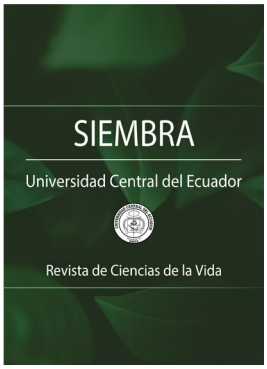
# *Effects of COVID-19 on pea farmers, a case study in the department of Nariño, Colombia*




## *Efectos del COVID-19 en productores de arveja, estudio de caso en el departamento de Nariño, Colombia*

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**Abstract**

The COVID-19 pandemic has had a profound effect on food security worldwide. Colombian farmers were adversely affected by prolonged periods of lockdown, disruptions in the agricultural supply chain, increased poverty levels, and heightened socioeconomic uncertainty. The objective of this study is to evaluate the perceptions of pea producers with regard to the impact of the COVID-19 pandemic. To this end, and ex-ante (2019) and ex-post (2020-2022) diagnostic analysis was conducted in the south of Nariño. We carried out semi-structured interviews with 35 farmers, four key informants, and three focus groups. A sentiment analysis (text mining) was conducted to process sensitive information on environmental, economic, and intrinsic aspects of the productive system. The results revealed that participants maintained constant levels of happiness and confidence across the two-time periods. However, in the period subsequent to the pandemic, higher levels of anger and sadness were reported, attributed to effects of the pandemic itself and the inherent challenges associated with pea cultivation. The implementation of confinement measures resulted in an increase in feelings of uncertainty and sadness, in addition too the emergence of challenges in fieldwork context. Moreover, the increased production costs were attributed to the greater demand for agricultural inputs and labour in 2020. However, in 2022, the increased the price paid per kilogram of pea grains helped mitigate the adverse impact of the pandemic. The study concludes that the econ economic uncertainty introduced by the COVID-19 pandemic affected crop profitability. Nevertheless, small-scale farmers exhibited remarkable resilience and adaptability, allowing them to persist in growing and selling their pea harvest.

**Keywords:** food security, pandemic, production costs, rural population.

**Resumen**

La pandemia de COVID-19 ha tenido un impacto significativo en la seguridad alimentaria en todo el mundo. El agricultor colombiano se vio afectado por bloqueos prolongados, interrupciones en la cadena de suministro agrícola, mayores niveles de pobreza y una mayor incertidumbre socioeconómica. Este estudio tiene como objetivo evaluar la percepción

de los productores de arveja sobre el COVID-19, realiza un diagnóstico ex ante (2019) y ex post (2020-2022) en el sur de Nariño. Se realizaron entrevistas semiestructuradas a 35 agricultores, 4 informantes clave y 3 grupos focales. A través de un análisis de sentimiento (Text Mining) se procesó información sensible sobre aspectos ambientales, económicos e intrínsecos del sistema productivo. Los resultados revelaron que los participantes mantuvieron niveles constantes de felicidad y confianza durante dos períodos de tiempo. Sin embargo, en el período posterior a la COVID-19, se informaron niveles más altos de ira y tristeza, atribuidos a los efectos de la pandemia y los desafíos inherentes asociados con el cultivo de arvejas o guisantes. Las medidas de confinamiento intensificaron los sentimientos de incertidumbre y tristeza, además de desafíos en el trabajo de campo. Asimismo, atribuyeron el aumento de los costos de producción a la mayor demanda de insumos agrícolas y mano de obra en 2020. Sin embargo, en 2022, el aumento del precio pagado por kilogramo de granos de arvejas ayudó a mitigar el impacto adverso de la pandemia. El estudio concluye que la COVID-19 introdujo incertidumbre económica en la región y, en consecuencia, afectó la rentabilidad de los cultivos. Sin embargo, los pequeños agricultores mostraron una notable resiliencia y adaptabilidad, lo que les permitió persistir en el cultivo y venta de su cosecha de guisantes.

**Palabras clave**: seguridad alimentaria, pandemia, costos de producción, población rural.

## 1. Introduction

The COVID-19 pandemic caused significant disruption to international trade, with an immediate impact on the world economy (Shafiullah et al., 2022). The implementation of social distancing measures and prolonged lockdowns affected the productivity of all types of organizations resulting in a decline in revenues, increased operating costs, and significant cash flow challenges for civil society and entrepreneurs (Bora & Basistha, 2021). These consequences have been compared to other natural and anthropogenic disasters, including climate change, geopolitical conflicts, etc. (Ramos Zambrano, 2023).

However, it has been determined that the ramifications of the COVID-19 pandemic have been far more significant (Ramos Zambrano, 2023). In addition, to impacts on stock markets, main economic sectors such as trade, education, and food were paralyzed (Chowdhury, et al., 2022; Hsiang, et al., 2020). Before the pandemic in Latin America and the Caribbean, the prevalence of rural and extreme rural poverty was estimated at 46% and 20.4%, respectively. By 2020, these rates had risen to 56.2 and 23.4% respectively (Trivelli, 2020).

Since the 1990s, the pea has become established as a crop in the region, providing a reliable source of fresh produce for the country's interior (Cadena Pastrana et al., 2022). Despite the challenges posed by the pandemic, pea commercial dynamics remained operational, albeit with the involvement of intermediaries who influenced pricing, incorporating costs associated with transportation, weighing, and other factors. Colombia was no stranger to the effects of the COVID-19 pandemic, with a reduction in economic growth of 5.5%, the suspension of international trade, and the interruption of the value chain. These factors contributed to a decrease in consumption, a reduction in income, and an increase in public spending (Bonet-Morón et al., 2020). In 2019, the unemployment rate was 10.5%, however, by 2020 and 2021, it had risen to 15.9% and 13.7%, respectively (Departamento Administrativo Nacional de Estadística [DANE], 2021). This behavior is attributed to the low development of productive activities due to mandatory social distancing measures (Buelvas Porto & Guevara Otálora, 2020).

In the southern Nariño region of Colombia, the effects of the COVID-19 pandemic also reached one of the region's main productive activities: pea cultivation and commercialization. This crop represents a significant economic activity for the families of producers who have been harvesting and selling green peas in pods for over two decades. It generates approximately 1.5 million daily wages per year and involves 20,140 families. Consequently, the Nariño department is Colombia's largest producer of this legume (Ramos-Zambrano et al., 2022). During the pandemic, the commercial dynamics of the product did not stop but were conditioned to the involvement of intermediaries, who set prices, and added costs for transport and weighting, among other expenses.

This situation resulted in an imbalance in the solidarity-based economy and a notable impact on the food and nutritional security nutrition of smallholder farmers in the southern Nariño region. Hence, given the gradual relaxation of confinements, short marketing circuits were defined as a strategy for family and community agriculture in several Latin American countries (Alberdi Collantes, 2022; Fernández & Clara, 2022; Paz & Infante, 2020). This approach aimed to facilitate the collection of healthy and fresh food, reduce intermediaries, and minimize post-harvest losses.

This study aimed to assess the impact of the COVID-19 pandemic on the production dynamics of pea small farmers in southern Nariño. The two specific objectives were: i) to identify the perceptions of smallholder farmers in the context of the emergency caused by the COVID-19 pandemic and their resilience, considering their family economy and environment; and ii) to recommend alternatives for future decision-making in similar events that may influence the agricultural sector in the region.

This research enabled the characterization of three groups of producers and their methods of adapting to the COVID-19 pandemic. Among the farmers interviewed in the ex-post period, feelings of uncertainty were recurrent. However, positive emotions such as happiness and confidence were maintained in the evaluated periods, influenced by inclusive work, less physical effort, and higher profitability. This motivated the development of alternatives for resilience and continuity in pea production.

## 2. Materials and Methods

### *2.1. Study area and data collection*

The research was conducted in the southern region of Colombia, specifically in the department of Nariño, within the sub-region of the "Ex Provincia de Obando and Sabana de Túquerres" a region renowned for its production of peas. The sub-region is characterized by its location in the high Andean zone with an average altitude of 2,898 m a.s.l. It is home to peasant and indigenous communities that rely on pea, potato, and livestock production systems (Figure 1).

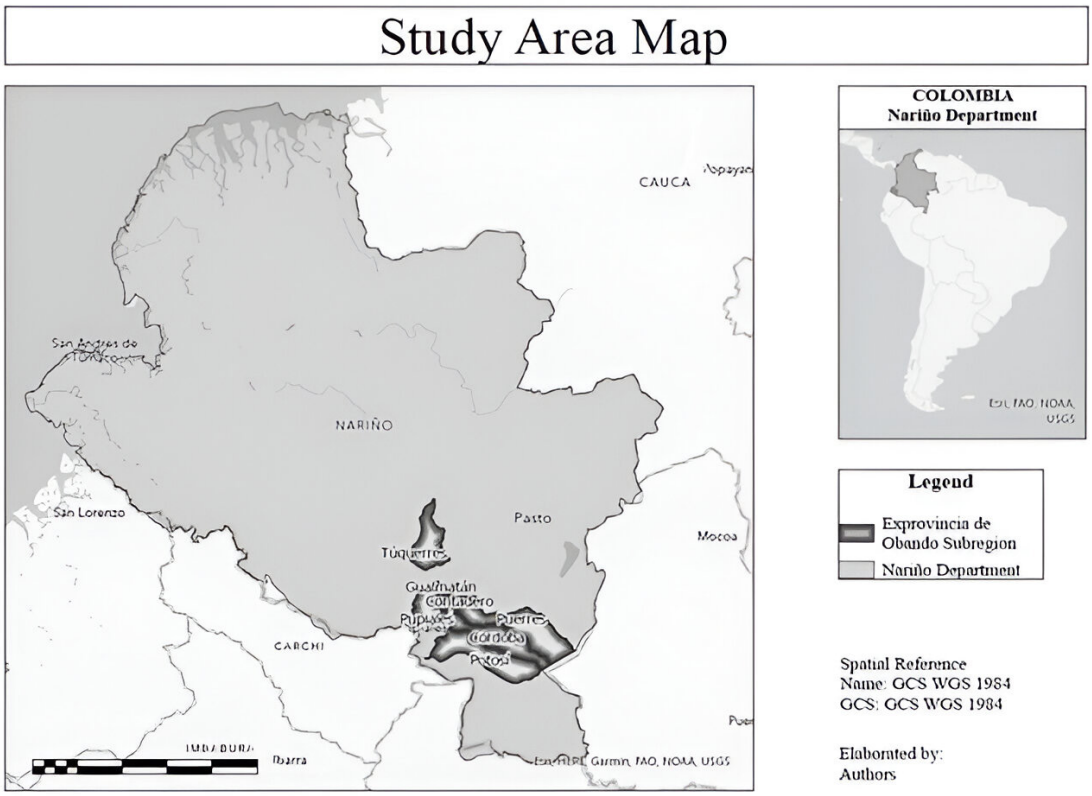


**Figure 1.** Study area for pea crop analysis (period 2019 to 2022)**.**

Semi-structured interviews were performed over the specified period to smallholder farmers, with 35 total interviews conducted according to the methodology outlined by Casas Anguita et al. (2003). Individual interviews were conducted with four key informants, comprising two Colombian Corporation for Agricultural Research [AGROSAVIA] researchers with experience in the southwestern region and two technical managers of the National Federation of Cereal Growers [FENALCE]). The variables collected during the meetings are presented in Table 1 for reference.

**Table 1.** Categorization of variables used in interview development.

| Variables | Type | Required to |
|---|---|---|
| Age of farmer (in years) | Quantitative | Characterization and context |
| Crop experience (in years) | Quantitative | |
| Sowing area (in ha) | Quantitative | |
| Quantity and price of agronomic inputs (in kg and U.S. dollar [USD]) | Quantitative | Costs |
| Amount and value of day labour (in hours and in U.S. dollars [USD]) | Quantitative | |
| Yields (in kg and U.S. dollar [USD]) | Quantitative | |
| Price per bundle of peas (in U.S. dollars [USD]) | Quantitative | |
| Gender (men/women) | Qualitative | Characterization and context |
| Level of schooling (primary, high school, technician, technologist, university, postgraduate) | Qualitative | |
| Land tenure (yes /no) | Qualitative | Characterization and context; text mining |
| Alternative crops to the pea system (in number) | Quantitative | |
| Impact on natural resources (soil and water) (yes /no) | Qualitative | Text Mining |
| Perceived environmental damage (yes /no) | Qualitative | |
| Use of agrochemicals (yes /no) | Qualitative | |
| Well-being of your community (yes /no) | Qualitative | |
| Quality of employment (yes /no) | Qualitative | |
| Food security (yes /no) | Qualitative | |
| Health risk (yes /no) | Qualitative | |
| Involvement of women, children, youth and older people (yes /no) | Qualitative | |
| Agricultural technical assistance (yes /no) | Qualitative | |

A non-probabilistic "snowball" method was employed to select the farmers to be interviewed. This method is often used to access low-incidence populations and individuals who are difficult for researchers to identify (Lorenzo Ortega et al., 2017).

To identify the farmers who participated in the case study, the following criteria were considered: their involvement in the Social Balance project, which has been implemented by AGROSAVIA since 2017; their experience of cultivating peas for more than five years; and their willingness to engage in virtual and field interviews during the "agricultural strike" and pandemic.

Considering the circumstances surrounding the COVID-19 pandemic, it is pertinent to acknowledge that the interviewing process for 2020 and 2021 was conducted by combining telephone, virtual, and face-to-face interviews. This approach was adopted following the prevailing conditions regarding communication technologies and the prevailing sanitary restrictions for entering the prioritized study areas.

### *2.2 Analysis of the information*

The interviews were analyzed using machine learning techniques, specifically *text mining.* The processing was conducted using the statistical software R Studio following the methodology proposed by Silge & Robinson (2017). Concerning the text cleaning process, all content that did not pertain to the subject matter, structure, or content was excluded. This included abbreviations, single characters, numbers, spaces, and punctuation marks.

After preparing the data, a sentiment analysis was conducted for the pre and post-pandemic periods. The analysis helped us measure and visualize four main emotions: happiness (red), sadness (green), anger (orange), and confidence (blue). The resulting graphs display the distribution and changes in these emotions over time,

thereby allowing for a direct comparison between the two periods. Furthermore, the positive and negative cases were analyzed using graphs, with positive cases represented by red and negative cases represented by blue. This visual representation facilitates the identification of patterns and changes in farmers' perceptions before and after the pandemic. Additionally, word clouds were generated for each category (positive and negative), with word size indicating their frequency of use. This multi-level approach allowed for an in-depth understanding of how the emotions and perceptions of pea farmers evolved during the study period, offering insights into the impact of the pandemic on their experiences and perspectives.

The economic analysis of the evaluation involved a comparison of production costs, which was structured according to the consensus methodology with smallholders in the region based on the methodology proposed by Wilches Torres et al. (2016). The values evaluated in dollars were calculated based on the average exchange rate in Colombia between 2019 and 2022.

The period under analysis was four years, extending from 2019 to 2022. For the purpose of analysis, this period was subdivided into two scenarios for the analysis. The ex-ante period (2019) encompassed events preceding the advent of the COVID-19 pandemic, whereas the ex-post period (2020-2022) encompassed all occurrences during and after the pandemic.

Regarding the selection of variables for typifying the surveyed pea producers, the methods proposed by Álvarez-Sánchez et al. (2019) and González Flores et al. (2018) were employed for analyzing quantitative variables. In addition, the coefficient of variation [CV] was calculated using a threshold of 40% or above, and categorical variables, such as the qualitative variability index [QVI], were considered significant when the value was greater than 0.6. Statistical significance of the results was validated by principal component analysis [PCA]. Moreover, following the selection of variables, multivariate factor analysis of mixed data [FAMD] and hierarchical grouping were conducted using Ward's algorithm proposed by Rodríguez Puertas et al. (2021).

## 3. Results and Discussion

### *3.1. Typology of surveyed pea producers*

The interviewed farmers had, on average, 21 years of experience in pea cultivation. Most of them were over the age of 50 (45.7%), while 11.5% were under 35 years old. Even though 82.8% of the interviewees were male, they all referred to the crop as socially inclusive, benefiting the wider community. Most of the population (74.3%) reported receiving a primary education (74.3%), while 14.3% of the interviewees indicated that they had completed secondary education, and 11.4% reported having a higher education degree. Regarding land tenure, 45.7% of the pea producers rent the land, 34.3% own land for agricultural work, and 20% have both alternatives. Of the interviewed population, 68% perceived environmental damage from pea planting. Concerning planting material, 54% of farmers preferred the Obonuco San Isidro variety, 22% Obonuco Andina, and 14% preferred both, while the remaining percentage planted the new variety, Afila, or had no preference. The variables collected in the interviews with producers and prioritized by PCA were as follows: area planted (CV:114.75), experience in the crop (CV:43.17), variety (ICV:0.67), agricultural technical assistance (ICV: 0.93), economic situation (LCI: 0.86), farming systems (LCI: 0.91), health risk (LCI: 0.99), quality of employment (LCI: 0.57), impact on soil and water resources (LCI: 0.86) and use of agrochemicals (0.99), which were the most relevant for the production system. The information obtained from the statistical analysis was reduced to four dimensions that collectively accounted for 60% of the total variance. The clusters demonstrated the presence of three groups at a Euclidean distance of 1.8 (Figure 2). Cluster one was comprised of 20% of the sample, cluster two accounted for 60%, and cluster three was represented by 20%.

#### 3.1.1. Cluster 1. Producers with low adaptive capacity

Producers with an average of 0.5 ha planted in peas, had an average experience of 14 years in the crop, and a preference for the Obonuco Andina varieties. They lack both land and technical assistance and do not report any health risks from farming activities. The main challenges they faced were the global COVID-19 pandemic and the "agricultural strike". Alternative production crops included potatoes, corn, dairy cattle, and fruit trees. Most producers report no significant changes in the quality of employment and no impacts on soil and water resources. The use of agricultural inputs was oriented towards chemical and organic alternatives.

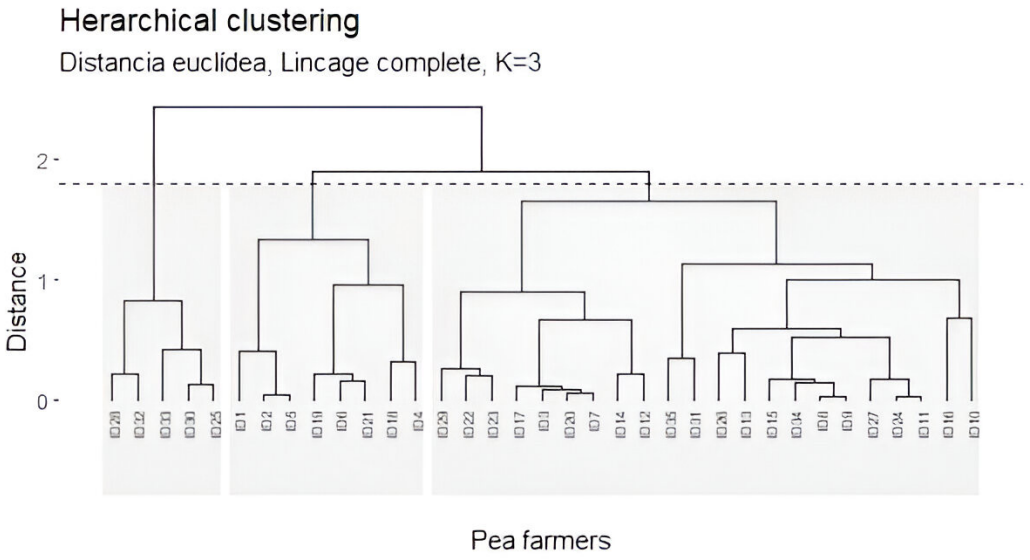


**Figure 2**. Dendrogram of pea producers surveyed between the period 2019-2022.

3.1.2. Cluster 2. Producers with a medium level of adaptation.

The mean area planted with peas was 1.2 ha, with an average of 23 years of experience in the crop. The Obonuco San Isidro variety was the most frequently cultivated. Among producers who own the land asset, only 33.3% had access to technical assistance from local public or private entities and did not report any health risks. The commercial dynamics were affected by the COVID-19 pandemic and the agricultural strike. However, 11.4% of producers did not report any impact from these events. The most relevant production systems were potatoes, vegetables, minor species (such as "cuyes" and hens), and dairy cattle. With regard to quality of employment, they report significant changes concerning the remuneration paid to a worker for a day. Additionally, smallholders reported that pea farming affected soil and water in terms of soil erosion, soil compaction, and nutrient depletion. The use of agricultural inputs was oriented towards chemical and organic alternatives.

3.1.3. Cluster 3. Producers with a high level of adaptation

The mean area planted with peas was 3.3 hectares, with farmers showing greater experience cultivating this crop, having worked for an average of 24 years. Compared to the other groups, the farmers in this cluster utilize varieties of Obonuco Andina and Obonuco San Isidro on their land, as well as on rented land. Furthermore, they receive technical assistance and report health problems due to farming activities. Most producers were not affected by any social or economic circumstances. Regarding production systems, there was clear crop diversification, including potatoes, vegetables, small livestock, dairy cattle, and fruit trees. There is evidence of an improvement in the quality of employment. Concerning soil and water alteration, there was a similar dichotomy between those who were and were not affected. Similarly, the use of agronomic inputs was oriented towards chemical alternatives.

These results are consistent with the characteristics of the Colombian rural population, which has been typified by low levels of education and income, as well as limited participation of young people in the various production processes, resulting in a reduction of generational exchange (Arias Gaviria, 2017; Tenjo Galarza & Jaimes, 2018). Moreover, smallholder farmers in the department of Nariño are distinguished by their limited land tenure, modest cultivated areas, and the prominence of pea cultivation as their primary economic activity (Ramos-Zambrano et al., 2022).

3.2. Perception of small farmers' feelings about peas, ex-ante and ex-post COVID-19 period.

Regarding the perception of feelings, happiness, and trust, commonly used words, such as good, work, harvest, and change, were identified in the ex-ante and ex-post periods (Figure 3 and Figure 4). This follows Plutchik's theory of emotions, which posits that when combined, these words would represent the primary dyad of love towards the pea crop. These changes may be attributed to the fact that, since the 1990s, pea cultivation has become a successful alternative for crop reconversion, facilitating the transition from a cereal-growing region

to the use of high-yielding pea varieties, which continue to predominate in the fields of southern Nariño. Moreover, this transformation has been decisive in facilitating the integration of young people, women, and the elderly into the agricultural workforce (Cadena Pastrana et al., 2022).


**Figure 3**. Perceived feelings of pea farmers, ex ante COVID-19 pandemic.

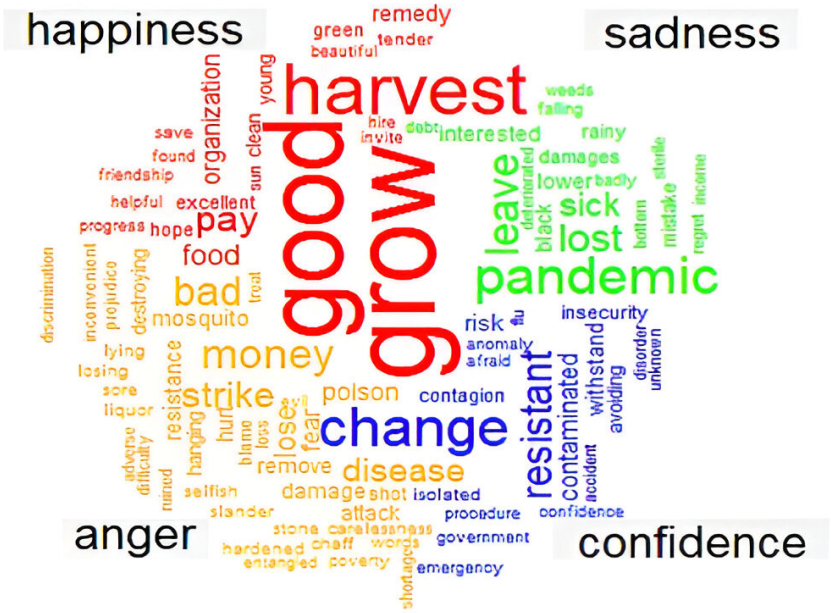


**Figure 4**. Perceived feelings of pea farmers, ex post COVID-19 pandemic.

However, despite the favorable changes introduced by pea varieties, the respondents indicated a growing concern among pea farmers regarding the environmental impact of this crop. The interviews revealed that 96% of growers believe pea production harms the environment. As observed in the context and characterization of producers, 56.5% of the producers are using alternative methods to conventional methods, combining use of agrochemicals with organic fertilizers. The ex-post anger (in orange) directed at the disease (Figure 4) may be attributed to the imbalance caused by the utilisation of synthetic chemical inputs and the increased resistance to pests and diseases to such inputs. This results in a sense of impotence when attempting to control them.

On the other hand, respondents indicated that the sadness experienced during the ex-post period (illustrated in green) was associated with the pandemic (Figure 4). This reflected uncertainty regarding fieldwork due to the resumption of normal farming operations in groups of "Cuadrillas, - the Spanish term for a farming collective- given the limited labor supply resulting from confinement and/or preventive isolation. Consequently, farmers were compelled to carry out fieldwork in extended 12-hour shifts, without access to Sunday rest. These restrictions prompted many workers, particularly the elderly, to seek refuge in their homes. Furthermore, women were obliged to assume responsibility for their children's online education, a demanding task that did not allow time for their participation in remunerated activities outside the home, thereby reducing family income.

A comparison of the positive dimension of perception (in red, Figure 5) for both scenarios reveals the importance of the pea crop in the well-being of the producing communities. It was perceived as a source of growth, leading to an improvement in income. The interviewees also identified intangible factors that pointed to an improvement in living conditions. These related to words such as "house" and "family" that referred especially to improvements in housing and land acquisition, as well as the payment of day workers for support in the development of the cultivation. Furthermore, peas were integrated into to other conventional agricultural practices such as potato cultivation. This contributed to the food security of households by enhancing the nutritional value of their diet and increasing their buying power for essential household items.


**Figure 5**. Positive and negative feelings perceived by pea growers, ex-ante COVID-19.

From the negative perception (illustrated in blue in Figure 6), words associated with disease, soil, and poison, among other factors, have been a significant concern throughout the period under analysis. The circumstances occasionally resulted in high yields but with high production costs, which have sometimes endangered food security and the welfare of smallholder communities. This situation is compounded by the volatility of prices per sack of peas, which makes it impossible for producers to receive a significant return on investment.

The substantial increase in cases of COVID-19, social isolation measures, closure of supply chains, business closures, unemployment, and increased poverty, resulted in a collapse in all sectors of the global economy (Vidal Ledo et al., 2021). This reflects increased uncertainty among pea producers, as evidenced in the sentiment analysis (text mining). This phenomenon may be attributed to the scarcity of labor that arose due to the pandemic, which in the ex-post period has not returned to the levels observed before the crisis.

However, these challenges prompted producers to enhance their resilience. In response to the pandemic, they adapted to the new circumstances by introducing strategies such as short marketing channels between lo-

cal producers. These initiatives not only enabled them to maintain their operations but also facilitated the discovery new marketing avenues for their products. They exhibited remarkable resilience and flexibility in the face of adversity, transforming difficulties into opportunities for growth and adaptation.


**Figure 6**. Positive and negative feelings perceived by pea growers, ex-post COVID-19.

This scenario is consistent with what Luque Zuñiga et al. (2021) reported regarding the adverse effects on agriculture and food security, which resulted in a severe economic crisis. Likewise, authors such as Cadena Pastrana et al. (2022) assert that the issues affecting the technology analyzed include the excessive utilization of agricultural inputs, air pollution, deterioration in soil and water quality, and biodiversity loss.

On the other hand, the reduction in activities during the pandemic impacted the logistics of mobilizing raw materials, inputs, and food, as evidenced by the disruption to shipping traffic and ground and air transportation (Luiselli Fernández, 2020). This scenario reflected an increase and volatility in the prices of agricultural inputs, which might be attributed to the "finance overflow" effect on global market dynamics (Candelo-Viafara & Oviedo-Gómez, 2020).

*3.3 Pea production costs, ex-ante and ex-post periods*

Concerning production costs (Table 2), a gradual increase in production costs was evident. This may be attributed to the rise in inflation within the country and social unrest, such as what occurred at the end of November 2019 (Guerrero Hurtado, 2022; Mejía, 2021; Payares-Meza, 2019). However, the advent of the COVID-19 pandemic led to a disruption in the agricultural dynamics due to an increase in prices of essential agronomic inputs and transportation costs, which in cases exceed 100% for some agrochemical products (Chaves Romero & Cedeño Mangona, 2021; Ministerio de Agricultura y Desarrollo Rural [MADR], 2021). In the case of pea technology, the average increase in costs compared to the ex-ante period was 24.2%.

Price volatility had negative impacts at the outset of the pandemic in 2020 in comparison to the preceding year, with a decline rate of 96.7%. This scenario improved until 2022, with a growth rate exceeding one hundred percent compared to 2019.

In this context, the costs associated with the production of peas in the Department of Nariño exhibited a notable increase. As indicated by the cost of production per hectare, there was an increase of 9.5% between

2019 and 2022 (Ramos-Zambrano et al., 2024), primarily due to the rise in the cost of imported agricultural inputs. This phenomenon is not exclusive to peas; Luque Zúñiga et al. (2021) report a similar trend in other crops in South America, where they depend heavily on fertilizers, pesticides, and seeds (FAO, 2020). In the specific case of the production system under study, these inputs represent 26% of the total cost of production (Ramos-Zambrano et al., 2024).

**Table 2**. Production costs and income received in USD by pea producers in the ex-ante and ex-post COVID-19 period.

| Pea production system | Ex ante* (per ha) | Ex post* (per ha) | | | Average Ex post (per ha) |
|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2022 | |
| pea costs (USD) | $3,900 | $4,283 | $4,710 | $5,545 | $4,846 |
| Average yield (kg) | 8,320 | 8,320 | 7,124 | 8,060 | 7,835 |
| Gross income (USD) | $4.296 | $4,296 | $4,782 | $9,155 | $6,077 |
| Net income (USD) | $396 | $13 | $72 | $3,611 | $1,232 |

*Note: Production costs can be affected by higher or lower yields, topography, disease, incidence, worker efficiency, distances from purchasing centers to the farm, machinery labor efficiency, and land costs (rent).

The COVID-19 pandemic has exacerbated this situation. Cabra García et al. (2021) highlight that the monetary resources of agricultural producers were adversely impacted by the 60% decline in the income sources of Colombian households. Hence, between 2020 and 2021, the gross income of producers decreased by 7% (Unidad de Planificación Rural Agropecuaria [UPRA], 2020), thereby endangering food security in the region.

However, the impact was not uniform across all areas. Díaz Valderrama (2019) suggests that the impact on the food security of rural households related to pea cultivation may be contingent upon the specific production models and agricultural practices implemented. Despite the continuation of crop marketing by producers during the pandemic, the sustainability of their families was adversely affected by low prices and high living costs (Ramos-Zambrano et al., 2022).

Furthermore, the ongoing conflict between Russia and Ukraine since 2022 triggered an energy crisis in Russia that has had a ripple effect across the globe. These effects are particularly pronounced in the availability of fertilizers and food security in the region, as well as in the developing countries in Latin America and the Caribbean (Ben Hassen & El Bilali, 2022; Giordano & Michalczewsky, 2022).

Regarding the identification of clusters, our results concordant with what Álvarez-Sánchez et al. (2019) described. This approach identifies three groups of producers whose characteristics demonstrate adaptability in response to diverse circumstantial scenarios, such as crop diversification, technical assistance, land availability, use of agronomic inputs, and access to marketing channels. The latter represents a topic that requires further investigation in most farming systems. It is also worth mentioning that this type of characterization can vary in space and time due to the dynamics of each cultivar and environmental conditions. Therefore, it is essential to contextualize the periods of analysis, a point shared by Álvarez-Sánchez et al. (2019) and Rodríguez Puertas et al. (2021).

## 4. Conclusions

The agricultural value chain in the subregion of the Department of Nariño was significantly affected by multiple factors, which negatively affected the production, distribution, processing, and marketing of peas. Consequently, the economic, food, and nutritional security of pea farmers in the region was significantly undermined.

Pea producers confronted considerable challenges yet demonstrated a notable capacity for adaptation and resilience. However, it is essential to reinforce and enhance these processes to successfully confront future challenges.

It is crucial to consider potential adaptation strategies producers could implement to cope with uncertain scenarios and enhance resilience. Such strategies might include crop diversification, adopting production schemes with reduced dependence on chemically synthesized agricultural products, and establishing short marketing circuits.

Therefore, it is crucial to establish a link between research such as the present study and decision-making processes, the design of differential strategies in terms of resilience measures, and the identification of success factors. Finally, it is important to note that this research can serve as a baseline for further studies aimed at implementing adaptation strategies to address future scenarios of uncertainty that may impact the livelihoods of producers in the agricultural sector.

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## Contributor roles

- Housseman Steven Ramos-Zambrano: conceptualization, formal analysis, investigation, methodology, writing – original draft, writing – review & editing.
- Marcela Elizabeth Riascos-Delgado: formal analysis, investigation, writing – original draft, context of the problem, writing – review & editing.
- Jeisson Rodríguez-Valenzuela: formal analysis, investigation, writing – original draft, writing – review & editing.
- Alcira María Delgado-Sánchez: investigation, writing – original draft, writing – review & editing.
- Álvaro Mauricio Cadena-Pastrana: investigation, writing – original draft, writing – review & editing.

## Ethical implications

This research involved surveys and interviews with human subjects. Although approval from a Human Subjects Ethics Committee or analogous body was not required based on the country's standards, every effort was made to ensure compliance with fundamental bioethical principles. Informed consent was obtained before any interaction, in accordance to the principles of ethical research. This included a clear explanation of the study objectives, procedures, potential risks and benefits, and confirmation that the participants understood their participation was voluntary. The confidentiality and privacy of participants was protected through anonymizing and securely storing the data. Throughout the process, potential risks to participants were mitigated, and fair and non-discriminatory selection of participants was ensured.

## Conflict of interest

The authors declare that they have no affiliation with any organization with a direct or indirect financial interest that could have appeared to influence the work reported

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