





Article

Scientific Research in Ecuador: A Bibliometric Analysis

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Abstract: Ecuador has shown a growth in its scientific production since 2011, representing 85% of the total historical production. These investigations are reflected in scientific publications, which address world interest topics and serve as a link for the university, business, and society. This work aims to analyze the scientific production generated by Ecuador in the period of 1920–2020 using bibliometric methods to evaluate its intellectual structure and performance. The methodology applied in this study includes: (i) terms definition and search criteria; (ii) database selection, initial search, and document compilation; (iii) data extraction and software selection; and finally, (iv) analysis of results. The results show that scientific production has been consolidated in 30,205 documents, developed in 27 subject areas, in 13 languages under the contribution of 84 countries. This intellectual structure is in harmony with the global context when presenting research topics related to “Biology and regional climate change”, “Higher education and its various approaches”, “Technology and Computer Science”, “Medicine”, “Energy, food and water”, and “Development and applications on the Web”. Topics framed in the Sustainable Development Goals (SDGs), sustainability, climate change, and others. This study contributes to the academic community, considering current re-search issues and global concerns, the collaboration between universities and countries that allow establishing future collaboration links.

Keywords: bibliometric analysis; intellectual structure; universities; country scientific output; Ecuador



Citation: Herrera-Franco, G.; Montalván-Burbano, N.; Mora-Frank, C.; Bravo-Montero, L. Scientific Research in Ecuador: A Bibliometric Analysis. *Publications* **2021**, *9*, 55. <https://doi.org/10.3390/publications9040055>

Academic Editor:
Craig Aaen-Stockdale

Received: 22 September 2021

Accepted: 29 November 2021

Published: 1 December 2021

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1. Introduction

Ecuador is a natural laboratory that has aroused the interest of the academic world in recent years. This country has been among the 17 megadiverse countries in the world since 1998 [1–3], hosting various species, including birds (16%), amphibians and mammals (8%) and reptiles (5%) [4]. Additionally, this country has international recognition of eight world heritage sites [5–7], a world geopark declared by UNESCO and 11 national parks, where the Yasuní Park stands out for its biological wealth on a landscape and local scale [8,9].

Another of the attractions of Ecuador is its natural laboratories, the Galapagos Islands, and the Amazon region. The first is one of the most pristine places on the planet, [10], and received attention from the academy since the 18th century due to Charles Darwin's research [11–13] and subsequent contributions that allowed it to be declared as a natural heritage of humanity [14]. Galápagos is also considered one of the 137 irreplaceable protected areas globally [15], a hotspot of endemism [16] and a priority region for conservation [17]. The Ecuadorian Amazon is a relevant ecological zone due to the abundance

of tropical forests found in this region and the most remarkable biological diversity globally [15,18]. The region is of economic importance for the country for its oil and wood extraction activities and oil palm plantations [19].

This growing interest in Ecuador's research has allowed three of its universities to be ranked among the top 1000 worldwide, and six are among the top 100 in South America according to the 2021 QS World University Rankings. These events contributed to Ecuador obtaining more than 29,000 publications in the last ten years. These are publications with strong international collaboration and that are indexed in prestigious academic journals within the Scopus database, resulting in a significant and beneficial contribution, both for the country and for the academic world.

These investigations have presented diverse approaches in their areas of knowledge. However, few studies have attempted to cover the intellectual structure of Ecuador's research. Castillo and Powell [20–22] present studies on scientific production in a short period of time, 2006–2015. Other researchers considered using the Web of Science (WoS) database [23]. Despite these efforts, a global analysis of the Ecuadorian investigation has not been carried out. Bibliometric analyses give a clear and precise answer on a global analysis of a country, journal or field of study [24–28]. These types of studies allow the exploration of the structure of the country's scientific research publications, their patterns of collaboration, and predominant areas of knowledge [29,30].

This work aims to analyze the scientific production generated by Ecuador in the period of 1920–2020 using bibliometric methods to evaluate its intellectual structure and performance.

This study has been structured in five sections. The first contains an introduction to research, activity, and its relationship with the university; Section 2 presents the methodology for the treatment and use of the data that are described in four phases (definition of search terms and criteria; selection of the database, initial search, and document compilation; data extraction and software selection; analysis of results). Section 3 presents the intellectual structure of scientific research and analysis of university publications based on their quantity and quality. Section 4 presents the discussion of the exposed analyzes, and finally, in Section 5, this research's main conclusions and limitations are presented.

2. Materials and Methods

Bibliometric analysis is considered an alternative to studying these research fields. This tool presents a systematic, rigorous and transparent process that broadly examines an academic field or a specific study area [31,32]. Specifically, this allows to quantitatively evaluate the production and performance of the structure, as mentioned earlier when examining documents, authors, institutions and journals [33,34]. This analysis is complemented with bibliometric maps, which allow us to examine the behaviour of the intellectual structure by observing the connections, the interrelation of the various disciplines, and research fields [35,36]. It can examine these bibliometric studies in various fields of knowledge such as business and management [37–39], environmental sciences [40,41] and earth sciences [42]. Other studies have focused on the institution's evaluation [43,44], scientific journals [45–47], the scientific production evolution by regions [48–51] or countries [24,25,52,53].

This study shows a systematic process made up of four phases that allow the analysis of the scientific production of Ecuador (see Figure 1): (i) terms definition and search criteria; (ii) database selection, initial search, and document compilation; (iii) data extraction and software selection, and finally, (iv) analysis of results.

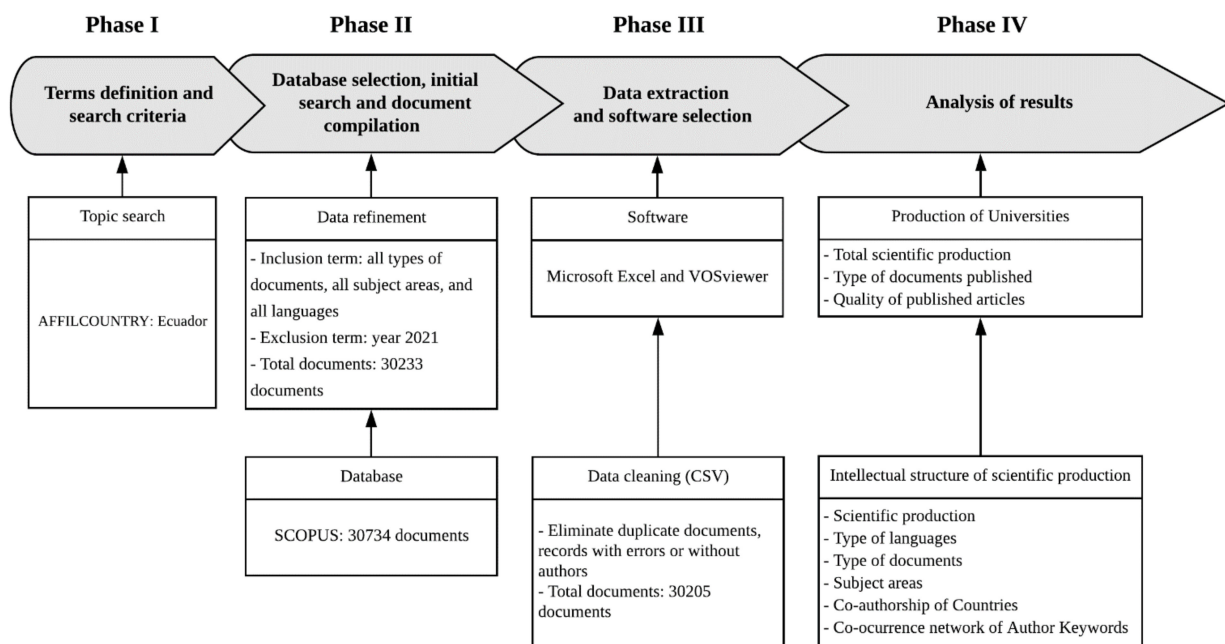


Figure 1. Investigation methodological scheme.

2.1. Terms Definition and Search Criteria

For this study, researchers focused on country affiliation [24,25], that is, publications that contain at least one affiliation from Ecuador. Therefore, it allows access to the scientific production in which they have participated, at least one researcher affiliated with universities, research centres, hospitals and other organisations belonging to the country.

2.2. Database Selection, Initial Search, and Document Compilation

The Scopus database was selected for three reasons: (1) its broad coverage in most fields of knowledge, access and visualization facilities allow adequate data analysis [54–56]; (2) its use in various bibliometric studies [57–59]; and (3) it is the source of information for the QS World University Rankings, the ranking most used by Latin American universities to determine their position in the region and the world [60,61].

The data collection was carried out in January 2021 using the descriptor ‘Ecuador’ in the country affiliation, allowing the search to be carried out: Topic Search (TS) = AFFILCOUNTRY (Ecuador). In total, 30,734 documents were obtained as an initial search. In the construction of the database, for bibliometric studies, it is necessary to fulfil several implicit and explicit selection criteria [42,62]. The first criterion considered was to use the following document types: article, conference paper, review, book chapter, letter, note, editorial, erratum, short survey, book, and data paper. Additionally, researchers considered all areas of knowledge, as well as all available languages of the publications. Thus, this allows the capture of the most information on published research. As a second criterion, it was considered to exclude the year 2021, as it is the current year, by applying these criteria, obtaining 30,233 documents.

2.3. Data Extraction and Software Selection

The results obtained from the search were downloaded in CSV format (comma-separated values), and they have bibliographic information, citation, abstract and Keywords, references, among others. In the analysis of the extracted data, two types of software were used:

- (i) Microsoft Excel. Software that allows the pre-processing of data (data cleaning) to minimise errors by eliminating records with inconsistencies (incomplete, duplicate, with errors or without authors) [63,64]. A final basis for the analysis of 30,205 docu-

- ments was obtained. Additionally, the software facilitates the analysis of scientific production based on documents, languages, subject areas, and journals [65,66].
- (ii) VOSviewer. It is free software developed by the University of Leiden (Leiden, Netherlands), which allows the analysis of the intellectual structure of an academic field through the construction and visualization of two-dimensional networks [67,68]. The software is applied to study various subject areas [55,69–73], and a country or region scientific production [52,74,75].

2.4. Analysis of Results

In this study, a bibliometric analysis is presented in two sections. First, the intellectual structure analysis of scientific production and the scientific production analysis carried out by universities in the country.

The first one analyzes the scientific production that has been generated in the country, based on the number of published documents, their types and languages, the subject areas, international collaboration, and the co-occurrence of author keywords. These analyses are necessary when implementing a bibliometric study.

The second analysis emphasizes an essential agent in scientific production, which is the university. This section examines its production, published documents type and journal articles quality. Some of these analysis combinations are essential when generating a bibliometric study [76–78].

3. Analysis of Results

3.1. Intellectual Structure of Scientific Production

3.1.1. Scientific Production

In Ecuador, scientific research is reflected in 30,205 documents and 344,183 citations, distributed over 100 years of research (1920–2020). For analysis purposes, it was divided into two stages. The first covers the first investigations in a range of 70 years (1920–1990). The second comprises the most significant production of documents and citations that the country generated during the following 30 years (1991–2020):

First Development Stage (1920–1990)

This stage presents the beginnings of research and scientific collaboration through 372 documents (less than 1.3% of the total production) and obtaining 5311 citations. The first records correspond to studies related to medicine where the International Health Board plays a leading role. This foundation was created in 1916 as part of the Rockefeller foundations to promote public health and the dissemination of new knowledge in medicine [79]. In 1918, the organization arrived in Ecuador to cooperate with the country's public health, who nominated M. E. Connor as deputy director of health [80]. In 1920, as mentioned above, the researcher presented the first two publications in the country related to the control and measures to eradicate yellow fever [81]. Connor's research was relevant to solving the problems related to this disease [82]. At the end of the year (1920), a third publication belonging to E. Ray Royer, who was Chief Surgeon of the hospital of the mining camp of the South American Development Company, located in the city of Portovelo, is presented. This researcher studied intestinal parasites through biochemical tests in mine workers, allowing subsequent control and treatment [83].

The first study of an Ecuadorian university appeared in 1921, which corresponds to the authors F. Rojas and J. Tanca Marengo of the University of Guayaquil in the area of medicine [84]. In this same decade (1920s), studies related to other areas of knowledge such as agriculture [85], botany [86] and zoology are evidenced [87]. Since 1926, the investigations on the Ecuadorian coast were carried out by the Anglo Ecuadorian Oil Fields oil company through geologist George Sheppard [88,89].

In the 1930s, correspondence articles appear analyzing Sheppard's work and the operations of an oil company by geologist H. G. Busk [90,91]. In this same period, the development of research by Ecuadorian universities continues, presenting studies from the

National Polytechnic School through its researchers E. Grossmann and E. Hiedemann [92] and F. L. Hahn [93–96], in the areas of physics and chemistry, respectively. In 1937, the first investigation was carried out with the private company collaboration, Central Valdez (currently known as Ingenio Valdez) [97].

In the decade of the 40s, the research continues, with the publication of the 'Escuela Politécnica del Litoral (EPN)' in the chemistry area [98], the 'Universidad Central del Ecuador (UCE)' in the area of medicine [99] and the 'Universidad de Loja' in the area of chemistry [100]. Other studies related to entomology [101] and geography [102], by the International Ecuadorian Petroleum Company and the American College of Quito, respectively.

In the 50s, the private company with LIFE Laboratories (1952–1953) reappeared [103,104]. In addition, the Laboratories of Tropical Medicine (1952) [105], Ecuadorian Center for Entomological Research (1952) [106], 'Instituto Nacional de Nutrición del Ecuador' (1953) [107], the 'Hospital Eugenio Espejo' (1955) [108] and the 'Universidad Central del Ecuador' (1958–1959) [109,110].

Since the 60s, there has been a notable increase in scientific production with 34 documents (see Figure 2). The new contributors are the 'Fundación Charles Darwin' (1961) [111], the 'Instituto Leopoldo Izquieta Pérez' (1961–1962) [112,113], the 'Universidad de Cuenca' (1967) [114], the 'Hospital Luis Vernaza' and the 'Hospital de Seguridad Social' (1969) [115], and the 'Instituto Nacional de Pesca' (1969) [116].

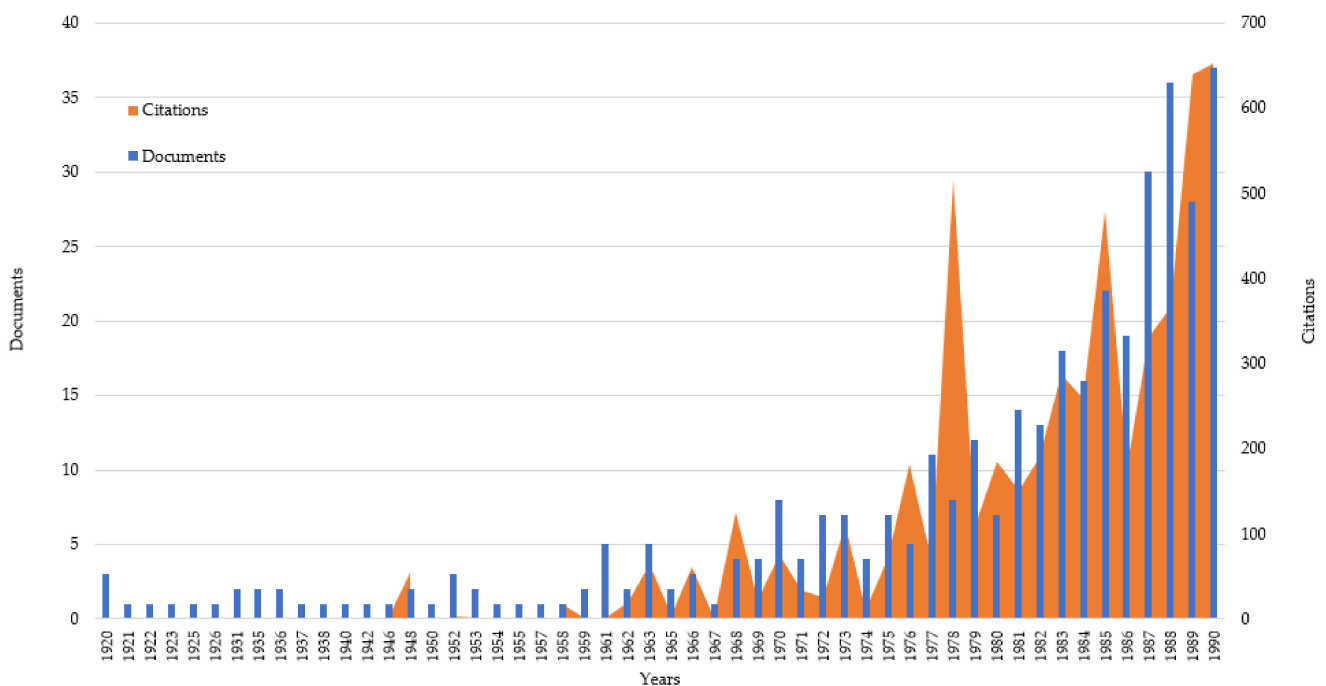


Figure 2. Scientific production of Ecuador (1920–1990).

In the 70s, scientific production continued to increase (72 documents) with the contribution of the 'Universidad de Cuenca', the 'Universidad Central del Ecuador', the 'Escuela Politécnica Nacional' and 'Fundación Charles Darwin'. The 'Escuela Superior Politécnica del Litoral' [117], the 'Pontificia Universidad Católica del Ecuador' [118], the 'Instituto Nacional de Investigaciones Agropecuarias' [119], and the 'Hospital Vos Andes' [120].

In the 80s, there were essential changes in the Higher Education system. In 1982, the 'Consejo Nacional de Universidades y Escuelas Politécnicas' (CONUEP) was created. This body provided the first public budget for research in the universities [121]. It allowed 233 documents to be published in this period.

It is necessary to consider that at this stage (1920–1990), the Ecuadorian university was focused on teaching existing knowledge rather than its creation; due to a poor legal framework and late government budget allocation for research and development [23,122]. The scientific production of this stage can be observed in greater detail in Figure 2.

Second Development Stage (1991–2020)

This period marks an exponential growth in Ecuador’s scientific production, registering 29,833 documents, equivalent to more than 98% of total production (see Figure 3).

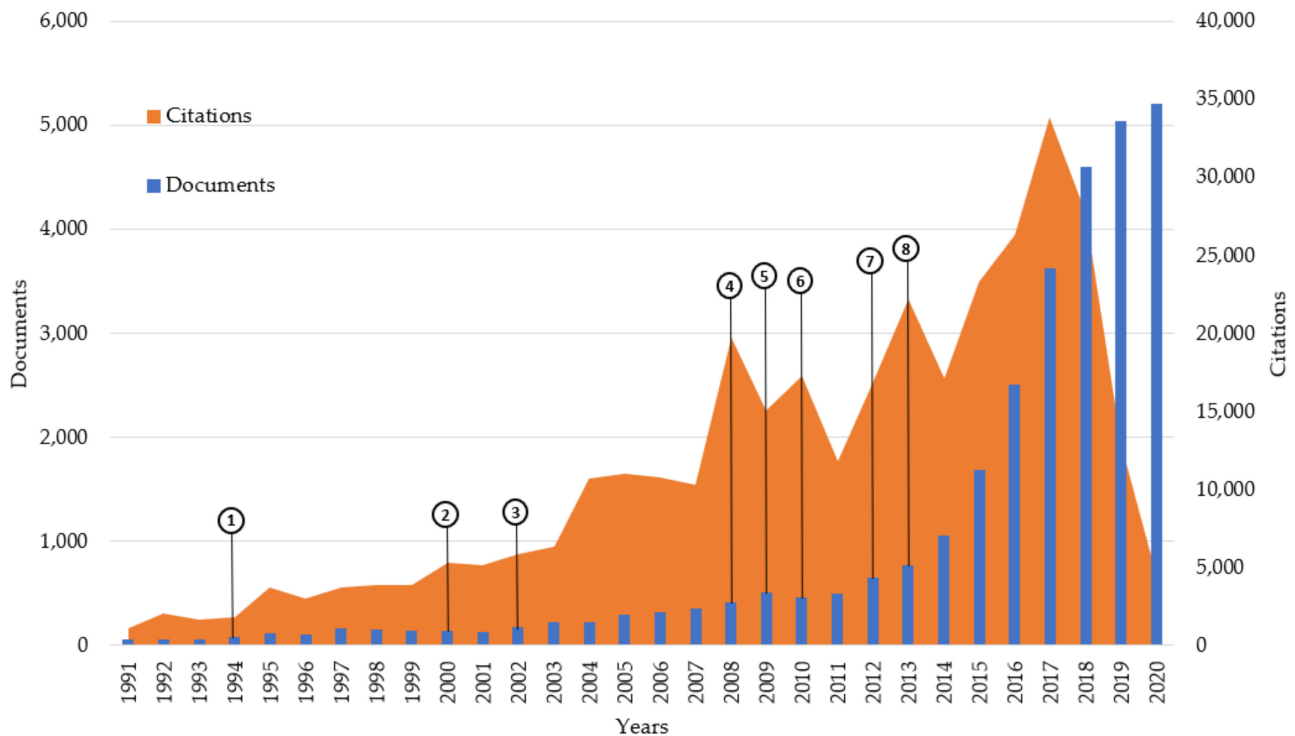


Figure 3. Scientific production of Ecuador (1991–2020). Milestones: 1. SENACYT and FUNDACYT creation; 2. LOES and CONESUP creation; 3. CONEA creation; 4. New Constitution; 5. Mandate 14 and its results; 6. New LOES, CEAACES and SENESCYT creation; 7. Evaluation of category “E” universities and ‘Reglamento de Escalafón Docente’; 8. Evaluation of venues and extensions, universities, and the ‘proyecto Prometeo’.

In the 1990s, educational reforms of the country’s legal framework continued. In 1994, the ‘Consejo Nacional de Ciencia y Tecnología’ (CONACYT) was abolished and later, the ‘Secretaría Nacional de Ciencia y Tecnología’ (SENACYT) and the ‘Fundación Nacional de Ciencia y Tecnología’ (FUNDACYT) were created [123]. In 2000, the ‘Ley Orgánica de Educación Superior’ (LOES) was created to guarantee the right to quality higher education. This body plan regulates and coordinates the higher education system [124]. In 2000, LOES replaced CONUEP with the ‘Consejo Nacional de Educación Superior’ (CONESUP) to provide financial resources in research projects and works.

In the 2000s, the course was charted for changes in the higher education system. In 2002, the “Consejo Nacional de Evaluación y Acreditación de la Educación Superior del Ecuador” (CONEA) was created to evaluate and ensure the quality of universities. This legal body considers scientific research in its evaluation processes for university accreditation. In 2008, the “Asamblea Constituyente” established a new constitution where the “Sistema Nacional de Ciencia, Tecnología, Innovación y Saberes” is created (art. 385 and 388) [125] and establishes the constituent mandate # 14. This mandate assesses the performance of 71 universities, which ended with the closure of fourteen universities due to poor quality [126]. In 2010, a new “Ley Orgánica de Educación Superior” (LOES) was created. This law abolishes CONESUP, CONEA and SENACYT, replacing them with the “Consejo de Evaluación, Acreditación y Aseguramiento de la Calidad de la Educación Superior” (CEAACES) and the “Secretaría Nacional de Educación, Ciencia, Tecnología e Innovación” (SENESCYT) [121]. The first, CEAACES, is in charge of executing the constitutional and legal provisions to guarantee the quality of university education.

The second, SENESCYT, promotes the training of human talent and the development of research.

In the 2010s, a considerable increase in scientific research begins (84.96%). During this period, the new control bodies carry out a series of evaluations and issuance of regulations that regulate the support of higher education [127]. Those who carried out a series of evaluations: universities in category “E” (2012), headquarters and extensions (2013), and universities (2013). About the regulations, the “Reglamento del Escalafón Docente” (2012) and the “Reglamento de Régimen Académico” (2013) that require publications from teachers of academic institutions came into force [128,129].

Additionally, the organizations carried out projects to strengthen scientific research, such as the “Proyecto Prometeo”, which was carried out between 2013 and 2017. Eight hundred forty-eight foreign researchers participated in this project, in which there was a production of more than 400 documents (indexed in the Scopus database) [21].

Finally, in this boom in scientific production, other additional elements were incorporated, such as the appearance of new universities (33), the use of international rankings to measure the university’s academic reputation in the national and international context, and ease of access databases.

Based on the statistical data of the scientific production of Ecuador, more detailed analyzes are generated: type of documents, languages, subject area, contribution of countries and analysis of author keywords, which are exhibited below.

3.1.2. Language Types

In the various areas of knowledge, the English language is predominant due to its relevance in the scientific community as the common link of international collaboration [130,131]. Scientific publications in Ecuador present a similar pattern, representing 80.7% in the English language. The second language that has been published the most is Spanish (16.5%). Other languages presented for studies are Portuguese, French, German, Italian, Russian, Chinese, Czech, Georgian, Korean, Polish, and Catalan.

This prominence of languages needs to be examined as a function of time. Figure 4 shows the first stage of development (1920–1990) and the second stage (1991–2020), the latter divided into decades. The English language shows its majority presence in all periods (over 76%), with a peak of publications in the 2000s. The Spanish language lost prominence in this same decade, resuming with force (the 2010s) due to an unusual increase in Spanish-speaking journals (e.g., *Risti Revista Iberica de Sistemas e Tecnologias de Informacao*; *Espacios*; *Investigación Clínica Venezuela*; *Archivos Venezolanos de Farmacología y Terapéutica*; *Revista Ecuatoriana de Neurología*; *Revista Bionatura*, among others).

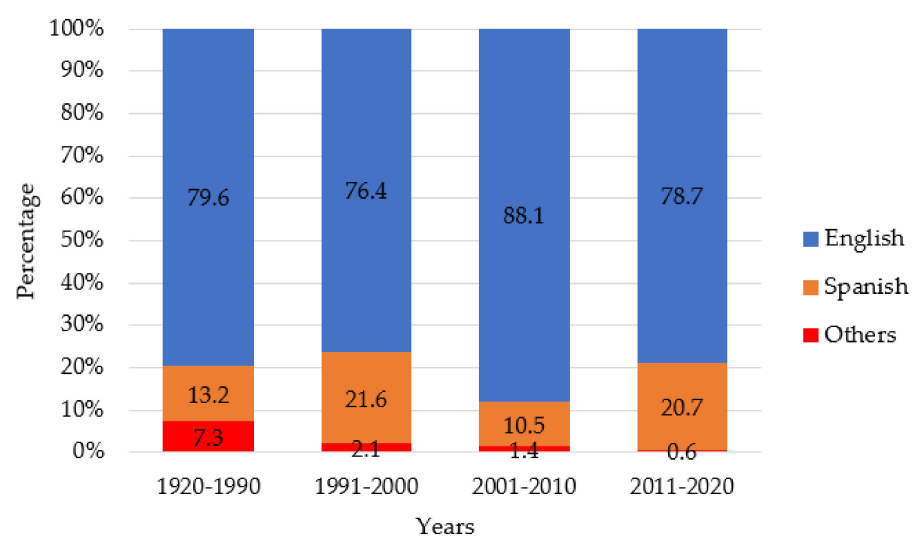


Figure 4. Language types used in Ecuadorian scientific production.

3.1.3. Documents Type

Scientific production has been reflected in 11 document types (see Figure 5). Journal articles are the majority (68.8%) because these are documents considered certified knowledge when examined by peer review and significant for the scientific community [42,132]. The conference articles are also representative (22.01%). However, the country entered this type of publication in 1989 [133], and its significant growth began in 2013.

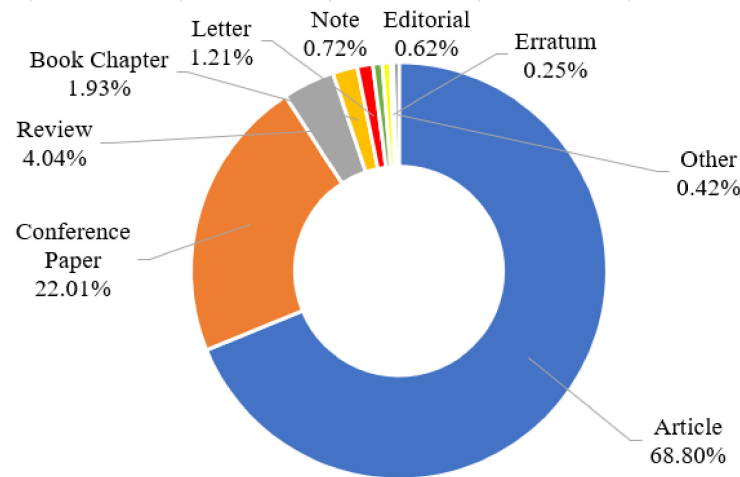


Figure 5. Document types.

3.1.4. Subject Areas

Ecuador has made contributions in 27 subject areas (see Figure 6). The areas with the highest contribution are 'Computer Science' (12.7%), followed by 'Agricultural and Biological Sciences' (11.3%) and 'Medicine' (11.2%). Other minor ones comprise 14.2%: Chemistry; Materials Science; Pharmacology, Toxicology and Pharmaceutics; Arts and Humanities; Neuroscience; Chemical Engineering; Multidisciplinary; Economics, Econometrics and Finance; Veterinary; Psychology; Nursing; Health Professions, and Dentistry.

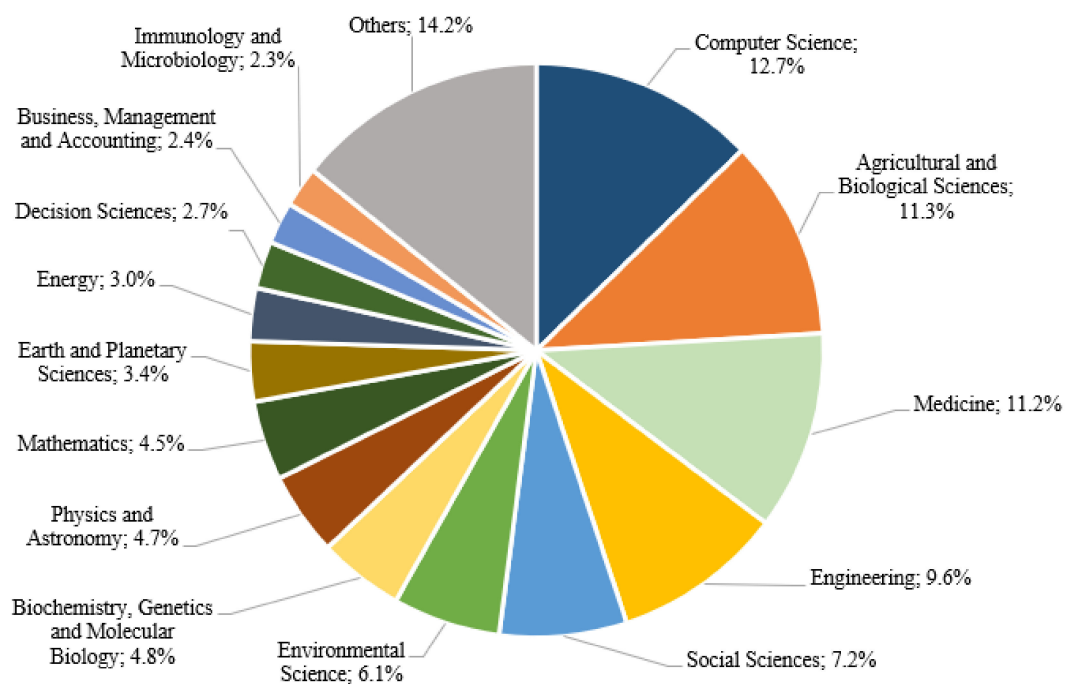


Figure 6. Main subject areas.

Figure 7 shows the ten main subject areas of Ecuador’s research analysis. This analysis allows us to know their current vital areas and how they have evolved.

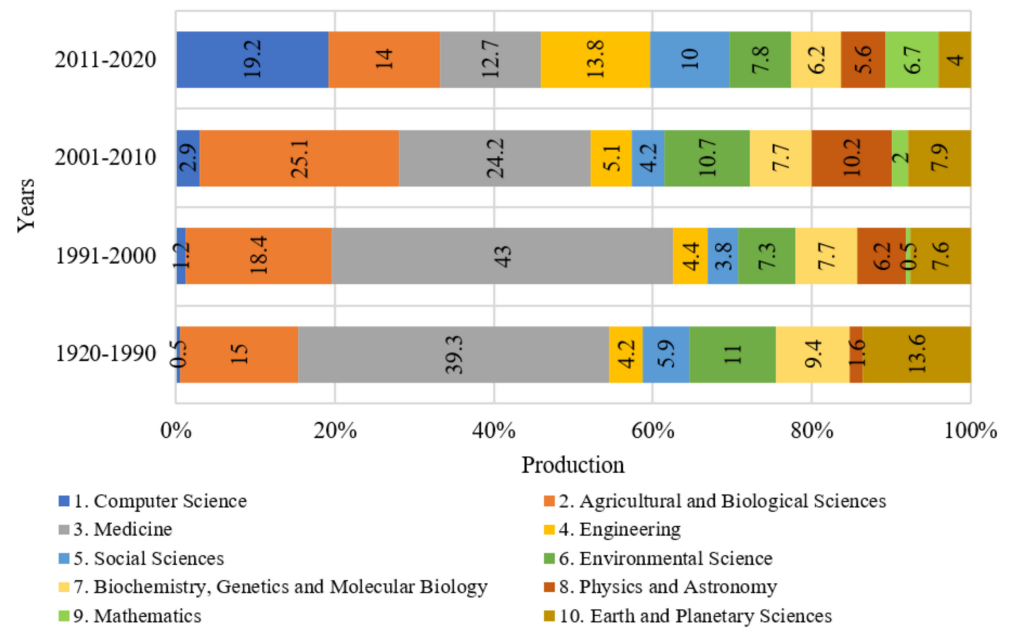


Figure 7. Top 10 of main subject areas.

Table 1 shows the five main authors in the top ten thematic areas of scientific research in Ecuador. The thematic areas in which Ecuadorian authors predominate are Agricultural and Biological Sciences, Environmental Sciences, Mathematics, and Earth and Planetary Sciences. Table S3 (in Supplementary Materials) contains information on these areas in the last ten years.

Table 1. Top 5 of authors in main subject areas.

| No. | Subject Areas | Authors | Actual Affiliation | Country | Documents | H-Index |
|-----|--------------------------------------|---------------------|---|-----------|-----------|---------|
| 1 | Computer Science | Andaluz, V.H. | Universidad de las Fuerzas Armadas (ESPE) | Ecuador | 118 | 14 |
| | | Guarda, T. | Universidad Estatal Península de Santa Elena (UPSE) | Ecuador | 95 | 4 |
| | | Aguilar, J. | Universidad Regional Autónoma de los Andes (UNIANDES) | Venezuela | 84 | 21 |
| | | Luján-Mora, S. | Universitat d’Alacant | Spain | 82 | 19 |
| | | Robles-Bykbaev, V. | Universidad Politécnica Salesiana (UPS) | Ecuador | 76 | 7 |
| 2 | Agricultural and Biological Sciences | Greeney, H.F. | Yanayacu Biological Station | Ecuador | 133 | 13 |
| | | Guayasamin, J.M. | Universidad San Francisco de Quito (USFQ) | Ecuador | 80 | 25 |
| | | Torres-Carvajal, O. | Pontificia Universidad Católica del Ecuador (PUCE) | Ecuador | 63 | 20 |
| | | Valencia, R. | Pontificia Universidad Católica del Ecuador (PUCE) | Ecuador | 63 | 39 |
| | | Dangles, O. | Université de Montpellier | France | 61 | 35 |

Table 1. Cont.

| No. | Subject Areas | Authors | Actual Affiliation | Country | Documents | H-Index |
|-----|--|---------------------|--|---------------|-----------|---------|
| 3 | Medicine | Del Brutto, O.H. | Universidad Espíritu Santo (UEES) | Ecuador | 315 | 49 |
| | | Chedraui, P. | Universidad Católica de Santiago de Guayaquil (UCSG) | Ecuador | 178 | 37 |
| | | Cooper, P.J. | Universidad Internacional del Ecuador (UIDE) | Ecuador | 124 | 47 |
| | | Mera, R.M. | Gilead Sciences Incorporated | United States | 114 | 36 |
| | | Pérez-López, F.R. | Universidad de Zaragoza | Spain | 105 | 35 |
| 4 | Engineering | Parashar, N. | Purdue University Northwest | United States | 74 | 122 |
| | | Wood, D. | Northeastern University | United States | 74 | 126 |
| | | Aarrestad, T.K. | European Organization for Nuclear Research | Switzerland | 73 | 67 |
| | | Abbaneo, D. | European Organization for Nuclear Research | Switzerland | 73 | 117 |
| | | Abbiendi, G. | Alma Mater Studiorum Università di Bologna | Italy | 73 | 120 |
| 5 | Social Sciences | Luján-Mora, S. | Universitat d'Alacant | Spain | 56 | 19 |
| | | Piedra, N. | Universidad Técnica Particular de Loja (UTPL) | Ecuador | 39 | 12 |
| | | Chicaiza, J. | Universidad Técnica Particular de Loja (UTPL) | Ecuador | 27 | 11 |
| | | Ochoa, X. | NYU Steinhardt | United States | 25 | 15 |
| | | Robles-Bykbaev, V. | Universidad Politécnica Salesiana (UPS) | Ecuador | 23 | 7 |
| 6 | Environmental Science | Dangles, O. | Université de Montpellier | France | 34 | 35 |
| | | Valencia, R. | Pontificia Universidad Católica del Ecuador (PUCE) | Ecuador | 31 | 39 |
| | | Céleri, R. | Universidad de Cuenca (UCUENCA) | Ecuador | 28 | 22 |
| | | Gómez-Salgado, J. | Universidad Espíritu Santo (UEES) | Ecuador | 28 | 12 |
| | | Crespo, P. | Universidad de Cuenca (UCUENCA) | Ecuador | 26 | 19 |
| 7 | Biochemistry, Genetics and Molecular Biology | Chedraui, P. | Universidad Católica de Santiago de Guayaquil (UCSG) | Ecuador | 88 | 37 |
| | | Paz-y-Miño, C. | Universidad Tecnológica Equinoccial (UTE) | Ecuador | 63 | 19 |
| | | Pérez-López, F.R. | Universidad de Zaragoza | Spain | 50 | 35 |
| | | Guevara-Aguirre, J. | LifeLabs | Canada | 44 | 32 |
| | | López-Cortés, A. | Universidad Tecnológica Equinoccial (UTE) | Ecuador | 39 | 13 |

Table 1. Cont.

| No. | Subject Areas | Authors | Actual Affiliation | Country | Documents | H-Index |
|-----|------------------------------|-----------------------|---|---------------|-----------|---------|
| 8 | Physics and Astronomy | Beri, S.B. | Panjab University | India | 952 | 123 |
| | | Lincoln, D. | Fermi National Accelerator Laboratory | United States | 951 | 117 |
| | | Ruchti, R. | University of Notre Dame | United States | 951 | 124 |
| | | Varelas, N. | University of Illinois at Chicago | United States | 951 | 125 |
| | | Wayne, M. | University of Notre Dame | United States | 951 | 124 |
| 9 | Mathematics | Andaluz, V.H. | Universidad de las Fuerzas Armadas (ESPE) | Ecuador | 81 | 14 |
| | | Camacho, O. | Escuela Politécnica Nacional (EPN) | Ecuador | 53 | 15 |
| | | Peluffo-Ordóñez, D.H. | Universidad Yachay Tech (YACHAYTECH) | Ecuador | 41 | 11 |
| | | Aguilar, W.G. | Universidad de las Fuerzas Armadas (ESPE) | Ecuador | 35 | 16 |
| | | Robles-Bykbaev, V. | Universidad Politécnica Salesiana (UPS) | Ecuador | 33 | 7 |
| 10 | Earth and Planetary Sciences | Toulkeridis, T. | Universidad de las Fuerzas Armadas (ESPE) | Ecuador | 54 | 21 |
| | | Mothes, P. | Escuela Politécnica Nacional (EPN) | Ecuador | 46 | 27 |
| | | Ruiz, M. | Escuela Politécnica Nacional (EPN) | Ecuador | 41 | 21 |
| | | Samaniego, P. | Université Clermont Auvergne | France | 37 | 22 |
| | | Yepes, H. | Escuela Politécnica Nacional (EPN) | Ecuador | 35 | 25 |

Although the areas of Computer Science, Agricultural and Biological Sciences, and Medicine are the largest areas of research in the country, they have evolved differently over time.

- *Computer Science* showed little contribution in 1920–1990 and regularly grew until 2001–2010 (2.9%). However, between 2011 and 2020, it grew exponentially, reaching 19.2% of the publications of the decade and placing this subject area as the most important in the country's scientific production. The development of this area is mainly due to the research disclosed in international conferences (over 70%) and the strong participation of the 'Universidad de las Fuerzas Armadas', 'Escuela Politécnica Nacional (EPN)', 'Escuela Superior Politécnica del Litoral (ESPOL)', 'Universidad Politécnica Salesiana' and 'Universidad Técnica Particular de Loja (UTPL)', who together represent approximately 47% of the publications. The research that presents the most citations in this area (562 citations) corresponds to a conference article by Rafael Fierro (ex EPN and is currently affiliated with The University of New Mexico). This document deals with a control structure implemented in nonholonomic mobile robots [134].
- *Agricultural and Biological Sciences*, an area that showed sustained growth until 2001–2010 and presented a decrease in the following decade (14%). However, the type of document that supports this area of research journals articles (greater than 88%), presented mainly by the 'Pontificia Universidad Católica del Ecuador (PUCE)', 'Universidad San Francisco de Quito (USFQ)', 'Escuela Superior Politécnica del Litoral (ESPOL)', 'Universidad Técnica Particular de Loja (UTPL)', and 'Escuela Politécnica Nacional (EPN)'. These universities represent 35.7% of the total. In this area, the most cited study corresponds to the work "GST and its relatives do not measure differentiation" with 1770 citations [135].

- *Medicine* is the third most important area in the country's publications. However, its global contribution has decreased in recent decades, standing in the 2011–2020 period at 12.7%. The universities that have contributed the most in this area are 'Universidad Central del Ecuador (UCE)', 'Universidad Espíritu Santo (UESS)', 'Universidad San Francisco de Quito (USFQ)', 'Pontificia Universidad Católica del Ecuador (PUCE)' and 'Universidad Católica de Santiago de Guayaquil (UCSG)', representing 34.4% of the total. The study that has received the most citations in this area corresponds to researcher Marcos Serrano's current affiliation to PUCE (4480 citations). In this study, the researcher is the co-author of an international classification on disorders related to headaches [136].
- *Engineering* is a subject area that has shown a considerable increase in the last decade (13.8%). Research in this area has been presented mainly in conference articles (58%) and journal articles (37%). The main contributors are 'Escuela Politécnica Nacional (EPN)', 'Escuela Superior Politécnica del Litoral (ESPOL)', 'Universidad de las Fuerzas Armadas (ESPE)', 'Universidad Politécnica Salesiana' and 'Universidad San Francisco de Quito (USFQ)'. One of the most cited documents corresponds to Claudio A. Cañizares (ex EPN and currently belongs to the University of Waterloo) [137].
- *Social Science*, whose studies have mainly appeared journal articles (70%) with a strong contribution from the 'Escuela Superior Politécnica del Litoral (ESPOL)', 'Universidad Técnica Particular de Loja (UTPL)', FLACSO Ecuador, 'Universidad de Cuenca' and 'Escuela Politécnica Nacional (EPN)'. The outstanding work corresponds to "Elevation-dependent warming in mountain regions of the world" (967 citations) [138] by E. Cáceres who is co-author of the work with affiliation to the 'Instituto Nacional de Meteorología e Hidrología (INAMHI)'.
- *Other subject areas* in the 2011–2020 decade present a contribution of less than 10% of the total scientific production (see Figure 7). These areas correspond to Environmental Science; Biochemistry, Genetics and Molecular Biology; Physics and Astronomy; Mathematics; and Earth and Planetary Sciences.

3.1.5. Co-Authorship by Countries Analysis

The analysis of co-authorship by countries allows the determination of the pattern of collaboration between researchers according to the country that represents it [68,139]. A bibliometric map is constructed using the VOSviewer software to carry out this analysis, considering the countries with at least 20 documents. Figure 8 shows the scientific contributions made by Ecuador in 84 countries. Most of the collaboration is related to Spain, the United States, Brazil, Colombia, and the United Kingdom. Other countries that collaborate with Ecuador are shown in the earlier mentioned figure.

Spain (purple colour) is Ecuador's main scientific collaborator with 5660 documents, emphasising Computer Science, Engineering, Physics and Astronomy, Medicine, Agricultural and Biological Sciences, Social Sciences and Environmental Science. This production focuses on universities (i.e., 'Universidad Autónoma de Madrid', 'Universidad de Oviedo' and 'Universidad de Cantabria'), institutes (i.e., 'Instituto de Física de Cantabria') and research centers (i.e., 'Center for Energy, Environmental and Technological Research').

The United States (yellow colour) with 5504 documents, has the majority of collaboration in Agricultural and Biological Sciences; Medicine; Physics and Astronomy; Environmental Science; Biochemistry, Genetics and Molecular Biology; Engineering; and Social Sciences. In contribution to the University of Kansas, Brown University, Northeastern University, Northwestern University, University of Nebraska–Lincoln, University of California–Riverside, and the University of Illinois at Chicago.

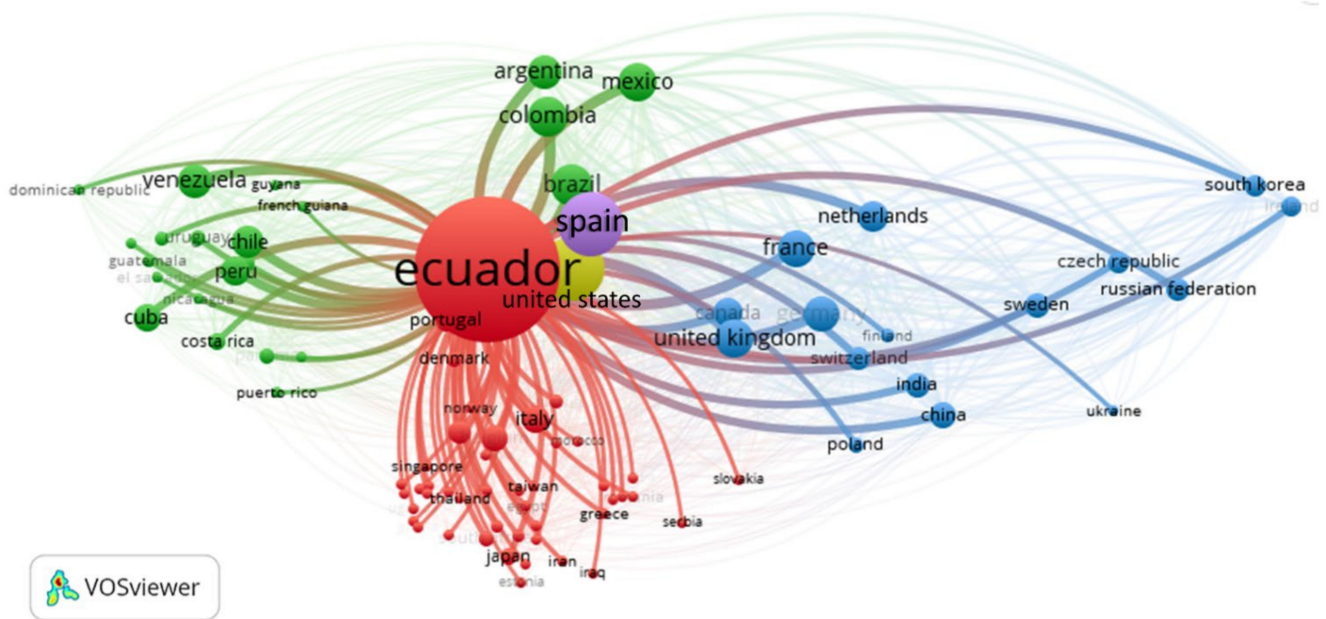


Figure 8. Countries co-authorship Network.

Brazil presents 2166 documents in co-authorship with Ecuador in the areas of Physics and Astronomy; Medicine; Agricultural and Biological Sciences; Environmental Science; Engineering; Biochemistry, Genetics and Molecular Biology; and Computer Science. In collaboration with 'Universidade do Estado do Rio de Janeiro', 'Universidade Estadual Paulista Júlio de Mesquita Filho', 'Universidade Federal do ABC', 'Universidade Estadual de Campinas', and 'Centro Brasileiro de Pesquisas Físicas'.

Colombia, with 2012 documents, presents most of the research in Physics and Astronomy; Medicine; Agricultural and Biological Sciences; Computer Science; Engineering; Biochemistry, Genetics and Molecular Biology; and Environmental Science. These research works are mostly in collaboration with the 'Universidad de Los Andes', 'Universidad Nacional de Colombia', 'Universidad de Antioquia', 'Pontificia Universidad Javeriana', and 'Universidad del Valle'.

The United Kingdom presents greater collaboration in the subject areas of Physics and Astronomy; Medicine; Agricultural and Biological Sciences; Environmental Science; Engineering; Biochemistry, Genetics and Molecular Biology; and Earth and Planetary Sciences. The main participants in these investigations are Imperial College London, University College London, University of Oxford, the University of Cambridge, and the University of Bristol.

Figure 8 shows five clusters and nodes representing each of the 84 countries that collaborate scientifically with Ecuador. The central and the biggest node is the red one, where 'Ecuador' is the main keyword. The yellow (United States) and purple (Spain) clusters are closely related to this largest node. Followed by the green and blue cluster described below.

The green cluster is the closest group to the central cluster, that is, shows the contributions with most Latin American countries, distinguishing those that present a high relationship, such as Brazil (2166), Colombia (2012), Mexico (1855), Argentina (1425), and Venezuela (1386). The nodes that make up the red cluster show less collaboration from other European, Asian, and African countries, which can be observed in the size of their nodes and links.

The blue and red clusters show a significant international contribution between some European and Asian countries. However, the blue cluster stands out for its substantial contribution to the cluster network. This is verified with the width of the connection lines (link strength) of the countries with Ecuador. That is, the wider the line, the greater

the relationship between the nodes. In the blue cluster, the most significant contribution is reflected with the United Kingdom with 1938 documents, followed by France (1715), Germany (1631), Netherlands (1154), China (849), India (716), Sweden (666), and Russia (596). While, in the cluster network, the contribution of countries such as Italy (953), Australia (581), Belgium (825), Japan (294), and South Africa (217) stands out.

3.1.6. Intellectual Structure of Scientific Production

When examining the intellectual structure, the author keywords co-occurrence analysis is required. This analysis consists of constructing a network of terms (author keywords) that appear more frequently in the field of study [73,140]. The network is a visual map that determines the cognitive structure, the thematic groups (clusters) and topics (author keywords), which are related [67,141]. The VOSviewer software generates this visual representation.

In the network generation, 59,847 author keywords were established, and the words that have a co-occurrence of at least ten times were chosen, obtaining a selection of 1213 words. The software selects the most vital relationships (link strength), choosing the first 1000. The main keywords for each cluster are shown in Table 2.

Table 2. Author keywords clusters.

| Cluster | Cluster Name | Colour | Main Author Keywords |
|---------|---|-------------|---|
| 1 | Biology and regional climate change | Red | Andes, taxonomy, south america, galapagos, conservation, climate change, biodiversity, new species, amazon |
| 2 | Higher education and its various approaches | Green | Latin america, higher education, education, social network, sustainability, university, innovation, ict, management, communication |
| 3 | Technology and Computer Science | Blue | Internet of Things (IoT), machine learning, model, data mining, optimization, virtual reality, monitoring, artificial intelligence, smart grid, fuzzy logic |
| 4 | Medicine | Yellow | epidemiology, risk factor, children, obesity, covid-19, pregnancy, diagnosis, population-based study, prevalence, menopause |
| 5 | Energy, food and water | Purple | essential oil, biomass, nutrition, growth, agriculture, water quality, antioxidant activity, nanoparticles, antioxidant, pesticides |
| 6 | Development and applications on the Web | Light blue | learning, cloud computing, accessibility, mobile application, usability, evaluation, e-learning, learning analytics, security, semantic web |
| 7 | Multidisciplinary | Orange | gis, incidence, aedes aegypti, banana, consumption, dengue, guayaquil, spatial analysis, income, weight |
| 8 | Physics and its applications | Brown | hadron-hadron scattering, cms, physics, beyond standard model, higgs physics, supersymmetry |
| 9 | Parasitic diseases | Violet | neurocysticercosis, cysticercosis, chagas disease, epilepsy, taenia solium, trypanosoma cruzi |
| 10 | Tourism and Gastronomy | Pink | tourism, motivation, segmentation, satisfaction, ecotourism, gastronomy |
| 11 | Native Forest | Light green | cloud forest, egg, behavior, nest, nestling, natural history |
| 12 | Allergic and Tropical Diseases | Bluish lead | asthma, tropics, atopy, geohelminths, rural, allergy |

Based on the number of co-occurrences, the clusters were analyzed in order of importance:

- Cluster 1 “Biology and regional climate change” (red colour), presents 184 keywords (18,4% of the total). This cluster focuses on various topics related to biodiversity in the national territory (especially in the Andes, Galapagos, and Amazonia) and the resulting impact of climate change. Some researchers have considered these effects on biodiversity [142,143], on the biological quality of water in rivers and lakes [144–146], soil moisture deficit [147], land use and land cover [148–150]. As well as the retreat of the glaciers, the decline of snow and ice in the Andes [151–153]. Other authors have studied its forests and their diversity [154], freshwater ecosystems [155], as well as the discovery of new species [156–163]. Due to the importance of the Galapagos Islands,

water security and water quality have been studied [164–166], the impact on fishery resources [167,168], damage caused by plastic waste [169], the effects on the soils of complex agrosystems [170] and air quality [171].

- Cluster 2 “Higher education and its various approaches” (green colour). It is the second-largest group with 179 keywords that corresponds to 17.9% of the total. The cluster relates the various investigations of the country with Latin America on issues related to higher education [172–176]. Acosta-Vargas et al. [177] presented the process of building a dataset to evaluate the accessibility of 368 university websites in Latin America. A study proposed a teacher training model linked to responsible consumption in Ecuadorian primary education [178]. On the other hand, the focus of research on sustainability has gained relevance in recent years [179–181].
- Cluster 3, “Technology and Computer Science” (blue colour), contains 169 keywords (16.9%). This cluster features technological and developmental research in computer science. Technological innovation in this cluster stands out as it is related to cloud computing, information systems and digital technologies, topics that were decisive for the development or production of the Internet of Things (IoT), over the last two decades [182,183]. However, data processing needed analytical power, leading to the generation of studies related to Big Data, becoming an increasingly challenging area [184]. On the other hand, this innovation has allowed computational sciences to strengthen control and access activities in various fields, such as environmental control. [185], electricity consumption [186], telemedicine [187], hydraulic systems, autonomous underwater vehicle [188] and agricultural production [189,190].
- Cluster 4, “Medicine” (yellow colour). The cluster presents a set of 153 keywords (15.3% of total). Epidemiology-related studies stand out, highlighting risk factors, obesity, and current issues such as covid-19. In Latin America, there are mainly epidemiological problems [191–194]. Physical inactivity in Ecuador is the highest reported worldwide and ranks fifth as a risk factor for mortality [195,196], obesity [197,198] and COVID-19 [199–201].
- Cluster 5, “Energy, food and water” (purple colour). This fifth group represents a connection of 128 nodes (12.8%). The main topics in this cluster are essential oil [202,203], agriculture [204–206], and water quality [144,207]. In essential oils, these substances are in great demand worldwide as they can be used without modification due to their different chemical and biological properties, including as natural sources of chemical compounds [208,209]. Concerning water quality, a study calculated two biotic indices to evaluate water quality with an ecological approach in the Guayas river basin, Ecuador [210]. Finally, oil palm cultivation is important in Ecuador’s agricultural sector because it generates sources of employment in some of the most vulnerable areas and contributes 4.35% of the agricultural gross domestic product [211].
- Cluster 6, “Development and applications on the Web” (light blue colour). It is made up of 118 nodes that represent 11.8% of words on the map. In Latin America and the world, the Web has evolved significantly during the last decade, becoming a main source of information, knowledge and research [212]. In Ecuador, the development of web applications has been developed for the benefit of society, such as websites of state entities (Geo-MOOC, WCAG 2.0) [213], website accessibility [214], educational websites [215,216] and models for quality evaluation in higher education [217,218].
- Cluster 7, “Multidisciplinary” (orange colour). The cluster contains several disciplines supporting other clusters. The cluster contains various disciplines existing in Ecuador that support other clusters (red, green, blue, and purple), with a total of 18 topics. The main studies are focused on simulation systems [219], analysis of Handytec Company [220], Collective Spatial analysis [221], dengue detection system [222], spatial distribution system [223], social-ecological analysis of dengue [224], disease control surveys [225] and livestock activities [226–228].
- Cluster 8, “Physics and its applications” (brown colour). It is made up of 13 nodes that comprise 1.3% of the total terms of the structure. It is located at the extreme

right of Figure 9. This cluster does not connect with the rest of the clusters because its area of knowledge is particular and does not require input from the other areas. Publications in this cluster are related to physics and the study of hadrons, Compact Muon Solenoid (CMS) y Higgs Boson. For the former, with studies related to its types: baryons [229,230], mesons [231,232], as well as its use Hadronic final states [233], Bose-Einstein correlations of charged hadrons [234] Finally, Quark and antiquark [235,236]. Studies have been carried out in the experiments related to CMS to analyse the Higgs Boson, concerning its production [237,238], measurement of mass, decay, neutrality [239,240] and dark matter particles [241,242].

- Cluster 9, “Parasitic diseases” (violet colour). This cluster contains 13 nodes. The publications related to Neurocysticercosis and Chagas disease, caused by the parasites *Taenia Solium* and *Trypanosoma cruzi*, respectively. Studies for the former have established criteria for its diagnosis [243–245]; it has been determined that it produces antibodies if it is extraparenchymal [246], treatments [247,248] and other studies of a general nature [249,250]. Regarding Chagas disease, its life cycle [251,252], alterations it generates in the human body [253], treatments [254] and controls [255] have been considered.
- Cluster 10, “Tourism and Gastronomy” (pink colour). The studies in this cluster are related to the development of tourism in diverse themes such as Coastal marine destinations [256], 3S (sea sun and sand) [257], Mining sites [258], Geoparks [259], protected areas [260], Heritage tourism [261], Eco-tourism [262,263], Community tourism [264,265] and Religious tourism [266]. Gastronomy is considered part of Ecuadorian cultural identity [267,268], considering the contributions on Food Tourism [269,270], indigenous food cultures [271], and gastronomic routes [272].
- Cluster 11, “Native Forest” (light green colour) and includes 9 nodes. In this cluster, topics such as cloud forest [273–275] and natural history mainly stand out [276,277]. In Ecuador, when about 13% of mining concessions were opened with protected forest areas, the threat of extinction of part of the country’s biodiversity became evident [278]. In terms of natural history, the investigation of Human Papillomavirus (HPV) infections has not been thoroughly studied. Previous studies have focused on the age group with the highest prevalence and incidence of VPH [279].
- Cluster 12, “Allergic and Tropical Diseases” (bluish lead colour), has a total of 7 nodes. This cluster presents studies related to helminth parasites, whose relative factor is allergic diseases in humans, mainly in tropical climates. In Ecuador, these infections affect rural areas in tropical environments [280] and disadvantaged urban populations [281]. However, studies have been carried out on protection against helminths, which is an advantage in combating these allergic diseases [282,283].

Figure 9 shows the bibliometric map of keyword co-occurrence that corresponds to the intellectual structure of scientific production, composed of 12 clusters, 1000 nodes (author keywords) and 12,812 relationships between nodes.

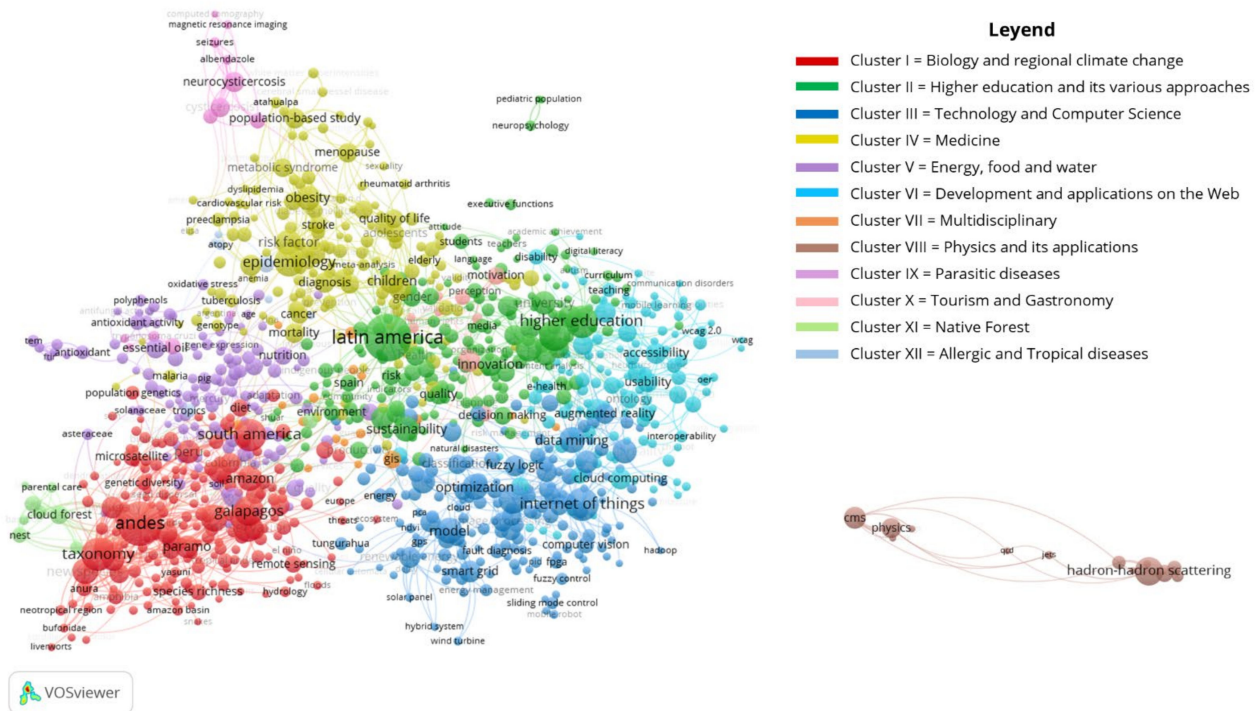


Figure 9. Map of co-occurrence author keywords of the Ecuador universities scientific publications.

3.2. Scientific Production of Universities

3.2.1. Total Production

In Ecuador, 59 universities are accredited, where 44 universities present scientific publications indexed in Scopus (see Figure 10). The total production by Higher Education institutions until 2020 is 28,796 documents, representing 95.3% of the country's publications.

- (a) *Production greater than 2000 scientific publications.* In Figure 10, it can be seen that three universities exceed this threshold: the 'Universidad San Francisco de Quito (USFQ)' (9.58% of total production), the 'Escuela Politécnica Nacional (EPN)' (8.89%), and the 'Escuela Superior Politécnica del Litoral Ecuador (ESPOL)' (7.49%). The combination of these institutions represents 25.96% of scientific publications. The 'Universidad de San Francisco de Quito (USFQ)' shows a strong presence in the subject areas of social sciences, agricultural and biological sciences, mathematics, environmental science, and energy. University that according to the QS World University Rankings of 2021 occupies the first place in the country, the position 65 in Latin America and worldwide it is between the positions 751–800. EPN shows a greater contribution in the areas of computer science, engineering, physics and astronomy, mathematics and earth and planetary sciences. This institution according to the QS World University Rankings of 2021, is located in second place nationally, in position 106 in Latin America and in the range of 1001 to 1200 worldwide. ESPOL presents an important scientific production in areas such as computer science, engineering, social sciences, agricultural and biological sciences, and mathematics. According to the QS World University Rankings of 2021, it ranks fourth nationally, 74th in Latin America and worldwide between 1001–1200.
- (b) *Production between 1501 and 2000 scientific publications.* Three universities represent 19.09% of this production. The 'University of the Armed Forces of Ecuador (ESPE)', 'Pontificia Universidad Católica del Ecuador (PUCE)', and 'Universidad Técnica Particular de Loja (UTPL)' are part of this group. These universities are in the QS World University Rankings of 2021, the PUCE (3rd place national, 109th Latin America and 1001–1200 worldwide), and the ESPE (6th place national, 191–200 Latin America and 1201+ worldwide).

- (c) *Production between 1001 and 1500 scientific publications.* Group made up of three universities: 'Universidad de Cuenca (UCUENCA)', 'Universidad Politécnica Salesiana (UPS)', and 'Universidad Central del Ecuador (UCE)'. These universities comprise 13.29% of the production. The UCE is the only university in this group located in the QS World University Rankings of 2021 (5th place national, 161–170 Latin America and 1001–1200 worldwide).
- (d) *Production between 501 and 1000 scientific publications.* The group makes up a total of eight universities (20.37%): 'Universidad de Guayaquil (UG)', 'Universidad de las Américas (UDLA)', 'Universidad Espíritu Santo (UEES)', 'Universidad Yachay Tech (YACHAYTECH)', 'Universidad Técnica de Ambato (UTA)', 'Universidad Católica de Santiago de Guayaquil (UCGS)', 'Universidad Tecnológica Equinoccial (UTE)', and 'Escuela Superior Politécnica de Chimborazo (ESPOCH)'.
- (e) *Production of less than 500 scientific publications.* In this group are most universities in Ecuador (27), representing 21.28% of total scientific research (see Figure 10). In this group is the 'Universidad Técnica del Norte (UTN)', 'Universidad Técnica de Manabí (UTM)', 'Universidad Tecnológica Indoamérica (UTI)', 'Universidad Nacional de Chimborazo (UNACH)', 'Universidad del Azuay (UDA)', 'Facultad Latinoamericana de Ciencias Sociales (FLACSO)', 'Universidad Técnica Estatal de Quevedo (UTEQ)', 'Universidad Estatal Amazónica (UEA)', 'Universidad Técnica de Machala (UTMACH)', 'Universidad Estatal Península de Santa Elena (UPSE)', 'Universidad Nacional de Loja (UNL)', 'Universidad Católica de Cuenca (UCACUE)', 'Universidad Laica Eloy Alfaro de Manabí (ULEAM)', 'Universidad Internacional del Ecuador (UIDE)', 'Universidad Regional Amazónica Ikiam (IKIAM)', 'Universidad Regional Autónoma de los Andes (UNIANDES)', 'Universidad Estatal de Milagro (UNEMI)', 'Universidad Técnica de Cotopaxi (UTC)', 'Universidad Internacional SEK Ecuador (UISEK)', 'Universidad Andina Simón Bolívar (UASB)', 'Universidad Estatal de Bolívar (UEB)', 'Universidad Nacional de Educación (UNAE)', 'Universidad Tecnológica Ecotec (ECOTEC)', 'Universidad Técnica de Babahoyo (UTB)', 'Universidad Tecnológica Israel (UISRAEL)', 'Universidad Metropolitana del Ecuador (UMET)', and 'Universidad del Pacífico (UPACÍFICO)'.

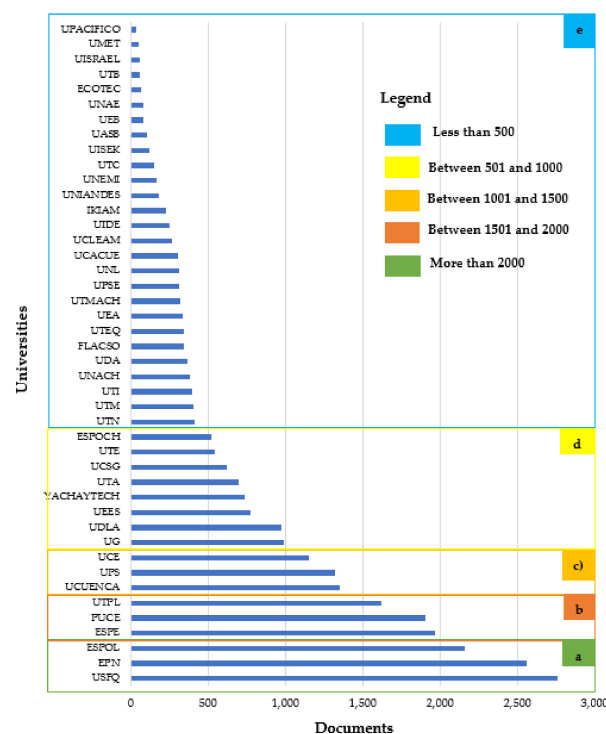


Figure 10. Universities total production.

3.2.2. Documents Published Type

The 44 universities have published scientific publications mainly in journal articles (67%) and conference articles (25.4%). Other documents (7.55%) include 'book', 'book chapter', 'review', 'letter', 'note', 'editorial', 'erratum', 'data paper', and 'short survey'.

Next, researchers proceed to indicate the universities in the country that have used this type of document:

- (a) *Journal articles*. The scientific production has been reflected in 5390 journals (a figure that includes those sources that do not currently register continuity in the Scopus database). Of this group of journals, 13 exceed 100 publications; 331 contain between 96 and 10 documents; 2297 between 9 and 2 documents; and 2749 journals show a single publication. Table S1 shows the top 25 journals most used by Ecuador, in which 3,886 documents have been published (14.1% of the total). Among the journals most used by the universities of Ecuador are 'Revista Ibérica de Sistemas e Tecnología de Información (RISTI)' (513 documents); 'Espacios' (511). These first two sources have a percentile lower than 25 (which corresponds to Q_4), and Espacios' journal discontinued Scopus in 2020. Locations three to five correspond to Q_1 journals.
- (b) *Conference articles*. Ecuador, through its universities, has participated in 1367 conferences around the world with 6677 conference articles. The predilection of these conferences can be observed in Table S2, where the first four conferences correspond to the fields of Information Systems and Technology. The conference with the most significant participation is "Advances in Intelligent Systems and Computing, "a Book Series that compiles the research presented at conferences, symposia, and congresses. The second conference is the "Iberian Conference on Information Systems and Technologies", an annual technical-scientific event, where knowledge, perspectives and innovations in the area are presented and discussed. The third and fourth correspond to "Communications in Computer and Information" Science and "Lecture Notes in Computer Science", a Book Series of the proceedings of computer science conferences. These conferences have in common the SJR indicator (see Table S2), a prestige indicator that classifies information sources according to their average prestige per document. Consider the quotes as the prestige of the source [284]. Of the conferences shown in Table S2, 66.7% do not indicate the conference's performance or prestige. Instead, they are registered only in Scopus.

3.2.3. Quality of Articles Published by University

One issue that has caused debate in the academic world is the relationship between the number of scientific publications and their perceived quality, which allows us to understand how these publications can influence the field of study [285,286]. These investigations allow the generation of new knowledge valuable for the academy and the socio-economic growth of a region or country [287,288].

The production of scientific knowledge occurs globally. However, its development differs between developed and developing countries [289]. In developed countries, it is considered that there should be a balance between the quantity and quality of scientific publications [290]. Along the same lines, Haslam [291] considers that researchers must publish frequently and with a certain quality to generate scientific impact. Other authors consider that the higher the production, the higher the quality, which is about the world's largest universities [292]. In developing countries, especially South American countries, scientific productivity is considered a long and hard road to travel, but it is essential to consolidate the system, and that quality ends up exceeding quantity [289,293].

In Figure 11, the production of journal articles by the university is presented, divided according to their equivalent quartile using the CiteScore metrics 2019. In the construction of the figures, journals whose coverage has been discontinued in Scopus or are recently created. Therefore, they do not present a valuation in the CiteScore indicator for the year 2019 (data obtained in January 2021), which allowed to obtain a total of 20,244 articles.

In Figure 11, higher education institutions with production more significant than 300 documents can be seen, representing 81.96% of scientific production.

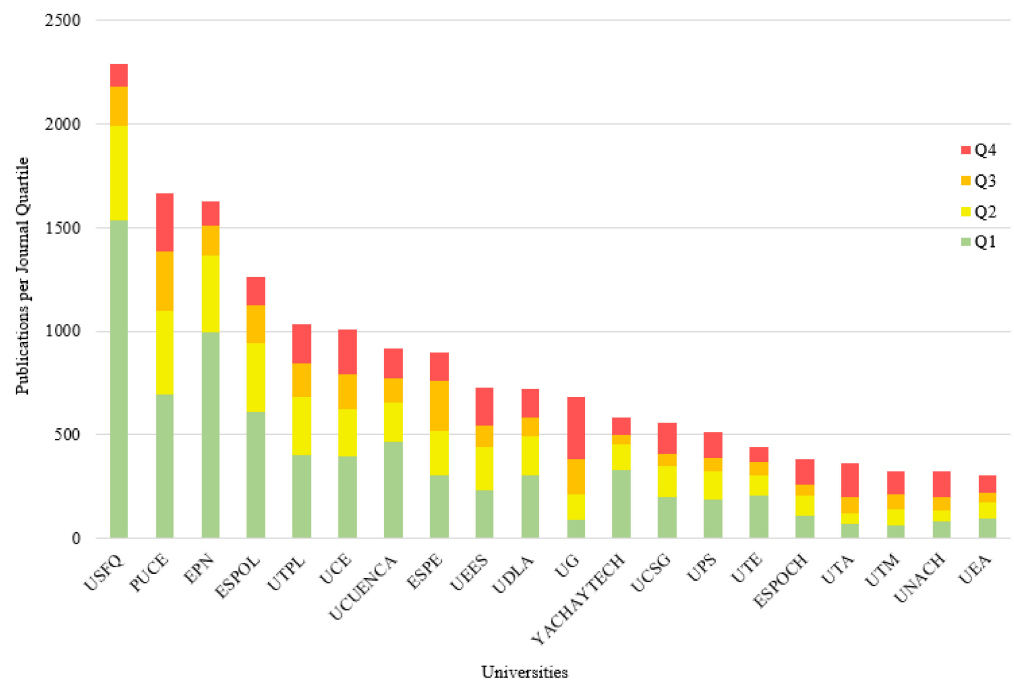


Figure 11. Publications by Journal Quartile (up 300 publications).

Ecuador's universities in the period 1920–2020 present a scientific production categorized according to quartiles (Q_1 to Q_4), which are shown in Figure 11.

1. Q_1 (*quartile 1*). They are those publications that are between the 99th–75th percentiles of the CiteScore, representing 41.47% of the production. In this quartile, five universities contribute 51.2%: 'Universidad San Francisco de Quito (USFQ)', 'Escuela Politécnica Nacional (EPN)', 'Pontificia Universidad Católica del Ecuador (PUCE)', 'Escuela Superior Politécnica del Litoral (ESPOL)', and 'Universidad de Cuenca (UCUENCA)', in their order. Most universities (26) have less than 100 documents, which represents 13.1% of the total quartile.
2. Q_2 (*quartile 2*). Corresponds to the 74th–50th percentile of the CiteScore. This quartile comprises 22.5% of scientific production, where five universities represent 40.4% of the publications in this quartile. In this cluster, most of the universities mentioned in Q_1 appear in different order: 'Universidad San Francisco de Quito (USFQ)', 'Pontificia Universidad Católica del Ecuador (PUCE)', 'Escuela Politécnica Nacional (EPN)', and 'Escuela Superior Politécnica del Litoral (ESPOL)'. Entering the 'Universidad Técnica Particular de Loja (UTPL)' instead of the 'Universidad de Cuenca (UCUENCA)'. It is observed that 30 universities present less than 100 documents (25.2%) in this quartile.
3. Q_3 (*quartile 3*). They are those that are in the 49th–25th percentile of the CiteScore and that represent 15.04% of scientific production. In this quartile, the main contributors are in order: 'Pontificia Universidad Católica del Ecuador (PUCE)', 'Universidad de las Fuerzas Armadas (ESPE)', 'Universidad San Francisco de Quito (USFQ)', 'Escuela Superior Politécnica del Litoral (ESPOL)', and 'Universidad de Guayaquil (UG)', contributing 35.2% of the publications in this quartile.
4. Q_4 (*quartile 4*). Represents the lowest percentile of the CiteScore (24th–0). It ranks third in production by quartiles (20.95%), placing 21 universities with more than 100 articles. This group includes the 'Universidad de Guayaquil (UG)', 'Pontificia Universidad Católica del Ecuador (PUCE)', 'Universidad Central del Ecuador (UCE)', 'Universidad Técnica Particular de Loja (UTPL)', 'Universidad Espíritu Santo (UEES)', 'Universidad Técnica de Ambato (UTA)', 'Universidad Católica de Santiago de Guayaquil (UCSG)',

'Universidad de Cuenca (UCUENCA)', 'Universidad Católica de Cuenca (UCACUE)', and 'Universidad of the Americas (UDLA)'. When examining the scientific production of each university, we can observe the proportion of publications in Q4, led by the 'Universidad Regional Autónoma de los Andes (UNIANDES)' with 82.76%, the 'Universidad Tecnológica Ecotec (ECOTEC)' (82.26%), the 'Universidad Católica de Cuenca (UCACUE)' (65.74%), the 'Universidad Tecnológica Israel (UISRAEL)' (62.5%), the 'Universidad Técnica de Cotopaxi (UTC)' (62.18%), the 'Universidad Técnica de Babahoyo (UTB)' (60%), and 'Universidad Metropolitana del Ecuador (UMET)' (50%). These universities also share the group of less than 300 publications and most of them share the latest locations.

4. Discussion

In emerging countries, such as Ecuador, a long and complex process of scientific production is ongoing, wherein quantity is more important than quality. This research evaluation in Ecuadorian universities is annual; therefore, it presents limitations of resources and time to publish. Consequently, these institutions and researchers opt for journals with short publication times, mainly in the Q2–Q4 quartiles, representing 58.5% of the total production. In contrast, a minority group of universities (six) are in close competition to improve their research indexes to climb international rankings (see Figure 11). Ecuadorian universities have managed to position themselves in the world rankings due to existing changes in the legal framework (laws and regulations), government evaluations, and international rankings. According to the QS World University Ranking, three universities are in the top 1000, and in the South American ranking, six are in the top 100.

Since 2015, Ecuador has shown the highest growth in scientific production compared to the rest of Latin American countries [294]. These publications resulted from close collaboration with foreign researchers and universities that allowed them to participate in international research projects, doctorate training for Ecuadorian teachers, recruitment of foreign researchers through the Prometheus Project [23,295,296], and priority attention to areas of national interest and plans for ancestral knowledge management [294]. International collaboration has focused on Spain, the United States, and some South American countries (see Figure 8). Spain, a country with profound cultural, social and economic ties since colonial times [297], has made it the primary destination for masters and doctorate courses [298]. The United States has been considered by Ecuadorian researchers for the experience and quality of the research of their North American colleagues, as well as access to funds [20]. It is a destination for the undergraduate, doctoral and postdoctoral levels of scholarship [298]. These countries show their importance when collaborating with Ecuador in the areas of Computer Science, Engineering, Social Science and Medicine mainly.

In the South American context, its relations with Brazil, Colombia and Mexico are due to their proximity and geopolitical relations in their cooperation and collaboration agreements, especially with Colombia as they are bordering neighbours and share part of the Amazon region [20]. This international collaboration is given in general terms by the megadiversity of the regions of Ecuador, the presence of natural laboratories (Galapagos Islands and the Ecuadorian Amazon), the appearance of new endemic species [16], their international recognition as World Heritage Sites and Global Geoparks [7], as well as for its cultural, gastronomic and tourist diversity. These characteristics have led Ecuador to awaken the interest of the world scientific community in recent years.

Latindex is a regional online information database for scientific journals from Latin America, Spain, and Portugal. The system has disadvantages due to the low visibility and quality of the articles, and the journals do not have an impact or prestige indicator [299,300]. Therefore, journals cannot be classified in the respective subject areas. In addition, they do not have a centralised repository approach, so it is not possible to have a unified view of their publications, limiting the possibility of carrying out bibliometric studies or integrating all the information [301].

In the coming years, the country should observe and imitate what is happening in the academic world, such as publishing English-language articles and seek an appropriate balance between production and quality [23,130].

5. Conclusions

This study examines 100 years of scientific production in Ecuador (1920–2020), indexed in a central academic database such as Scopus. The intellectual structure of 30,205 documents, written in 13 languages in collaboration with 84 countries, was analysed using bibliometric methods.

The analysis of scientific production shows a sustained growth over time that has allowed to approach it in two stages: (i) 1920–1990 and (ii) 1991–2020. In the first stage, 372 documents were registered (1.3% of the total), with the first research by foreign authors (M. E. Connor and R. Royer) and Ecuadorian authors (F. Rojas and J. Tanca Marengo). The areas of Medicine, Agricultural and Biological Sciences, Earth and Planetary Sciences were consolidated at this stage, thanks to private enterprise, public bodies, hospitals, foundations, and universities. In the 70–80s, there was a 4.5-fold increase in publications compared to the previous years due to changes in the legal system and the creation of other universities. In the second stage, there was a sustained increase until 2008, when an exponential growth in scientific publications began. In particular, new changes in the Higher Education System related to national legislation, universities' evaluation, and new guidelines for their teaching staff. This stage accounts for 98.77% of the publications.

The country's scientific research has an essential component of international collaboration, with Spain, the United States and most South American countries standing out. Production has been mainly in the form of journal articles (68.8%) and conference papers (22.01%), with a preference for English (80.7%). This scientific production has allowed research development in 27 subject areas, mainly Computer Science, Agricultural and Biological Sciences and Medicine (35.2%).

In the co-occurrence analysis of author keywords, the intellectual structure of the country's scientific research is revealed in 12 research lines (clusters) and 1000 topics (nodes) that make them up. These lines broadly incorporate the 27 subject areas mentioned above.

The role of universities is predominant in the country's research, where 44 universities are contributing 95.3% of the publications. However, balancing the publications quantity and quality is an unfinished task. The 63.97% are between quartiles 1-2, mostly carried out by six universities. In addition, there is low participation in the scientific production of 24 universities that contribute less than 300 documents each and have a preference to publish in quartile 4.

This study contributes to the academic world because: (i) Ecuador is considered a natural laboratory for researchers, as it is a megadiverse and irreplaceable country; (ii) scientific research has increased exponentially since 2011 due to changes in public policy and collaboration with 84 countries; (iii) international links with foreign universities and the establishment of collaborative networks; iv) the research addressing Ecuador has been developed in 12 research themes in 27 subject areas; (v) the subject areas have the participation of foreign authors recognised in the main lines of research that have been developed in the country.

Finally, this work is limited to the Scopus database due to the limitations of other databases. Nevertheless, we hope this study will encourage future research on the country's quantity and quality of academic publications.

Supplementary Materials: The following tables are available online at <https://www.mdpi.com/article/10.3390/publications9040055/s1>. Table S1: Most representative journal articles of the universities scientific production. Table S2: Most representative conference articles of the universities scientific production. Table S3: Top 5 of author in main subject areas (2011–2020).

Author Contributions: Conceptualization, G.H.-F. and N.M.-B.; methodology, G.H.-F., N.M.-B. and C.M.-F.; software, C.M.-F.; validation, G.H.-F.; formal analysis, G.H.-F., N.M.-B., C.M.-F. and L.B.-M.;

investigation, N.M.-B. and C.M.-F.; data curation, N.M.-B. and C.M.-F.; writing—original draft preparation, G.H.-F., N.M.-B., C.M.-F. and L.B.-M.; writing—review and editing, G.H.-F., N.M.-B., C.M.-F. and L.B.-M.; supervision, G.H.-F. All authors have read and agreed to the published version of the manuscript.

Funding: This research does not receive funding by external factors.

Data Availability Statement: Not applicable.

Acknowledgments: The preparation of this study counted with the collaboration of various scientific research projects, as the “Península Santa Elena Geopark Project” of the UPSE University project (Universidad Estatal Península de Santa Elena) with code no. 91870000.0000.381017; and the project “Factores Geoambientales de los Pozos Petroleros y su Incidencia en el Desarrollo Territorial en los Cantones Salinas y La Libertad de la Provincia de Santa Elena”, code no: 91870000.0000.385428. Also, to projects of the ESPOL Polytechnic University such as “Registry of geological and mining heritage and its impact on the defense and preservation of geodiversity in Ecuador” with code CIPAT-01-2018, and “Ruta del Oro Geopark” with code CIPAT-02-2018. The authors appreciate the feedback received by the reviewers and editor in the review process of this article.

Conflicts of Interest: The authors declare no conflict of interest.

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