

Exploring challenges and opportunities for bio-based business models to strengthen Ecuador's rural economy

Erika Luzon, Krisztián Ritter

Abstract

The imperative transition from a linear to a circular business model is a critical factor in achieving sustainable development. Bioeconomy offers sustainable, long-term economic growth by efficiently utilizing natural resources and integrating bio-based business model innovations alongside circularity principles. As part of a long-term research project searching for bio-based solutions for helping Ecuador's rural economy, this paper aims to investigate bio-based business models in Ecuador to enhance the understanding of bioeconomy and help rural development within the country. The study employed two methodological approaches: a systematic literature review (SLR) of bio-based business models and graphical visualization. The findings encompass 22 relevant publications from 2020 to 2025. The study identified (1) the nexus between the circular economy and bioeconomy; (2) the framework of bioeconomy in Ecuador for implementing bio-based business models; (3) challenges and opportunities associated with bio-based business models in Ecuador; (4) network visualization of the bio-based models in Ecuador; and (5) top authors in the research field analyzed. This investigation underscores the connection between bioeconomy and bio-based business models for their implementation in rural Ecuador. The results indicate that despite Ecuador's abundant biodiversity, the country faces several challenges, including a lack of collaboration among stakeholders, insufficient public and private funding, limited research and innovation (R&I), inadequate technological resources, and undefined public policies for the implementation of the bioeconomy. The barriers are especially in rural areas, where infrastructural and technological gaps hinder the implementation of bio-based business models. Fostering sustainable models in Ecuador can drive national growth while revitalizing rural economies through employment generation, income diversification, and community resilience. Given that this study was conducted through an online review of diverse scientific articles and reports concerning Ecuador, it is recommended that future research incorporate comprehensive case studies involving interviews and field visits. Such an approach would enable a more nuanced understanding of the specific added value and potential of diverse bio-based enterprises, especially in rural areas. Additionally, a cross-national comparative analysis would be advantageous to explore the coexistence of different bio-based business models and their impact on rural economies. Finally, a life cycle assessment of activities within the bioeconomy framework is crucial, particularly in relation to the agri-food sector in Ecuador, given its importance for rural livelihoods and national food security.

Keywords: bioeconomy, sustainability, rural development

JEL: O18, Q59, R10, R19

Introduction

In an era characterized by escalating environmental challenges, such as resource depletion, climate change, and waste accumulation, there is an urgent need to develop sustainable and resilient economic models even in rural areas. Traditional linear consumption patterns, often described as “take-make-dispose,” are increasingly constrained by the limits of resource availability (Ellen

MacArthur Foundation, 2013). In this sense, the need for new economic alternatives that prioritize resource efficiency and environmental responsibility is a key component to achieving the United Nation's Sustainable Development Goals (SDGs). The circular economy emerges as an alternative solution for addressing these challenges by promoting resource efficiency, waste minimization, and closed material loop closure (Nußholz, 2017). By focusing on these principles, the circular economy aims to reduce environmental impacts and foster long-term sustainability. Complementing these principles, bioeconomy emerges as a pathway that aims to fostering economic growth, innovation, and improve food security (IACGB, 2024). Moreover, bioeconomy has the potential to revitalize rural economies by creating new markets, increasing the value of biological resources, providing jobs, and strengthening resilience in frequently neglected regions. In rural areas where traditional economic activities rely heavily on agriculture and natural resources utilization, the creation of bio-based business models can be a key tool fostering long-term rural development (FAO, 2024).

Bio-based business models, which sit at the crossroads of the circular economy and bioeconomy, incorporate sustainability components and concepts into market-focused approaches. These models arise from the requirement to promote bio-based solutions' competitiveness and sustainability potential within the bioeconomy (Hatvani et al., 2022). However, despite its potential, the adoption of bio-based business models within the bioeconomy framework remains scarce, with companies struggling to implement sustainable and profitable business models (Reim et al., 2019).

Many governments worldwide have included bioeconomy in their national strategies, and the Latin America and the Caribbean (LAC) region is no exception. Nevertheless, despite Ecuador's status as one of the most biodiverse countries globally, the potential of the bioeconomy remains unexplored in terms of bio-based business model innovations, especially in rural contexts where economic diversification is urgently needed. Given Ecuador's rich biodiversity and the increasing significance of bio-based economic strategies in achieving sustainable development, further research is necessary to understand the potential of bio-based business models within the country.

To address this research gap, this study employs two complementary methodologies. First, a systematic literature review (SLR) and a bibliometric analysis using VOSviewer to explore the framework of the bio-based business models, along with the challenges and opportunities in Ecuador. SLR has been gaining attention in social sciences due to its reputation as one of the most precise methods for conducting literature reviews. It has also demonstrated its value in more theoretical studies and has become an essential component in the development of academic work across various disciplines (Mangas-Vega et al., 2018). Several SLR studies on topics such as forestry (Reim W., et al., 2017), bioenergy (Radics et al., 2015), biofuels (Wahied & Sachdeep, 2021), biomass (Milagros et al., 2024), bioeconomy strategies (Papadopoulou et al., 2022) have been conducted.

However, SLR studies focusing specifically on bio-based business models in Ecuador are still lacking, particularly with regard to their role in enhancing rural economies, highlighting the need for further exploration. Additionally, bibliometric analysis using VOSviewer enables the efficient management of datasets, enabling systematic reviews and improving comprehension of knowledge domains (Lu et al., 2020). To ensure a comprehensive dataset, documents were obtained from Scopus, Science Direct, Web of Science, and Google Scholar, supplemented by reports discovered using snowball sampling. Therefore, the objectives of the study were to identify the challenges and opportunities for bio-based business models in Ecuador and analyze the scientific landscape within bio-based business models, the trend topics, and the collaboration of authors within the bioeconomy framework, with special attention to the implications for rural economic development.

Materials and methods

A systematic literature review (SLR) was employed to examine the challenges and opportunities associated with bio-based business models in Ecuador. Figure 1 represents the workflow applied to this study.

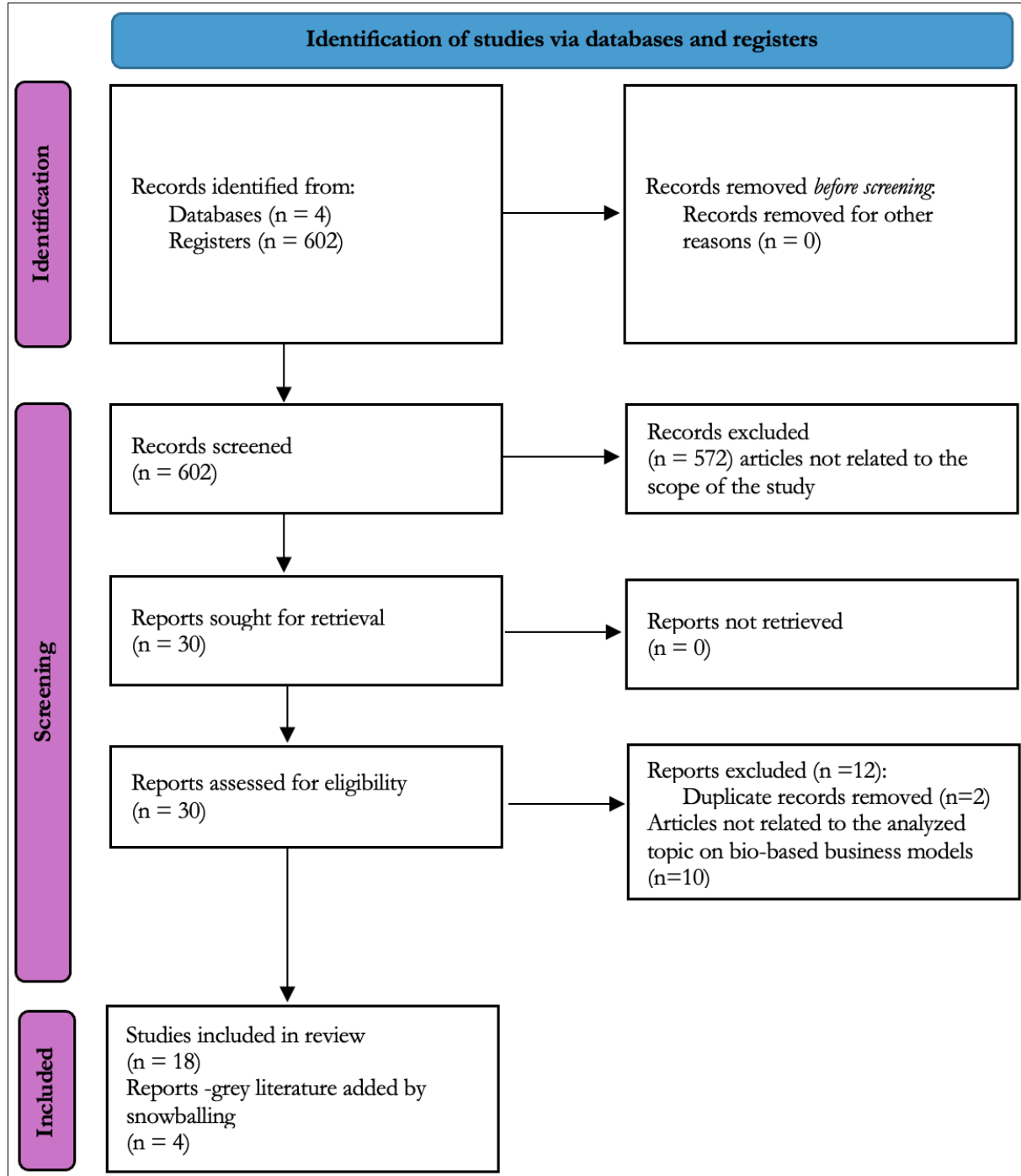


Figure 1 Workflow of the research based on PRISMA 2020 to analyze the systematic literature review

Source: own editing adapted from Page et al. (2021), 2025

According to Klatt (2023), SLR is an independent methodology designed to comprehensively identify and critically evaluate all relevant research pertaining to a specific research question. This

rigorous approach involves a transparent and replicable process, executed independently by at least two researchers, with the goal of formulating well-founded conclusions based on the analyzed literature. The SLR has garnered significant attention in the social sciences due to its reputation as one of the most rigorous methodologies for conducting literature reviews. It has also demonstrated its efficacy in more theoretical studies and has become an essential component in the development of academic work across various disciplines (Mangas-Vega et al., 2018).

Furthermore, bibliometric analysis in VOSviewer version 1.6.20 was employed for graphical visualization of the key research themes and patterns. VOSviewer allows effective management of a large dataset, enabling systematic reviews and enhancing understanding of knowledge domains (Chen & Song, 2019). It also offers significant advantages, including its reliability and wide acceptance, its utilization in comparable studies, and its open-source nature with free accessibility (Papadopoulou et al., 2022).

Data collection and sources

The SLR was conducted utilizing four distinct databases, Web of Science, Science Direct, Scopus, and Google Scholar. The databases were consulted with year-based filtering; specifically, research and review articles were selected from the period 2020 to 2025, with a total of 602 documents. The timeframe was chosen for three main reasons. First, bio-based business models represent an emerging novel topic with scholarly and policy interest, notably increasing after 2020 in response to the global sustainability goals and post-COVID-19 recovery strategies (Galanakis et al., 2022; Gould et al., 2023; Mougenot & Doussoulin, 2022). Secondly, the key policy frameworks, most notably the European Green Deal and complementary national bioeconomy strategies, were adopted during this period, making it especially relevant for capturing current developments (European Commission, 2020). Third, concentrating on 2020-2025 ensures a manageable and comprehensive corpus for advanced text-mining and bibliometric analysis. The choice is further supported by our previous bibliometric study, which examined 7.863 documents from 1990 to 2024 and document significant surge of publications with an inflection point post 2020 (Ordoñez et al., 2025). Extending the period further back may lack direct relevant literature from the pre-policy-shift era, which obscures recent development and policy-driven trends.

Text-mining techniques were employed to identify the most appropriate keywords. As stated by Feng et al. (2017), this methodology is advantageous in literature reviews as it facilitates the efficient extraction of large volumes of text, substantially reducing the time and effort required for manual reviews while providing a comprehensive overview of the existing body of knowledge. The research queries applied to the databases included the following keywords:

- Web of Science: TS = (((“bio based*”) OR (“bioeconomy business”) OR (bio based economy)) AND ((“circular econom*”) OR (“bioeconom*”) OR (“circular*”) OR (“sustainable econom*”))AND ((“america*”) OR (“south america*”)))
- Science Direct and Scopus: modified search strings without wildcard symbols (*) due to the databases restrictions.
- Google Scholar: the keywords used for the search remained the same, with the addition of the term “Ecuador” to ensure country-specific results. The final query included as follows (biobased OR biosource AND bioeconomy AND business bio OR industrial business OR circular economy OR sustainable economy AND Ecuador OR South America).

Taking into consideration the geographical scope of the review, this study also used research articles written in the Spanish language. Table 1. illustrates the article selection process for the systematic literature review.

Table 1 Article Selection Process for the Systematic Literature Review

Database	Articles Screened	Full-text articles assessed for eligibility	Articles Included
Scopus	201	9	4
Science Direct	215	7	4
Web of Science	18	4	1
Google Scholar	168	10	9
Other (Reports)	0	0	4
Total	602	30	22

Source: own editing, 2025

Data Analysis

A detailed systematic literature review was carried out following the PRISMA 2020 by Page et al. (2021). The titles of the articles, abstracts, and keywords were analyzed to identify those directly related to “bio-based business models, bioeconomy, or circular economy principles”. Subsequently, given that the scope of the study is Ecuador, research articles discussing the country or South America were also selected for further review. Upon assessing the eligibility of 30 research articles, of which 12 were excluded: 2 due to duplication across the databases, 1 was not directly related to bio-based business models, 5 solely discussed bioeconomy concepts, and 5 focused on theoretical discussions without practical applications of bio-based business models. This first screening totaled 18 research articles for review. Furthermore, 4 additional reports directly related to business models and a bioeconomy concept paper from Ecuador were incorporated through snowball sampling to obtain more relevant information, particularly on the scope of the study. The final selection of 22 documents, including grey literature, was stored in Mendeley for reference management.

Bibliometric analysis was performed on 22 documents using the software tool, VOSviewer version 1.6.20. VOSviewer employs distance-based visualizations, illustrating the relatedness of nodes by the spatial separation between them, hence facilitating the display of larger networks (van Eck & Waltman, 2014). For this study, multiple network, overlay, and density maps were generated in order to identify key clusters linked to bio-based business models by analyzing co-occurrence and co-authorship analysis using the author’s keywords as shown in Table 2.

Table 2 Types and units of analysis in the VOSviewer software

Types of analysis	Unit of analysis
Co-occurrence analysis	Authors keywords: to identify emerging trends and research gaps.
Co-authorship	Authors: to identify key researchers studying bio-based business models within the bioeconomy framework.

Source: own editing, 2025

Results

The current study offers the findings of a comprehensive literature review and bibliometric analysis designed to investigate the challenges and opportunities for bio-based business models in Ecuador. This section is arranged as follows: first, the key concepts of bio-based business and its nexus to the bioeconomy and circular economy are examined. The findings are then contextualized by providing an outline of Ecuador's bioeconomy framework. The bibliometric analysis, conducted using VOSviewer software, is then shown to demonstrate co-occurrence and co-authorship analysis trends in bio-based business model research. Finally, the challenges and opportunities for bio-based business models in Ecuador, utilizing literature pertinent to the LAC context and specifically to Ecuador, in alignment with the study scope.

The nexus between circular economy, bioeconomy, and bio-based business models

To understand the nexus between circular economy, bioeconomy, and bio-based business models, this study elucidates its interconnections by presenting key insights derived from the SLR. According to the European Parliament (2023: p. 1.), the circular economy is a “*model of production and consumption that involves sharing, leasing, reusing, repairing, refurbishing, and recycling existing material and products as long as possible*”. Nußholz (2017) argues that the nexus between circular economy and circular business models is rooted in redesigning the linear traditional economic system. This transformation seeks to improve resource efficiency by extending the useful life of products and parts and closing material loops. Consequently, transitioning from conventional linear business models to circular and bio-based alternatives is increasingly recognized as a key factor in achieving sustainability.

Considering the previous statement, bioeconomy offers a pathway to sustainable and long-term economic growth. The notion of bioeconomy has attracted considerable attention over the years, usually stressing economic production and a broad, cross-sectoral focus (McCormick & Kautto, 2013). As defined by the Global Bioeconomy Summit (2024: p. 1), “*bioeconomy is the production, utilization, conservation, and regeneration of biological resources, including related knowledge, science, technology, and innovation, to provide sustainable solutions (information, products, processes, and services) within and across all economic sectors and enable a transformation to a sustainable economy*”. Barañano et al. (2021) propose a holistic approach combining ethical considerations with circular economy principles to enhance human well-being and environmental sustainability. Given its cross-sectoral nature, the bioeconomy has important implications for practical domains in which farmers play a key role (Schmid et al., 2012). In this context, the bioeconomy requires not only the sustainable utilization of natural resources but also “a sustainable supply chain that includes biomass feedstock production, logistics, sustainable biomass conversion processes, and sustainable products” (Tan & Lamers, 2021). As a result, bioeconomy aligns with the circular economy's principles by encouraging the responsible use of natural resources and incorporating biological cycles into economics (D'Amato et al., 2020). Both concepts intersect in promoting sustainable practices such as casting biomass consumption and generating goods that contribute to a circular, resource-efficient system (Lange, 2022). Nevertheless, as Reim et al. (2019) point out, the bioeconomy implementation remains slow, with enterprises unable to build successful business models.

For these reasons, the bio-based business models emerge from the necessity to emphasize bio-based solutions' competitiveness and sustainability potential within the bioeconomy (Hatvani et al., 2022). The transition from linear to circular economies using bio-based business models is crucial, especially in the agri-food sector, since this model focuses on valorizing agricultural waste and by-

products driven by macro-environmental conditions, market trends, and the pursuit of economic, environmental, and social objectives (Donner & de Vries, 2021). In this context, particularly within the agri-food sector, greater emphasis should be placed on upcycling to promote added-value products in comparison to traditional recycling methods (Klein et al., 2022). To support this transition, Salvador et al. (2023) suggest different types of circular business models that integrate bio-based strategies, fostering innovation and regional development as key drivers for the transition to a circular bioeconomy.

In this sense, Bröring & Manaker (2022) claim that identifying bioeconomy business model types helps to set a clear research agenda for business models, address a wide range of innovations, and raise awareness of the numerous challenges that might arise in the bioeconomy. Conversely, Donner & de Vries (2023) claim that collaboration among diverse stakeholders is essential for the development of circular business models within the bioeconomy. This collaboration may facilitate resilient territorial development, thereby addressing the anticipated future bioresource gap. Expanding on this perspective, Salvador et al. (2020) identify key drivers for circular bioeconomy and its business model development. Their findings highlight the importance of staying informed about market trends and innovations, considering customer perspectives, recognizing the value of biomass, and building resilient value chains, among others, as crucial factors in advancing circular bioeconomy initiatives.

Context of Latin America and Ecuador: bioeconomy and bio-based business models

Latin America and the Caribbean (LAC) region possesses significant potential for the advancement of the bioeconomy due to its abundant biodiversity and natural resources, particularly in regions such as the Amazon rainforest (da Silva et al., 2023). This potential positions bioeconomy as a viable strategy for productive diversification and value-added opportunities, especially in rural areas where the agricultural and agro-industrial sectors play a key role (Rodríguez et al., 2017). Over the years, interest in the bioeconomy in LAC has been expanding with a considerable increase in scientific production, with a predominant focus on biofuels as the main source of bioenergy (Ordoñez & Lakner, 2023). However, for the bioeconomy to reach its full potential, advancements in biomass production, processing technologies, product development, business models, and governance structures are essential to ensuring value chain evolution and sustainable performance (Vargas-Carpintero et al., 2023). Moreover, Salvador et al. (2022) highlight the role of public policies and government regulations in fostering regional circular bioeconomy systems, emphasizing the importance of promoting environmentally responsible practices, such as requiring reverse logistics, to enhance sustainability and resource efficiency in bio-based business models.

Ecuador has endeavored to incorporate circular economy (CE) strategies to achieve sustainable development. However, studies such as Sucozhañay et al. (2022) indicate that although environmental, economic, and social dimensions are considered within CE practices, the social dimension is often limited to job creation. Furthermore, the predominant focus of CE components and metrics is the production and end-of-life stages, with less attention given to the phases of extraction, design, use, marketing, and distribution. Conversely, bioeconomy provides a comprehensive approach by advocating for upcycling resource efficiency, and sustainability throughout the entire value chain rather than just waste management. Bioeconomy implies an approach that addresses biodiversity conservation and economic growth, leading to a sustainable path for the future of communities and the planet (García-Samaniego, 2024). In this context, a circular bioeconomy model could provide the CE with a robust conceptual framework for the use

and exploitation of renewable natural resources, allowing for the sustainable management of agricultural and industrial production systems aiming to achieve sustainable well-being in harmony with nature (Chafla-Martínez & Lascano-Vaca, 2021).

It has been asserted that Ecuador has significant potential for hydrogen synthesis and energy generation from biomass, a view supported by the findings of Ponce et al. (2021). Nevertheless, it is imperative to acknowledge that research and innovation (R&I), collaboration among stakeholders, and both public and private investment are essential components for the development of the bioeconomy. Important contributions within the bioeconomy framework in Ecuador have been made; for example, studies such as Cuestas-Caza et al. (2024) which discuss the importance and how the indigenous concept of the Sumay Kawsay (Good Living) influences bio-based production practices in Ecuador. The research also contends that comprehensive knowledge systems represent harmony-oriented ideals such as economic objectives, political recognition, and community-led activities. In this regard, considering the involvement of indigenous groups, creating frameworks centered around communities, and offering significant support to Amazonian communities is crucial.

According to Lesenfants et al. (2024), the bioeconomy holds the potential to alleviate poverty and improve overall well-being. They recommend that Ecuador should capitalize on its abundant biodiversity, reduce poverty, and utilize specific natural resources for specialized scientific and medical purposes. Additionally, it is important to enhance the value of bioeconomy products and ensure that the resulting benefits are fairly distributed, especially among local communities that supply the raw materials. The Ecuadorian Amazon region has been recognized as a key area for economic growth due to its diversity, which can be utilized in the agri-food and pharmaceutical industries (García-Samaniego, 2024). Therefore, it is important to continue to develop studies that allow the state of conservation, reproductive biology, and sustainable industrialization as an alternative source of income for Indigenous rural communities. Given Ecuador's diverse potential, the bioeconomy and its economic benefits are crucial for reducing fossil fuel imports and inequities in rural areas. In this context, prioritizing biodiversity is critical for shaping a productive matrix (Ortega-Pacheco et al., 2018).

As demonstrated by the SLR, there is a clear interest in developing sustainable strategies in Ecuador. Researchers, policymakers, and various stakeholders emphasize the significance of bioeconomy as a pathway to achieving the Sustainable Development Goals (SDGs). A notable contribution to this endeavor is the formulation of the Bioeconomy White Paper. This document is the product of collaboration between the French Development Agency (AFD) and the national government of Ecuador. It serves as a strategic tool for political decision-making and the advancement of bioeconomic production chains across different regions. Furthermore, this document facilitates the positioning of Ecuador and its products at both regional and international levels, highlighting a strong commitment to sustainability in all its dimensions and the preservation of biodiversity. This study underscores the significance of examining the integration of the Bioeconomy White Paper into the Ecuadorian framework. It is essential to identify the challenges encountered in this process as well as to delineate the primary stakeholders involved in the bioeconomy.

García-Samaniego (2024) reports that initiatives to create a development framework for bioeconomy were initiated in 2019. Consequently, Bioemprende, a center dedicated to fostering and advancing enterprises based on the sustainable use of natural resources, was established as a strategy for sustainable development within the country (Ministry of the Environment, 2019). In October 2020, a national pact for sustainable bioeconomy in Ecuador was endorsed by entities from the public, private, academic, and cooperative sectors.

“For Ecuador, the bioeconomy represents an alternative development strategy based on directing economic activities toward the generation of knowledge and the sustainable use and exploitation of natural biodiversity resources, agrobiodiversity, and their derivatives. This is achieved through a set of policies, production processes, and practices grounded in the creation and transfer of knowledge, innovation, and new technologies that provide products and services, thereby contributing to the transition toward a sustainable, socially inclusive, competitive, and resilient economic system” (García-Samaniego, 2024, p. 21).

The National Constitution of Ecuador, enacted in 2008, affirms the principles of conservation and sustainable resource use through specific protection mechanisms associated with environmental rights, principles, guarantees, and institutions (SENPLADES, 2009). Despite the constitutional recognition of the rights of nature, the prevailing economic model remains linear and extractivist, heavily reliant on oil extraction. In addressing the challenges of developing a coherent vision and strategies within the bioeconomy framework, the literature emphasizes the critical importance of implementing public policies, R&I and both public and private investment. Given its scope, the bioeconomy implicitly calls for inter-institutional, public policy, and multi-sector coordination. To date, there remains a separation between entities that regulate the same resources, in the same territory, and with different approaches and inputs (García-Samaniego, 2024).

To evaluate the role of the stakeholders in developing bioeconomy solutions, technological advancements, and the existing R&I capacity for bio-based technologies, a methodology based on interviews was used by the Ecuadorian National Government. As a result of this method, a total of 292 people were found related to bioeconomy, 16% represent nongovernmental organizations (NGOs), 39% represent the public government agencies, and the private sector, including universities. In addition to engaging stakeholders, financial investment plays a key role in fostering bioeconomy activities. In this context, it is essential to highlight the investment made by the Inter-American Development Bank (2024) under the BASE Program – Bio-business Financing for a Sustainable Amazon in Ecuador, launched in August 2024. This program aims to encourage nature-based productivity to support economic and inclusive growth without harming the environment in the Ecuadorian Amazon. Its specific goal is to enhance access to credit and investment in bio-business through the second-tier financial mechanisms of the National Corporation for Popular and Solidary Finance (CONAFIPS).

Bio-based business models and Rural Development

The SLR results show the significance of relevance on business models with bio-based activities, particularly in rural areas. Therefore, business models are crucial for rural development as they provide frameworks for creating value-added that address local needs and challenges (Galardi et al., 2022). Moreover, innovation and sustainable business models can strengthen rural development by promoting inclusive economic strategies grounded in the sustainable use of biological resources and fostering collaboration among stakeholders (Bracco et al., 2018). By leveraging bio-based business models can help to create adaptable solutions supporting economic, environmental, and social sustainability in rural areas where co-creating and participatory approaches need to be developed. In this sense, through place-based value generation, circular use of biomass and the rehabilitation of regional traditions, bio-based business models foster territorial cohesion and inclusive rural development (Colmorgen & Khawaja, 2019). These findings align with the perspective of local economic development (LED) that aims to develop local economic capacity, increase business competitiveness, and boost productivity. This concept is closely related to bio-

based business models due to it is connected to sustainable business for rural development since it seeks to establish a sustainable economy, raise living standards, and create jobs using local resources (Ritter & Nagy, 2017).

At the policy level, both the European Commission (EC) and the Food and Agriculture Organization (FAO) recognize the potential of a bio-based economy in rural regions. The EC (2018) contains the new bioeconomy strategy that underscores the need for strengthening the connection between economy, society, and environment through regionally targeted activities that value local biomass, encouraging innovative ecosystems that decrease territorial imbalances among Member States. It emphasizes that rural regions have different advantages in transitioning to circular bio-based systems due to its abundant resources and established agri-food infrastructure, while enhancing economic growth. In a similar way, FAO (2024) emphasizes that bioeconomy is a “global opportunity” to improve the sustainability of food systems, equality, and resilience. In this sense, it encourages policymakers to develop policies and establish clear bioeconomy strategies that promote local involvement, creating agroecological value chains, and improve rural livelihoods. These regional and global frameworks promote the notion that bio-based business models should strive not just for economic competitiveness, but also for complex objectives such as rural resilience, spatial inclusiveness, and territorial sustainability that align with the sustainable development goals.

Challenges and Opportunities for bio-based business models in Ecuador

Ecuador, with its abundant biodiversity and natural resources, is uniquely positioned to capitalize on high-value-added bioeconomy opportunities, particularly in its rural regions. According to García-Samaniego (2024), the country has shown a strong commitment to environmental conservation and sustainable growth. The creation of the Bioeconomy White Paper exemplifies the initial steps toward integrating innovative strategies for the responsible consumption of its biological resources, with relevance to rural development agendas. In rural areas, the sustainable production of premium agricultural products and the utilization of biodiversity for pharmaceutical and cosmetic research provide tangible opportunities to enhance local economies, generate employment, and foster inclusive growth.

Nevertheless, one of the principal challenges lies in the model of waste utilization in harvesting and agro-industrial processes, which is a key factor for promoting sustainable rural development. Despite its importance, the linear economy model persists in many rural productive systems, limiting the potential for a full transition to circular bio-based models (Cuestas-Caza et al., 2024). The literature reveals a notable gap regarding the specific implementation of a bio-based business model in Ecuador, particularly in rural contexts. Consequently, the SLR, along with the additional reports added, indicates that bio-based business models are gaining significant recognition in the European Union, while systematic efforts in Ecuador remain incipient. Given this gap, the findings from the European Horizon Project 2020 BERural project, emphasized by Colmorgen & Khawaja (2019), provide valuable and transferable insights for this study. The project emphasizes the Business Model Canvas (BMC) as a useful tool for analyzing bio-based businesses, a perspective also examined by Hatvani et al. (2022). In this context, it is noted that BMC serves as an effective framework for evaluating business models, with Hatvani et al. (2022) advocating for the integration of sustainability elements to assess long-term viability, especially in rural areas where resilience is crucial for socio-economic stability.

While these findings are predominantly observed in the European region, the report offers valuable insights that can be transferable in the implementation, adoption, and assessment of the

bio-based business models in Ecuador. To elucidate the insights derived from the SLR concerning the challenges and opportunities for bio-based business models in Ecuador, the authors of this study utilized review articles, research articles, and reports that explicitly address the challenges and opportunities of the bioeconomy in LAC and Ecuador, given the research scope. As previously described, key challenges include limited private and public investment, technological barriers, infrastructural deficiencies in rural areas, and inadequate policies, among others. In contrast, opportunities involve the sustainable use of natural resources, agricultural waste valorization, and the promotion of community-based bio-business initiatives aimed at achieving sustainability and resilience in rural communities. Table 3 summarizes these drivers and opportunities for bio-based business models in Ecuador, along with the authors who have discussed them in their studies and reports.

These findings underscore the significance of stakeholder collaboration for the effective development of the bioeconomy in Ecuador, with special focus on rural regions. In this sense, robust collaboration among policymakers, research institutions, and businesses is essential to drive innovation and address current challenges. Furthermore, the implementation of bio-based business models with value added is a pathway for sustainability, aligning with the SDGs while simultaneously achieving economic growth. The summary of the SLR is presented in the Appendix, detailing the principal authors referenced in this study, the type of documents analyzed, their main characteristics, and the specific bio-based business models discussed in each document.

Table 3 Challenges and Opportunities of bio-based business models in Ecuador

Challenges	Opportunities	Reference
<ul style="list-style-type: none"> • Low technological capacity. • Lack of collaboration among stakeholders. • Insufficient investment in bio-based industries • Limited policy impact assessments. • Lack of empirical case studies (R&I). • Difficulties related to logistics. • Lack of awareness and education about circular bioeconomy. <ul style="list-style-type: none"> • Inadequate policies/regulations. 	<ul style="list-style-type: none"> • Agricultural waste valorization. • Rich biodiversity and natural heritage hold a potential to develop high value-added products. • Sustainable management of biomass could reduce pollution and environmental impacts. • Diversification of rural economies proving green jobs and awareness of biodiversity. • Potential to produce and utilize energy from biomass residues. • Agro-industrial potential. 	<ul style="list-style-type: none"> • Torres et al. (2022) • Ponce et al. (2021) • Garcia-Samaniego, J. (2024) • Vargas-Carpintero et al. (2023) • Lesenfants et al. (2024) • Salvador et al. (2022)

Source: own editing, 2025

Network analysis and mappings of the database

The present study used bibliometric analysis using the software VOSviewer version 1.6.20 to analyze the research field based on 22 documents obtained by the SLR retrieved from the databases Scopus, Science Direct, Web of Science, and Google Scholar, and supplemented by reports identified through snowball sampling. The analysis concentrated on two main networks: co-

occurrence, which was used to identify thematic areas and research trends, and co-authorship, which was employed to assess patterns of collaboration. The following section shows the graphical visualization of these two networks, illustrating the nexus between authors and research themes. These visual representations provide clear insights into collaboration structures and the research themes in the field.

Co-occurrence analysis – author keywords

Author keywords are the terms selected and listed by the authors in the keywords section to encapsulate the essence of scientific research (Lu et al., 2020). Author keyword co-occurrence analysis involves identifying the presence of various terms that appear together across different sets of research articles (Sinha & Dhillon, 2024). Analyzing the co-occurrence of keywords through visualization tools offers guidance for future and cross-disciplinary studies (Radhakrishnan et al., 2017). In VOSviewer, 64 out of 74 keywords met the threshold of a minimum of one occurrence of keyword occurrence in a research article. The network mapping resulted in 11 clusters, 233 connection links, and 269 total link strengths. The clusters were reduced from 11 to 5 by changing the clustering resolution from 1 to 0.20 in the analysis section of the VOSviewer software. The decision to reduce the cluster was a methodological choice made by the authors aimed at improving the interpretability and coherence of the co-occurrence analysis. By reducing the number of clusters, we aim to show better conceptual clarity and strong thematic grouping; merging smaller clusters that shared similar themes helps identify broader research trends, minimizing overlapping topics.

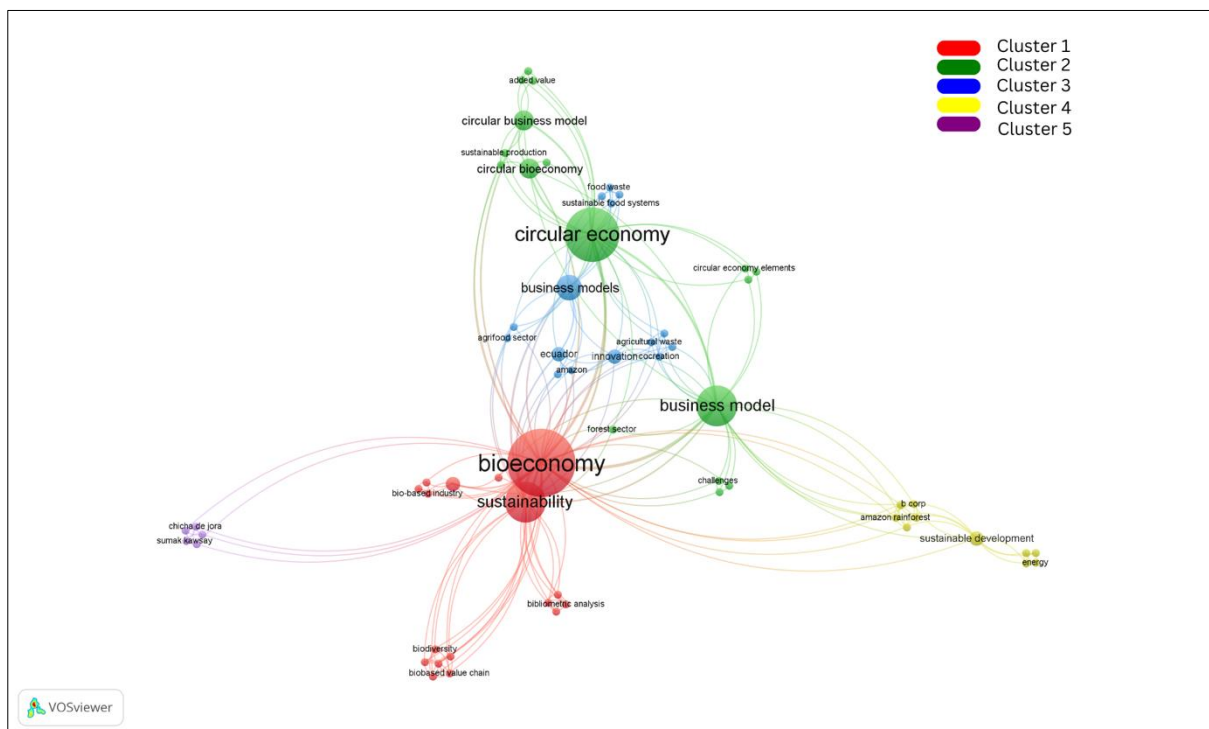


Figure 2. Network map of co-occurrence - authors keywords

Source: own editing, 2025

The network map of co-occurrence author keywords with 5 clusters is shown in Figure 2. Evidently, the word “bioeconomy” was the biggest node. Node size represents the number of

publications in which the keyword appeared. The larger the size of the node, the higher the frequency of those keywords in several publications. The distance and linkages between keywords determine the co-occurrence of different keywords in the same article. Smaller distances between two keywords indicate that the keywords appeared together frequently. If the distance between two keywords is large, the frequency of the keyword occurrence is lower.

The top 10 keywords based on the number of occurrences were bioeconomy (13), circular economy (10), business model (8), sustainability (7), circular business model (3), innovation (2), circular bioeconomy (3), sustainable development (2), Ecuador (2), business model canvas (2). The 5 different clusters in a network represent five different bio-based business model research areas. The cluster of keywords with the same color represents the co-occurrence of those keywords in a publication. The five different clusters focused on scientific themes are listed below.

Red cluster (17 items) represents studies that include keywords such as bibliometric analysis, bio-based industry, bio-based value chain, biodiversity, bioeconomy, biofuels, business model canvas, business modelling, business opportunities, business readiness level, governance, LAC region, *Lippia origanoides*, multi-disciplinary research, natural capital, R software, and sustainability. This cluster is of significant relevance to this study, as it concentrates on the keyword "bioeconomy". Additionally, the cluster addresses sustainability and biodiversity, which are essential components of the bioeconomy. Moreover, it incorporates the keyword "LAC," indicative of the growing interest in this field. The importance of the cluster is further substantiated by the findings of Hatvani et al. (2022), which underscore the interconnection between the bioeconomy and bio-based business models, highlighting exemplary practices in Europe. The co-occurrence of keywords within this cluster reflects these critical elements, reinforcing the centrality of the bioeconomy in the study of bio-based business models.

Green cluster (17 items) represents studies that include keywords such as added value, bioresource, business model, challenges, circular bioeconomy, circular business model, circular economy, circular economy elements, circular economy framework, Ecuadorian companies, forest sector, Latin America, literature review, sustainable consumption, sustainable production, typology, and valorization. This cluster underscores the significance of this study by highlighting the key components related to bio-based business models. The keyword "circular economy" indicates the theoretical basis in sustainability-driven economic transitions. This is consistent with the broader aim of the bioeconomy strategies, which seek to reduce waste and enhance value derived from biological resources. Furthermore, the inclusion of the keywords "Ecuadorian companies" and "Latin America" suggests the increasing attention to this novel topic. This aligns with the study's focus on exploring the challenges and opportunities for bio-based business models with a specific geographical context. The importance of this cluster is further supported by the findings of Donner & de Vries (2023); Klein et al. (2022); Salvador et al. (2023), who emphasize that the key elements for bio-based business models depend on circular economy principles, resource efficiency, and sustainable production and consumption.

Blue cluster (15 items) represents studies that include keywords such as agricultural waste, agrifood sector, Amazon, business models, by-products, cocreation, Ecuador, food waste, France, innovation, potato industry, qualitative research, sustainability, and sustainable food systems. This cluster supports the significance of this study by focusing on the agrifood sector. The presence of keywords such as "agricultural waste" and "by-products" highlights the role of waste valorization and circular strategies, which are key elements for the implementation of bio-based business models, reinforcing the idea of transforming waste streams into value-added products, which is a crucial component of the bioeconomy. Moreover, the inclusion of the keywords "Ecuador" and "Amazon" is particularly relevant for this study as it aligns with the increasing demand on research

of bio-based business solutions in LAC. The significance of this cluster and its importance for the previously mentioned region are corroborated by the findings of Cuestas-Caza et al. (2024); Lesenfants et al. (2024). These studies highlight the rich biodiversity of the Amazon region and the substantial potential for bio-based business models, which are expected to benefit indigenous communities by promoting sustainable economic growth and resilience.

Yellow cluster (10 items) Amazon rainforest, B Corp (Benefit Corporation), case study, energy, potential, production process, SDG, sustainable business model, sustainable development, waste. This cluster shows a strong focus on “sustainable business models” and “sustainable development”, suggesting the increasing relevance of integrating economic, social, and environmental components into business strategies. Particularly, the keyword “b corp” is also highlighted, which indicates a focus on businesses that assess sustainability performance beyond profitability. The significance of this cluster is supported by the findings of da Silva et al. (2023), who emphasize the importance of incorporating sustainability elements in business models.

Purple cluster (5 items) chicha de jora, guayusa, plurinational state, Sumac Kawsay, and transculturality. This cluster highlights themes related to agricultural products and the concept of “Sumak Kawsay” (Good Living), which holds significant cultural and economic relevance for Ecuador. These results suggest a growing interest in bio-based business solutions that integrate traditional knowledge, sustainability, and local economic development. Moreover, the keyword “plurinational state” is particularly relevant for this study since the results of the SLR emphasize the importance of recognizing indigenous communities in the bioeconomy framework. Developing sustainable economic activities that preserve biodiversity while fostering inclusive economic growth is a fundamental component of the bioeconomy. Finally, for Ecuador, aligning such initiatives with the SDGs is a key priority, reinforcing the need for policies that support indigenous participation and sustainable business practices.

Co-authorship – Authors

Co-authorship networks provide an abundant and carefully recorded account of the social and professional connections among scientists (Newman, 2004). Over time, researchers and scientists have increasingly shifted from working in isolation to engaging in collaborative efforts to enhance fundamental understanding of complex topics (Ullah et al., 2022). Analyzing co-authorship not only reveals the key contributors in a particular research field but also highlights collaborative structures, influential groups within the research community, and potential areas for future partnerships. This study analyzed the co-authorship connections among researchers. The network mapping resulted in 3 clusters, 40 connection links, and 46 total link strengths, illustrating the intensity of these collaborations. With that being said, the results show that while there are multiple authors contributing to the bio-based business models research field, some researchers have stronger or more frequent collaborations than others. The identification of these co-authorship patterns is relevant for understanding the most influential contributors to the research scope.

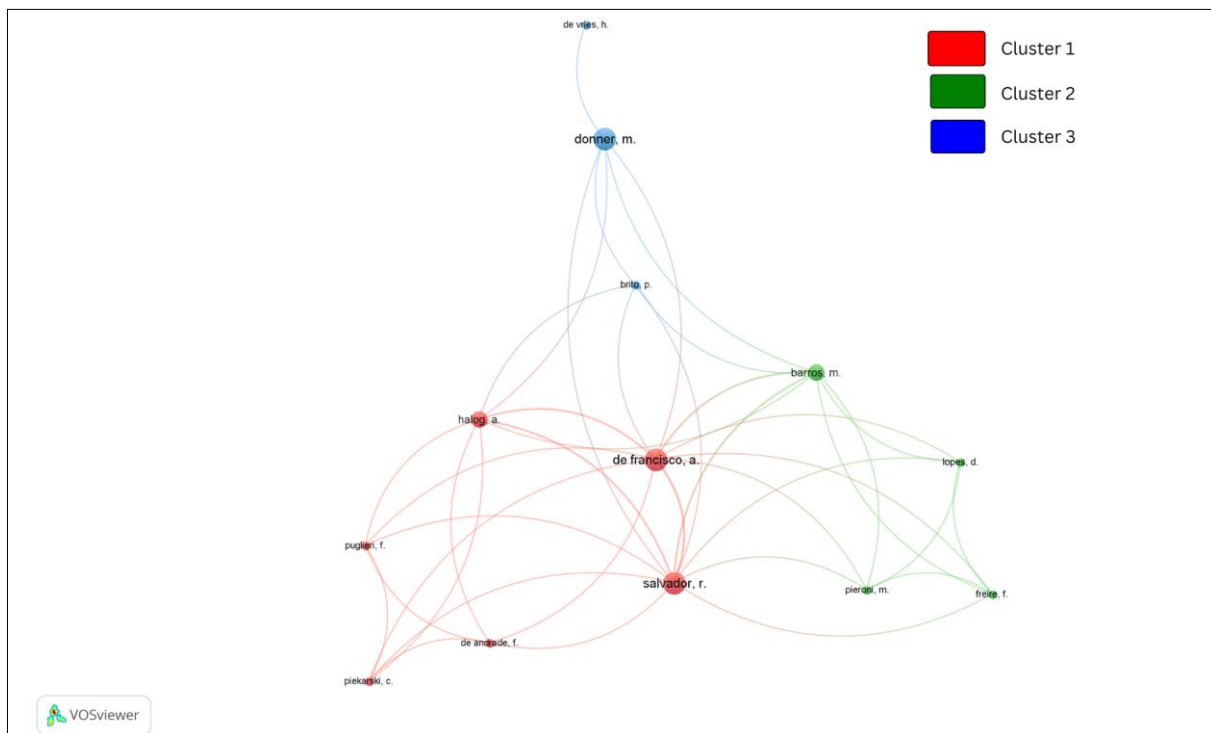
Table 4 presents the top five authors with the most robust co-authorship connections, detailing the number of documents published, the total strength of these connections, and the authors' country affiliations. The findings indicate that authors affiliated with Brazil, such as De Francisco and Barros, are among the most influential researchers collaborating in the field of bioeconomy and bio-based business models in LAC. Conversely, Salvador and Donner are identified as influential researchers affiliated with European countries, reflecting the growing interest in this emerging topic. Additionally, Halog affiliated with Australia, exemplifies the influence of researchers from the Southern Hemisphere.

Table 4. Top five authors with the strongest co-authorship link.

Author	Documents	Total Strength	Country Affiliation
De Francisco, A.	3	15	Brazil
Salvador, R.	3	15	Denmark
Barros, M.	2	10	Brazil
Hallog, A.	2	10	Australia
Donner, M.	3	6	France

Source: own editing, 2025

Figure 3 illustrates the graphical visualization of the co-authorship analysis of authors.

**Figure 3. Co-authorship analysis of authors**

Source: own editing, 2025

Conclusions

The findings indicate a growing interest in the emerging research area of bio-based business models within the bioeconomy framework. Specifically, the integration of systematic literature review and bibliometric analysis of scientific documents and reports from 2020 to 2025 has yielded significant insights into the challenges and opportunities associated with the transition to bio-based business models in Ecuador. The country's rich biodiversity, particularly within its rural areas, is identified as a key pathway for developing sustainable, high-value-added business models that can simultaneously foster environmental conservation, rural economic development, and social inclusion. However, the analysis also highlights critical barriers, including a lack of stakeholder engagement, clear public policies related to the bioeconomy, and insufficient public and private investment in R&I. These barriers are particularly more evident in rural areas, where infrastructural and technological gaps can further hinder the implementation of bio-based business models. It is, therefore, imperative to recognize that fostering sustainable business models in Ecuador not only

contributes to national economic growth but also plays a key role in revitalizing rural economies by generating employment, diversifying income sources, and strengthening community resilience. The mapping network results reveal that the five most pertinent topics are bioeconomy, circular economy, business model, sustainability, and circular business model, as evidenced by the strong connections in the co-occurrence analysis. Furthermore, the co-authorship analysis identifies the top five authors contributing to the global nature of bioeconomy research and its rising demand across various regions, including its potential for rural development. Given that this study was conducted through an online review of diverse scientific articles and reports concerning Ecuador, it is recommended that future research incorporate comprehensive case studies involving interviews and field visits, particularly in rural areas. Such an approach would enable a more nuanced understanding of the specific added value and potential of diverse bio-based enterprises in diverse territorial contexts. Additionally, a cross-national comparative analysis would be advantageous to explore the coexistence of different bio-based business models and their impact on rural economies. Finally, a life cycle assessment of activities within the bioeconomy framework is crucial, particularly in relation to the agri-food sector in Ecuador, given its significant role in rural livelihoods and national food security.

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Authors (s)

Erika Luzon

ORCID <https://orcid.org/0009-0006-6655-2547>

PhD Student

Hungarian University of Agriculture and Life Sciences, Doctoral School of Economics and Regional Sciences

E-mail: luzon.erika@phd.uni-mate.hu

Krisztián Ritter

ORCID <https://orcid.org/0000-0003-1206-3159>

Associate professor, PhD

Hungarian University of Agriculture and Life Sciences, Institute of Rural Development and Sustainable Economy,

E-mail: Ritter.Krisztian@uni-mate.hu

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Appendix

Appendix 1 Summary of the SLR for bio-based business models

No.	Author(s)/Year	Type of document (RA),(RHA)& (R)	Key characteristics of the document	Bio-based business models studied
1	Hatvani et al. (2022).	RHA	The traditional model Business Models Canvas should include sustainability-related components.	Waste valorization Agri-food waste recycling Bio-based building materials Biorefinery Biomass Biofuels Bio-plastics
2	Donner & de Vries (2021)	RHA	External factors that drive bio-based business model innovations include stakeholder demands, competitive changes, trends in consumer awareness, and corporate social responsibility.	Waste valorization models Cooperative models Integrated supply chain
3	Lange L. (2022)	RHA	Life cycle assessment (LCA) is a critical tool for evaluating business models that enhance higher-value products while boosting commercial viability and sustainability.	Upgrade of in-house production side streams Biomass-specialized biorefinery Cooperatively owned value chain organized biorefinery Industry clusters as the preferred biobased business model Consortium-owned production of biobased products
4	Donner & de Vries (2023)	RHA	Collaboration among many stakeholders is required to strengthen circular bioeconomy business models, improve resilient territorial development, and close future bioresource gaps.	Waste and by-product valorisation in the agri-food sector
5	Klein et al. (2022)	RHA	Upcycling offers a great pathway in the agri-food sector aimed at promoting added-value products.	Agri-food by-products
6	Cuestas-Caza et al. (2024)	RHA	Indigenous communities' ancestral knowledge plays a crucial role in the formulation and implementation of policies within the bioeconomy framework.	By-products in the agri-food sector
7	da Silva et al. (2023)	RHA	Integrating sustainability into business models may require a commitment to sustained actions over a period of 30 years, influenced by both internal and external factors.	Activated carbon
8	Salvador et al. (2023)	RHA	Proposes 7 archetypes for business models for a circular bioeconomy enhancing sustainable bio-based solutions.	Biorefineries Waste valorisation
9	Bröring & Vanacker (2022)	RHA	Implementation for innovation and technology to develop products that serve as substitutes for fossil-based fuels, such as biofuels.	Bio-based products Bio-based processes Bio-based services
10	D'Amato et al. (2020)	RA	Bioeconomy strategies for enhancing sustainability and efficiency in SMEs.	Forest industry bio-based potential
11	Torres et al. (2022)	RHA	Rice and sugar cane residues offer great energy potential for implementing circular economy strategies to enhance sustainability and local development in Ecuador.	Agri-food sector Waste valorisation Biomass Bioplastic
12	Vargas-Carpintero et al. (2023)	RA	Due to the abundant biodiversity of LAC, there is an enormous opportunity to produce bio-based goods with value chain added.	Biomass
13	Garcia-Samaniego, J. (2024)	R	The national report is a strategic instrument for political decision-making and the advancement of bioeconomy production chains within various regions in Ecuador.	Waste valorisation Bio-based products
14	Lesenfans et al. (2024)	R	Ecuador should prioritise increasing the value of bioeconomy goods and ensuring that the advantages are dispersed fairly, particularly among rural communities who source raw materials.	-
15	Sucozhañay et al. (2022)	RHA	CE components and metrics focus on the production and end-of-life stages, with less attention given to the phases of extraction, design, use, marketing a distribution.	-
16	Ponce et al. (2021)	RHA	Ecuador, an agriculture-based economy, has the ability to meet its energy needs while adhering to environmental rules through the conversion of self-generated residual biomass.	Biomass
17	Chafra-Martinez & Lascano-Vaca (2021)	RA	The circular bioeconomy offers a comprehensive framework for the utilization and conservation of natural	-

			resources, thereby facilitating a sustainable agricultural production system.	
No.	Author(s)/Year	Type of document (RA),(RHA)& (R)	Key characteristics of the document	Bio-based business models studied
18	Salvador et al. (2020)	RA	This paper sets out the key aspects of implementing and managing business models for the circular bioeconomy.	Biomass
19	Salvador et al. (2022)	RA	Public policies, government regulations, R&I, and investment are essential factors for promoting circular bioeconomy in LAC.	-
20	Ordóñez & Lakner (2023)	RA	Biofuels is the main focus of LAC as a primary source of bioenergy.	Biofuels
21	Bracco S. (2019)	R	The proposed indicators are designed to assess the sustainability of the bioeconomy strategies integrated in each country.	-
22	European Union, Horizon Project 2020 BERural (2019)	R	The report provides a framework for analysing bio-based business models using Business Model Canvas	-

Type of document: (R) stands for review article, (RHA) stands for research article, and (R) stands for report. (-) means that no bio-based business models have been mentioned into the document.

Source: own editing, 2025