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Research Article

Agroindustrial transformation in the era of the fourth industrial revolution: big data and business intelligence for startups in Colombia and Latin America

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Abstract

Latin American agribusiness faces a dual challenge: meeting growing food demand while advancing toward sustainability. The Fourth Industrial Revolution (4IR) offers major opportunities in this context. This article combines a narrative review of Big Data and Business Intelligence applications in the sector with the design of a viable Business Model Canvas for a Colombian startup that would provide data analytics and consulting services to small and medium-sized technified swine farms. The findings show that technology adoption can reduce production costs by up to 30%, increase agricultural yields by 10% to 27.3%, and save up to 40% of water. However, major barriers remain, including limited rural connectivity, high upfront costs, cultural resistance to adoption, and regulatory uncertainty.[1,2]

The proposed Canvas model, structured around nine blocks and three differentiated business lines, is designed to capture market opportunities and mitigate the specific risks of Colombian agribusiness. A favorable regulatory environment stands out, driven by Law 2069 of 2020, which enables regulatory sandboxes,[3] R&D tax incentives, and institutional support from iNNpulsa Colombia, FINAGRO, and Banco Agrario. Together, these instruments create strong legal and public-financing conditions for technology-based ventures. From a financial perspective, the model projects an attractive average contribution margin of 80.6% and an operating profit of 42.3% in the first year. The startup also incorporates a strong sustainability component aligned with the Sustainable Development Goals.

Keywords: Agribusiness 4.0, big data, business intelligence, canvas model, swine farms, tax incentives

Abbreviations: 4IR, Fourth industrial revolution; AI, Artificial intelligence; AgTech, Agricultural technology; BI, Business intelligence; CTeI, Science, Technology, and Innovation; EBITDA, Earnings before interest, taxes, depreciation, and amortization; IoT, Internet of things; KPI, Key performance indicators; SAM, Serviceable addressable market; SDGs, Sustainable development goals; SMEs, Small and medium-sized enterprises; SOM, Serviceable obtainable market; TAM, Total addressable market; VAT, Value added tax

Introduction

Agriculture and agribusiness are pillars of food security and employment in Latin America and the Caribbean. In 2025, the global population surpassed 8 billion people, increasing pressure on food production systems.[4] Colombia, the world's second-largest exporter of flowers and a leading producer of coffee and bananas, faces major productivity, sustainability, and competitiveness challenges in global markets. The Fourth Industrial Revolution (4IR) provides tools such as connected sensors, advanced analytics, robotics, and automation that help optimize resource use and respond more efficiently to variable environmental conditions.[5] The transition toward Agriculture 5.0 goes beyond digitalization: it combines artificial intelligence, IoT, robotics, 6G communication technologies, and block chain to build more resilient and human-centered models.[4]

Latin America already offers examples of digital transformation. Some platforms use Big Data and machine learning to optimize irrigation and save up to 30% of water. In Colombia, pilot projects led by the Ministry of ICT and the Center for the Fourth Industrial Revolution (C4IR.CO) have implemented IoT sensors and satellite imagery in coffee, cocoa, and avocado crops, reducing costs and improving yields.[6] At AgroDataCuriti farm in Santander, smart sensors and AI platforms reduced water consumption by 40%, while the Cafe Inteligente cooperative in Quindio used drones and image analysis to improve harvest quality and anticipate pest outbreaks. Despite these advances, technology adoption remains uneven: rural connectivity constraints, high initial costs, and training gaps persist.[7] In addition, many innovations come from startups that still operate without a clear regulatory framework and face severe capital-access constraints, as reflected in the financial and investment barriers documented for SMEs.[5,7]

Against this backdrop of opportunity and constraint, strategic structuring becomes critical. The Business Model Canvas is widely used to organize value propositions and understand the key components of an emerging venture. In the agribusiness context, combining the Canvas with a rigorous review of scientific literature and the Colombian regulatory framework-especially Law 2069 of 2020-makes it possible to design data-driven startups that are viable, scalable, and aligned with public incentives. This article addresses three research questions: How is the 4IR (Big Data and Business Intelligence) transforming agribusiness, and what gaps remain? What regulatory framework and startup benefits exist in Colombia, and how do they shape strategic decisions? And how can this evidence be integrated into a viable Business Model Canvas for a data-analytics-based agribusiness startup?

Methodology

This study uses a guided narrative review that integrates academic literature, reports from multilateral organizations, and official Colombian regulations covering the 2015-2025 period. The search was conducted in multidisciplinary databases (Scopus, Web of Science, SciELO, and Google Scholar) and on institutional portals (.gov.co) using keywords in Spanish and English: agribusiness, big data, business intelligence, Industry 4.0, Canvas model, startup, and Colombia/Latin America. The review included peer-reviewed articles (Q1/Q2), institutional reports, and documented cases of technological applications. Selection was based on relevance to the research questions, and blogs or sources without academic support were excluded. For the regulatory review, the study examined Law 2069 of 2020 through the Public Service Regulatory Manager and the iNNpulsa guide titled “ABC of the Entrepreneurship Law,” as well as the Ministry of Science’s portal on STI tax incentives and tax analyses produced by specialized firms.

The findings were synthesized into four axes: (i) theories and models of technology-based entrepreneurship, (ii) 4IR applications in agribusiness (IoT, Big Data, analytics), (iii) the Colombian regulatory framework and incentives, and (iv) opportunities and risks. Based on that synthesis, the study develops a Business Model Canvas and a Value Proposition Canvas, justifying each block with empirical evidence. This methodological approach improves transparency and reduces selection bias in the use of evidence, while also anticipating the challenges inherent in this type of research.[8]

To develop and refine the proposed business model, primary data was gathered through semi-structured interviews with diverse strategic stakeholders within the agro-industrial value chain. This qualitative approach involved representatives from the corporate sector—specifically from the swine, mushroom, and floriculture subsectors—as well as officials from government agencies dedicated to rural development and technological innovation. The insights derived from these dialogues facilitated an iterative construction of the Business Model Canvas components, ensuring that the startup’s operational and strategic framework aligns closely with regional idiosyncrasies and identified production gaps. Consequently, a highly adaptable business model was configured, designed to maximize the probability of scalability and long-term sustainability for new technology-based ventures within the Latin American context.

Results

Synthesis of the state of the art

Adaptation of entrepreneurship methodologies to Latin American agribusiness

Methodologies such as Lean Startup, the Value Proposition Canvas, and the Business Model Canvas are foundational and widely recognized tools for developing and structuring innovative ventures. Their value lies in the ability to iterate quickly between hypotheses and validation, allowing startups to identify clear value propositions and build scalable business models.[9,10] These tools are essential for understanding market needs and designing solutions that resonate with customers.[11] Identifying customer value is especially important in startups operating under high uncertainty and with still-unsettled business models, because it helps entrepreneurs test assumptions and deliver relevant value propositions.[9]

Although these methodologies have proven useful across sectors, their application in agribusiness - especially in Latin America - raises distinctive considerations. Efforts to adapt and extend these tools already exist. For example, an “extended Canvas business model” has been proposed to support the sustainable transfer of agricultural technology in developing countries.[12] Likewise, studies on AgriFood-Tech have used the Business Model Canvas to analyze innovative agribusiness models,[13] including business development for coffee-growing groups through the Triple Layered Business Model Canvas[14] and the analysis of urban agriculture business models.[11] Even so, the literature notes that the use of these methodologies in agribusiness in emerging economies still requires considerable development.[15]

The central challenge lies in the gap between theoretical knowledge and the practical implementation of innovative strategies in agribusiness firms. That gap often translates into low levels of innovation and competitiveness.[16] Research on rural entrepreneurship, particularly in developing countries, remains limited. This reinforces the need for studies that explicitly adapt these methodologies to rural settings and agri-food chains in Latin America.[17] In the region, youth entrepreneurship shows a fundamental contradiction and an implementation gap between academic theory and contextual complexity, which calls for approaches that account for local diversity.[18] Agribusiness firms in the region also face the challenge of creating value beyond the farm gate.[19] Traditional business models are therefore insufficient and require deeper adaptation to address sector-specific constraints, including weak rural connectivity, high upfront costs, and training gaps that hinder technology adoption (Table 1).[1,20]

In summary, the literature confirms that entrepreneurship methodologies are powerful and widely recognized tools, yet their explicit and context-adapted application to Latin American agribusiness remains a significant area for both research and practical development.

Digital transformation and the 4IR in agribusiness

Digital transformation in agriculture combines smart sensors, digital platforms, and advanced analytics to improve productivity and sustainability. The Inter-American Development Bank (IDB Invest) notes that the adoption of IoT sensors, traceability systems, satellite imagery, and drones is reshaping agricultural competitiveness in Latin America, while limited connectivity and weak strategic vision remain serious obstacles.[1,2] In Colombia, Agriculture 4.0 is understood as an evolution of precision agriculture. It integrates sensors, digital platforms, and predictive analytics to optimize all phases of the value chain. The integration of Fourth Industrial Revolution (4IR) technologies into agribusiness has become a decisive factor for optimizing production processes and strengthening sustainability. Big Data and advanced analytics have proven instrumental in generating meaningful operational efficiencies. Empirical evidence suggests that adopting these digital technologies can reduce production costs by roughly 18.7% to 30%.[22,23] Studies also report agricultural yield increases ranging from 10% to 27.3%.[23] These economic gains derive from more precise resource management and better-informed decision-making, both of which are central to profitability and efficiency across the agri-food value chain.

Table 1 Summarizes how these methodologies are applied and what challenges they face in the Latin American agribusiness context

Methodology	General Use/ Recognition	Application in Agribusiness	Challenges / Gaps in Latin American Agribusiness
Lean Startup	Tool for iterating hypotheses and validating innovative products/ services, thereby reducing uncertainty in startups[9]	Proposed as a suitable innovation tool for rural regions in Colombia[10]	Low explicit application in the Latin American agribusiness sector.
Value Proposition Canvas	Helps define value propositions and understand market and customer needs[9]	Used to analyze urban agriculture business models.[11] Also integrated into methodologies for prioritizing value-added options in agricultural products.[10]	Needs adaptation to rural contexts and agri-food chains.
Business Model Canvas	Structures the key components of an emerging company and facilitates a clear understanding of the business[21]	Used to analyze AgriFood-Tech business models[13] support coffee-grower business development,[14] serve as an extended canvas for agricultural technology transfer,[12] and examine urban agriculture business models.[11]	Persistent gap between theory and practice in agribusiness;[16] limited rural entrepreneurship research in developing countries;[17] contextual tensions in Latin America that require policy-sensitive justifications;[18] difficulty creating value beyond the farm gate;[19] and adoption barriers linked to connectivity, costs, and training.[1,20]

In practice, these technological solutions take shape through pilot projects and crop-specific applications. The combination of the Internet of Things-including connected sensors and wireless networks - with remote sensing and cloud-based analytics enables detailed, real-time monitoring of environmental and crop conditions. This technological synergy supports task automation and optimizes the use of inputs such as water and fertilizers.[24–26] Precision agriculture, powered by IoT analytics and machine learning, is producing additional benefits by improving both the quantity and quality of agricultural output to meet rising food demand.[27] These innovations reflect a shift toward smart and sustainable agriculture, where digital technologies become the backbone of advanced farm management.[28,29] As illustrated in Figure 1, the thematic map of the Fourth Industrial Revolution (4IR) in agribusiness synthesizes the three core pillars of this revolution within the sector: data and analytics (encompassing high-volume data storage, AI algorithms, and big data); automation and the Internet of Things, including sensors, drones, robotics, and 6G networks; and decision-making and business intelligence, which integrates management dashboards with descriptive, predictive, and prescriptive analytics.

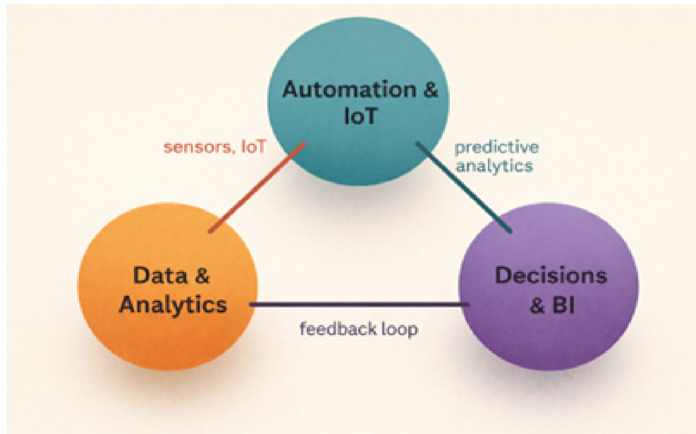

Figure 1 Conceptual framework integrating IoT, data analytics, and business intelligence for data-driven decision making.

Specific examples illustrate this shift. AgroDataCuriti farm reduced water use by 40% through sensors connected to AI platforms, while the Cafe Inteligente cooperative in Quindio uses drones and satellite-image analysis to determine bean maturity and anticipate pests, thus improving competitiveness. Research on smart greenhouses also details systems based on temperature, humidity, and light sensors that record and transmit data to MySQL databases, allowing remote control of agricultural variables.[30]

Regulatory framework and incentives in Colombia

The Colombian regulatory framework for entrepreneurship was consolidated through Law 2069 of 2020. This law establishes a broad structure to promote the creation and consolidation of enterprises by simplifying procedures and fees and reorganizing support institutions. One of its most important innovations is the creation of regulatory sandboxes, that is, controlled environments where startups can test innovative business models with legal certainty.[3] The law also improves the tax regime for microenterprises by modifying registration-tax rates and authorizing simplified accounting.

These regulatory and tax provisions have direct positive implications for the dynamization of the Colombian entrepreneurial ecosystem. They foster innovation by lowering entry and experimentation barriers for new firms, encourage the growth of new ventures, and contribute to national economic development.[31,32] More specifically, startup benefits include income-tax exemptions during the first years of operation, which facilitates profit reinvestment, as well as deductions for research and development investments. In addition, tax incentives managed by the Ministry of Science, Technology and Innovation - including tax discounts for R&D projects and VAT exemptions for research equipment - stimulate private investment in science, technology, and innovation activities, thereby strengthening the competitiveness and innovative capacity of startups and SMEs.[33,34]

The Colombian government complements this framework with support policies and acceleration and incubation programs through institutions such as iNNpulsa Colombia, which provides financing, technical assistance, acceleration programs, and access to investor and mentor networks. For agribusiness specifically, institutions such as the Ministry of Agriculture and Rural Development can provide institutional and financial support, facilitate public policy, and promote rural and technological development programs. ProColombia helps identify export opportunities for agribusiness products, provides market intelligence, and supports participation in international events. Finally, specialized financial institutions such as FINAGRO and Banco Agrario offer preferential financing, help structure business plans, and provide guarantees and agricultural insurance. These favorable legal and public-financing conditions are a key factor in the development of technology-based ventures in the sector. Law 2069 and programs such as iNNpulsa Colombia and CEmprende also coordinate financing sources and provide entrepreneurial training, reinforcing Colombia's position as a regional reference point for transforming its business ecosystem.[31]

Opportunities and risks

The integration of Big Data and Business Intelligence into agribusiness creates major opportunities: higher productivity, lower costs, water savings, stronger traceability, and the creation of new data-driven business models. At the same time, the reviewed sources identify several risks and challenges: (1) limited rural connectivity, which restricts real-time data transmission; (2) high upfront costs for equipment and platforms, especially for smaller producers; (3) training gaps and cultural resistance to technology use; and (4) regulatory uncertainty regarding data protection and ownership. A rigorous understanding and management of these risks is essential if the potential of the 4IR is to be translated into tangible results for Latin American agribusiness. In other words, innovation only becomes meaningful when it is matched by operational feasibility, regulatory discipline, and credible adoption pathways (Table 2).

Table 2 Summarizes the main risks and the proposed mitigation strategies

Category	Risk	Mitigation
Technical	Weak rural connectivity and low 4G/5G/6G network coverage hinder real-time data transmission; sensor and IoT infrastructure failures may also occur.	Implement hybrid solutions (local storage plus delayed synchronization), invest in infrastructure, partner with operators to improve coverage, and establish preventive maintenance and redundancy protocols.
Market	High initial investment and cultural resistance among producers to adopting technology; digital-skills gaps in small firms.	Offer subscription and leasing models to lower entry barriers, design field-based training and support programs, and demonstrate economic benefits through pilots.
Regulatory and legal	Uncertainty regarding data-protection requirements and ownership of generated data; potential changes in tax incentives and regulations.	Work with legal experts, comply with Law 1581/2012 on data protection, adopt cybersecurity protocols, and maintain ongoing regulatory monitoring.
Financial and sustainability	Dependence on public incentives and fluctuations in agricultural commodity markets; difficulty scaling and diversifying income streams.	Diversify funding sources (seed capital, soft loans, corporate alliances), develop differentiated service lines (consulting, software licensing), and design contingency plans for price volatility.

Proposed business model

The business model is developed using the Canvas layout, adapted to the specificities of the agro-industrial sector and based on the review findings. The following proposal is formulated: the higher purpose of the startup is to generate synergy with agro-industrial producers in their businesses, using technology to increase value; its value proposition consists of increasing confidence in agro-sector businesses by maximizing profitability; and its business concept lies in managing business uncertainty through the control of agro-ecological variables in livestock production, mitigating the risk of financial losses through the implementation of Fourth Industrial Revolution technologies. This approach seeks to transform data into strategic information, allowing for more informed and proactive decision-making for producers.[35]

Customer segments

Swine producers who own technified farms located in Colombia. These producers have more than 10 growing pigs and wish to adopt emerging technologies to maximize their business profitability. Early Adopters, Producers who own technified farms in the department of Antioquia; with them, the product can be validated and recurrent income obtained. In Colombia, by 2019, there were 11,765 farms. In the department, there are approximately 1,279 technified farms. In the municipality of Betania, there are 78 farms, and including the surrounding areas, they total 576 farms. The market analysis for the proposed startup follows a hierarchical quantification of potential reach, categorized through the Total Addressable Market, Serviceable Available Market, and Serviceable Obtainable Market frameworks. In the Colombian context, the TAM represents the maximum potential market available to the spin-off upon commencement of operations, with an estimated valuation of 1,513,044,000 Colombian pesos. This reflects the broader national demand for technological integration in the livestock sector, aligning with the growing trend of high-tech entrepreneurship promoted by national agencies like iNNpulsa Colombia.

The Serviceable Available Market is strategically focused on the Antioquia region, which possesses a robust agro-industrial infrastructure. This market segment encompasses 18,768 technified swine production facilities and backyard plots. Based on a projected acquisition frequency of one service per year and a mean transaction value of 6,500,000 COP, the SAM is estimated at 121,992 million Colombian pesos for the initial fiscal year. This regional focus allows for a more efficient allocation of resources and a deeper understanding of localized agro-ecological variables.

Furthermore, the Serviceable Obtainable Market is defined by a target acquisition rate of 45% within the Antioquia region. This specific objective targets 8,445 swine farm owners, leading to a projected annual revenue of 54,896 million Colombian pesos. To ensure the initial validation of the value proposition and generate recurrent income, the strategy identifies early adopters within the municipality of Betania, Antioquia. This localized cluster, comprising 78 technified farms, serves as the primary validation site; applying the 45% market penetration strategy within this municipality yields expected initial revenue of 228,150,000 Colombian pesos. This phased entry strategy mitigates financial risk while leveraging the existing regulatory frameworks and innovation incentives provided by the Colombian government.

Value proposition

Technology design and assembly

Design, assembly, and commercialization of a traceability system that will include sensors installed to measure necessary agro-ecological variables, as well as the adaptation of an Internet of Things system allowing the collection and transmission of data to the cloud for storage and control. This technology has an approximate sales price of $12,000,000 Colombian pesos.

Information management

With agro-ecological data in the cloud, Big Data processing is initially performed correctively to improve the productivity of swine production centers through integration into Power BI visualization dashboards. Subsequently, the aim is to reach predictive levels through the generation of Artificial Intelligence algorithms that, integrated into Power BI, will allow for important predictions for business competitiveness. This business line will focus on: centralizing information, performing Big Data analysis to determine trends, and business intelligence. The monetization model will be subscription-based, including support in data handling and the use of the processing tool. Information is provided so the producer can make faster and more assertive decisions in swine production.

Distribution, communication, and sales channels

An omnichannel approach will be used, integrating both digital and traditional channels, seeking to attract and retain customers through different articulated channels for the best experience in purchasing products and services.

Traditional channels: Human resources and consultative sales, office presence, participation in fairs and events, radio stations, local TV channels, and printed information.

Digital channels: A strategy will be created involving social media and the creation of an agro-industrial website, focusing on:

1. Defining digital strategy objectives (visibility, interaction, and sales monetization).
2. Value content creation via YouTube (educational videos, tutorials, success stories).
3. Facebook for updates and interactive content.
4. LinkedIn for B2B connections and case studies.
5. Optimized website with SEO techniques and a future e-commerce line.
6. Chatbots and data analysis to monitor ROI and engagement.

Customer relationships

To achieve greater effectiveness in the acceptance and acquisition of the Value Proposition, a direct, personalized, long-term relationship (virtual/in-person) will be used, characterized by applied emotional intelligence in:

- Updating comprehensive business management.
- Presentations and demonstrations of the Value Proposition.
- Motivation based on competitive advantages and innovation benefits in times of crisis.
- Long-term business alliances and creation of sectoral productive CLUSTERS.

Revenue streams

Three business lines were defined to obtain income:

1. Monitoring and Control Business Line: Design, construction, and installation of the sensor system. Services include:
   A. Automatic cleaning system and its maintenance.
   B. Capture and structuring of physicochemical data.
2. Information Management Business Line: Using captured data in the cloud via Power BI to build management dashboards. This is monetized through a monthly subscription, offering real-time access to farm graphics for decision-making. Figure 2 shows an example of a management dashboard.
3. Offers consultancy for business projection based on acquired data and additional company areas. Services include:
   - Market Opportunity Identification: Using BI and AI predictive analysis for trend mapping.
   - Price Optimization: Dynamic pricing models based on historical and real-time data.
   - Operational Efficiency Improvement: Process mapping and bottleneck analysis.
   - Offer Personalization: Customizing services based on customer feedback and behavior.
   - Risk Management: Predictive models for climate changes, pests, or input price fluctuations.

Key resources

1. Human Resources: Sales experts (agro-sector), technical support for IoT/sensors, platform monitoring, and BI/Big Data specialists.
2. Technical and Technological Resources:
   A. Technical: IT Infrastructure, BI Software, Databases, ETL Integration.
   B. Technological: IoTsensors, Agricultural Management Platform, and AutomationTechnology.

Figure 2 Agricultural supply monitoring dashboard for agroindustry. Adapted from the Ministry of Agriculture and Rural Development of Colombia (2023).

Key activities

Productive Area: Requirements gathering, technology placement, connection/integration, technical support, and testing. Commercial Area: Customer needs assessment, quoting, after-sales/ loyalty, and market positioning strategies (Table 3).

Table 3 Key allies. By authors based on available information

Entity	Contribution
Gobernación de Antioquia	Institutional and financialsupport; publicpolicyimplementation.
INNpulsa Colombia	Financing, technical advice, and acceleration programs.
Alcaldía de Betania	Connection with local producers and pilot project facilitation.
Procolombia	Exportopportunities and internationalmarketinformation.
PORKCOLOMBIA	Technical advice and training for swine producers.
FINAGRO / Banco Agrario	Preferential rate financing and agricultural insurance.
ICA	Sanitary certifications, regulations, and biosecurity support.

Cost structure and required investment

In order to conduct the costing process, all measurable activities performed by each functional area were initially listed, defining their monthly frequency and the time required for their execution. This initial registry serves to validate current personnel requirements based on demand and the activity components inherent to any project development. It should be clarified that, given the 'intellectual' nature of these activities, any decimal value—regardless of how low—is consistently rounded to a valuation of '1 Resource'. Similarly, values between 0.7 and 1.0 require an assessment of whether the resource operates under effective hours or payroll hours; for instance, a resource value of 0.5 under effective hours might be rounded up to 1, whereas under payroll hours, the resource value could be zero. This is illustrated in the following Table 4.

Table 4 Key Activities and Drivers

Activity	Driver
Technicalcommercialmanagement	138
Supplylogistics	10.9
Cleaningsysteminstallation	172
Automatedmonitoring	0.77
Cleaningsystemmaintenance	21.5
Farm indicatoranalytics	7.87
Personalizedfarmindicatoranalytics	0.00
Consulting	59.3
Analyticsdevelopment	0.00
Research and innovation	3.24
Incidentreporting	0.04
Technicalcommercialmanagement	138

The data indicates a theoretical requirement of three technical and commercial employees. Under the condition of daily adherence to work schedules and an effective time of 7.4 hours within an 8-hour workday, a reduced value is adopted. This adjustment accounts for intervening activities such as travel, interaction with technological resources (e.g., computer usage), active breaks, and hydration, among others. Timeframes and activity volumes for each functional area were projected to ensure operational reasonableness and standardization; however, these parameters remain adjustable to simulate various scenarios. The projected workforce for the spin-off is categorized as 2.5 employees for direct labor costs, 0.5 for commercial costs, and 1 for administrative expenses. A detailed list of these valuations, including social benefits and non-statutory payments, is presented in the following Table 5.

It is essential to note that first item (Technical Operations Staff) in the preceding table corresponds to direct operational costs. In some organizations, commercial efforts are categorized as consultative sales and therefore contribute to the company's operational capacity; for this study, such personnel are classified as indirect costs.

Subsequently, administrative, sales, financial, and indirect expenses are added, alongside the accounting cost component (depreciation and amortization), to determine the operating profit and the minimum break-even point for the spin-off's operations. This input is fundamental for calculations related to EBITDA and projected free cash flows (Table 6).

According to the general cost theory regarding the Contribution Margin, Cost of Capital, and Earnings Before Interest and Taxes for mixed-model companies (products and services), the following principles apply:

A manufacturing company should aim for a Contribution Margin (Price – Variable Costs) exceeding 40% across all product lines. While specific lines may not achieve this threshold, it is recommended that the weighted average exceeds a minimum CM of 40%. Fixed costs, administrative expenses, and general and sales expenses typically range between 10% and 20% of total sales, resulting in an EBIT (Price – variable costs – fixed costs – administrative, general, and sales expenses) of at least 20% to 30%. This figure must be equal to or greater than the Cost of Capital, representing the return expected by both owners and lenders after investing their capital in the business. The contribution margin for commercialized products should be at least 25%, while the contribution margin for services should be at least 60%. Manufacturing and commercialization companies face regular demand, yet selling prices are influenced by raw material cost fluctuations and competitive pricing. Consequently, managing free cash flow to mitigate price volatility is vital for such enterprises.

Table 5 Description of personnel costs. Source: Authors' estimates.

Description	Monthly Unit Cost	Quantity	Monthly Cost	Subtotal
TECHNICAL OPERATIONS STAFF (Engineering)				
Operations Coordinator	$ 3.300.000	0.50	$ 2.545.389	$6.609.286.12
Operations Technician	$ 1.317.172	2.00	$ 4.063.897	
ADMINISTRATIVE AND FINANCIAL STAFF		Valor/Año		
Administrative Assistant	$1.317.172.00	12.00	$24.080.854.63	$24.080.854.63
COMMERCIAL STAFF				
Operations Coordinator – Commercial	$3.300.000.00	0.50	$2.513.808.00	$2.513.808.00

Table 6 Subcontracted operational services and maintenance costs for the automated monitoring system.

Item	Description	Unit Cost (COP)	Quantity (Units/Year)	Monthly Cost (COP)	Subtotal (COP)
	Subcontracted Operational Services				$6,155,715
1	Automatic Cleaning System				
1.1	solenoidvalve	$120,000	1.00	$120,000	
1.2	Treated Wood Boards (10 m × 10 m)	$8,500	1.00	$8,500	
1.3	Arduino SD Module + 32 GB SD Memory	$90,000	1.00	$90,000	
1.4	Air Extractor and Humidifier (17-inch Air Extractor)	$490,000	1.00	$490,000	
1.5	Temperature and Humidity Sensor SHT20 I2C	$125,000	1.00	$125,000	
1.6	Seed Studio Digital NDIR COX Sensor (CO_2)	$420,000	1.00	$420,000	
1.7	Seed Studio Digital NDIR NOX Sensor (NO and NO_2)	$420,000	1.00	$420,000	
1.8	Seed Studio Digital NDIR SOX Sensor (SO_2 and SO_3)	$420,000	1.00	$420,000	
1.9	Contact Relay CX32-1810 AC 110V	$94,875	1.00	$94,875	
1.10	Relay Module with Noise Filter	$30,800	1.00	$30,800	

Table Continue..

Item	Description	Unit Cost (COP)	Quantity (Units/ Year)	Monthly Cost (COP)	Subtotal (COP)
1.11	Electrical Cable with Low Noise – 3 Wires, 12 AWG	$165,000	1.00	$165,000	
1.12	ElectricalAdapter and Connectors	$135,000	1.00	$135,000	
1.13	CAT6 UTP Cable Roll – 100 m	$15,890	1.00	$15,890	
1.14	1/2 HP Mini Water Pump with Pressure Module	$509,900	1.00	$509,900	
1.15	10 m Pipe, 2 Unions, 5 Glue Fittings and 10 PVC Connectors for 1/2" Water Line	$110,000	1.00	$110,000	
1.16	TransportationLogistics	$200,000	1.00	$200,000	
1.17	MaintenanceTransport	$100,000	9.00	$900,000	
1.18	Maintenance Cable	$100,000	9.00	$900,000	
1.19	Cloud Service (Azure)	$750	1.00	$750	
2	CLEANING SYSTEM MAINTENANCE				$200,000
2.1	MaintenanceTransport	$100,000	1.00	$100,000	
2.2	Cable	$100,000	1.00	$100,000	

Source: Authors' estimates.

It is fundamental for companies to identify the break-even point for each product or business line, as this allows for evaluating the feasibility of covering fixed costs and generating profits from the contribution margin.[36,37] Based on the modeled data, with projected annual sales of $1,403,700 million, the spin-off presents an average contribution margin of 80.6%. With administrative and sales expenses of $74 million, it generates an operating profit before interest and taxes of $181 million for the first year. The contribution margin exceeds 40%, and administrative and sales expenses represent 6.5% of sales; therefore, an EBIT margin of 42.3% is generated. This return is attractive to investors as it surpasses the yield of risk-free investments, such as a Certificate of Deposit.

Business model canvas

The following summary canvas presents the main findings of the work carried out using the Business Model Canvas framework (Figure 3).

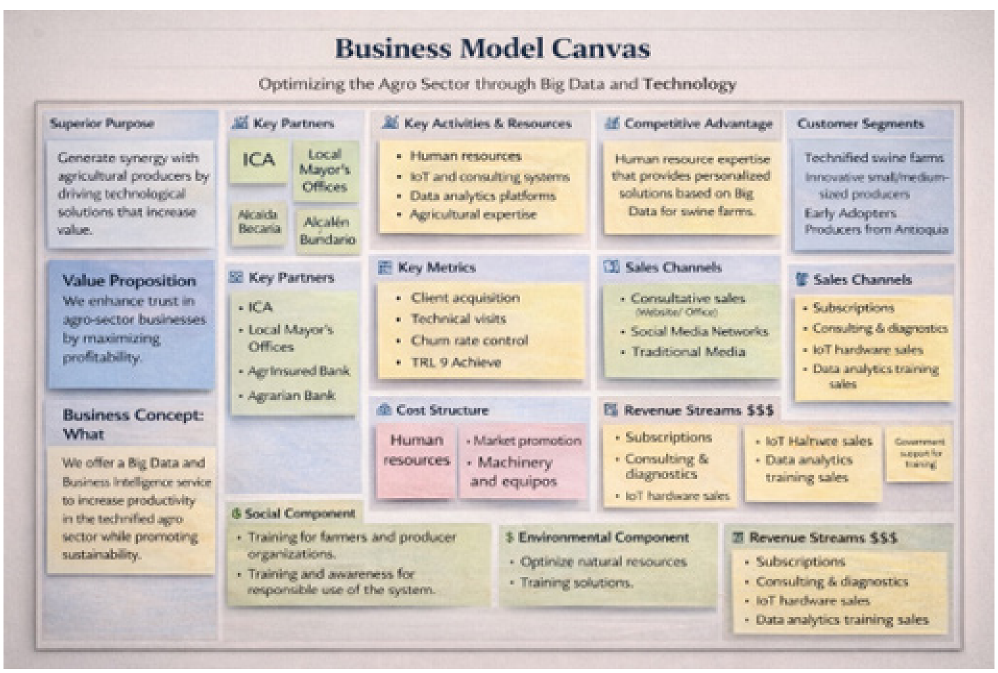

Figure 3 Conceptual Business Model Canvas for Data-Driven Decision Support in Technified Swine Farms.

Regulatory framework and its impact on the canvas

The startup's viability depends on its ability to capture existing incentives while managing legal obligations. Law 2069 of 2020 can reduce incorporation costs through lower registration fees and enable the use of regulatory sandboxes to test IoT-based solutions with legal certainty. Simplified accounting reduces administrative burden and facilitates financial reporting, which benefits an early-stage company. STI tax incentives allow deductions for R&D investments and exempt VAT on the import of sensors and equipment. In practical terms, this can lower the startup's tax burden and support more competitive pricing. Programs such as iNNpulsa, CEmprende, and the SENA Fondo Emprender provide seed capital, mentoring, and network access, making them key partners in the Canvas. At the same time, the regulatory framework requires compliance with Law 1581 of 2012 on personal-data protection and the implementation of safeguards for the security and privacy of producer-generated information. Changes in tax policy may alter the current benefits, so the startup must maintain active regulatory monitoring. Table 7 summarizes regulations and incentives in Colombia for business creation.

Table 7 Selected regulations and incentives in Colombia for business creation.

Regulation / Program	Scope / Period	Benefits / Incentives
Law 2069 of 2020 (Entrepreneurship Law)	Since 2020, Colombia	Establishes a regulatory framework to promote entrepreneurship, simplifies procedures and fees, reorganizes support institutions for MSMEs, includes sandbox mechanisms for testing innovative business models with legal certainty, lowers registration-tax rates for microenterprises, prohibits surcharges, and authorizes simplified accounting for microenterprises.
STI Tax Incentives (Tax Incentives Council)	Permanent program, MinCiencias	Encourages science, technology, and innovation projects through tax discounts for investors and executors, includes VAT exemptions on imported research equipment and materials, and allows certain project-related income to be treated as non-taxable income.
iNNpulsa and CEmprende programs (2021-present)	Colombia, entrepreneurship	iNNpulsa coordinates entrepreneurship actions and financing sources; Law 2069 reorganizes support institutions and includes programs such as CEmprende Junior to promote entrepreneurial culture and technology training.
Registration tax and electronic signature (Law 2069)	2021, Colombia	Departmental assemblies set lower registration rates for microenterprises; the national government is empowered to regulate electronic and digital signatures and to incorporate virtual tax and accounting inspections.

Discussion

The results of this study confirm that the Latin American agribusiness sector, and specifically the Colombian one, is at a turning point, evidencing significant potential in the adoption of Fourth Industrial Revolution (4RI) technologies. The literature and the pilot cases analyzed demonstrate substantial improvements in productivity, production cost reductions of up to 30%, and increases in agricultural yields ranging between 10% and 27.3%, in addition to considerable water resource savings, such as the 40% observed in cases like the AgroDataCurití farm.[22,23,30] These findings align with international studies that underline the benefits of precision agriculture and digitalization for more efficient and sustainable management of the sector[4]. However, the adoption of these technologies is heterogeneous, often concentrating in pilot projects or large companies, leaving a significant niche for startups that can offer modular and accessible solutions to small and medium-sized producers.

The main contribution of this article lies in the methodological integration of a narrative review of the state of the art on 4RI in agribusiness with the design of a Business Model Canvas adapted to the Colombian context. Unlike other works that focus on technological analysis or isolated cases, our study proposes a viable business structure that combines the Internet of Things, Big Data, and Business Intelligence, considering the local regulatory and incentive environment. This approach is novel because it explicitly addresses the gap between theoretical knowledge and the practical application of innovative strategies in agribusiness companies in emerging economies, recognizing the need to adapt entrepreneurship methodologies such as Lean Startup, Value Proposition Canvas, and Business Model Canvas to the particularities of the Latin American rural sector, which presents unique challenges in terms of connectivity, costs, and training.[1,20]

The Business Model Canvas proposed in this study, with its nine blocks and three differentiated business lines, is specifically designed to overcome the identified barriers and capitalize on opportunities. By focusing on technified swine producers in Colombia, the model seeks to maximize profitability through uncertainty management by controlling agro-ecological variables. The omnichannel strategy for distribution and sales, along with direct and personalized customer relationships, seeks to address cultural resistance and training gaps, facilitating technological adoption. Furthermore, the diversification of income sources through subscription services and advisory mitigates dependence on a single revenue stream and reduces entry barriers for producers.

The Colombian regulatory framework, particularly Law 2069 of 2020, stands as a fundamental pillar for the startup's viability. The existence of regulatory sandboxes, tax benefits for R&D (such as income tax and VAT exemptions), and the support of entities like iNNpulsa Colombia, FINAGRO, and Banco Agrario, create a favorable environment for the creation and consolidation of innovative companies in the sector. These "favorable legal and state financing conditions" are crucial for the development of technology-based companies, although the sustainability of the model depends on the startup's ability to leverage these incentives and navigate the uncertainty regarding the permanence of such advantages and the protection of generated data.

While the opportunities are vast, the implementation of this model is not without risks. Limited rural connectivity, high initial investment costs, cultural resistance to new technologies, and the digital training gap, as well as regulatory uncertainty and dependence on public incentives, represent significant challenges. Nonetheless, the Canvas integrates mitigation strategies such as the development of hybrid connectivity solutions, subscription and leasing models to reduce entry barriers, training and field accompaniment programs, and strict compliance with data protection regulations such as Law 1581 of 2012. The financial projection of the model, with an average contribution margin of 80.6% and an operating profit of 42.3% in the first year, suggests attractive profitability for investors, exceeding the cost of capital and risk-free investments.

Conclusion

This study has demonstrated that the integration of Fourth Industrial Revolution (4RI) technologies, such as Big Data and Business Intelligence, possesses significant transformative potential for the Colombian and Latin American agribusiness. We have confirmed that the adoption of these innovations can generate tangible benefits, including production cost reductions of up to 30%, agricultural yield increases between 10% and 27.3%, and substantial savings in water resources, such as the 40% observed in pilot cases. These results underscore the need and opportunity to move toward more efficient and sustainable agricultural models.

However, the full materialization of this potential is hindered by persistent barriers, including limited rural connectivity, high initial investment costs, cultural resistance to technological adoption, and the digital training gap in the sector. Added to this is the regulatory complexity and uncertainty regarding data protection and intellectual property.

The financial projection of the proposed model, with an average contribution margin of 80.6% and an operating profit of 42.3% in the first year, confirms the attractive profitability for investors. Likewise, the alignment with the Sustainable Development Goals reinforces the sustainability component of the model, demonstrating its potential to generate a positive social and environmental impact.

Finally, this study emphasizes the need for future research that includes longitudinal case studies to validate the Canvas Model in real contexts and evaluate its long-term economic and environmental impact. It will be pertinent to analyze the appropriation of emerging technologies such as 6G and blockchain in the Colombian agribusiness, as well as to explore innovative financing mechanisms for startups in this evolving sector.

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Conflicts of interest

Declare no conflicts of interest.

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