The Pontifical Bolivarian University and 2030 Agenda: Scientific Production, Access Modalities, and Social Media Impact

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ABSTRACT

The 2030 Agenda and Sustainable Development Goals promote global resilience. Universities play a crucial role in their implementation through research and education. Recent studies analyze Sustainable Development Goals-related scientific production, but evaluating the accessibility and social impacts of these results remains lacking. The article aims to analyze the intersection between Sustainable Development Goals, open access, and social impact of science, based on an analysis of Pontifical Bolivarian University academic production in Colombia. A mixed-method approach is employed, combining quantitative and qualitative elements with scientometric techniques and data mining analysis, as well as big data from the perspective of Social Sciences. Pontifical Bolivarian University scientific production analysis reveals increased research activity, with most publications available in open access. Thematic focuses such as health, sustainable development, and energy are highlighted. Thematic diversity reflects a multidisciplinary approach, but there is low production in key areas of sustainable development. Social media attention highlights topics like health, equality, and energy. Open access shows a strong correlation with online attention, emphasizing its importance in amplifying research impact. Although closed research also receives online attention, especially from academics. Greater focus is needed on inclusive publishing strategies and social media dissemination to address global challenges.

Keywords: 2030 Agenda, Accessibility, Pontifical Bolivarian University, Scientific production, Sdgs, Social impact.

INTRODUCTION

Sustainable development is a continually evolving issue that drives changes in societal behavior and institutional practices aimed at balancing the social, economic, and environmental dimensions of development. Since the 1980s, this topic has seen significant advancements and gained substantial relevance in 2015 with the launch of the 2030 Agenda and the Sustainable Development Goals (SDGs).[1]

The declared scope of the 2030 Agenda is to guide the world towards a path of resilience, focusing on fostering sustainable development. To achieve this, the 2030 Agenda is governed by five fundamental principles, formally known as the 5 Ps: People, Planet, Prosperity, Peace, and Partnerships.[2] Based on these pillars, the Agenda establishes 17 SDGs and 169 specific targets to be achieved within a 15-year timeframe, highlighting the magnitude and deep ambition of this new approach.

The SDGs aim to provide a universally oriented framework for a new model of sustainable development, as called for by the international community since the Earth Summit of 1992.[3] Despite their potential, the SDGs have also faced criticism for their vagueness, lack of robustness, and perceived lack of ambition. Criticisms include the simplicity of the SDGs, which may lead to a limited and reductionist view of development,[4] the issue of measurement, where quantifying the goals risks oversimplifying them and overlooking their interconnections,[5] and difficulties related to specifying less tangible and visible aspects of their qualitative nature, such as inclusive development and green growth.[6] In this regard, previous research asserts that the successful implementation of the SDGs requires greater attention to cross-sectoral linkages, among social actors, and between countries with different income levels.[7]

Despite these criticisms, the SDGs have undoubtedly become the framework for what the Brundtland Report defined as our common future. The broad range of development issues has led

to new realities that must be examined under the fundamental principles of the SDGs, involving scholars from various disciplines. According to Saric *et al.*,[8] it is imperative that academic research undergoes a shift to effectively contribute to the achievement of the 2030 Agenda. There is a need to identify critical pathways to success through robust research to inform a new set of policies and interventions designed to realize and operationalize the SDGs.[9]

In this context, universities emerge as key actors in promoting and implementing the 2030 Agenda. As centers of knowledge generation, research, training, and outreach, universities have the potential to make significant contributions to the achievement of the SDGs. Their role extends beyond mere knowledge transmission; universities can act as catalysts for the social, economic, and environmental changes necessary to achieve the SDGs on a global scale. Universities have the responsibility to raise awareness among citizens about their responsible role and to equip future professionals with the skills and competencies needed to tackle the challenges of sustainable development, as highlighted by García-Feijoo *et al.*[10]

The increase in research on the SDGs has driven a meta-research approach to analyzing this scientific production.[11] Some studies have attempted to assess and compare the scientific output related to certain SDGs. Most of the literature has examined this topic from a natural and experimental sciences perspective,[12,13] while SDGs focusing more on economic or social aspects have received less attention in terms of both the quantity of publications and their impact.[13,14] Researchers have particularly focused on SDG 3 ("Good Health and Well-being")[12] and SDG 13 ("Climate Action"),[15] addressing issues such as healthcare costs, health policies, and greenhouse gas emissions.[16]

However, a regional breakdown reveals differences in priorities according to different geographic contexts. For example, SDG 4 ("Quality Education") is especially relevant in the scientific output from Latin America, Europe, and, to a lesser extent, Asia.[17,12] In specific places such as Austria, most work on SDGs focuses on "Quality Education".[18] Additionally, there is greater interest in health-related goals in developing countries.[19]

Other previous research has focused on measuring scientific productivity related to the SDGs at universities through scientific databases such as Web of Science and Scopus.[11,20-25] These studies have documented an exponential increase in scientific literature on the subject.

However, no previous research has analyzed the visibility and accessibility of research results related to the SDGs, highlighting how accessible these research outcomes are to the scientific, governmental, and general social community, as well as the interactions and social impacts related to SDG research outputs. It is in this direction that this study aims to contribute novelty.

Another novelty of this work is to provide a perspective on the scientific production by SDGs at a prestigious Colombian university recognized at the Latin American and international levels (Pontifical Bolivarian University, hereinafter PBU), serving as a precedent for future research integrating this objective in the country.

The PBU has been selected as a case study in this research due to its academic relevance and its commitment to scientific production aligned with the SDGs. PBU is a higher education institution recognized in Colombia and Latin America for its multidisciplinary approach and its growing involvement in research on sustainability, open access, and socially engaged science.

In this regard, it is insightful to study how PBU is developing and communicating its engagement with the 2030 Agenda. To what extent are the principles and goals of the 2030 Agenda being integrated into its research activities? How is this information being disseminated, and what impact is it having on society and the academic environment? What is the relationship between the access to and attention received by the research outputs on digital social media? These are fundamental questions that help us better understand the role of universities in achieving the SDGs and promoting sustainable development.

This article aims to address these questions through a detailed analysis of PBU's scientific production in relation to the SDGs. Supported by scientometric techniques and data mining analysis, this article presents the objective of exploring the intersection between SDGs, open access, and the social impact of science, based on an analysis of PBU's academic output in Colombia.

METHODOLOGY

Research design

This study employs a mixed-methods approach that combines quantitative and qualitative elements to explore the intersection of sustainable development, access, and the social impact of science in the academic production of PBU. The research utilizes tools such as scientometrics to analyze the behavior and evolution of scientific output related to the SDGs from a meta-analytical perspective, as well as big data from the perspective of the Social Sciences.[26-29]

By employing big data tools from the Social Sciences perspective, this study leverages advanced technologies and methodologies for analyzing complex issues related to the interaction between science and society. Big data tools facilitate the collection, storage, and analysis of large volumes of data efficiently, enabling the identification of significant patterns, trends, and correlations in academic production. This approach also recognizes the importance of understanding the social, cultural, and political context in which scientific research is conducted.

Sample selection

The population addressed by this research encompasses all publications produced by the scientific community at PBU indexed in the Dimensions database.[30] This data source was chosen because it is a comprehensive platform that collects diverse information on funding, scientific outcomes, policies, and grants. This platform includes a citation database, a research analytics suite, and modern functionality for accessing and discovering research outputs. A notable aspect of Dimensions is its promotion of open science, offering a public version accessible to all interested users. Additionally, it continuously updates citation metrics and provides Altmetric measurements using both socio-digital media and scientific networks.

The sample selection was based on the following inclusion criteria: temporal window, research outputs indexed under the SDGs category, and PBU affiliation. A temporal window covering the last five years (2019-2023) was established. This period allows for a focus on the most recent academic production from PBU, which contributes to the analysis of up-to-date data reflecting the latest trends and practices related to the SDGs, access, and the social impact of science.

The following search equation was used for the dataset selection:

("1 No Poverty" OR "2 Zero Hunger" OR "3 Good Health and Well Being" OR "4 Quality Education" OR "5 Gender Equality" OR "6 Clean Water and Sanitation" OR "7 Affordable and Clean Energy" OR "8 Decent Work and Economic Growth" OR "9 Industry, Innovation and Infrastructure" OR "10 Reduced Inequalities" OR "11 Sustainable Cities and Communities" OR "12 Responsible Consumption and Production" OR "13 Climate Action" OR "14 Life Below Water" OR "15 Life on Land" OR "16 Peace, Justice and Strong Institutions" OR "17 Partnerships for the Goals") AND (2019 OR 2020 OR 2021 OR 2022 OR 2023) AND ("Pontifical Bolivarian University")

Data on the social impact of scientific production in socio-digital media were obtained and downloaded through the Altmetric. com platform using its public exploration function.[31] The research dataset is available for open access.[32]

Data analysis

A quantitative analysis was conducted to determine the proportion of articles available by access modality in relation to the total sample. Altmetrics were examined to assess the social impact of the selected scientific products. Descriptive analyses were carried out to identify patterns and trends in academic production related to the SDGs, access modalities to scientific production, and its impact in socio-digital media.

The following indicators were considered for the quantitative analysis:

- **Proportion of Articles by Access Modality:** This indicator provided information on the availability of the university's academic research for public access. It was calculated as the number of articles available by access type divided by the total number of articles analyzed.

- **Altmetric Attention Score (AAS):** This metric quantified the attention received by a scientific publication on digital socio-media platforms. It allowed for the evaluation of the impact and visibility of academic production online. The AAS was calculated based on a variety of data sources, including mentions on socio-digital media platforms such as X and Facebook, news media, policy documents, blogs, videos, Wikipedia, Reddit discussions, Mendeley reads, presence on prominent research platforms, and peer review sites. The AAS calculation was based on an algorithm that weights the quantity and quality of mentions received by a research product.

- **Distribution by Thematic Areas:** This indicator analyzed how academic production is distributed across different fields or disciplines of knowledge. This distribution provided valuable insights into priority research areas, institutional strengths, and emerging trends in the dataset. The calculation of thematic distribution involved categorizing academic articles based on research areas and dividing the number of articles in a particular thematic area by the total number of articles analyzed.

- **Distribution by SDGs:** This indicator analyzed how academic production is distributed in relation to the SDGs. The calculation of SDG distribution involved categorizing academic articles based on the SDGs they address. It was calculated by dividing the number of articles associated with a specific SDG by the total number of articles analyzed.

- **Correlation Between Access Modality and Altmetrics by SDGs:** This indicator assessed the relationship between three key variables in the academic and scientific realms. The correlation between these variables involved examining whether there is a statistical relationship among them. Correlation calculations were performed using statistical techniques such as Spearman's rank correlation coefficient, which determined whether there is a linear association between the variables, as well as the strength and direction of that association.

- **Keyword Co-occurrence:** This indicator showed the frequency with which certain keywords appear together in a set of documents. This metric helped to identify semantic relationships and recurring themes within the text corpus. The calculation of keyword co-occurrence

involved first identifying the most relevant or significant keywords in the analyzed document set using natural language processing and text analysis techniques to identify frequent terms and their associations. Keyword co-occurrence was calculated using network analysis techniques to visualize and analyze relationships between terms.

Qualitative constructs include the scientific works produced by PBU on the SDGs, research thematic lines, and the relationship of each with the modalities of science access and the resulting social interactions. The theoretical sources for analysis include the meanings of PBU's research thematic lines identified in scientific production, their relationship with the SDGs and sustainable development, and theories associated with open access to science, knowledge democratization, and the social impact and appropriation of science.

Analytical framework

For analyzing the most prominent topics in the scientific production indexed under the SDGs category, the software VOSviewer (version 1.6.20) was employed. This tool was used to design a keyword co-occurrence map based on the variables of title, keywords, and abstracts of the publications. The binary counting method was applied, with a minimum threshold of 10 co-occurrences per term. Out of 19,146 terms, 395 met the threshold. For each of the 395 terms, the relevance score was calculated, and the top 60% of the most relevant terms were selected for better visualization. Consequently, the final number of terms selected was 237.

To analyze the correlation between scientific production, access types, alternative metrics, and the SDGs, a matrix was created with data corresponding to scientific production by access type, the metrics for each altmetric indicator recorded on Altmetric.com for each research product, and each SDG. The data collected from the selected publication sample were entered into an ad hoc database and subsequently processed using the software JASP (Jeffreys's Amazing Statistics Program; version 0.17.3), which enabled descriptive, inferential, and correlational data analyses.

Univariate descriptive analyses of the data were performed, followed by bivariate correlation techniques using Spearman's rank correlation coefficient,[33] and simple linear regression models to determine the relationships between variables. For the qualitative interpretation of the magnitude of Spearman's correlation coefficient (Table 1), Cohen's guidelines were used, which are among the most widely accepted and respected in the scientific community.[34]

The behavior of the indicators over time and their trends were analyzed using software developed by the scientific community for these purposes (Tableau Public, version 2024.1; Power BI, version 2.126.927.0; RStudio, version 2023.12.1+402).

RESULTS

Overview of scientific production

As part of the scientific production indexed in the SDG category, a total of 736 publications were obtained. Figure 1 provides a detailed view of the academic output at PBU, highlighting trends by year, access modality, types of research products, focus areas, contributing researchers, and sources with the highest number of publications. This information is initially useful for understanding the dynamics of scientific production conducted by the institution in relation to the SDGs.

A growing trend in the number of publications over the past five years is observed, with a peak in 2022 followed by a slight decrease in 2023. This indicates an increase in research activity in the more recent years. Of the publications, 67.53% are available in open access, with a higher proportion of Gold Open Access publications (49.46%). Most of the publications are articles (79%), although there are also edited books (6.39%), book chapters (5.16%), and other types of publications, indicating a diversity in the formats used for disseminating research.

Regarding research categories, the main areas represented are Biomedical Sciences (26.90%), Engineering (20.38%), and Clinical Sciences (16.44%). This suggests a multidisciplinary approach in scientific production. The most prolific researchers indicate areas of specialization and leadership in SDG-related research both within the university and in collaboration with researchers from other countries and external institutions. Among the primary publication sources where the research results have been disseminated are the journals *Sustainability* (1.77%), *Energies* (1.63%), *Medicina UPB* (1.36%), and *Bulletin of the Pan American Health Organization* (1.36%).

Research themes and SDGs

To analyze research fronts based on the scientific production of PBU with respect to the SDGs, both research categories and SDGs were considered, as well as the analysis of thematic research group configurations based on keyword co-occurrence in titles, abstracts, and keywords of research products.

Figure 2 provides a detailed overview of the priority research areas and SDG-related themes in PBU's academic production. This information is essential for understanding the research approaches and the potential impact of the university in advancing the SDGs at local, national, and international levels.

The research categories with the highest number of publications are Biomedical and Clinical Sciences (26.90%), Engineering (20.38%), and Health Sciences (13.18%). This suggests that research in these areas is both active and significant at PBU. There is also a variety of research fields, although less represented, such as Human Society, Law and Legal Studies, Education, Commerce,

Table 1: Qualitative interpretation of the magnitude of the Spearman correlation coefficient according to Cohen's suggestions.

Range of values for r_{xy}	Interpretation
$0.00 \leq |r_{xy}| < 0.10$	Null correlation
$0.10 \leq |r_{xy}| < 0.30$	Weak correlation
$0.30 \leq |r_{xy}| < 0.50$	Moderate correlation
$0.50 \leq |r_{xy}| < 1.00$	Strong correlation

Management, Tourism, and Services, among others. This indicates a diversity of research interests within the university.

Regarding the SDGs with the highest number of publications, the most prominent is Good Health and Well-being (41.17%), followed by Affordable and Clean Energy (17.66%), and Peace, Justice, and Strong Institutions (14.54%). However, there is also a broader distribution of publications across a range of other SDGs, though with very low representation in scientific production: Clean Water and Sanitation (0.95%) and No Poverty (0.54%).

To gain a deeper understanding of the relationships and patterns within PBU's scientific production in relation to the SDGs, a keyword co-occurrence network was designed (see Figure 3). For each keyword, the font size of the label and the size of the circle are based on the corresponding weight. The number of links between keywords was calculated, grouping them into clusters according to their interactions (indicating a close interrelation).

As a result of the term visualization, 3 major clusters were identified, comprising 186 items, with a total of 8,642 relationships and an association strength of 25,391. These clusters represent a high degree of interrelation among the keywords and configured the thematic research focuses on SDGs at PBU.

The cluster with the highest number of co-occurrences was the red one (comprising 75 items). This cluster represents a broad spectrum of research in the field of medicine and health, addressing clinical, epidemiological, demographic, and therapeutic aspects of various diseases and health conditions. The main research focuses represented by this cluster are summarized below:

- **Medical Care and Treatments:** This focus is on medical care, clinical practices, and treatments for various health conditions. It includes research on the effectiveness of different therapies, treatment protocols, medication adherence, quality of medical care, hospital admissions, clinical features, complications, diagnosis, etiology, disease incidence, symptoms, mortality, and morbidity. Predominant keywords: "patient", "treatment", "care", "intervention", "therapy", "adherence", and "drug".

- **Diseases and Risk Factors:** This focus aims to understand diseases, their causes, complications, and associated mortality rates. It encompasses research on the etiology of specific diseases, risk factors, prevention strategies, and management of chronic illnesses. Representative keywords: "disease", "risk factor", "complication", "HIV", "cancer", "COVID", "cardiovascular disease", and "mortality".

- **Epidemiology and Health Statistics:** This involves research on disease prevalence in different populations, mortality rates, associated risk factors, and demographic characteristics of affected populations. Representative keywords: "prevalence", "mortality rate", "rate", "variable", "adult", "woman", "man", "mean age", and "age".

A second cluster in green (comprising 69 items) illustrates a multidisciplinary research focus in the field of social sciences and politics, addressing issues related to development, education, sustainability, governance, inequality, and peacebuilding. This cluster represents an area of research aimed at understanding and addressing social and political challenges in specific contexts such as Latin America. The main research focuses represented by this cluster are summarized below:

- **Sustainable Development and Public Policy:** This focus includes research on sustainable development, social and environmental justice, as well as analysis of public policies, governance, and transitions toward sustainability. Representative keywords: "development", "public policy", "sustainability", "sustainable development", "climate change", "governance", and "transition".

- **Education and Knowledge:** This encompasses research on formal and informal education, educational theories, the role of students in the educational process, educational inclusion, and knowledge transfer. Representative keywords: "education", "higher education", "teacher", "student", "university", "knowledge", and "theory".

- **Latin American Perspectives and Context:** This involves research on regional perspectives, specific challenges, and opportunities in Latin America related to topics such as development, education, public policy, sustainability, and the relationship between science, innovation, and society in the context of sustainable development. Representative keywords: "Latin America", "science", "innovation", "emergence", "knowledge", "researcher", "scholar", and "society".

- **Inequality, Violence, and Peace:** This includes research on the causes and consequences of social inequality, interpersonal and structural violence, as well as strategies for promoting peace and social justice. Representative keywords: "inequality", "violence", "poverty", "human rights", "peace", and "victim".

A third cluster in blue (comprising 41 items) represents a multidisciplinary research focus centered on energy efficiency, sustainable resource management, and the pursuit of innovative and sustainable energy solutions. This research area aims to address global energy challenges and promote more sustainable and environmentally friendly development. The main research focuses represented by this cluster are summarized below:

- **Energy Efficiency and Sustainable Technology:** This focus evidences research aimed at improving energy consumption and production efficiency, reducing greenhouse gas emissions, and developing more reliable and sustainable technologies for energy generation. Representative keywords: "efficiency", "consumption", "cost", "demand", "emission", "energy consumption", "generation", "performance", "potential", "power", "reduction", "reliability", and "technology".

- **Resource Management and Sustainable Production:** This area addresses research on optimizing natural resources, reducing waste, and implementing more sustainable and environmentally friendly production practices. Representative keywords: "resource", "raw material", "production", "property", and "reliability".

- **Energy Simulation and Scenarios:** This includes research on evaluating different energy scenarios, simulating complex energy systems, and identifying solutions to address current and future energy challenges. Representative keywords: "scenario", "simulation", and "solution".

Correlation between open access modalities and altmetrics by SDGs

It was observed that for the Closed Access modality, the SDGs with the highest percentage of products are SDG 1-No Poverty (75%), SDG 10-Reduced Inequalities (66.67%), and SDG 2-Zero Hunger (53.85%). For the Gold Access modality, the prominent SDGs are SDG 5-Gender Equality (70.59%), SDG 9-Industry, Innovation, and Infrastructure (66.67%), and SDG 16-Peace, Justice, and Strong Institutions (58.33%). The Green Access modality shows a predominance of SDGs 1-No Poverty (25%), SDG 10-Reduced Inequalities (16.67%), and SDG 6-Clean Water and Sanitation (14.29%). Conversely, the Hybrid Access modality shows a predominance of SDGs 15-Life on Land (18.75%) and SDG 14-Life Below Water (18.18%). Finally, the Bronze Access modality is primarily represented by SDGs 3-Good Health and Well-being (5.94%) and SDG 4-Quality Education (2.63%).

39.95% of the publications received some form of attention in socio-digital media, with 11.41% receiving only one Altmetric Attention Score (AAS). Publications with AAS are primarily related to topics in health sciences, sustainable development, and energy. The altmetric indicators with the highest scores were Mendeley reads (69.48%) and mentions on X (25.65%), while those with the lowest scores were mentions in Videos (0.01%), presence on prominent research platforms (0.012%), and in peer review sites (0.012%).

Research products with the highest altmetric attention (based on the total sum of the AAS for each access modality) were those corresponding to the Gold modality (45.41%), followed by Closed
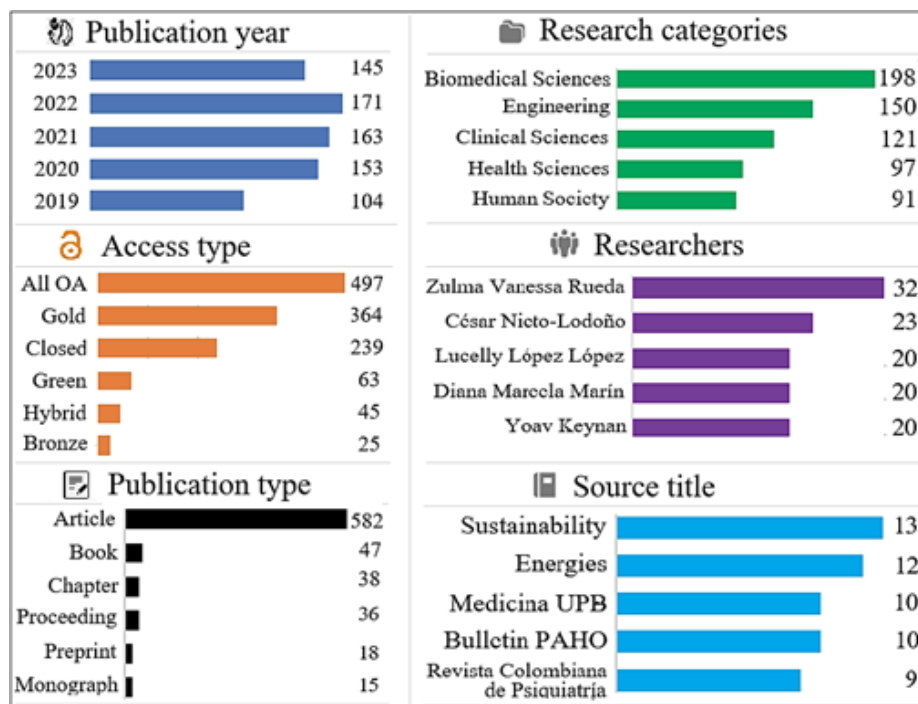
Figure 1: Distribution of scientific publications by year, access type, research categories, researchers, and sources.

Access (20.59%) and Hybrid Access (17.45%). The research products with the lowest altmetric impact were associated with the Green Access (10.71%) and Bronze (5.84%) modalities. However, a more detailed analysis of the altmetric attention received by each research product for each access modality revealed the following percentages (Green: 67.19%; Hybrid: 56.52%; Bronze: 54.17%; Gold: 37.09%; Closed: 31.51%).

For the SDGs, research products that achieved the highest altmetric impact were associated with SDG 3-Good Health and Well-being (50.53%), followed by SDG 7-Affordable and Clean Energy (14.26%), SDG 13-Climate Action (8.78%), SDG 4-Quality Education (6.74%), and SDG 16-Peace, Justice, and Strong Institutions (6.46%). Conversely, SDGs with less than 5% of the total attention were SDG 11-Sustainable Cities and Communities (3.10%), SDG 12-Responsible Consumption and Production (2.41%), SDG 15-Life on Land (1.88%), SDG 9-Industry, Innovation, and Infrastructure (1.09%), SDG 5-Gender Equality (1.03%), SDG 14-Life Below Water (1.02%), and SDG 2-Zero Hunger (1.01%). Research products related to the remaining SDGs had altmetric attention below 1%.

A more detailed examination of the altmetric attention received by each research product for each SDG revealed the following percentages (SDG 10-Reduced Inequalities: 75%; SDG 1-No Poverty: 75%; SDG 5-Gender Equality: 52.94%; SDG 3-Good Health and Well-being: 48.84%; SDG 2-Zero Hunger: 46.15%; SDG 14-Life Below Water: 45.45%; SDG 13-Climate Action: 44.90%; SDG 6-Clean Water and Sanitation: 42.86%; SDG 11-Sustainable Cities and Communities: 36.67%; SDG 16-Peace, Justice, and Strong Institutions: 36.11%; SDG 9-Industry, Innovation, and Infrastructure: 33.33%; SDG 15-Life on Land: 31.25%; SDG 4-Quality Education: 30.67%; SDG 7-Affordable and Clean Energy: 25.38%; SDG 12-Responsible Consumption and Production: 24%; SDG 8-Decent Work and Economic Growth: 21.43%).

The correlation map between altmetrics and open access by SDGs (Figure 4, left side) shows a strong correlation between scientific production in open access and Mendeley reads, Wikipedia mentions, mentions on X, policy documents, Facebook pages, Reddit, news media, and blogs; whereas there is a moderate correlation between open access and mentions in videos and prominent research platforms. In contrast, there is a weak correlation between open access and peer review sites.

The correlation map between altmetrics and closed access by SDGs (Figure 4, right side) shows a strong correlation between scientific production in closed access and Mendeley reads, blog mentions, news media mentions, policy documents, and mentions on X. A moderate correlation is observed between closed access and prominent research platforms, Wikipedia mentions, and Facebook pages. In contrast, there is a weak correlation between closed access and peer review sites.

DISCUSSION

Based on the results obtained, it is evident that the scientific production indexed under the SDG category at PBU in Colombia has been substantial. A key observation is the growing trend in the number of publications over the past five years, which corresponds to the exponential global growth of scientific research on the SDGs.[12,14] This pattern reflects a renewed commitment to SDG-related scientific research at the university.

Regarding the modes of access to scientific information, it is encouraging that a significant percentage of publications are
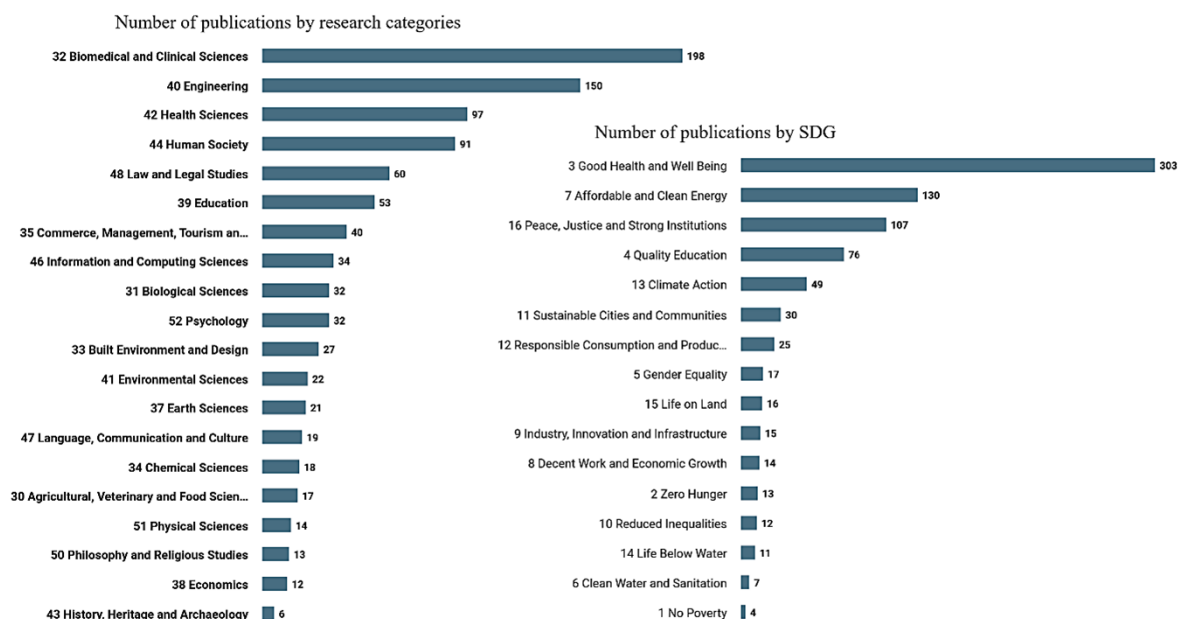
Figure 2: Scientific production by research categories and SDGs.

available in open access. This indicates a strong commitment to transparency and the accessibility of scientific knowledge. Notably, the Gold open access type represents the largest proportion of these publications. Although Gold open access allows articles to be freely available to readers, it often involves high Article Processing Charges (APCs), raising concerns about the commercialization of scientific knowledge and the potential influence of commercial interests on editorial decisions.[35,36]

The commitment to open access in research dissemination aligns with the principles of equity and transparency in sustainable development. By providing free and open access to scientific information, there is a contribution to the democratization of knowledge and the strengthening of local communities' capacity to address sustainable development challenges. Therefore, exploring scientific communication channels with greater potential for knowledge access and reuse is essential.

However, it is alarming that a considerable portion of the SDG-related scientific production is in Closed Access, especially compared to more open access models that align with the broader need for knowledge sharing, such as Green,[37] Hybrid,[38] and Bronze[39] access models. A critique emerging from this study regarding the access mode classification by the Dimensions database is that it does not include the Diamond or Platinum open access model,[40] a model in which Latin America is a global leader and which does not charge authors for publication or readers for access, thus facilitating the free circulation and unrestricted reuse of knowledge.

From the perspective of sustainable development, the diversity of research areas represented in PBU's academic production reflects a multidisciplinary approach that addresses multiple dimensions of sustainability. The predominance of research categories such as Clinical and Biomedical Sciences, Engineering, and Health Sciences generally signifies a strong focus on critical areas for sustainable development, such as human health and engineering. These findings are consistent with other studies.[11,12,14,16,19]

It is important to highlight the uneven distribution of publications across different SDGs. The low scientific output related to key SDGs such as 1. No Poverty, 10. Reduced Inequalities, and 2. Zero Hunger, among others, has also been documented in previous global studies.[14] This result may be linked to the low scientific production in research categories like Social Sciences, and aligns with an intense discussion within the research community about a set of biases related to coverage in international databases, language particularities, and especially local and specific contexts that inherently reflect this type of social research.[41-43]

On the other hand, the PBU's efforts regarding the development, funding, and interest in topics as sensitive to local communities as sustainable development are controversial, and this issue warrants further exploration in future research. This disparity indicates areas where the university could focus more research

efforts to address underlying challenges and contribute more effectively to the 2030 Agenda.

The presented findings highlight several important trends with significant implications for the publication strategy and visibility of research related to the SDGs. The scientific production in open access on topics centered around gender equality, innovation and infrastructure, peace and justice, and health and well-being suggests a commitment to the open dissemination of research in areas considered crucial for sustainable development. This is an encouraging outcome considering that research published in open access modalities can have a wider reach and potentially greater impact by being accessible to a more diverse audience, including researchers, policymakers, professionals, and the general public.

It is controversial and even paradoxical that the Closed Access modality is strongly associated with SDGs related to the eradication of poverty, the reduction of inequalities, and zero hunger. These SDGs address critical issues affecting social communities and require urgent solutions, yet research published in closed access modalities limits its availability and usefulness for those outside certain academic or institutional circles. In contrast, the open availability of research on these topics facilitates the rapid and broad exchange of knowledge, which can accelerate the development and implementation of effective strategies to address these challenges. Consequently, it increases the likelihood that proposed solutions will be adopted and implemented by governments, organizations, and other relevant social actors, including the communities themselves.

In this regard, it is essential to promote strategies aimed at publishing in open access sources,[44,45] also in response to Target 12.8 of the 2030 Agenda, which seeks to ensure that people worldwide have the information and knowledge necessary for sustainable development; and generally to SDG 9 ("Industry, Innovation, and Infrastructure") which focuses on developing resilient infrastructure and fostering innovation, particularly by expanding access to information and communication technologies. These aspects reaffirm the importance of education and access to information for achieving sustainable development, which in turn must involve a profound change in the way we think and act.[25]

The analysis of attention in socio-digital media through alternative metrics offers a suggestive perspective on the impact and reach of scientific production related to the SDGs. The fact that less than 40% of the publications have received any form of attention in socio-digital media raises several questions regarding the significance of these platforms as vehicles for disseminating academic research. Particularly, from the perspective of diffusion strategies in socio-digital media for research and its derived products by the research community. In this sense, the presence of authors across various social and scientific platforms, and

their constant interaction, will lead to greater visibility and social impact of their productivity.[46]

It is also noteworthy that a significant percentage of publications with attention in socio-digital media received only one altmetric score, suggesting that while these publications generate interest within the online community, the depth of interaction may be limited. This finding raises questions about the nature and quality of interaction in these virtual spaces concerning academic research. Another important aspect to highlight in this context is whether accessible language is provided in the communication of research results through social media by the scientific community, so that it is understandable to a general non-specialist audience.

The fact that publications with higher altmetric attention scores are primarily related to thematic areas such as health sciences, sustainable development, and energy indicates a particular interest from the public in these areas. However, this result is also correlated with the fact that these are research categories and SDGs with higher representation in scientific production, which also contributes to achieving higher altmetric attention scores.

On the other hand, the analysis of socio-digital media impact for each SDG reflects a greater interest in topics related to health and well-being, reduction of inequalities, end of poverty, and gender equality. This is a very interesting result, as several of these SDGs had very low levels of scientific production and were mostly published under closed and gold access modalities. This indicates that these are highly relevant social issues, and thus there is a need to strengthen research processes and develop more inclusive open access publishing strategies as well as their dissemination through socio-digital media.

Regarding specific altmetric indicators, readings on Mendeley emerge as the most prominent indicator, aligning with findings from other studies,[47,48] suggesting a high degree of interest and engagement from the academic community in the research produced by PBU. Conversely, presence on prominent research platforms and peer review sites shows less impact, indicating lower visibility in these specific academic contexts.

The analysis of altmetric attention by access modalities reveals interesting patterns. Publications under the Gold open access modality show the highest altmetric attention, followed by Closed access and Hybrid modalities. This finding suggests that while open access generally tends to receive more social media attention, the Gold modality may be particularly effective in increasing the visibility and online impact of research. However, it is significant to note that this result corresponds with the fact that the highest levels of scientific production are associated with the Gold open access and Closed access modalities, which may contribute to higher levels of attention due to the volume of production. In contrast, it is noteworthy that the Hybrid open access modality, despite being one of the modes with lower scientific production volume, has received substantial online attention. This result indicates that publications under this open access modality have greater potential for visibility and social media engagement.

On the other hand, publications under the Green and Bronze open access modalities show less altmetric impact compared to other modalities. However, a more detailed analysis reveals that individual publication altmetric attention is significantly higher in these modalities compared to Gold, Closed, and Hybrid modalities. This suggests that while these modalities may have generated less overall attention on social media due to lower volumes of scientific production compared to Gold and Closed access modalities, individual publications within Green, Hybrid, and Bronze modalities tend to receive more online attention. According to this finding, strengthening publication strategies
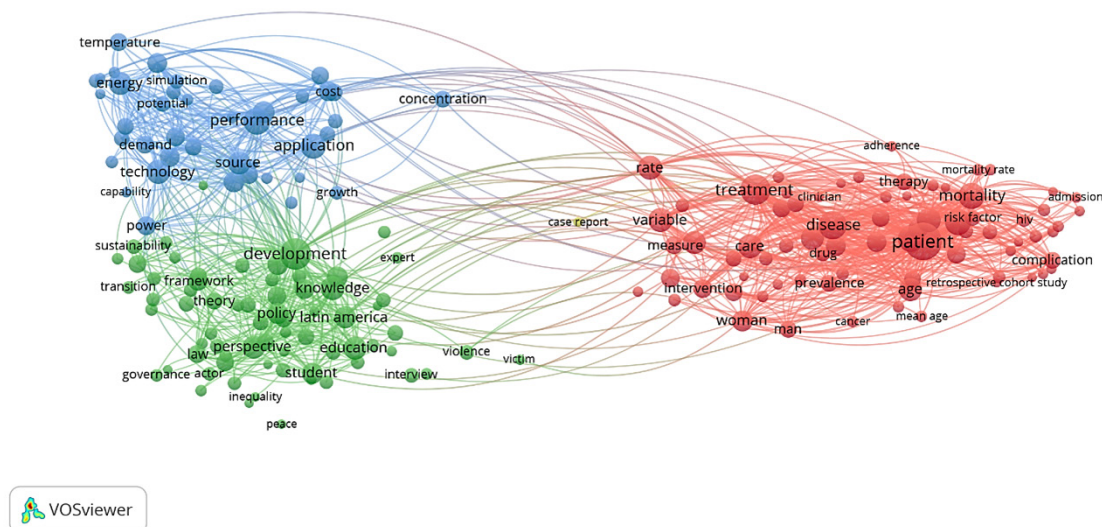
Figure 3: Keyword co-occurrence network on publications indexed in the SDG category.
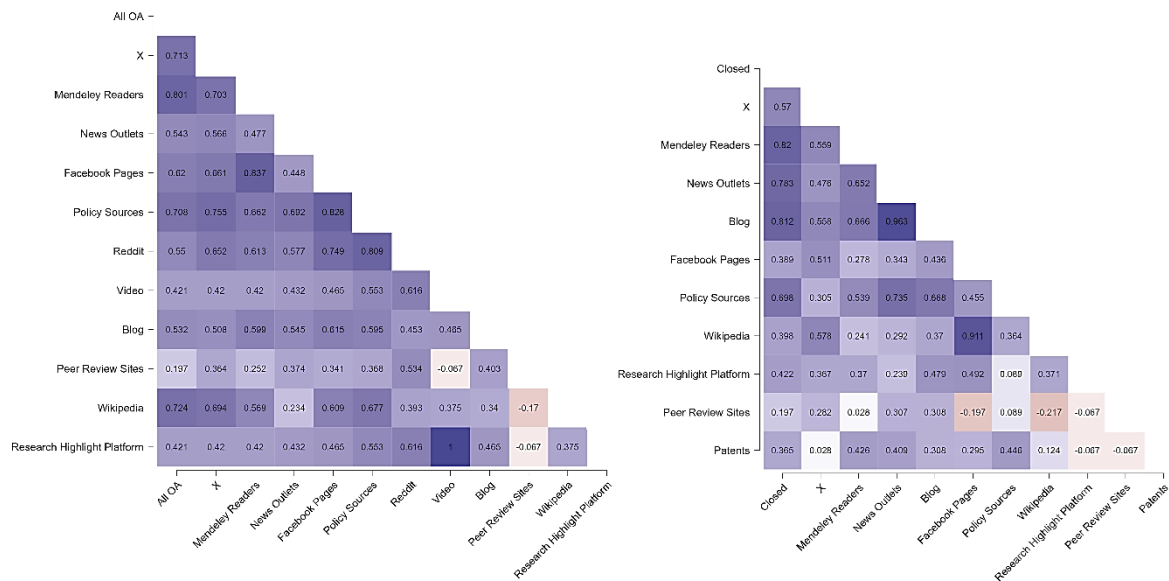
Figure 4: Spearman Correlation Map between Scientific Production by Access Types and Altmetrics by SDG.

in these open access modalities could lead to higher levels of scientific impact on social media.

The analysis of the correlation between altmetrics and open and closed access modalities provides a detailed insight into how online visibility relates to the availability of academic research. The strong correlation between scientific production in open access and a variety of alternative metrics spans a range of platforms and social media channels, such as readings on Mendeley, mentions on Wikipedia, and engagement on social media platforms like Facebook and Reddit, as well as in news media and blogs. This finding suggests that open availability of research is closely associated with increased online attention and dissemination, supporting the importance of open access in amplifying the impact and visibility of research. Previous studies corroborate this result.[37,49,50]

However, there is also a moderate correlation between open access and mentions in videos and prominent research platforms. While this correlation is weaker compared to other metrics, it remains significant and highlights the diversity of channels through which open access research can gain online attention. On the other hand, the weak correlation between open access and peer review sites suggests that visibility in these specific contexts may not be directly related to the open availability of research.

In contrast to the previous observations, the correlation between altmetrics and closed access by SDGs reveals a strong correlation with metrics such as Mendeley reads, mentions in blogs, news media, policy documents, and on social media platforms like X. This suggests that, although closed access research may be restricted in terms of availability, it can still receive significant online attention, particularly in social media and academic content dissemination platforms. This indicates that closed access publications are noticed by academics, publishers, and the scientific community in general who have institutional access to these closed access publications. For example, this leads to a lower correlation between closed access and metrics such as mentions on Wikipedia and mentions on Facebook pages.

In general, the analysis of PBU's scientific production in relation to the SDGs positions it within the broader context of sustainability research in higher education institutions at a global level. In Spain, Vállez *et al.*,[25] identified that universities leading SDG-related research have integrated these goals into their institutional strategies, ensuring visibility and presence in impact rankings such as the Times Higher Education University Impact Ranking.[51] In Latin America, Arroyave *et al.*,[52] found that the countries with the highest impact in SDG-related research include Argentina, Mexico, Costa Rica, and Panama, whereas Cuba and Venezuela exhibit lower visibility. Comparatively, PBU demonstrates a growing scientific output but lacks the consolidation of international impact strategies implemented by Spanish and Latin American universities with stronger representation in global databases. In Brazil, Del-Rio-Sánchez *et al.*,[53] analyzed the concentration of SDG-related research in a few leading universities, suggesting that PBU could enhance its impact by building strategic scientific networks and increasing the internationalization of its publications. Similarly, the University of Holguín in Cuba has shown a strong commitment to the SDGs, with a higher concentration of research in education, economic growth, and strong institutions, while having less presence in areas such as renewable energy and sanitation,[54] trends that are also reflected at PBU.

At a global level, Bautista-Puig *et al.*,[19] highlighted an exponential increase in SDG-related research output since 2000, with significant contributions in health, gender equality, and

climate change, areas where PBU has made notable progress but still has opportunities to improve its international positioning. In this regard, the University of Córdoba in Spain has developed a cross-cutting strategy that integrates the SDGs into teaching, research, and knowledge transfer, enhancing its academic and social impact.[55] While PBU is aligned with the 2030 Agenda, it could benefit from adopting similar strategies to increase its global visibility and strengthen international collaboration. These findings suggest that, although PBU has demonstrated a commitment to sustainability research, its impact could be further enhanced through greater integration into international, national, and local scientific networks, as well as strategic positioning in diverse databases and socio-digital platforms.

CONCLUSIONS, LIMITATIONS, AND FUTURE RESEARCH DIRECTIONS

This study conducted a comprehensive analysis of the scientific production related to the SDGs at PBU in Colombia. Through this research, several significant trends have been identified that offer a detailed view of the dynamics of research and knowledge dissemination related to the SDGs, as well as their impact on social media.

The findings reveal a substantial commitment from PBU towards scientific production related to the SDGs. The increasing trend in the number of publications over the past five years reflects a renewed interest and commitment to scientific research at the university. It is encouraging to observe that the majority of PBU's SDG-related publications are available through open access. However, there is a need for greater openness in scientific production, particularly in open access modalities that reflect a commitment to transparency and accessibility of scientific knowledge, thereby broadening its availability to a wider audience and promoting the democratization of knowledge.

Academic research at PBU covers a wide range of SDG-related topics, reflecting a multidisciplinary approach and concern for social, economic, and environmental challenges. Despite the general commitment to SDG research, there is a disparity in scientific production concerning some key SDGs, with goals such as No Poverty, Zero Hunger, and Reduced Inequalities having lower representation in the scientific output. These results underscore the importance of focusing more research efforts on critical areas for sustainable development.

The correlation between SDGs, access modalities, and social media impact reveals that the open availability of research is closely associated with increased online attention and dissemination, reinforcing the importance of open access for amplifying the impact and visibility of research. Open access significantly contributes to the visibility and dissemination of SDG-related research, enabling broader knowledge exchange and facilitating practical application, especially in areas where urgent solutions are needed to address critical social challenges.

In this context, the convergence of open academia, open science, open education, and open government emerges as a promising area for collaboration in achieving the SDGs of the 2030 Agenda. Although they arise in diverse contexts, these movements share essential principles that can catalyze important transformations in research and decision-making with social impact.

On another note, it is important to acknowledge that this research is not without limitations. Firstly, the selection of a five-year period is not representative of the total scientific production of the university concerning the SDGs. Secondly, the choice of a specific database does not represent a comprehensive coverage of scientific production. Future research could benefit from combining multiple specialized databases to cross-check results, minimize indexing biases, and expand the scope of the scientometric analysis. Therefore, future studies could address these limitations and complement the results presented in this particular study.

Finally, this study proposes several future research directions on the topic discussed. Firstly, it would be beneficial to investigate how different social media dissemination strategies, such as the use of accessible language, multimedia content, and active author engagement, affect the visibility and impact of SDG-related research. In this regard, another promising research avenue is to examine the impact of institutional and governmental open access policies on the visibility and dissemination of SDG-related research, as well as on inter-institutional collaboration and knowledge transfer.

These future research directions could enhance our understanding of how SDG-related scientific production is disseminated and utilized by various communities, and inform policies and practices related to scientific communication and open access in the context of sustainable development.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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