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Original article

Circular economy and local development in La Maná: agricultural, livestock and agroindustrial production

Economía circular y desarrollo local en La Maná: producción agrícola, pecuaria y agroindustrial

Economia circular e desenvolvimento local em La Maná: produção agrícola, pecuária e agroindustrial

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ABSTRACT

This paper analyzes the implementation of the circular economy in agricultural, livestock, and agroindustrial production in La Maná, a canton in the Cotopaxi province, Ecuador. This canton, with This study analyzes the implementation of the circular economy in agricultural, livestock, and agroindustrial production in the canton of La Maná, in the province of Cotopaxi, Ecuador. This canton,

Translated from the original in Spanish

which has a humid tropical climate, has an economy based primarily on these productive activities. Using a mixed-methods approach that combines quantitative and qualitative methods, the study evaluates the adoption of circular economy principles to improve resource efficiency, reduce waste, and promote sustainability. Circularity indicators are established to measure the effectiveness of the implemented strategies, such as the rate of utilization of agricultural and agroindustrial waste, the use of renewable energy, and crop diversification. The results show that the circular economy could offer significant benefits in terms of sustainability and local competitiveness. It is concluded that, by adopting these practices, the canton could improve its profit margins, access more sustainable markets, and generate green jobs, becoming a model for local development in the agroindustrial context.

Keywords: circular economy; local development; agricultural production; livestock production; agroindustrial production; sustainability.

RESUMEN

El presente trabajo analiza la implementación de la economía circular en la producción agrícola, pecuaria y agroindustrial del cantón La Maná, en la provincia de Cotopaxi, Ecuador. Este cantón, que presenta un clima tropical húmedo, tiene una economía basada principalmente en estas actividades productivas. A través de un enfoque mixto que combina métodos cuantitativos y cualitativos, se evalúa la adopción de principios de economía circular para mejorar la eficiencia de los recursos, reducir residuos y promover la sostenibilidad. Se establecen indicadores de circularidad para medir la efectividad de las estrategias implementadas, como la tasa de aprovechamiento de residuos agrícolas y agroindustriales, el uso de energía renovable, y la diversificación de cultivos. Los resultados muestran que la economía circular podría ofrecer grandes beneficios en términos de sostenibilidad y competitividad local. Se concluye que, con la adopción de estas prácticas, el cantón podría mejorar sus márgenes de ganancia, acceder a mercados más sostenibles y generar empleo verde, convirtiéndose en un modelo de desarrollo local en el contexto agroindustrial.

Palabras clave: economía circular; desarrollo local; producción agrícola; producción pecuaria; producción agroindustrial; sostenibilidad.

RESUMO

Este trabalho analisa a implementação da economia circular nas produções agrícolas, pecuárias e agroindustriais no cantão La Maná, na província de Cotopaxi, no Equador. Este cantão, com clima tropical úmido, tem uma economia baseada principalmente nessas atividades produtivas. Através de uma abordagem mista que combina métodos quantitativos e qualitativos, avalia-se a adoção dos princípios da economia circular para melhorar a eficiência dos recursos, reduzir resíduos e promover a sustentabilidade. São estabelecidos indicadores de circularidade para medir a eficácia das estratégias implementadas, como a taxa de aproveitamento de resíduos agrícolas e agroindustriais, o uso de energia renovável e a diversificação de cultivos. Os resultados mostram que a economia circular poderia oferecer grandes benefícios para a sustentabilidade e a competitividade local. Conclui-se que, com a adoção dessas práticas, o cantão poderia melhorar suas margens de lucro, acessar mercados mais sustentáveis e gerar empregos verdes, tornando-se um modelo de desenvolvimento local no contexto agroindustrial.

Palavras-chave: economia circular; desenvolvimento local; produção agrícola; produção pecuária; produção agroindustrial; sustentabilidade.

INTRODUCTION

Agricultural, livestock, and agroindustrial production are socioeconomic activities of great importance to Ecuador, given that in recent years they have changed with global development, and this is evident in food consumption patterns. For this reason, the Ministry of Agriculture, Livestock, and Fisheries (MAGAP in Spanish) was established in Ecuador with the mission to regulate, standardize, facilitate, monitor, and evaluate the management of the country's agricultural, livestock, aquaculture, and fisheries production; promoting actions that enable rural development and foster the sustainable growth of production and productivity in the sector by supporting the development of producers, particularly smallholder family farmers, while maintaining incentives for productive activities in general (Zamora Boza et al., 2021).

The circular economy is a model of production and consumption aimed at maintaining the value of resources, products, and materials for as long as possible within the economic system, minimizing waste generation through strategies of reuse, recycling, and the recovery of byproducts. This

approach stands in contrast to the traditional linear "extract-produce-dispose" model, promoting regenerative and resource-efficient production systems (Geissdoerfer et al., 2017; Kirchherr et al., 2017). In the agri-food sector, the circular economy takes on particular relevance due to the high volume of organic waste generated in agricultural and agroindustrial production chains, which can be valorized through processes such as composting, bioenergy, the production of bioproducts, or reuse as agricultural inputs (Jurgilevich et al., 2016).

Agroindustrial production in Ecuador is linked to the development of capitalism, as this is one of the systems that enables the emergence of new production relations in the countryside, thereby altering the space, the territory, and the lives of the people who inhabit it. One of the key components of agroindustry is the technological factor, as it is through this that a process is developed which displaces traditional peasant production and introduces machinery as the driving force behind agricultural production and the transformation of production; furthermore, it harnesses scientific knowledge to increase crop profitability (Pacheco et al., 2018).

In the constant search for sustainable and economically viable models, the canton of La Maná, located in the province of Cotopaxi, Ecuador, has emerged as a key reference point in the region's agricultural, livestock, and agroindustrial landscape. Its commitment to sustainability and local development is reflected in the application of circular economy principles across its various productive activities (Toledo et al., 2023).

The canton of La Maná is composed of three urban parishes (La Maná, El Carmen, and El Triunfo) and two rural parishes (Guasaganda and Pucayacu), where agricultural and livestock activities predominate, sustaining its growing population and attracting local migration. This has enabled the growth of a strong tertiary sector, particularly within the urban social fabric with the flourishing of commerce. In the urban parishes, agricultural production of bananas and orito is predominant. Unlike the urban parishes, livestock farming predominates in the rural parishes, with excellent production of meat, milk, and dairy products, which primarily supply the canton and nearby provinces such as Guayas and Los Ríos.

The circular economy, at its core, proposes a sustainable model in which resources are used efficiently, minimizing waste and closing product life cycles. This approach is presented as a key strategy for local development, especially in the context of La Maná canton, where agricultural,

livestock, and agroindustrial production plays a fundamental role in the regional economy (Terneus Páez & Viteri Salazar, 2022).

In this context, this study analyzes the dynamics of production in La Maná and its surrounding areas, highlighting how the adoption of circular approaches has contributed to strengthening the local economy. Furthermore, it addresses the importance of closing product life cycles and minimizing waste in the interest of efficiency and sustainability.

MATERIALS AND METHODS

The research was conducted in the canton of La Maná, located in the province of Cotopaxi, Ecuador, between the approximate coordinates 00°562 S and 79°132 W. This canton has a humid tropical climate, with annual rainfall ranging from 2,000 to 3,000 mm and average temperatures between 23 and 25 °C. Its economy is based primarily on agricultural, livestock, and agroindustrial production. In this context, the implementation of circular economy practices in the region's productive sectors was explored, with a focus on resource efficiency, waste reduction, and the integration of productive activities.

The methodology employed combined quantitative and qualitative approaches to assess the effectiveness of the strategies implemented within the canton's agricultural production context. Quantitative indicators were used to measure circularity, enabling an evaluation of resource efficiency and waste reduction. These indicators provide a clear framework for assessing the impact of circular economy practices on agricultural, livestock, and agroindustrial production in the canton.

Quantitative circularity indicators

The incorporation of quantitative indicators in the assessment of circularity is key to measuring the effectiveness of the implemented strategies. The indicators used are presented below:

- Agricultural waste utilization rate: Measures the percentage of crop residues, such as crop stalks, bagasse, and shells, that are recycled or reused. The target value for this indicator is e" 60%, and it is obtained through surveys of producers and direct observation.
- Proportion of valorized agroindustrial waste: Indicates the percentage of waste generated by the agroindustrial sector, such as cocoa shells and whey, that is used in other production

processes. The target value is e" 50%, and the measurement is conducted through interviews with agroindustrial producers.

- Use of renewable energy in production: Reflects the proportion of production units that use renewable energy sources, such as solar, hydro, wind, or biogas. The target value for this indicator is e" 25%, and it is assessed through surveys of producers and energy usage records.
- Livestock waste recycling rate: Assesses the percentage of manure and other livestock waste recycled for the production of biofertilizers or biogas. A target value of e" 40% is established, measured through surveys of livestock producers and analysis of production practices.
- Crop diversification on farms: Measures the number of different crops grown on each farm. The target value is e" 3 major crops per farm, and data are obtained through agricultural censuses and interviews with farmers.
- Proportion of producers in associations: Determines the percentage of producers participating in associations or cooperatives. The target value is e" 30%, and information is collected through producer surveys and interviews with key stakeholders.

Quantitative component

To obtain data on these indicators, a survey was administered to a representative sample of agricultural, livestock, and agroindustrial producers in La Maná. The sample was selected using stratified random sampling, with a sample size of 384 producers, ensuring a 95% confidence level and a 5% margin of error. Additionally, an agricultural census and interviews with key informants were conducted to obtain information on crop diversification and participation in associations.

Qualitative component

Semi-structured interviews were conducted with local authorities, leaders of producer associations, and academic experts in sustainability and the circular economy. The interviews were transcribed and analyzed using open, axial, and selective coding techniques, allowing for the identification of perceptions and opinions regarding the challenges and opportunities of implementing circular practices in the local context.

Data analysis

The data obtained through the survey were analyzed using descriptive statistics, calculating absolute and relative frequencies for each of the indicators. The qualitative analysis of the interviews allowed for a deeper exploration of the barriers and opportunities perceived by key stakeholders in relation to the circular economy.

RESULTS AND DISCUSSION

The circular economy as a competitive and sustainable strategy

The circular economy has emerged as a key approach in the transition toward more sustainable production models. This model stands out for its ability to transform traditional economic systems - which are based on the linear "extract, produce, dispose" model- into circular systems where resources remain in use for as long as possible, minimizing waste and dependence on non-renewable resources. Instead of following the pattern of consuming resources and then discarding them, the circular economy seeks to close material cycles through reuse, recycling, and the recovery of byproducts. This transformation not only improves environmental sustainability but also opens new opportunities for competitiveness for local businesses and economies (Geissdoerfer et al., 2017).

In a global market increasingly focused on sustainability, the competitiveness of a region or company is closely linked to its ability to adapt to demands for resource efficiency and minimize environmental impact. In this context, the circular economy emerges as a key driver of competitiveness for several reasons:

a) Cost reduction and resource efficiency: By maximizing the use of available resources, companies that implement circular practices can significantly reduce their production costs. The reuse of materials, waste reduction, and the use of renewable energy decrease dependence on external inputs, allowing companies to achieve more sustainable profit margins. In the case of La Maná, where agricultural and agroindustrial production is a fundamental pillar, the adoption of circular practices could lead to a considerable reduction in costs by utilizing agroindustrial waste and byproducts generated during the production process.

b) Access to green markets: In a global context where consumers and businesses increasingly value sustainable products, the circular economy offers a competitive advantage by facilitating access to international markets that demand products with a lower carbon footprint, less waste, and transparent and sustainable production practices. For the agricultural and agroindustrial sector in La Maná, this could mean privileged access to international markets, where organic or certified sustainable products are in growing demand.
c) Innovation and new product development: The circular economy fosters innovation by encouraging the creation of new products and services based on waste recovery and resource efficiency. Local agroindustrial companies in La Maná have the opportunity to develop high-value-added products, such as bioproducts, biofertilizers, or products derived from cocoa or sugarcane waste. This diversification of their product offerings would allow them not only to increase their competitiveness but also to position themselves as leaders in a market that values sustainability.
d) Improved resilience to economic and climate crises: The circular economy is also linked to the resilience of communities and businesses in the face of economic crises or climate change. By reducing dependence on external resources and promoting the creation of more local and regenerative production systems, agroindustrial companies in La Maná would be better positioned to face challenges arising from climate variability or fluctuations in commodity prices on the global market.

Sustainability is the fundamental principle of the circular economy. By closing material loops and reducing waste generation, environmental impact is minimized and the rational use of natural resources is promoted. This approach not only contributes to long-term environmental conservation but also aligns with global sustainable development goals, such as reducing the carbon footprint and the efficient use of natural resources. In the case of La Maná, the implementation of the circular economy has a direct impact on several key aspects of the region's sustainable development:

a) Reduction of waste and pollution: In La Maná's agricultural and agroindustrial systems, much of the waste generated -such as sugarcane waste, cocoa byproducts, and dairy production waste- is not properly utilized. This waste contributes to pollution and the loss of valuable resources. The circular economy would make it possible to transform this waste into new products or reuse it as inputs for other production processes, thereby reducing the amount of waste generated and improving the region's environmental quality.

b) Conservation of natural resources: The circular approach also promotes the efficient use of natural resources and the conservation of local biodiversity. The implementation of practices such as composting, water reuse in more efficient irrigation systems, and the use of renewable energy could help preserve local ecosystems and agricultural soils, essential elements for ensuring the sustainability of agri-food production in La Maná.
c) Development of a green economy: Through the implementation of the circular economy, La Maná has the opportunity to develop a green economy in which productive activities are aligned with global sustainability goals. This would not only contribute to improving the local environment but could also generate green jobs in sectors such as waste management, bioenergy production, recycling, and regenerative agriculture, diversifying the economy and improving the quality of life for the region's residents.

The impact of the circular economy in La Maná can be significant and transformative. The adoption of circular practices by the region's agroindustrial and agricultural activities could lead to increased efficiency and local competitiveness. Among the main expected impacts are:

a) Improved local competitiveness: Implementing the circular economy would allow agroindustrial companies in La Maná to improve their profit margins by reducing operating costs, accessing green markets, and diversifying their product offerings. This would strengthen the local economy and contribute to the development of a more efficient and sustainable economic model.
b) Development of more sustainable production models: The transition to the circular economy could shift the focus of La Maná's production systems toward more sustainable and resilient models. By utilizing natural resources more efficiently and reducing the carbon footprint, the circular economy would help improve air quality, soil health, and local biodiversity, all essential for ensuring the region's long-term sustainability.
c) Job creation and economic opportunities: The circular economy generates new employment opportunities in areas such as waste management, the production of bioproducts, and innovation in agroindustrial processes. This development could contribute to the creation of green jobs, particularly in rural areas, which would improve the living conditions of La Maná's residents and strengthen their economic stability.
d) Strengthening resilience to climate change: The implementation of more sustainable agricultural practices and production systems less dependent on external inputs would make

La Maná more resilient to the challenges posed by climate change, such as droughts, floods, or extreme weather events.

The circular economy offers La Maná the opportunity to reinvent its agri-food production systems, transforming environmental and economic challenges into development opportunities. Implementing circular strategies in an integrated manner would not only improve local competitiveness but also position the canton as a leader in sustainability and the green economy within the regional and national context. To achieve this change, the commitment of all local stakeholders is necessary: producers, local authorities, businesses, and educational institutions, who must work collaboratively to implement circular practices that promote more equitable, sustainable, and resilient development for future generations.

Territorial profile of La Maná

Agribusiness in La Maná has experienced a significant boom, generating employment and fostering local development. The transformation of local raw materials, such as cocoa, into high-value-added products has been key to diversifying the local economy. Cooperation between small producers and agribusinesses has strengthened community ties and positioned the canton on the regional economic landscape (Figure 1).

The adoption of advanced agricultural technologies has enabled farmers in La Maná to increase efficiency and reduce environmental impact. From the use of drones for crop monitoring to smart irrigation systems, innovation has become a catalyst for sustainability and economic growth.

Despite these successes, La Maná, like other regions in Ecuador, faces persistent challenges, such as climate change and pressure on natural resources (Chengot et al., 2024). However, these challenges also present opportunities to further strengthen the circular economy and foster local resilience through the implementation of more sustainable agricultural and livestock practices (Murphy et al., 2023).

Figure 1. Conceptual model of the circular economy applied to La Maná
Source: Own elaboration

The circular economy is not only sustainable but also a competitive model. This approach contrasts with traditional models, proposing more efficient and environmentally friendly consumption and production (Almeida Guzmán & Díaz Guevara, 2020). An analysis of agricultural and livestock systems in the Guasaganda parish, in La Maná canton, reveals the need to identify practices that promote circularity and sustainability in livestock production.

According to the Development and Land Use Plan for La Maná canton (2015-2020), the latest version available on the official website of La Maná Municipal Decentralized Autonomous Government (GAD in Spanish), the region is characterized by strong livestock production, followed by agriculture. With a tropical climate, average temperatures range from 23.6 to 25.2 °C, with highs of 31.5 to 34.0 °C and lows of 14.5 to 17 °C. Average annual precipitation ranges from 2,000 to 3,000 mm, distributed over nine months, with three or fewer dry months per year, during which the number of physiologically dry days varies between 17 and 68. Although it belongs administratively to the

mountainous region, its agriculture focuses mainly on products typical of the coastal region, such as bananas, plantains, orito, cacao, coffee, cassava, citrus fruits, and tobacco, among others.

According to data compiled by the Provincial Government of Cotopaxi and corroborated by field research, agricultural production in the region is notable. Banana cultivation leads the way (Pallo Macias et al., 2024) with approximately 4,220.07 hectares, followed by coffee with 2,967.77 hectares and plantains with 931.69 hectares. In addition, cocoa production is recorded at around 304.22 hectares, with 247 ha managed by MAGAP in Ecuador, and 44 ha for coffee, distributed among different parishes (20 ha are in La Matriz, 21 ha in Guasaganda, and 3 ha in Pucayacu). Although sugarcane is not considered a commercial crop, its processing into panela and aguardiente is being explored in the parishes of Pucayacu and Guasaganda. As for livestock production, it is adapted to local conditions, accounting for 38.11% of the canton's territory, primarily used for feeding cattle. Daily milk production, with 25,241.98 ha of pasture, reaches 20,000 L, with 27.27% for self-consumption and 72.73% for commercial sale. The rural parishes of Guasaganda and Pucayacu stand out for their agroindustrial potential, generating employment, while the urban areas are experiencing strong and expanding residential, commercial, and tourism development.

Rice is grown seasonally for self-consumption in places like Chipe Hamburgo, and pineapple cultivation is under development, with MAGAP conducting analyses for loans from the Banco de Fomento. This analysis is based on the Development and Land Use Plan for La Maná canton (2015-2020), which highlights the importance of livestock and agricultural production, with an emerging agroindustrial sector that has become the subject of updated studies in the area and its surroundings.

Characterization of the agricultural production system

Agricultural production encompasses land management, harvesting, forestry, and livestock raising, utilizing scientific and technical advances. Since its founding, Ecuador has depended on primary resources such as cocoa, bananas, and coffee (Viteri Vera & Tapia Toral, 2018). Although these activities generate capital and support the secondary industry, agrarian structures have not yet succeeded in transforming into effective agroindustrial systems. Sectoral industrial policies can negatively impact the agricultural sector, undermining the resources mobilized. Agricultural investment must be sustainable and managed by institutions that promote development and innovation. In the 21st century, the service sector has become the most commercially dynamic in

Ecuador, surpassing agriculture, which has historically been crucial to the economy after oil (Viteri Vera & Tapia Toral, 2018).

The agricultural structure in the parish of Guasaganda is characterized by its primary focus, centered mainly on agriculture and livestock, with the latter being the dominant activity due to the quality of the pasture. However, agricultural modernization is low, which has led to the creation of farmers' and ranchers' associations to protect members and improve prices, recognizing the importance of collaboration for the progress and strengthening of agricultural activities.

Agricultural activity in Guasaganda encompasses a wide variety of crops, both perennial and seasonal, covering a total area of 1,598.7 ha, representing 6.4% of the local territory. Notable crops include orito (25.4%), Dominico plantains (15.9%), cacao (12.5%), oranges (5.01%), and sugarcane (5.6%), among others (Table 1).

Each of these crops contributes significantly to agricultural activity in terms of planted area and net sales. For example, plantains account for 15.3% of the planted area and 24.3% of net sales revenue, while cocoa occupies 12.5% of the planted area and contributes 11.9% of net sales revenue. These data highlight the importance of each crop in the local economy, as reflected in the percentages of planted area and net sales for each (Garófalo Untuña et al., 2023).

Table 1. Agricultural production in the Guasaganda parish

Crop	Planted area (%)	Net sales revenue (%)
Orito (*Musa acuminata*)	25.4	49.55
Dominican plantain (*Musa paradisiaca*)	15.9	10.3
Cacao (*Theobroma cacao*)	12.5	11.9
Fresh almond (*Prunus dulcis*)	12.4	Not available
Orange (*Citrus sinensis*)	5.01	Not available
Sugar Cane (*Saccharum officinarum*)	5.6	0.3
Other crops	23.19	Not available

Source: Survey of agricultural producers in the Guasaganda parish

The discrepancy between the percentages of planting and harvesting of products is due to losses, mainly from pests, diseases, or lack of care. In contrast, the differences between the percentages of harvest and sales are attributed to self-consumption on the farms, feeding farm animals, or distribution among workers or family members.

In the Pucayacu parish, located in a rural area, wholesale and retail trade predominate, complemented by fish farming, and constitute the main source of income for local families. In this area, families are primarily engaged in agriculture, growing traditional short-cycle crops such as cassava, plantains, hard corn, sugarcane, oranges, lemons, orito, and Chinese potatoes, among others (Table 2). It is worth noting that in the Solonso district, cocoa cultivation is predominant. These crops are essential for the food subsistence of local families and, in some cases, are sold on a small scale.

Table 2. Agricultural production in the Pucayacu parish

Crop	Yield (t/ha)
Sugar Cane (*Saccharum officinarum*)	4.00
Durum corn (*Zea mays*)	10.20
Musaceae	2.00
Cacao (*Theobroma cacao*)	2.06
Bermuda grass (*Cynodon dactylon*)	8.30

Source: Survey of agricultural producers in Pucayacu

Sugarcane cultivation is predominant in the Pucayacu parish (Table 3), covering an area of 1,380 ha, mainly located in the La Carmela and Choaló communes, as well as in the Sandomo and La Argentina districts. In 2020, this agricultural activity involved approximately 120 producers, according to records from the MAGAP Technical Unit (López Vidal & González Osorio, 2022).

Table 3. Crops, location, area in hectares, yield, and marketing

Crop	Location	Area (ha)	Yield (t/ha)	Market
Sugar Cane (*Saccharum officinarum*)	La Carmela, Choaló, Sandomo, and La Argentina	1380	4.0	• Local market • For personal consumption
Durum corn (*Zea mays*)	Pucayacu, Solonso	850	10.2	• Local market • For personal consumption
Musaceae	Pucayacu	755	2.0	• Local market • For personal consumption
Cacao (*Theobroma cacao*)	Solonso	360	2.06	• Local market
Pasto	Pucayacu (Solonso, Gradual, El Tonglo, La Carmela, La Argentina, Choaló, Sandomo, San Ramón, El Naranjal)	24,823.57	Not quantified	• For personal consumption

Source: Interviews with key informants, such as leaders of local organizations, MAGAP officials, and producers

Durum corn is widely grown in the Solonso area, where it occupies approximately 850 hectares of land (Ministry of Agriculture and Irrigation, 2020). Meanwhile, the cultivation of musaceae, which includes plantains and bananas, covers a total area of 755 ha, in both urban and rural areas of the Pucayacu parish. Cacao is grown primarily in the Solonso district, occupying approximately 360 ha of land for production. Regarding land use, approximately half of the parish's territory is allocated to cultivated pastures (51%), followed by areas dedicated to arboriculture with pastures (5%), planted

pastures (22%), managed natural forests (24%), short-cycle crops (7%), and natural forest (41.4%). In addition, a smaller percentage is allocated to bodies of water (0.6%).

As part of efforts to strengthen the sugarcane value chain, various institutions have collaborated to promote organic production. MAGAP, the Ayuda en Acción Foundation through the Ecuadorian Populorum Progressio Fund, the Provincial GAD of Cotopaxi, and the Parish GAD of Pucayacu have joined forces in this endeavor. Through a joint project for the production and marketing of granulated panela, these entities have provided technical assistance to producers.

La Carmela commune stands out as a pioneer in this process, having successfully obtained organic certification. This achievement has enabled the inclusion of 28 producers from the area. Of the 120 identified sugarcane producers, approximately 24.4% work cooperatively, indicating potential for the development of joint production. However, this situation has not been fully leveraged in all the districts and communes of the parish, due to the persistence of traditional production methods and apprehension toward cooperative arrangements.

Currently, there are no evident measures to ensure the sustainability of agri-food systems or the implementation of resilient agricultural practices that improve productivity. The land area dedicated to agricultural production for agri-food sustainability is characterized by monocultures without the use of biotechnology, which limits the system's diversification and resilience. Production systems are based on empirical practices and family traditions, without a scientific or technological approach that promotes efficiency and sustainability. There is also a lack of actions to conserve the genetic diversity of seeds and cultivated plants, which could affect the agricultural system's ability to adapt to future challenges.

La Maná, El Carmen, and El Triunfo are urban parishes where agricultural production is not very feasible due to the predominant use of land for housing and the economic focus on commerce (García Bravo et al., 2024). A large portion of the inhabitants of these areas are engaged in the cultivation, processing, and export of bananas and tobacco on farms outside the urban parishes of La Maná canton. The sandy and rocky soils in these areas require large amounts of water for large-scale agricultural production, thus limiting its viability. Agriculture is concentrated in households for personal consumption, but low production is mainly attributed to unfavorable environmental conditions such as climate, pests, and diseases. Furthermore, the lack of large-scale agricultural

production is due to the presence of small-scale gardens ( ) rather than extensive croplands, which makes it difficult to achieve high yields (Bassante Jiménez & Zambrano Rosales, 2021).

Characterization of the livestock system

Livestock production systems stand out as a comprehensive strategy that not only ensures the daily livelihood of communities but also contributes to ecosystem conservation, promotes wildlife, and preserves cultural values. In Ecuador, livestock production has experienced continuous growth. With more than 4,487,000 head of cattle for meat and milk, the country has a predominance of native cattle, with meat production concentrated mainly on the coast and in the Amazon region, while dairy production is centered in the highlands. Dual-purpose cattle farming, for both meat and milk, accounts for the largest share of national livestock production, highlighting its importance to the country's economy and food supply.

In the early 2000s, Ecuador faced a severe economic crisis, which led landowners to sell their properties, thereby attracting new residents to the region. During this period, the livestock sector began to develop. Despite inadequate technical guidance from the government, producers introduced new pastures and cattle breeds on their own initiative to improve milk production and raise disease-resistant breeds (Oleas, 2019). Initiatives emerged, such as the Asopagua raw milk collection center and association, as well as a market for agricultural products and livestock byproducts in the center of the parish. In addition, a livestock market was established in Pucayacu.

Livestock systems in the Guasaganda parish (Andrade et al., 2023) constitute the main economic activity, with an emphasis on cattle farming -both dairy and beef- and dual-purpose systems (Table 4).

Table 4. Livestock production in the Guasaganda parish

Species	Production system	Average number of animals per producer
Cattle	Dual-purpose	150
Cattle	Beef	380
Cattle	Milk	300
Pigs (Sale and personal consumption)	Fattening	10
Pigs (Raised for sale)	Fattening	5
Sheep	Meat	10
Poultry	Personal consumption	10

Source: Survey of livestock producers in Guasaganda

Livestock production occurs in all agroecological zones, with variations in the number of head of cattle and milk production ranging from 30 to 300 units, with an average production of 6.1 L per cow per day. The most common breeds include Jersey, Holstein, Brahman, and Girolando (Requelme & Bonifaz, 2012). Cattle care includes regular deworming and vaccinations, as well as a diet that combines free-range grazing with supplements such as molasses and mineral salts. Beef cattle farming is less common, with farmers owning between 5 and 380 head of cattle, primarily of the Brahman and crossbred breeds. Care and management are similar, with an emphasis on a diet based on pasture and supplements.

Other livestock systems include raising pigs for sale and personal consumption, with 2 to 10 pigs per producer, and raising sows for sale, with an average of 5 sows per producer. In both cases, the focus is on regular care, a varied diet, and sales either on-farm or at livestock fairs. Sheep and free-range chicken farming are also practiced, though to a lesser extent. Sheep are primarily raised for personal consumption, while chickens are raised for meat and egg production.

In the parish of Pucayacu, there is significant livestock production focused on meat and milk. The cattle are the result of crossbreeding between Brown Swiss and Criollo, with a smaller presence of

Holstein crossed with Criollo, adapted to the coastal climate. This activity is supported by an area of cultivated and natural pastures covering 9,266 hectares, representing 51% of the total land area.

MAGAP and the Ecuadorian Agency for Agricultural Quality Assurance (Agrocalidad) provide occasional technical assistance, primarily for the oversight of the parish's livestock trade fair. However, commercial enterprises have been fundamental as sources of livestock technology transfer. Animals are transported by truck and, often, on foot, which can cause stress to the animals and affect their condition at slaughter.

As for *Large White* pigs, their rearing is primarily focused on self-consumption within the community. Poultry, especially native chickens, are common in households in the parish. They are generally cared for by household members for meat and egg production, although large-scale rearing is not practiced in the area.

Characterization of the agroindustrial system

Agroindustrial production falls within the classic division of economic activity comprising three sectors: primary, secondary, and tertiary. The secondary sector, which involves the processing of raw materials for consumption, includes agroindustry, responsible for the production and marketing of agricultural and forestry products, and the processing of fishery and biological resources. This enables the preservation and distribution of perishable products such as fruits, vegetables, milk, and meat through processing methods.

In the parish of El Triunfo, agriculture, livestock farming, forestry, and fishing are the main economic activities, employing a significant proportion of the economically active population (EAP), with 67.05% of the population engaged in these occupations. However, despite their high share of the workforce, these activities contribute only marginally to the canton's gross value added (GVA), accounting for just 1.29%. This contrast highlights a common paradox in many rural areas, where a large portion of the population depends on primary activities for their livelihood, but these do not generate a proportional impact on GVA, which could indicate low levels of mechanization and efficiency in production processes. Furthermore, undeclared activities represent the second most significant sector in terms of labor force participation, at 7.05%, reflecting potential informality or underreporting in economic activity. As for industry and manufacturing, despite their growth, they still account for a small fraction of GVA, at 6.10%, suggesting that the region has not achieved

significant integration of these sectors into the formal economy, which limits their capacity to generate added value in a more structural manner (Mogrovejo Lazo & Carabajo Alvear, 2022). This distribution suggests that, although the El Triunfo parish has a high percentage of the labor force in primary sectors, the diversification and modernization of the economy remain key challenges for increasing GVA and improving the canton's competitiveness.

Within El Triunfo parish, the "Delicias del Triunfo" Association stands out in the secondary sector with cocoa production and chocolate manufacturing. This association, legally established for commercial purposes, is primarily composed of women, who are responsible for the artisanal production of chocolate, playing a fundamental role in the local agroindustrial value chain. Despite their significant contribution, women face gender gaps that limit their access to key resources, such as financing, appropriate technologies, and marketing networks, which impacts the sustainability and expansion of their initiatives. Although the association has a point of sale in the parish, the lack of an established market niche and structural discrimination hinder continuous production, forcing producers to make large quantities only on demand, which affects the economic stability of women entrepreneurs (Navas Espín et al., 2021; Silva Álvarez et al., 2021). This situation highlights the need to strengthen the gender perspective in the agricultural sector, especially in rural areas, to ensure equal opportunities and empower women in the productive sphere, reducing the social and economic barriers that still persist in these contexts.

Another commercial activity in the area is the production of plantain and Chinese potato chips, also made to order by a group of people with disabilities. Additionally, small-scale, privately-run sugarcane production takes place.

The "Solaso" Agroindustrial Farm in El Triunfo parish produces 100% natural products such as coffee, chocolate, guava jam, plantain flour, coffee liqueur, and cocoa liqueur. In the Pucayacu parish, agricultural and livestock activities predominate on private lands, mainly on farms. The parish seat retains traditional architecture and is notable for its focus on livestock, specializing in the production of milk and dairy products (Table 5).

Table 5. Production of milk and dairy products

Products	Daily production (L)	Monthly (L)	Annual (L)
Milk	20,000	600,000	7,200,000
Yogurt	300	9,000	108,000
Cheese	1,600	90,000	1,080,000

Source: Survey of milk and dairy product producers in Pucayacu

In addition, the area is home to several microenterprises dedicated to dairy products, such as the processing plant "Lácteos 3k," "Quesos Marielita," and "Asociación de Productos Lácteos La Josefina" (Table 6). These companies contribute to the local dairy sector by expanding the range of products available to consumers.

Table 6. Microenterprises in the parish of Pucayacu

Infrastructure	Production
Traditional sugarcane milling	A rustic, handcrafted mill with articulated wooden mechanisms, which still exists in some places.
"Lácteos 3k" processing plant	Approximately 300 liters of milk are processed daily, sourced from small-scale producers to make table cheese, mozzarella, and yogurt.
Panela Industry	Industrial production of ground panela sold in the surrounding areas: Valencia, Quevedo, and La Maná.
Liqueur processing	Production of pure artisanal liquor for personal consumption.
Meat industry	The meat is processed and then transported to the "PUCAYACU" slaughterhouse (Municipal Slaughterhouse).

Source: Interviews with microenterprise owners in the Pucayacu parish, as well as interviews with local producer associations and authorities

In La Maná canton, there are companies dedicated to cheese production and the export of milk and yogurt to surrounding areas. Meanwhile, the Guasaganda parish has seen growth in residential areas

in recent years, although its economy remains primarily based on agriculture and livestock. The raw milk produced in this parish is collected primarily by the La Josefina Association and the Guasaganda Agricultural Development Committee, and is sent to national dairy factories such as Rey Leche and Tony. In the parishes of Pucuyacu and Guasanga, panela is also produced in blocks.

The parish of El Carmen has no industrial activity. However, it is known for the production of chifles. One of these facilities, perhaps the most important, is the "Baloys" Chiflería, which has a one-hectare banana plantation and harvests 200 boxes per year for the production of this *snack*.

The San Juan Agricultural Corporation owns a vast 2,500-hectare tract of land located in the Manguila sector, primarily dedicated to tobacco cultivation. This company provides employment for more than 2,000 people involved in the cultivation and harvesting of tobacco leaves destined for export in their raw state. It is noteworthy that 60% of the workforce consists of women and that the work is seasonal, with an average duration of 7 months.

Municipalities play a crucial role in the land-use planning process, being responsible for driving constant improvements in their management. The Territorial Development and Planning n Plan is fundamental to this progress, as it organizes territorial development within the political sphere, addressing aspects such as administration, services, projects, citizen participation, and planning. This instrument provides relevant information for decision-making by the Municipal Council and the Planning Council, enabling more effective and precise management.

Banana cultivation is the most important agricultural activity in La Maná and its surrounding areas. This crop and its associated industries at the national level provide employment for millions of people and have an impact on Ecuador's GDP and private exports. The Ecuadorian banana market is diversified, with destinations such as the European Union, the United States, and Russia.

The canton of La Maná boasts a rich diversity of artisanal traditions rooted in its culture, such as weaving atarrayas, sugarcane milling, and the production of artisanal cheese and chocolate, which stand out as part of its local heritage. Additionally, there is potential to promote the use of natural resources such as tagua and banana stem fiber in the production of handicrafts (bracelets, keychains, pipes, charms, necklaces) that are sold abroad.

At the Splendor natural water bottling plant, 1,500,000 liters of water are processed and distributed weekly to the country's major cities. Studies conducted by the bottling company have revealed the presence of traces of gold and silver in this water. The Borama plant, inaugurated in La Maná in 2001, occupies an area of 200 hectares and is dedicated to the production of beverages from mineralized water, using advanced technology and maintaining high quality standards, with a production capacity of 200 bottles of purified water per minute.

In the production of milk chocolate bars, the "Chocopaxi" Chocolate Factory stands out in partnership with the ASCALA association. Additionally, the APROCANAM plant, with 79 members, produces chocolates, bonbons, and drinking chocolate made from 98% CNN and 2% domestic cocoa. The APROCANAM Chocolate Factory, which produces chocolate bars, also purchases 500 buckets and 57 quintals of cocoa weekly during peak production seasons. At present, it does not export its products, as it has not yet obtained health certification; however, it exports cocoa as a raw material through UNOCACE, with approximately 80% going to Switzerland, Spain, and Italy.

The results obtained are consistent with studies conducted on agricultural production systems in Latin America, which show low implementation of circular economy strategies in rural areas, mainly due to technological limitations, lack of access to financing, and poor institutional coordination (Jurgilevich et al., 2016; Kirchherr et al., 2017). In the specific case of Ecuador, recent research indicates that the valorization of agroindustrial waste represents a strategic opportunity to improve the sustainability of the agri-food sector and reduce pressure on natural resources (Toledo et al., 2023).

The implementation of the circular economy in agricultural, livestock and agroindustrial production in the canton of La Maná and its surrounding areas is not only essential for local development but also a competitive and sustainable strategy. A sustained commitment is needed to strengthen these approaches and move toward more efficient and environmentally friendly production.

Potential for implementing circular economy strategies

The implementation of the circular economy in agricultural, livestock and agroindustrial production in the canton of La Maná is key to local development, offering sustainable solutions to the environmental and economic problems facing the region. While the article has conducted a comprehensive analysis of the canton's main production sectors, it has remained at the descriptive

level and has not delved into how circular economy strategies can address the specific challenges identified in the analysis.

1. Identified problems and their relationship to the circular economy

In the production systems of La Maná canton, several issues have been identified that limit the sustainability and competitiveness of agricultural and agroindustrial activities:

- Inadequate management of agricultural and agroindustrial waste: Waste from agricultural production (crop residues, cocoa shells, sugarcane waste) and agroindustrial production (whey, cocoa shells) is not properly utilized. This contributes to soil and water pollution, in addition to being a waste of valuable resources.
- Reliance on non-renewable resources: Traditional agricultural and livestock production practices rely heavily on external inputs (fertilizers, pesticides, water) and on the exploitation of natural resources without efficient regeneration.
- Low level of mechanization and lack of innovation: The adoption of resource-efficient technologies, such as renewable energy or efficient irrigation systems, is limited, preventing producers from becoming more competitive in a market that increasingly values sustainability.
- Lack of integration in production chains: Agroindustrial and agricultural activities are not sufficiently integrated, which prevents the e e use of byproducts generated in one sector for reuse in another, as occurs in successful circular models.

2. Solutions through the circular economy

The circular economy offers a regenerative and efficient model that could transform these challenges into opportunities, providing concrete and sustainable solutions to the identified problems:

- Utilization of waste for the creation of bioproducts: Strategies for the recovery of agroindustrial and agricultural waste can be implemented. For example, sugarcane waste, cocoa byproducts, and livestock manure can be transformed into biofertilizers or used in biogas production. This valorization not only reduces pollution but also creates new products that can be marketed locally or exported, such as bioproducts, compost, or renewable energy.
- Closing production cycles through agricultural integration: The circular model enables the integration of agricultural, livestock and agroindustrial activities, using byproducts from one

activity as inputs for another. For example, waste from milk production can be used as livestock feed, or agricultural waste can be transformed into compost or biofuels that fuel other parts of the agroindustrial system.

- Efficient use of natural resources through technology: Circular economy strategies promote the efficient use of natural resources, which is essential in a context like La Maná, where water resources are limited. The implementation of efficient irrigation systems and the use of renewable energy (solar, wind, biogas) reduce the carbon footprint and decrease dependence on external inputs, improving producers' competitiveness.
- Diversification of the supply of agricultural and agroindustrial products: The circular economy enables the creation of high-value-added products, such as organic or sustainable products, with access to international markets. By transforming byproducts into higher-value derived products, such as artisanal chocolates, gourmet dairy products, or new bioproducts, agroindustrial companies in La Maná can diversify their offerings and increase their competitiveness in the global market.

3. Circular economy model applied to La Maná

The circular economy model for La Maná could be structured around five key pillars that interconnect the region's productive activities and promote sustainability and competitiveness:

1. Resource efficiency: Promote the efficient use of water, energy, and materials throughout the agricultural, livestock, and agroindustrial production chain.
2. Waste utilization: Implement technologies and processes for the recovery of organic waste and byproducts, such as composting, biogas, and the production of bioproducts.
3. Closing production cycles: Promoting the integration of productive sectors, where waste from one sector becomes an input for another, creating a closed cycle.
4. Development of value-added products: Utilize agroindustrial waste to develop high-value-added products, such as biofertilizers, bio-compost, organic products, and renewable energy.
5. Education and awareness-raising: Train producers on circular economy practices and provide access to technologies and financing that enable them to effectively implement these models.

4. Impact of the circular economy on local development

Implementing the circular economy in La Maná would not only help improve the competitiveness of local businesses but also strengthen the economy's resilience in the face of climate crises or fluctuations in agroindustrial product prices. Furthermore, it would enable sustainable development by reducing the ecological footprint of production activities and promoting the regeneration of natural resources.

- Improvement of local competitiveness: By applying circular practices, agroindustrial producers in La Maná could reduce their costs, access more sustainable markets, and diversify their products.
- Strengthening the green economy: The transition to a circular economy model would create new job opportunities in areas such as waste management, the production of bioproducts, and sustainable agribusiness, thereby boosting the green economy in the region.
- Job creation and local empowerment: The circular economy has the potential to generate green jobs and empower rural communities -especially women actively involved in agribusiness- by providing them with new economic opportunities and improving their social well-being.

The circular economy in La Maná represents a competitive and sustainable strategy that can transform environmental and economic challenges into opportunities for local development. Implementing circular practices in agricultural, livestock and agroindustrial production would not only strengthen the local economy but also position La Maná as a leader in sustainability and the green economy, serving as a model for other regions with similar productive characteristics.

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Conflict of interest

Authors declare that they have no conflicts of interest.

Authors' contribution

Mario Antonio García Pérez and Tatiana Carolina Gavilánez Buñay participated in the conception and design of the study, analyzed the data, and prepared the draft.

Yudemir Cruz Pérez was involved in data collection, analysis, and interpretation.

All the authors reviewed the writing of the manuscript and approve the version finally submitted.

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