilience. Conversely, accessing financial services and labor can prove challenging.

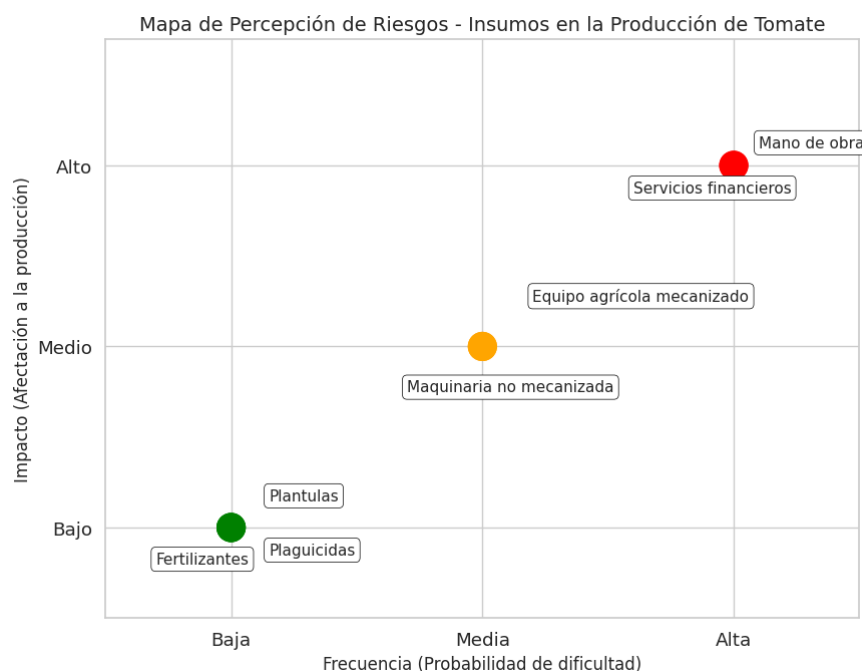


Figure 4. Input risk perception map (own elaboration).

Figure 4 shows a map of risks and observes those inputs that have a greater impact and that can affect the operation of the production chain.

- Labor: it is required in the different stages of the process, in preparation and sowing about 1 to 5 people are needed for a month in small crops, 5 to 10 in medium crops and more than 10 people in large crops; In these crops, labor can last 2 or more

months. In the growth stage, people are usually required between 1 to 3 months regardless of the size of the crop; This stage is the one that requires the fewest people. Finally, for the harvest stage the time is usually longer than two months, this stage being the one that requires the largest number of operators, with around 5 to 10 operators in small areas and increasing proportionally in the other areas.

- Financial services: 80% of the producers have started their projects through agricultural loans and the rest have had to use their own resources. However, when requesting other types of loans for maintenance or expenses, they have had to resort to other entities such as lenders.

Given that production is conducted within greenhouses, an additional critical factor that must be considered is the type of plastics utilized in these facilities. Typically, the task of lifting the greenhouses is entrusted to external contractors. However, the responsibility for maintenance and upkeep falls upon the individuals responsible for cultivating the crops. A survey of greenhouses revealed that 68% of them utilize plastics with a durability of between 3 to 5 years, while 20% employ plastics with a durability exceeding 5 years. According to 49% of producers, the climate constitutes one of the most significant challenges. 26% of producers indicate that the issue lies in durability, while 22% attribute it to the escalating costs. The remaining producers attribute the challenges to the supply of the input.

DISCUSSION

Reflecting through resilience

The resilience of this supply chain, as gauged by the responses of farmers in Sutamarchán, Santa Sofia, and Villa de Leyva, confronts substantial challenges, chiefly those associated with climate shocks, uncertain market prices, and constrained access to financial services and labor. As previously indicated, the present analysis substantiates the three fundamental components of resilience: robustness, adaptability, and transformability.

Robustness:

Given the variability of weather patterns and the high market pressure, producers have managed to maintain continuity in production, as demonstrated by the results. Cultivation is carried out biannually, and the utilization of greenhouses, soil care, and pest control indicates a strong commitment to preserving the quality of the agroecosystem. This practice aligns with the findings of studies on agricultural resilience, which demonstrate that preserving the diversity of agricultural production and the sustainable management of agroecosystems enhances the system's resilience to disturbances [22].

Adaptability:

Adaptability, therefore, is defined as the manner in which farmers address the various challenges they face, including the cultivation of alternative sources of income and, in certain circumstances, the modification of crops, all with the objective of mitigating losses. Consequently, enhancing the adaptability and resilience of the system is imperative. This can be achieved by providing access to resources that facilitate the understanding of strategies concerning adaptive and sustainable practices. Such knowledge will empower farmers to adopt a more practical and less reactive approach in their preparation, as evidenced by the findings. Research has demonstrated that access to timely climate

information and simple technologies significantly enhances adaptive capacity, particularly in rural contexts [23].

Transformability:

While farmers retain the capacity to modify their production systems, the viability of such modifications is hindered by salient factors, including the dependence on intermediaries, a lack of familiarity with public policies, and a paucity of communication among chain actors, which collectively impede such transformative endeavors. The absence of both vertical and horizontal integration, as conceptualized within the paradigm of the collaborative supply chain, engenders considerable challenges in the development of collective and innovative solutions.

From a market perspective, the absence of autonomy in negotiating fair prices, compounded by the prevalence of high competition, results in diminished profit margins and exacerbates the vulnerability of producers' economies. Despite the prevalence of productive inputs, access to formal financial services remains constrained, thereby diminishing investment options in innovation and sustainability. A dearth of labor further curtails the transformability of the supply chain.

The study's findings indicate that farmers, despite possessing individual measures to address various crises or disturbances due to a paucity of collectivity, adaptability, and sustainability measures, demonstrate resilience that is not particularly structural or sustainable over time. Research in Latin America suggests that the implementation of innovative financial schemes, such as indexed climate insurance or weather-related loans, has the potential to enhance financial access and bolster the resilience of production systems [24].

CONCLUSION

This research was conducted through a survey that assessed the resilience of the tomato supply chain by evaluating farmers' capacity to respond to various crises and their perspective on the matter. The findings of the study enabled the identification of the pivotal factors influencing the resilience of the tomato production chain. These factors encompass climatic disturbances, access to financial services, labor, water availability and utilization, price determination uncertainty, and the absence or ignorance of public policies.

The tomato supply chain in this region of Boyacá exhibits partial resilience when assessed against several key factors. Robustness is evident in the stable production with widespread use of greenhouses and inputs, though economic fragility persists. Adaptability, typically reactive, includes alternative employment opportunities, crop modifications, tank car utilization, and limited access to technical information. Transformability remains constrained due to intermediaries, low associativity, inadequate knowledge of public policies, and limited alternative channels. In this regard, research has demonstrated that farmers' cooperatives can serve to reduce transaction costs and increase access to credit by providing financial institutions with enhanced information regarding the financial activities of organized smallholders. This necessitates the enhancement of resilience through a collaborative and inter-institutional approach, which fosters cooperation among producers, distributors, public entities, research centers, and the government. To address these challenges, it is imperative to enhance access to financial services, adopt sustainable technologies, and provide relevant technical training [25].

The study's findings indicate a paucity of public policies that effectively assist farmers in coping with various disturbances. There is also a dearth of transparency in price determination, and the absence of peasant associations hinders the enhancement of systemic resilience. It is imperative to devise and advocate for diversified strategies for vulnerable agricultural regions, accounting for their distinct climatic, social, and economic circumstances. Absent such measures, agricultural producers will persist in grappling with disruptions, confronting diminishing resources and diminished capacity to respond.

Consequently, it is proposed that resilience should not be conceptualized exclusively as the capacity to resist adversity. Instead, it should be regarded as the capacity to transform the practices, relationships, and structures that render farmers vulnerable, thereby transforming crises into catalysts for change. Future studies could concentrate on the formulation of pilot strategies to enhance coordination among relevant parties, investigate novel forms of vertical integration (e.g., agricultural cooperatives), and evaluate the impact of resilience policies adapted to the local context. The present study was conducted during the period between January and February of 2024.

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