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ARTÍCULOS

Scientometric for the evaluation of the scientific production: Analysis of the National Institute of Agricultural Research (INIAP) in the period 2020-2024, Ecuador

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ENG **Abstract.** Scientific production is an indicator associated with the productive and economic development of a country. Currently, Scientiometric is a tool used to analyze the products generated by science and that allows identifying research trends. The objective of this study was to analyze the scientific production of the National Institute of Agricultural Research (INIAP) in the period 2020-2024 to determine its contributions and limitations. Bibliometric analysis, descriptive statistics and correlation were used to analyze the information related to the study period. The results showed that INIAP's research production has increased its scientific quality by focusing on publishing in high visibility and ranking journals. The research area where there is the greatest scientific production is “Productivity Increase”, as well as in the research lines of “Integrated Crop Management” and “Agricultural Economy, Agroecology, and Climate Change”; themes focused on current problems and that allow to contribute to the promotion of sustainable agriculture. Investment in research has decreased over time, thus it is necessary to generate actions and policies that allow maintaining stable investment to develop agricultural research in the country, with the aim of contributing to the productive and economic development of Ecuador.
Keywords. Agricultural gross domestic product, Ecuador, Instituto Nacional de Investigaciones Agropecuarias (INIAP), Investment, research areas, research lines.

ES Cienciometría para la evaluación de la producción científica: Análisis del Instituto Nacional de Investigaciones Agropecuarias (INIAP) en el periodo 2020-2024, Ecuador

ES **Resumen.** La producción científica es un indicador asociado al desarrollo productivo y económico de un país. Actualmente, la cienciometría es una herramienta utilizada para analizar los productos generados por la ciencia y que permite identificar tendencias de investigación. El objetivo de este estudio fue analizar la producción científica del Instituto Nacional de Investigaciones Agropecuarias (INIAP) en el periodo 2020-2024 para determinar sus aportes y limitaciones. Para analizar la información relacionada al periodo de estudio se utilizó análisis bibliométrico, estadística descriptiva y correlación. Los resultados mostraron que la producción de investigación del INIAP ha incrementado su calidad científica al enfocarse en publicar en revistas de alta visibilidad y ranking. El área de investigación donde existe mayor producción científica es “Incremento de la Producción”, así como en las líneas de investigación de “Manejo Integral de Cultivos” y “Economía Agraria, Agroecología y Cambio Climático”; temáticas enfocadas en problemáticas actuales y que permiten contribuir al fomento de una agricultura sustentable. La inversión en investigación ha disminuido a través del tiempo, por lo que es necesario generar acciones y políticas que permitan mantener una inversión estable para desarrollar la investigación agropecuaria en el país, con el objetivo de contribuir al desarrollo productivo y económico del Ecuador.

Palabras clave. Áreas de investigación, Ecuador, líneas de investigación, Instituto Nacional de Investigaciones Agropecuarias (INIAP), inversión, producto interno bruto agrícola.

Sumario. 1. Introduction. 2. Materials and methods. 3. Results and Discussion. 4. Conclusions. 5. References.

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1. Introduction

Scientific development has been continuous in the last years around the world; however, the understanding of all the factors involved in this process is complex. It has been a transition between the culture of "science" to the culture of "research because the former is reliable, precise, direct and detached but research is uncertainty, involving and risky (Latour, 1998). The above mentioned can also fit to agricultural research where daily there are new problems related to crop production and industrialization that needs to be solved. Consequently, agricultural technologies have long been promoted by governmental organizations or institutions as effective ways to improve farm productivity and reduce poverty (Ruzzante; Labarta; Bilton, 2021).

Research produces a vast number of benefits for the countries, such as it increases economic activity, generates skilled labor, is a source of international prestige and visibility, is a marker of economic independence, and for researchers is a way to improve knowledge and apply it (Estenssoro; Friedman; Hernández, 2016). Latin America has increased the number of its scientists and research institutions in the current years; however, there is still a startling gap between Latin American and developed countries, thus the main importance of science and technology for the nation's development persist unacknowledged (Ciocca; Delgado, 2017). The principal factors influencing a low scientific productivity are the limited access to grant opportunities, inadequate budgets, substandard levels of laboratory infrastructure and equipment, the high cost and limited supply of reagents, and inadequate salaries of scientists (Ciocca; Delgado, 2017). In addition, the financial support for research is insufficient to reach the high expectations that research institutions have for their investigators and their scientific production to be published in high impact journals (Thomaz; Mormul, 2014). Therefore, the political and economic instability in many countries of Latin America causes a lack of long-term goals that are crucial for science development.

Scientometrics is the discipline that applies quantitative analysis to scientific data from scientific production (Belfiore; Cuccurullo; Aria, 2022), allowing to investigate and identify the development and dynamics of scientific trends among a diversity of research opportunities (Cruz; Escalona; Cabrera; Caridad, 2014) (Cardona; Sánchez, 2017). It analyses the evolution of documented scientific knowledge, taking as secondary source of information academic contributions such as publications indexed in scientific data bases (Cardona; Sánchez, 2017). Among the parameters used to measure the innovation incorporated in a process (technologies) are scientific publications (Vélez; Ortiz, 2016); however other criteria more specific at local level related to productivity indicators may allow to visualize the effect of the scientific production in the country development; due to technological advances has a positive impact in economic growth (Hillier; Pindado; Queiroz; Torre, 2011). There are few studies focused on the research outputs produced by the investment on scientific production using a production function approach. It is often difficult to associate research outputs with the country´s socio-economic benefits because of it takes long-periods to be able to visualize the returns from investment in science in terms of its most direct outputs such as scientific publications (Crespi; Geuna, 2008).

The scientific publication is the final step of the research cycle that allows the dissemination of the findings and technologies generated that have been the result of the investigative process (Viera ; Sánchez; Merino; Domínguez, 2020). Ecuador is a country of emerging economy where the scientific production has follow a similar trend than other Latinamerican countries; however this country has shown an exponential increase in its scientific production since 2011 (representing 85% of the total historical production) due to changes in public policy (Herrera-Franco et al., 2021) such as the "Regulation for the Accreditation, Registration and Categorization of National and Foreign Researchers who carry out Research in Ecuador" created by the Secretariat of Higher Education, Science, Technology and Innovation (SENESCYT) in 2014 (Viera-Arroyo et al., 2022); establishing salary policies that allow the research community obtains remuneration according to their scientific achievements (Da Silveira; Lermen; Amaral, 2021), which allowed the increase in the salary for researchers from Public Research Institutes.

Agriculture has a main role in the economic development of developing countries because it accounts 4% of the global gross domestic product and exceeds 25% in some emerging nations (Herrera-Franco et al., 2023); and in Ecuador, agriculture is essential for the country's economy and food security (Arroyo; Sánchez; Quiñonez, 2020). The National Institute of Agricultural Research (INIAP) has the purpose of generating new scientific or technological knowledge to meet the demands in the agricultural sector in Ecuador; for that reason, the intervention of the State is required in the promotion of research, training of human talent and the necessary funds for caring out the investigations. Research not always produces profits to cover the high costs involved in the development of new processes or products, that is why the State has to create and adapt legal norms to make the research processes possible (Zambrano et al., 2023). Therefore, research investment is a requirement and an essential factor to encourage the development of the different processes related to scientific research because of the growing role of scientific expertise in public policy.

INIAP carries out research in 3 areas: a) increase of the productivity, b) management and c) conservation of natural resources, and value-added incorporation; and 8 research lines: 1) plant breeding, 2) agrobiotechnology, 3) integrated pest management, 4) soil and water conservation, 5) genetic resources conservation, 6) agricultural economics, agroecology and climate change, 7) transformation and added-value of vegetal and animal products, and 8) transformation and added-value of byproducts (Zambrano et al., 2023). However, scientific production between 2022 and 2024 has not been analyzed quantitatively and thus the evolution of scientific knowledge provided by INIAP in this period is not known. Consequently, the objective of this research was to analyze the scientific production of the National Institute of Agricultural Research (INIAP) in the period 2020-2024 to determine its contributions and limitations.

2. Materials and methods

2.1. Bibliometric analysis

An analysis based in the methodology stated by Viera et al. (2020), with certain modifications, was used to quantify the status of the technical and scientific publications carried out by INIAP between the years 2020 and 2024. The INIAP´s Repository (https://repositorio.iniap.gob.ec/) was used as a reference to obtain the technical publications, as well as their report of views and downloads. For the analysis, scientific publications published in different databases such as Scopus, Scielo, Latindex, ResearchGate and Google Scholar were considered. They were classified according to different indexes obtained from Web of Science and Scopus to measure the relevance of a journal in its field. The following indexes were used: a) SCImago Journal & Country Rank (SJR) index, a tool that evaluates the quality of the journal and uses data from Scopus; b) Cite Score that measures the average number of citations received in a year by all documents published in a journal during the previous four years; c) Journal Impact Factor (JIF) which is calculated and published by Clarivate Analytics using the Web of Science database, based on the average number of citations received in a specific year by articles published in a journal during the previous two years.

Descriptive statistics were used to calculate the compound annual growth rate, downloads, visualizations, distribution in the indexed bases and their indexes. The distribution of the percentage of scientific publications by areas and research lines established in the INIAP Institutional Strategic Plan 2023-2026 (Zambrano et al., 2023) was analyzed during the study period. The investment on research was also visualized by the time to show the variation. The increase in INIAP's scientific production during the period 2020-2024 was calculated through the total number of publications per year. The compound annual growth rate (CARG) was used to measure scientific growth over time (Hassan; Sarwar; Muazzam, 2016).

$$CARG = \left(\frac{Production\ in\ the\ last\ year}{Production\ in\ the\ first\ year}\right)^{\frac{1}{años}} - 1$$

On the other hand, the categorized researchers were grouped and the frequencies for variables related to their scientific production were analyzed to visualize the contribution based on the indexed database.

2.2. Linear regression

A regression model was used to describe the relationship between the “number of scientific publications”, as a response variable, with a set of variables X1, X2, X3,....,Xp that represent the independent variables with some linear relationship with the dependent variable. It is common that some variables used in a multiple regression model are not associated with the response variable, therefore it is necessary to take the regression to a zero value to obtain a model that is easy to interpret (Muller; Fetterman, 2003). Therefore, the least squares technique was used, where the coefficients were calculated and a stepwise selection procedure was incorporated to obtain the linear model (Markovsky; Van Huffel, 2007). In addition, to comply with the assumptions of the regression model, the dependent variable was transformed into a natural logarithm plus 1 (Marques De Sá, 2007).

A multiple linear regression analysis was conducted, with the following equation:

$$Y=\beta 0+\beta 1X1+\beta 2X2+\cdots+\beta kXk+\epsilon$$

Where Y represents the dependent variable, and X1+X2+⋯+Xk are the independent variables. Each βk indicates the expected change in Y for a one-unit change in Xk. Lastly, ϵ is the error term, which accounts for the unexplained component of the model, and its analysis is essential to ensure that the conclusions drawn are robust and reliable.

The dependent variable in this study was the number of citations of scientific articles, transformed using the natural logarithm. Citation data were collected through Google Scholar and were considered a measure of the impact or attention that the scientific article generated among its audience. To explain the citation behavior, independent variables were selected based on prior literature. Furthermore, as a means to measure the significance of different research areas at INIAP, the research lines established in its 2023–2026 Strategic Research Plan (Zambrano et al., 2023) were included.

The software Stata/MP 14 was used, and the assumptions of homoscedasticity and normality of residuals were reviewed. The linearity assumption was not examined since the independent variables were dichotomous; however, multicollinearity was analyzed. Homoscedasticity was tested using White's test, and heteroscedasticity issues were addressed with the "robust" command. Multicollinearity was assessed using the variance inflation factor (VIF) with the "vif" command. The average VIF value should be less than 10. To analyze the error term, residuals were calculated, and their normality was evaluated using histograms. The coefficient of determination (R) was also estimated to determine the explication of the variables in the model.

2.3. Lotka model

The Lotka model (inverse square model) was used to evaluate the scientific productivity of the categorized researchers of INIAP during the period 2020-2024. The analysis over time of components associated with both the generation and use of scientific information is characterized by having behaviors that show statistical regularity, making it feasible to define the patterns evidenced through the so-called “bibliometric laws” like it is established by the Lotka model (Cáceres, 2019) which is based on a discrete probability distribution to describe the productivity of the authors (Urbizagástegui, 2005). According to Lotka's model, the number of authors who have "x" contributions in an area of science is around 1/x2 that of the authors who have a single contribution (Urbizagástegui.; Lane, 2007). Consequently, it is deduced that the contributions made by the authors show an unequal distribution, with the largest proportion of contributions agglomerating in a few authors, who with respect to the authors with the lowest contribution of contributions present a negative relationship of around 2 (Urbizagástegui R, 2005) (Urbizagástegui R, 1999).

The Lotka model is expressed by the following formula (Cáceres-Ruiz, 2019) (Urbizagástegui, 2005)

$$Y_x = \frac{C}{x^n}$$

Where: Yx is the probability that an author makes “x” contributions; C is the number of researchers who generate a single publication; an xn is the number of publications where n= 2.

To determine if the results fit the Lotka model, the critical value of the Kolmogorov Smirnov test was calculated at a significance level of 1%, applying 1.63/√N, with “N” being the total number of researchers observed (Cáceres-Ruiz Díaz, 2019); as well as the maximum absolute deviation was estimated. This test is a simple non-parametric method to determine if there are significant differences between the observed frequencies and the calculated frequencies of a distribution (Urbizagástegui, 2005) (Portal, 2005). The Kolmogorov-Smirnov decision criterion was applied:

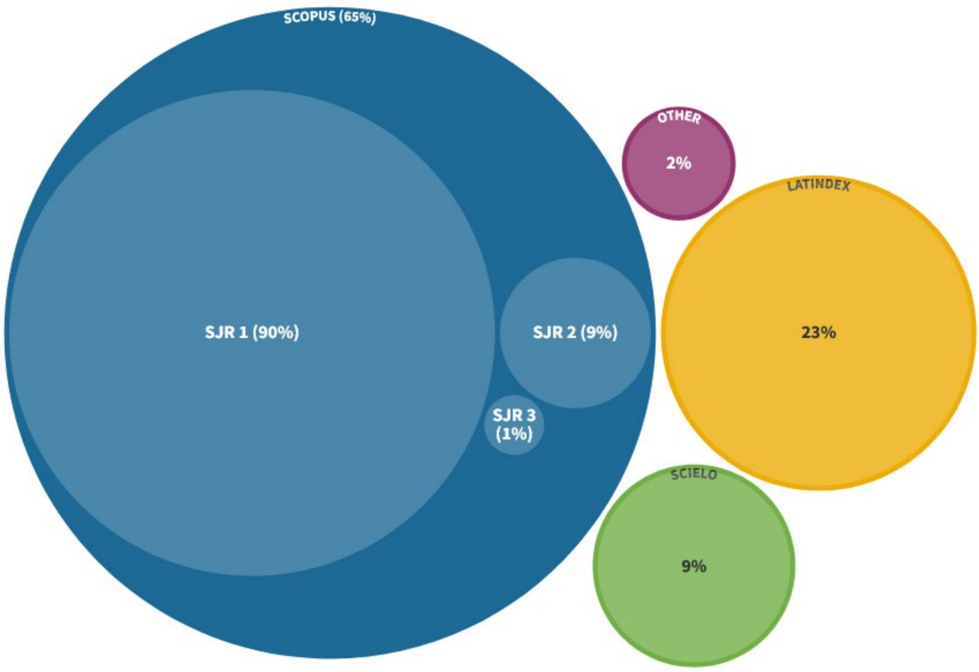
If the critical value is greater than or equal to the maximum absolute deviation calculated, the null hypothesis is not rejected; if the critical value is less than the maximum absolute deviation calculated, the null hypothesis is rejected.

3. **Results and Discussion**

3.1. Bibliometric analysis

The evolution of scientific production in Ecuador has had a pattern similar to that of other Latin American countries, where the lack of government incentives has given rise to a scenario of low scientific production (Brunner; Ferrada, 2011). However, in recent years, through the generation of laws, policies and regulations, the Ecuadorian government has been promoting the increase in scientific production (Medina et al., 2016: 461-494). In the analysis of scientific productivity, a set of regularities come together that contribute to identifying not only the quantitative proportion of the authors' production of scientific literature, but also within this regularity are other characteristics of productivity more associated with social problems and that entail the form or structure of the population that produces or publishes scientific results (Portal, 2005).

Figure 1 shows the percentage distribution of scientific publications carried out by INIAP across various databases and platforms during the 2020–2024 period. The largest proportion of publications (65%) is indexed in Scopus, followed by 23% in Latindex, 9% in SciELO, and 2% in other indexing databases. Of 65% indexed in Scopus, 90% is in SJR1 (between 0 to 1), 9% in SJR2 (between 1 to 2) and 1% SJR3 (between 2 to 3).

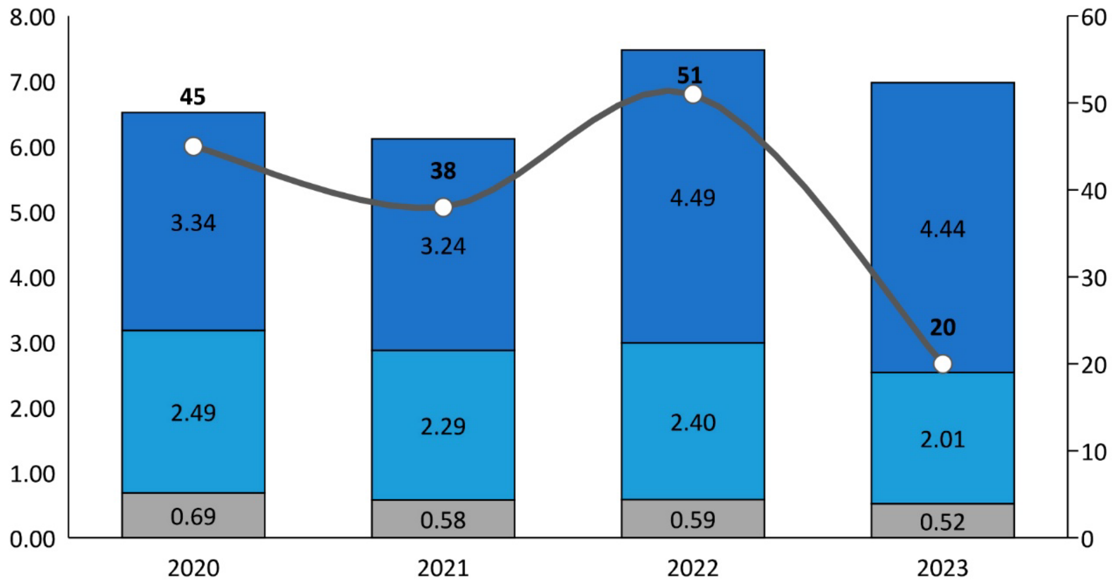


(figure 1) Production of scientific publications at INIAP, period 2020-2024.

The highest percentage of INIAP scientific publications in the period analyzed were indexed in Scopus, reflecting a focus on quality in scientific content; furthermore, this fact would also be reflected in greater international visibility by publishing in journals of greater recognition in the scientific area. It was observed that the trend of scientific production this database was similar compared to what was reported in the previous period (Viera-Arroyo et al., 2020). A moderate percentage was maintained in the Latindex databases and to a lesser extent in Scielo, which denotes the interest in disseminating research generated on platforms with relevance in Latin America and the Caribbean.

During the period 2020–2024, INIAP's scientific publications exhibited variations both in quantity and quality indicators of the journals where they were published. Figure 2 illustrates the trends in Scimago Journal Ranking

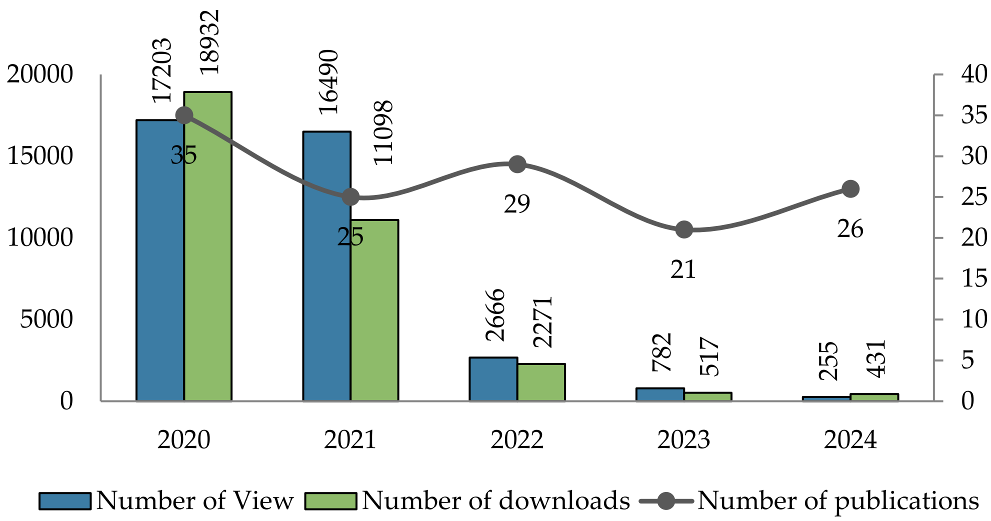
(SJR), CiteScore, Impact Factor (IF), and the number of publications (NP) of the journals where INIAP published during the analysis period. The number of publications fluctuated, peaking at 51 in 2022 and dropping to 20 in 2023. CiteScore values increased from 3.34 in 2020 to a maximum of 5.16 in 2024. The SJR index remained stable (around 0.69–0.86), while the IF experienced a slight decline from 1.82 in 2023.



SJR: Scimago Journal Ranking; IF: Impact Factor; Cite Score and NP: Number of publications
(figure 2) Evolution of the SJR index, Cite Score and impact factor, in scientific journals to which INIAP scientific publications are indexed, in the period 2020-2024.

During the study period, the values obtained for the SJR index were higher than the average value (0.48) of the journals in the “Agriculture and Biological Sciences” category of the Scimago Journal & Country Rank (www.scimagojr.com). The IF values were close to or greater than 2, which indicates that it has mostly been published in journals of scientific relevance. This index is broadly considered as a prominent proxy for assessing the quality, importance, and influence of journals to their respective discipline (Garfield, 1996). The CiteScore indicates the average number of citations received per document issued in a serial (Atayero et al., 2018), most of the values were higher than 3, which indicates that the INIAP´s publications are being published in high impact journals. This index gives a more comprehensive, transparent, and current view of the impact of the journal (Roldan-Valadez et al., 2019); therefore, the higher the index, the greater the impact of the journal.

Figure 3 shows the trend in views, downloads, and technical publications from INIAP's repository during 2020–2024 period. In 2020, the highest number of views (17,233) and downloads (13,322) was recorded, corresponding to a higher volume of publications. However, both indicators decreased starting in 2022, reaching their lowest point in 2024 with 255 views and 401 downloads.

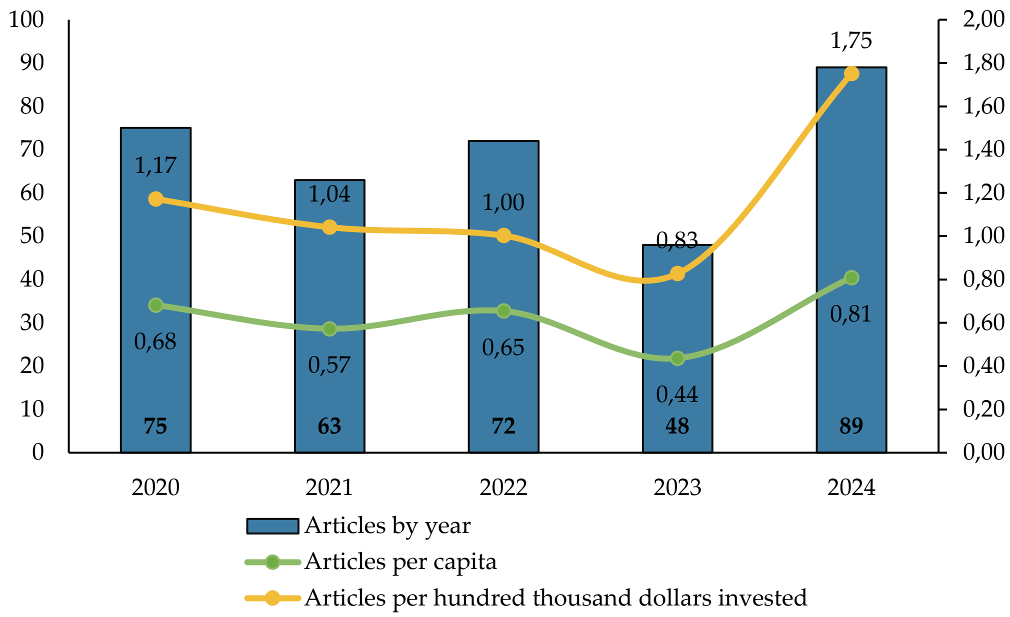


(figure 3) Number of views and downloads of INIAP technical publications in the repository, by year of publication

The highest number of views occurs at the beginning (2020) and decreases by 2023; which is explainable because the older the publication, the more time it has to be viewed and consulted (Viera-Arroyo et al., 2020). However, the number of publications has had a slight reduction over time, which could be related to the drastic budget decrease observed since 2015 that the Institute has had to carry out research; maintaining in most years a percentage close to 50% compared to 2014 where there was a greater investment due to the existence of the “Support for the National Agricultural Development Plan”. A main problem in Latin America is a lack of clear rules for the distribution of research funds, which usually are distributed based on political alliances and aggravated by economic instability, producing an undesirable impact on the development of technology innovation (Coccia; Rolfo, 2007). Scientific production, measured by the number of articles published for every 1% investment in research, constitutes an indicator powerfully correlated with accumulated economic growth; which makes sense that emerging countries should invest in science with the objective of accelerate the growth of their economies (Arana-Barbier, 2023). It is required to increase investment in science and technology; however, the technical assistance must also be strengthened to facilitate the adoption of the generated technologies and to contribute to the sustainable and reference agriculture of the region (Sánchez; Mendoza, 2019).

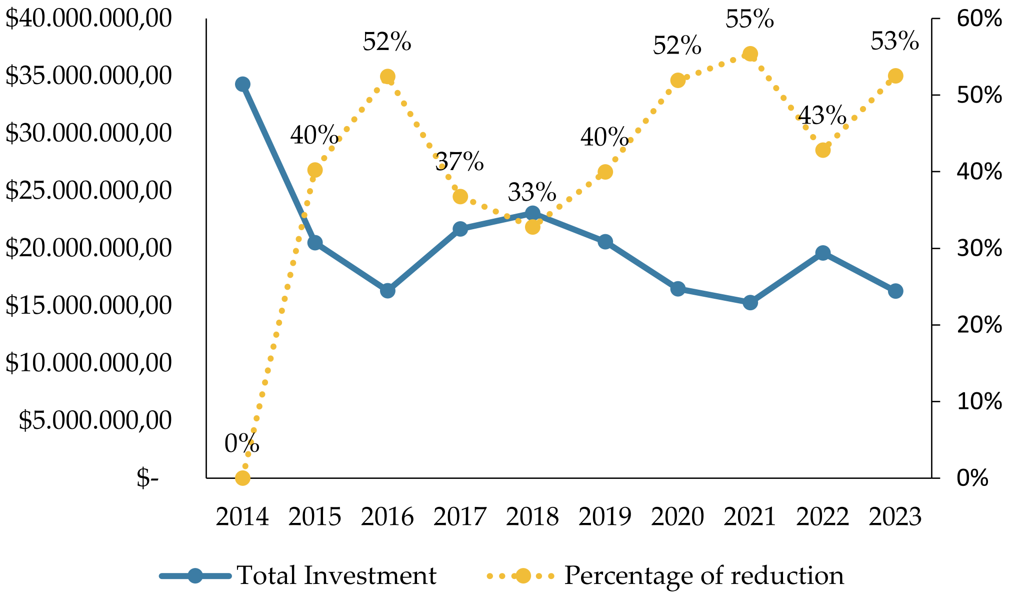
On the other hand, (Viera et al., 2020) mentions that INIAP publications increased from 2014 to 2019, largely influenced by the implementation of the "Regulation for the Accreditation, Registration and Categorization of National and Foreign Researchers", a Regulation that motivated scientific production in that period. However, in 2021 a reform to the Regulation was carried out (SENESCYT, 2022), which limits the continuous escalation of the categories because to move from one to another, it requires "2 years of experience in a specific category", which would also directly affect scientific production because during that period the researcher's production does not need to be increased, and in a certain way limits the professional development of the researcher. In addition, the lack of State´s economic resources to cover salaries for new categorized or re-categorized researchers constitutes an issue to encourage more scientific production.

The number of views was higher in 2020 and 2021 because a publication with a longer stay in the institution's digital repository is more viewed; this tendency has also been reported by (Viera et al., 2020). This trend was also reflected in the number of downloads; however, this factor would be related to the topic of interest of external users. The decrease in views and downloads from 2022 could be partially explained by the existence of a short citation window, such as that described in various bibliometric reviews in terms of citations and visibility. Consequently, articles published in previous years have the advantage of being more cited and more visible in research repositories (Donner, 2018). Figure 4 shows that the highest number of articles per capita were observed in the years 2020 and 2024; while there was a reduction from 2021 to 2023. In terms of the number of articles for each hundred thousand of American dollars invested in research, it had been observed a continuous decrease from 2020 to 2024; which would be related to the reduction of research investment during these years.



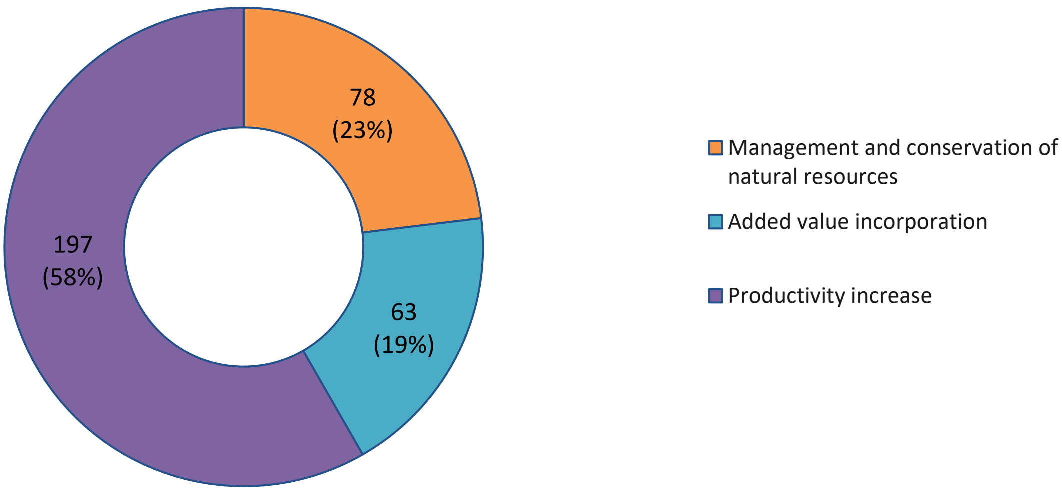
(figure 4) Number of articles per year, per capita, and for each hundred thousand of American dollars invested in research.

Figure 5 shows the variation over the years in terms of total investment that INIAP received for research, considering the different sources of financing (Governmental funding, Technichal Asistance, International cooperation), It can be seen that the year 2014 had the greater economic contribution; after that there was a drastically reduction of the total investment until 2016. Then, there was a slight increase between 2017 and 2018 due to the greater governmental investment allocated to the institute, particularly in the thematic area of "seeds"; In addition, the Institute received substantial funding from international development partners, including the Spanish Agency for International Development Cooperation (AECID), Crop Trust, PROIMPA, FONTAGRO, and the University of Copenhagen, to conduct research on biodiversity, food security crops, and perennial crops. Finally, it was observed a downward trend from 2019-2023, due to a reduction in public investment in agricultural research. The overall trend observed in total research investment had drastically collapsed, showing a significant reduction of 52.52% between 2014 and 2023.



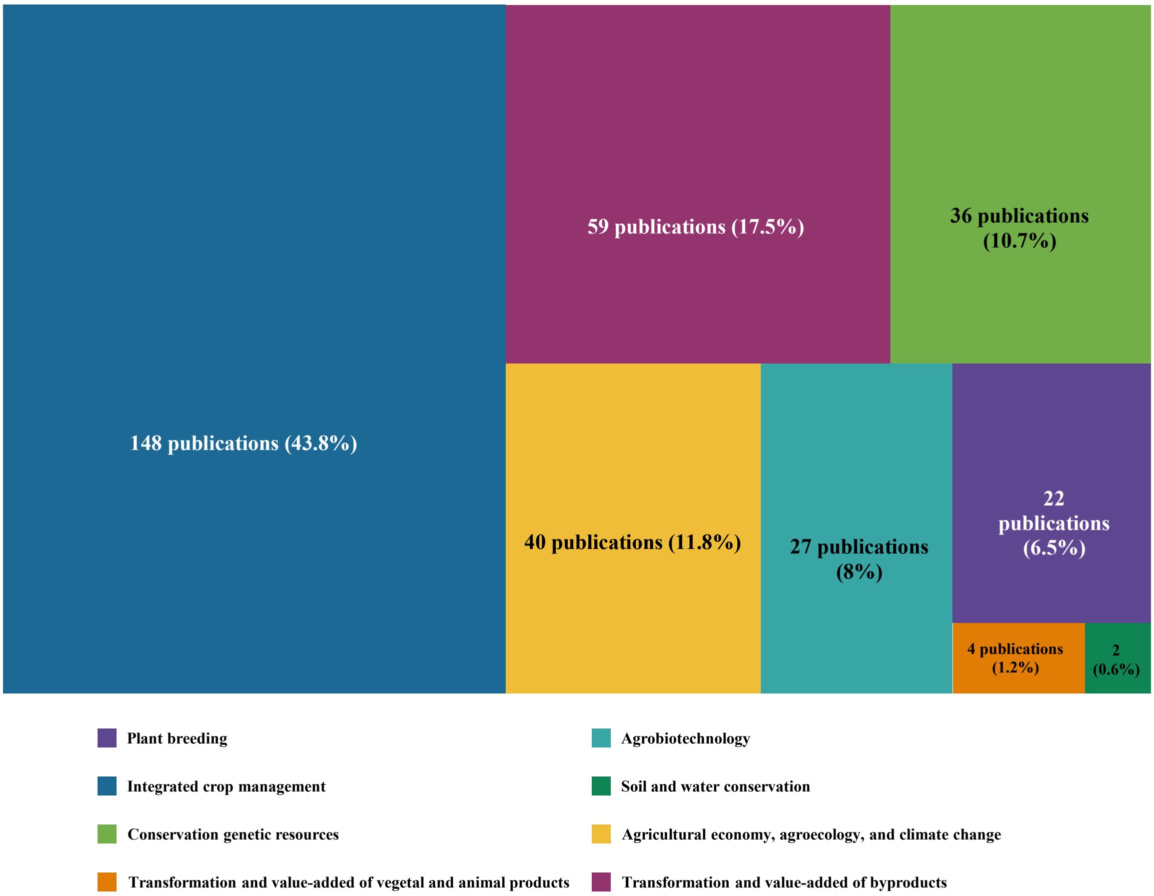
(figure 5) Investment on research that INIAP received from 2014 to 2023.

Figure 6 shows the percentage distribution of indexed publications according to the research areas, defined in INIAP's Strategic Institutional Plan (Zambrano et al., 2023). The largest number of publications (58%) corresponds to the area of Productivity Increase, followed by Management and conservation of natural resource (23%), and Value-added incorporation (19%).



(figure 6) Percentage of publications indexed according to the research area according to the INIAP PEI, during the period 2020-2024.

In the study period, a priority focus was evident in the area of Increase of the Productivity, which reflects the interest in directing research to increase the performance of productive systems (Sánchez; Mendoza, 2019). However, compared to the results reported by (Viera et al. 2020), the number of publications in this research area has decreased by 11%, while in the Management and Conservation of Natural Resources area almost doubled. Finally, the Value-added Incorporation area increased by 8%, compared to the results of the aforementioned author. This behavior would be associated with the current growth of scientific interest in the integrated management processes of productive systems (Deguine et al., 2021: 38), as well as, in the transformation and processing processes of the primary agricultural product (Zambrano et al., 2023) (García, 2024), which reflects an interest in the sustainability and innovation of the value chain. The distribution of INIAP's indexed publications by research lines (Figure 7) reflects a primary focus on Integrated crop management (43.8%), followed by Transformation and value-added of vegetal and animal products (17.5%), Agricultural economy, agroecology, and climate change (11.8%), , Conservation genetic resources (10.7%), Agrobiotechnology (8%), Plant breeding (6.5%), Transformation and value-added of byproducts (1.2%) and Soil and water resources conservation (0.6%).



(figure 7) Number and percentage of publications indexed according to the research line according to the INIAP PEI, during the period 2020-2024.

The Integrated Crop Management research line was relevant in relation to the number of publications, which would be directly related to the result obtained that the research area with the highest number of publications was Productivity Increase. The preponderance of scientific production in this line of research shows its strategic relevance within the INIAP research priorities; an approach that integrates various agricultural management practices and technologies aimed at increasing crop yields, minimizing environmental impact and guaranteeing the sustainability of production systems with a systemic approach, based on knowledge for the understanding of local ecosystems and the adaptation of management practices to specific conditions (Hussain; Ul-Allah; Farooq, 2023). The research lines Plant Breeding, and soil and Water Conservation had lower percentages; however, this would indicate that currently there are other research lines more modern such Agrobiotechnology, Agricultural Economy, Agroecology and Climate Change, and Transformation and Value-added, which are growing in terms of research. It is worth mentioning that the research line on Transformation and Value-added also stands out due its the importance of the agroindustry in the agricultural sector (Vieira; Fornazier, 2016) to generate new products that allow taking advantage in the optimizing of the final product for its commercialization. It is important to emphasize that the research line of Agricultural Economy, Agroecology, and Climate Change has increased its scientific production by 8% compared to the results reported by (Viera et al. 2020); which would indicate the Institute's perspective of promoting and moving towards an agricultural transition to promote sustainable agriculture in Ecuador. These current research trends such as bioeconomy, sustainable agriculture and agroecology have been reported by (Flórez-Martínez, 2024).

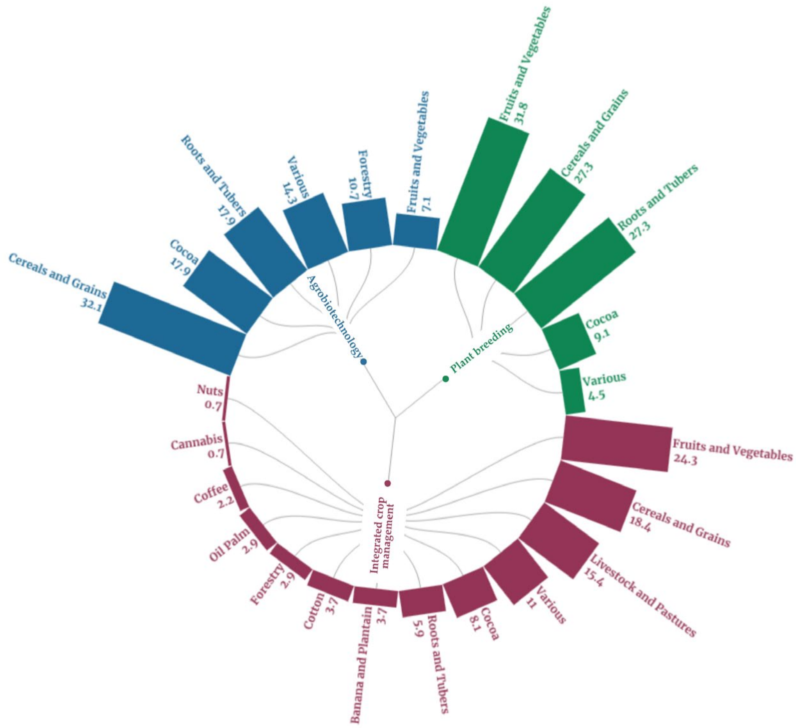
3.2. Research areas and lines of INIAP

Sánchez and Zambrano (2019) mention that the average adoption rate at the national level of the technologies developed by INIAP has been 37%; indicating that the impacts generated by the Institute have been positive at the economic, environmental and productive levels for the farmers who adopted the technologies. Determinants of technology adoption are greatly dependent on cultural, contextual, and policy aspects; consequently, policy makers must combine high-level results with site-specific information to promote the adoption (Ruzzante; Labarta; Bilton, 2021). How is mentioned above, INIAP's research activities are aligned with four research areas and specific research lines. Consequently, scientific production is distributed within them, depending on the farmers and research demand.

3.2.1. Productivity increase

Figure 8 shows the distribution of scientific publications in terms of crops for the different research lines. In the research line of Plant Breeding, Fruits and Vegetable had the higher percentage of publications (31.8%); while the lowest was Cocoa (9.3%). For the research line of Agrobiotechnology, Cereals and Grains had the higher percentage of publications (32.1%); while Fruits and vegetables had the lowest (7.1%). In terms of Integrated

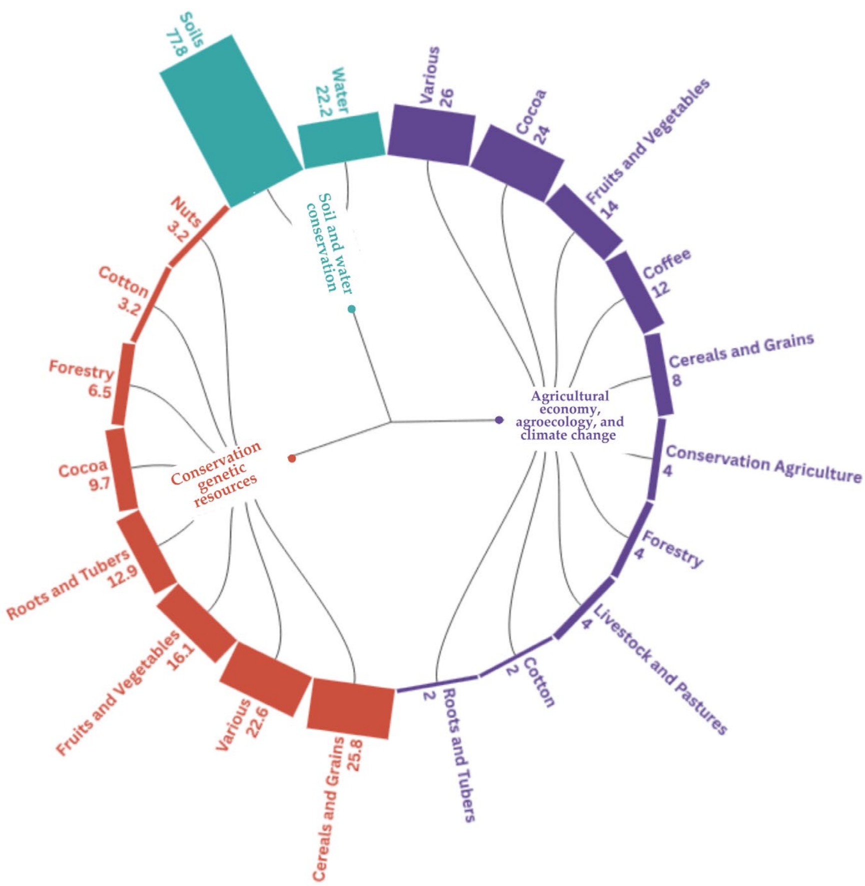
Crop Management, Fruits and Vegetables had the higher percentage of publications (24.3%); whereas Nuts and Cannabis had 0.7% each.



(figure 8) Percentage of publications in the research lines corresponding to the area of Increase of the Productivity.

3.2.2. Management and Conservation of Natural Resources

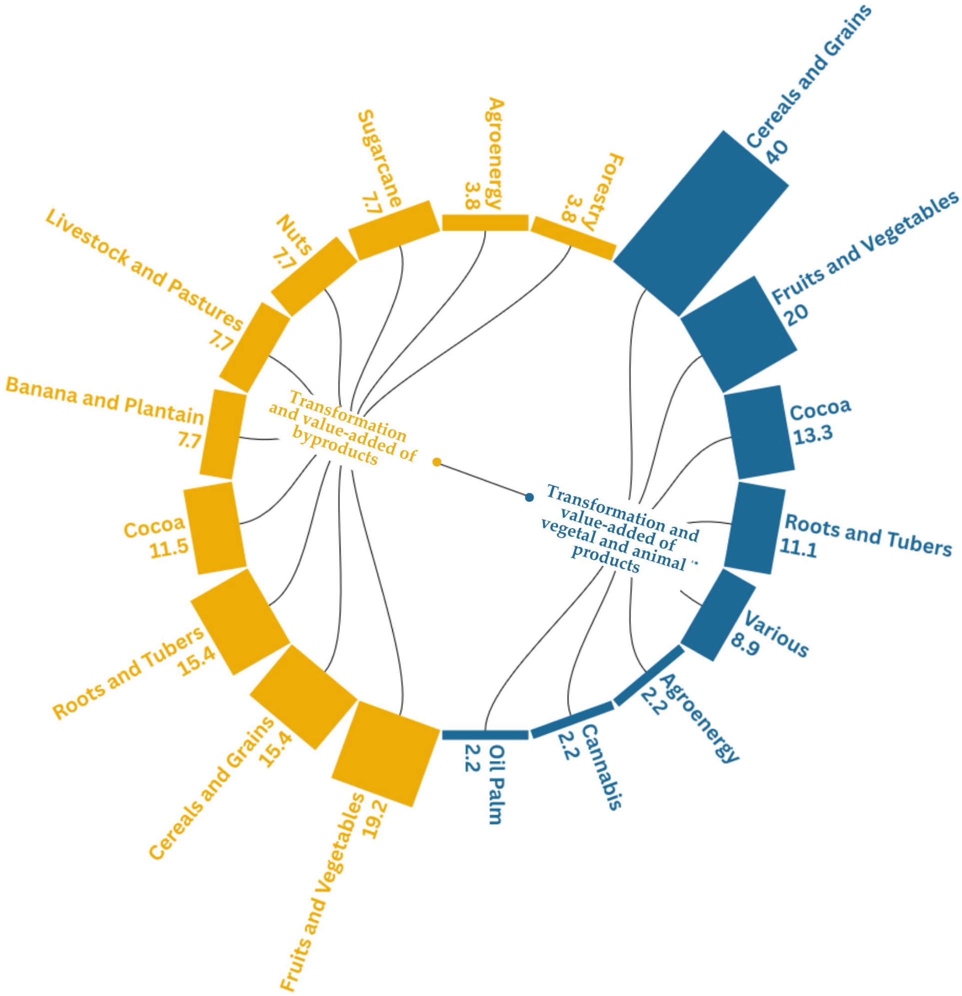
Figure 9 shows the distribution of scientific publications in terms of crops for the different research lines. In terms of Soil and Water Conservation, Soil had the highest percentage of 77.8%, while Water had the lowest with 22.2%. For Conservation of Genetic Resources, Cereals and Grains had the highest percentage (25.8%); while Cotton and Nuts had the lowest (3.2%). For Agricultural economics, agroecology and climate change, Various (production systems, food security, gender and bibliometrics) had the highest with 26%, while Roots and Tubers and Cotton had the lowest with 2% each.



(figure 9) Percentage of publications in the area of Management and Conservation of Natural Resources.

3.2.3. Value-added Incorporation

Figure 10 shows the distribution of scientific publications in terms of crops for the different research lines. In terms of Transformation and Value Addition of Vegetal and Animal products, Cereals and grains had the highest percentage (40%); whereas Oil palm had the lowest (2.2%). For Transformation and added-value of byproducts, Fruits and vegetables had the highest percentage (19.2%); while Agroenergy and Forestry had the lowest with 3.8% each.



(figure 10) Percentage of publications in the research lines corresponding to the area of Value-added Incorporation.

Specifically, it was observed that Fruits and Vegetables, and Cereals and Grains showed the highest percentage of publications in research lines such as Plant Breeding, Integrated Crop Management, Conservation of Genetic Resources, and Value-added Incorporation; which means that these crops are mainly focus in most of the INIAP´s research lines. Only in Agrobiothecnology, Cereals and Grains are the crops with mayor research while Fruits and Vegetables in the topic with less research. Therefore, crops such as corn, rice, chocho, wheat, barley, blackberry, avocado, pitahaya, tree tomato, naranjilla, passion fruit and others, are relevant to carry out research because of they are associated with food security and crops for exportation; thus they are important for the agricultural sector in Ecuador and it is essential to increase research investment to generate science and technology, and also consolidate a national system and technical assistance for Ecuadorian farmers to increase the technology adoption, contributing to develop a sustainable and reference agriculture of the region (Zambrano et al., 2023) (Sánchez; Mendoza, 2019: 28-39).

3.3. Scientific Production of INIAP´s Categorized Researchers

Table 1 provides an overview of the research output of the categorized researchers of INIAP for the period 2020–2024, according to their SENESCYT categorization (Auxiliary, Aggregate, and Principal). Most of the publications (156) were produced by the Auxiliary researchers. Even though, the Aggregate researchers are a limited number of people (15), they also had a high scientific production (155), they produced a little less than the former researchers. The Principal researchers had a considerable number of publications (25), in relation to their low number of people (3). The greatest amount of publications was located in high quartiles (113 in Q1). The number of publications in the Latin index database (76) was considerable.

Table 1. Publications and quartile distribution by researcher category.

Numbers of Researchers	Categorization level		Scopus				Scielo	Latin Index	Others
			Q1	Q2	Q3	Q4			
Auxiliar									
37	1	130	34	15	16	19	8	33	5
9	2	55	19	9	1	3	4	17	2
Agregate									
7	1	44	11	3	13	4	0	12	1
5	2	104	35	7	7	13	9	28	5
3	3	26	12	3	3	3		3	2
Principal									
2	1	10	1	3	1	1		3	1
-	2	0							
1	3	7	1	1	2	3			
1	4	12	7	2					3
Total		**388**	**120**	**43**	**43**	**46**	**21**	**96**	**19**

In Ecuador, the SENESCYT establishes the categorization of scientific researchers through the "Reglamento de Categorización, Carrera y Escalafón del Investigador Científico" formalized in Agreement No. SENESCYT-2021-029. This regulation defines the categories of researchers and the criteria for their classification, considering aspects such as academic background, scientific production, and professional experience. In the case of the National Institute of Agricultural Research (INIAP), researchers are subject to this categorization, which also determines their salary scale in alignment with SENESCYT guidelines. The evaluation of scientific contributions quality in agriculture underscores a direct correlation among food production, country's agricultural coverage extension, and the employment proportion within the agricultural sector (Herrera-Franco et al., 2023). Notably, the number of publications produced by INIAP´s categorized researchers are located across the Scopus quartiles (Q1 to Q4), with the highest number of publications in the quartile Q1; pointing out the high quality of the scientific production generated in the period of study. Thus, INIAP´s categorized researchers are concentrated in publishing in higher-impact journals to reach quality research outputs. Currently, Aggregate researchers have the highest scientific production being a reduced number of people but their scientific production largely influenced the results of this study. On the other hand, Principal researchers reflected a smaller group than the other categories, which explains their lower numerical contribution; nevertheless, their outputs are still significant on an individual basis. Although the number of researchers is not the only indicator that reflects the state of research, science and technology in a country; nevertheless, this parameter provides information for the evaluation and design of policies that benefit technological development (Mendoza, 2019). For further analysis, this indicator must be complemented with a financial analysis of the investment in research and the impact of the results generated. On the other hand, although there are laws that seek to promote the career of researcher, the lack of political decision, regulations and application of regulations prevents increasing the generation of knowledge and technologies, which delays the economic and productive development of the country (Mendoza, 2019).

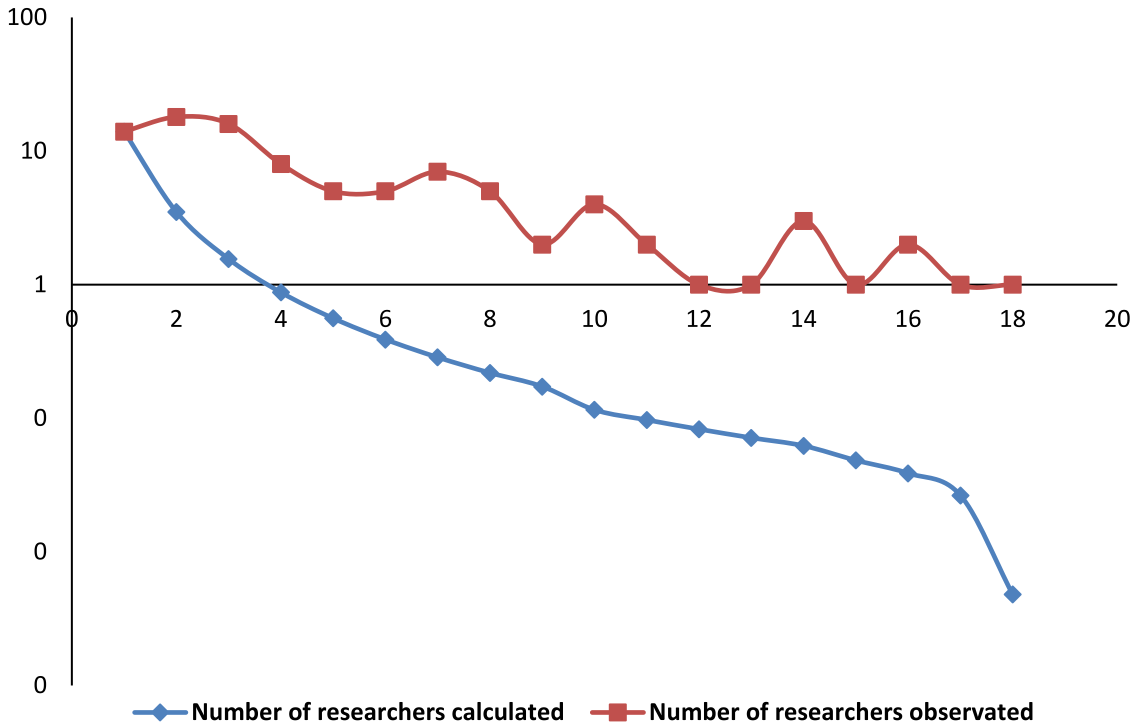
3.4. Lotka model

Table 2 and Figure 11 illustrate the comparison between the observed distribution of publications among INIAP researchers and the expected distribution, based on Lotka's Law. This model predicted that the number of researchers decreases exponentially as their number of publications increases. The Kolmogorov-Smirnov (K-S) test was used to evaluate the goodness-of-fit between the observed data and the theoretical distribution. Additionally, to determine the critical value of the Kolmogorov-Smirnov test at a 1% significance level ($\alpha=0.01$), the formula $1.63/\sqrt{N}$ was used, where "N" represents the total number of observed researchers (96); and the result value was 0.16636. On the other hand, the maximum distance found between the cumulative relative distribution of observed researchers and calculated researchers was 0.48752.

To accept or reject the null hypothesis in this study, a comparison between the critical value with the maximum absolute deviation was carried out. Upon comparing the values, it was found that: Dmax= 0.48752. > Critical value=0.16636. Therefore, the critical value is less than the maximum absolute deviation calculated, the null hypothesis was rejected, therefore, the observed data does not fit the mathematical model proposed by Lotka; which means that the frequencies, in terms of number of publications and the among of INIAP´s researchers is not homogeneous.

Table 2. Distribution of researchers by number of publications and statistical verification of Lotka Mathematical Model.

	Observed Distribution			Expected Distribution According to Lotka's Model			Goodness-of-Fit Test According to K-S	
Number of Publications (x)	**Number of Observed Researchers (y)**	**Accumulated Number of Observed Researchers**	**Relative Accumulated Number of Observed Researchers s(x)s(x)**	**Number of Expected Researchers C/X2**	**Accumulated Number of Expected Researchers**	**Relative Accumulated Number of Expected Researchers f(x)**	**f(x) - s(x)**	**|f(x) - s(x)|**
1	14	14	0.146	14.000	14.000	0.633	0.488	0.488
2	18	32	0.333	3.500	17.500	0.792	0.458	0.458
3	16	48	0.500	1.556	19.056	0.862	0.362	0.362
4	8	56	0.583	0.875	19.931	0.902	0.318	0.318
5	5	61	0.635	0.560	20.491	0.927	0.292	0.292
6	5	66	0.688	0.389	20.879	0.945	0.257	0.257
7	7	73	0.760	0.286	21.165	0.957	0.197	0.197
8	5	78	0.813	0.219	21.384	0.967	0.155	0.155
9	2	80	0.833	0.173	21.557	0.975	0.142	0.142
11	4	84	0.875	0.116	21.672	0.980	0.105	0.105
12	2	86	0.896	0.097	21.770	0.985	0.089	0.089
13	1	87	0.906	0.083	21.853	0.989	0.082	0.082
14	1	88	0.917	0.071	21.924	0.992	0.075	0.075
15	3	91	0.948	0.062	21.986	0.995	0.047	0.047
17	1	92	0.958	0.048	22.035	0.997	0.038	0.038
19	2	94	0.979	0.039	22.073	0.999	0.019	0.019
23	1	95	0.990	0.026	22.100	1.000	0.010	0.010
54	1	96	1.000	0.005	22.105	1.000	0.000	0.000



(figure 11) Distribution of the observed and expected researcher by the Lotka Mathematical Model.

The Lotka modell allowed a better understanding of the alignment between the research productivity at INIAP and the patterns described in the model. In terms of number of categorized researchers, there is a dominance of Auxiliary researches in the Institute, however the most productive group in terms of number of publications are the Aggregate researchers; which was corroborated with the Lotka model that showed the fewer researchers are generating a major number of publications.

The Lotka model has been tested in many areas involving databases; however, its fit has not always been adequate because author productivity measures should take into account all authors including collaborators

(Urbizagástegui, 2005). (Lotka, 1926). takes into account the first authors because multiple authors were less common at that time, and probably because that way the counting was easier. In a post-modern world of advanced capitalism, research is characterized by extensive collaboration that is reflected in the multiple authors of a single work; for that reason, the distribution of author productivity should be associated with their collaborators (Urbizagástegui, 2005). To investigate the fit of the distribution, the Kolmogorov Smirnov test is used, which is applied to the set of observed and expected values. This test compares the distribution of the observed frequencies with the distribution of the calculated or theoretical frequencies, using the cumulative function of both distributions. One of its advantages is that it works very well with small samples and does not lose information when grouping the distribution data into classes (Urbizagástegui, 2005). According to the results obtained, a considerable number of authors with 1 to 3 publications was observed. This implies that small producers predominate, that is, most of the productivity is found in a few researchers who represent the largest proportion of the publications (Sena Correa et al., 2023). However, the behavior of the parameters of this model would not only be associated in a differentiated way by topics, but would also be linked to cultural similarities in terms of habits and customs of the authors to generate their scientific production, as well as a different level of specialization in the scientific production they generate (Urbizagastegui, 1999).

3.5. Regression analysis

The statistical regression analysis (Table 3) indicated that the year of publication negatively influences the citation of the articles (-0.50), namely, older scientific papers are more cited. The regression also indicated that the research lines of Agricultural Economics, Agroecology and Climate Change, as well as Transformation and Added-value are relevant in relation to citations and consequently to the scientific production of the Institute. These results corroborate what was obtained in the bibliometric analysis.

The fit goodness of the model indicated that the independent variables explain a significant proportion of the variability of the dependent variable. In this case, the coefficient of determination (R^2) showed that the model explained 48% of the variability observed in the dependent variable.

Table 3. Multiple linear regression performed on the dependent variable "number of bibliographic citations" applied natural logarithm.

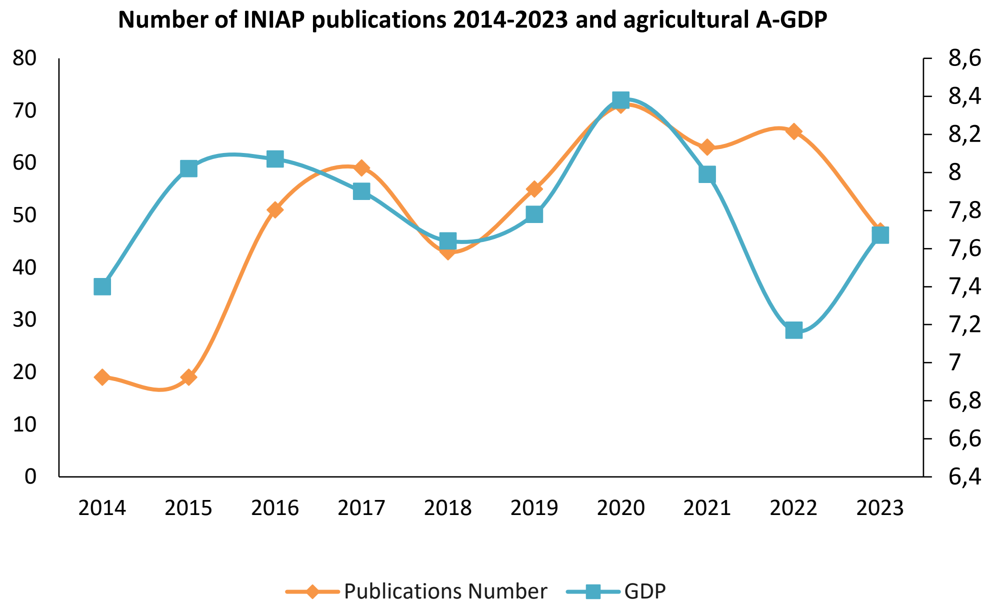
Dependent variable	Coef. (β)	Standard Error	P>|t|	Confidence Interval (95%)	
Year of publication	-0.50***	0, 03	0,00	-0, 56	-0,44
RL: Agricultural Economy, Agroecology, and Climate Change	0.35*	0.15	0.02	0.04	0.64
RL: Conservation Genetic Resources	0.28	0.17	0.10	-0.05	0.62
RL: Transformation and Value-Added of products	0.45**	0.16	0.00	0.14	0.77
English language	0.09	0.10	0.37	0.10	0.27
Cereals and Grains	0.30*	0.12	0.02	0.06	0.55
Cocoa	0.32*	0.15	0.04	0.02	0.61
Coffee	0.69*	0.30	0.02	0.09	1.29
Constant	1015.66***	59.47	17.08	0.00	1132.66

*p<0.10, **p<0.05, ***p<0.01, RL= Research Line

The regression model included variables that reflect the lines of research in which INIAP is involved, variables that are considered determinants in the literature, as well as the fields or crops related to scientific articles. The dependent variable, in this case, is the bibliographic citations, which serve as a measure of the impact and interest generated by the articles. The selection of the variables included in the model allows us to identify which are the most relevant and those that provoke the greatest interest on the part of users. The interpretation of the negative coefficient of the year of publication indicates that publications that are in a database for a longer time will have a greater chance of being cited, which corroborates what was indicated by (Sánchez Pereyra et al. 2015) who mention that documents published in previous years have a higher number of citations. The results indicated that the research lines Agricultural Economy, Agroecology, and Climate Change, as well as Transformation and Added-value of products, are relevant because they indicate a growth in the scientific interest in these topics at the Institute, which would be related to the country's research needs (Zambrano et al., 2023). In terms of specific crops, it was observed that cereals and grains and fruits such as cocoa and coffee, were relevant, corroborating the results obtained in the bibliometric analysis for the crops based on the research lines.

3.6. Agricultural Productivity

Figure 12 shows graphically the relationship between the scientific production of the INIAP and the variation of the Agricultural Gross Domestic Product (A-GDP); where it is evident that there is a similar trend in the behavior of the two mentioned parameters. Observing the highest peak in the year 2020 for both factors. In the period of study, the lowest point for the number of publications was in the year 2023 whereas for the A-GDP was in 2022.



(figure 12) Number of INIAP publications 2014-2023 and agricultural A-GDP.

Table 4 shows the number of publications in crops of economic importance for Ecuador reported in 2023 by the SIPA, with their respective contribution to the A-GDP. When a correlation was carried out between these two parameters (analyzing all the crops), a value of r=0.26 was obtained, which allows us to infer that there is a influence of the contribution of the INIAP´s scientific production in the A-GDP. However, when performing the calculation without considering the banana crop, which has the highest A-GDP value, the correlation increases significantly (r=0.51); therefore, to increase the correlation value considering all the crops, the number of publications of banana research has to be duplicated.

Table 4. Correlation between the number of publications of INIAP and the Agricultural Gross Domestic Product.

				Scenarios		
Item	**Scientific Publications**	**Technical Publications**	**Total Publications**	**A-GDP 2023 (All crops)**	**A-GDP 2023 (Without Banana and plantain)**	**A-GDP 2023 (Banana and plantain publications duplicate)**
Avocado	11	6	17	3.14	3.14	3.14
Rice	4	7	11	2	2	2
Banana and plantain	6	11	17	25.4	-	**34**
Cocoa	41	10	51	8.2	8.2	8.2
Coffee	9	1	10	1.3	1.3	1.3
Bean	2	1	3	1.1	1.1	1.1
Soursop	1	0	1	0.5	0.5	0.5
Hard corn	26	6	32	1.7	1.7	1.7
Soft corn	8	6	14	0.5	0.5	0.5
Passion fruit	4	2	6	1.1	1.1	1.1
Blackberry	9	0	9	4.8	4.8	4.8
Naranjilla	6	0	6	0.5	0.5	0.5
Oil palm	3	1	4	3	3	3
Potato	21	12	33	1.4	1.4	1.4
Pineapple	1	0	1	2.1	2.1	2.1
Pitahaya (Dragon fruit)	2	1	3	0.5	0.5	0.5
Quinoa	6	2	8	0.01	0.01	0.01
Tree tomato	6	1	7	4.85	4.85	4.85
Forestry	2	4	6	4	4	4
Correlation coefficient (r)				**0.26**	**0.51**	**0.51**

Guerrero-Casado (2017) reported that there is a positive relationship between the number of articles published per million inhabitants in each country and its per capita income, the percentage of gross domestic product allocated to research and development, and the number of researchers per million inhabitants. In order to determine common points that associate scientific production with the agricultural production sector, the A-

GDP was used to relate it to the number of publications. Visually, it was possible to see that there was a similar trend in the variation observed between the years 2014 and 2023 between these two parameters; however, it was observed that in the study period there was a decrease in both factors. These fluctuations observed in the study period could also have been influenced by external factors such as the restrictions derived from the COVID-19 pandemic that impacted the agricultural sector (Lara Haro et al., 2022).

When carrying out the correlation study between the number of publications and the A-GDP of several of the main agricultural products, it was observed that there was a small correlation between both parameters (0.26); but if the item that contributes the most to the A-GDP (Banana and plantain) is not considered, this correlation was doubled, constituting an acceptable value. However, if the number of publications in Banana and Plantain doubles, the correlation would reach the same value as when this item was not considered, inferring that if there is a greater investment to carry out research in these crops, it will generate greater scientific production, causing a positive effect on the association between the scientific and productive factor. Currently, banana cultivation is of great relevance due to the problems of Moko (*Ralstonia solanacearum*) and Fusarium oxysporum Race 4, which is why it is essential to invest in research in this crop to generate technological solutions that contributing to the productive development, and influence the positive increase of the A-GDP, enhancing to the growth of the agricultural sector of the country. Jaramillo Escobar (2023) mentions that investment in research and development expenses as a percentage of GDP is a determining factor, that is, the greater the investment, the greater the scientific production. (Tinoco, 2018) reported that every dollar the Ecuadorian State invests in developing new agricultural technologies in research (INIAP) generates 40 times its value. Developed countries invest more in this area, while developing countries such as Latin America invest less than the world average; however, it is important to improve this indicator, which should be no less than 1% of GDP (Escobar, 2023). In general, investment in research in the agricultural sector is a positive factor that influences the productive and economic development of the country and allows for the generation of innovative solutions to current and real problems faced by farmers. It is recommended that governments and different research institutions in emerging countries begin to measure their productivity in the generation of scientific articles in order to properly allocate their investment in research (Arana-Barbier, 2023).

4. **Conclusion**

The results of this study indicate that INIAP's scientific production has increased its quality because the highest percentage of publications are in indexed journals located in quartile Q1, which positively affects its international dissemination and citation, reflecting the institutional commitment to generate science and technology with high scientific standards, which allows contributing to solve the problems of the agricultural sector.

The progressive increase in publications indexed in high-visibility databases demonstrates a process of institutional scientific maturation, where research outputs are increasingly oriented toward international standards of quality, visibility, and academic competitiveness.

The diversification of research topics across multiple agricultural systems and value chains indicates that INIAP has expanded its scientific scope beyond conventional productivity approaches, incorporating interdisciplinary perspectives associated with sustainability, agroindustry, climate adaptation, and resource management.

The largest amount of scientific production is focused on the area of Productivity Increase; and within this area, the Integrated Crop Management line of research is predominant; however, there is a notable increase in research in the line of Agricultural Economy, Agroecology, and Climate Change, which reflects a focus on current problems and a contribution to promote sustainable agriculture for productive development.

The higher citation performance observed in research lines related to agroecology, climate change, and value-added transformation suggests that these thematic areas currently represent emerging scientific priorities with greater international relevance and visibility within agricultural research.

The limited adjustment of the observed productivity distribution to Lotka's theoretical model suggests that scientific production dynamics at INIAP are influenced by institutional, collaborative, and contextual factors that differ from classical bibliometric behavior reported in other scientific systems. The predominance of publications concentrated in a reduced group of highly productive researchers reveals structural asymmetries in institutional scientific productivity, emphasizing the importance of promoting broader participation, collaborative research environments, and capacity-building programs among early-career researchers.

Strengthening research in strategic crops with high economic contribution, represents an important opportunity to increase the impact of scientific production on agricultural productivity and enhance the contribution of research to Ecuador's agricultural GDP.

It is necessary to generate actions and policies that allow maintaining a stable investment to develop agricultural research, since it has been observed that the economic resources dedicated to this activity have decreased over the years and this directly affects scientific production, as well as the generation of technologies that allow obtaining solutions to the problems of the agricultural sector, consequently affecting the productive and economic development of the country.

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