DATA MINING ON THE USE OF GENERATIVE ARTIFICIAL INTELLIGENCE IN AGRICULTURE

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ABSTRACT: This paper conducts a bibliometric analysis with the purpose of mapping the academic production on the application of Generative Adversarial Networks (GANs) in agriculture. Focusing on articles indexed in the Web of Science and Scopus databases from 2015 to 2023, we explore the growth patterns and profiles of the scientific literature in this area of knowledge. As a basis for the methodology, we used the SSF method, enhanced by the incorporation of a greater number of digital tools. Integrating these tools enabled an improvement in the search process and bias mitigation. The results indicate an approximate 1800 percent increase in the number of publications on GANs in agriculture from 2015 to 2023. The main contributions include the identification of significant trends and potential research gaps in the use of GANs for carbon dioxide optimization in soils with applications of remote sensing from orbital images. We

conclude that the increase in articles is due to the growing use of GANs in agriculture. This study not only highlights key areas for future innovation but also demonstrates the importance of bibliometric methods for mapping progress and guiding academic writing.
KEYWORDS: Agriculture. Data Mining. Bibliometric Analysis. Generative Adversarial Networks. Carbon Dioxide. Soils. Remote Sensing.

DATA MINING SOBRE O USO DE INTELIGÊNCIA ARTIFICIAL GENERATIVA NA AGRICULTURA

RESUMO: Este capítulo de livro usa mineração de dados utilizando análise bibliométrica com a finalidade de mapear a produção acadêmica sobre a aplicação de Redes Adversariais Gerativas (GANs) aplicadas na agricultura. Com o foco em artigos indexados nas bases de dados Web of Science e Scopus, no período compreendido entre 2015 a 2023, exploramos os padrões de crescimento e perfis da literatura científica nesta área do conhecimento. Como base para a metodologia usamos o método SSF, aprimorado com a inserção de um número maior de ferramentas digitais, integrando estas ferramentas, foi possível observar um aprimoramento no processo de busca e mitigação de vieses. Os resultados indicam um aumento percentual no número de publicações sobre GANs na agricultura, do ano de 2015 ao ano de 2023, é aproximadamente 1800%. As principais contribuições incluem a identificação de tendências significativas e potenciais lacunas de investigação na utilização de GANs para otimização de dióxido de carbono em solos com aplicações de detecção via remota de imagens orbitais. Concluímos que o aumento dos artigos, se deu em função do crescente uso das GANs na agricultura. Este estudo não apenas destaca áreas-chave para inovação futura, mas também demonstra a importância dos métodos bibliométricos para mapear o progresso e direcionar da escrita acadêmica.
PALAVRAS-CHAVE: Agricultura. Data Mining. Análise Bibliométrica. Inteligência Artificial Generativa. Dióxido de Carbono. Solos. Sensoriamento Remoto.

INTRODUCTION

In the digital age, the academic field faces unprecedented challenges and opportunities (Oliveira and Neves, 2023, p.398). The explosion of information available online has radically transformed the way researchers access, analyze, and disseminate knowledge.

In this scenario, the ability to conduct effective literature reviews and produce high-quality scientific articles has become an important differentiator in the global academic community, the vastness of available data can also overwhelm researchers (Costa and Pires, 2014, p.157), making the process of identifying, analyzing, and synthesizing relevant information an arduous task.

This article aims to analyze the profile and growth pattern of academic production related to the application of artificial neural networks (GANs) applied to agriculture, for which a bibliometric analysis was carried out, in articles from the web of Science and Scopus databases, in several journals, in the period from 2015 to 2023.

The traditional research method, among others, were analyzed in the article "Demystifying the Literature Review as Basis for Scientific Writing: SSF Method" which identified gaps, for which the proposed solution was the SSF method. The analysis focused on the lack of detail, as stated in:

> "The gaps observed mainly refer to the lack of details about the flow of how to conduct a survey. This detailing could make the method more agile and practical." These needs can be met by combining the advantages and mitigating or eliminating the disadvantages of each model. [...] "The proposed model can be adapted to the type of review chosen, either by a single researcher or by a research group. In addition, suggestions for tools, techniques, and ways of using scientific databases are emphasized (Ferenhof and Fernandes, p. 555, 2016)."

The techniques of bibliometric analysis and writing of scientific articles were studied and modified in the SSF method, described in the article "Bibliometric Study: Machine Learning Applied in Agriculture" (Silva et al, 2022, p.4), in which improvements were implemented in the systematization and practice of searching for theoretical reference. This article will implement the procedure with some improvements and application of artificial intelligence through software and applications in order to improve the search and eliminate bias.

It is noteworthy that in this study, the use of Artificial Intelligence (AI) as a tool to expand the analytical capacity of researchers, and keeping under their supervision methodological decisions, including the choice and configuration of AI tools, were strategically determined to ensure and ensure the accuracy and relevance of the results. Critical analysis, along with validation of the data generated, was conducted manually, ensuring that the conclusions reflected an in-depth and contextualized understanding of the articles on the use of GANs in agriculture.

METHODOLOGY

In this work, the methodology used was based on the SSF method, which consists of 4 phases and 8 activities, the method was developed according to the authors, in order to systematize the process of search or searches to the scientific database. Thus, it serves both for the systematic review and for the integrative review, depending only on the definition of the strategy in its use (Ferenhof and Fernandes, 2016, p. 555), however, for the purpose of application, it had changes in phase 1, which consisted of the use of the R® software automating activities 3, 4 and 5.

In phase 2, the activity (data consolidation) was automated using the R® libraries, generating a Data Frame and converting it to MS Excel®, unifying the data obtained in the Web of Science and Scopus databases. The Data Frame obtained was used for treatment and preliminary analysis. Phase 3 was also automated by applying R® to analyze the Data Frame (Silva et al, 2022, p.4).

Also according to the authors,

> "In phase 4, the consolidation of the results was carried out through scientific writing, therefore, the objective of the work was rescued, compared with the result of the analysis and synthesis, in this phase the knowledge matrix recommended by the authors was eliminated, since the data were generated within the R® Library, Biblioshyne, as well as, the reports that were the basis for the writing of the results, concluding activity 8, proposed by the authors (Silva *et al*, p.4, 2022)."

Execution of the Survey

Phase 1 - Planning and Preliminary Research

In this phase, the problem object of study was defined, the search for bibliography in a preliminary way. At this stage, the criteria for selecting articles were established, that is, how you decide which studies to include in your review, for example: types of study, time periods, theoretical approaches, etc. (Pereira and Galvão, 2014, p.370).

Activity 1 - Problem Formulation: was carried out using the Gemini – Google tool, applying the following Prompt (Considering the innovations and technological advances of the last 10 years, I would like to explore the five most promising or innovative ideas related to the use of Generative Neural Networks in agriculture that is linked to CO2). For each idea, please provide a concise description that includes: The specific problem the idea seeks to solve in agriculture. In addition, I am particularly interested in identifying emerging areas or niches within this theme that are beginning to gain significant attention in the scientific community and could represent innovative research opportunities) < https://gemini.google.com/app>.

ChatGemini, returned 5 ideas, we chose only one for use in this article: Optimization of Carbon Sequestration in the Soil. From this idea, we derive the problem: Increasing the soil's capacity to sequester carbon from the atmosphere, fighting climate change. We use the following approach: Convulsion neural networks to analyze soil images and identify features that influence carbon sequestration.

Query strategy for preliminary research was created using the following prompt in Gemini: Based on the idea of optimizing soil carbon sequestration using neural networks, I need to develop a detailed search query for use in Google Scholar. Research should target articles that address the use of convolutional neural networks in the analysis of soil images and the optimization of soil management to sequester carbon. The query should be specific enough to filter relevant literature that discusses both the theory and practical applications of this technology in agriculture, focusing on the identification of soil characteristics that influence carbon sequestration, generation of predictive carbon sequestration maps, soil management strategies to maximize carbon sequestration, including crop rotation and mulching.

The return obtained was the following query:

"Convolutional Neural Networks" OR "Deep Neural Networks" OR "Deep Learning" AND "Soil Image Analysis" OR "Soil Image Segmentation" AND "Soil Carbon Sequestration" OR "Carbon Sequestria" AND "Soil Management" OR "Soil Management Practices" AND "Crop Rotation" OR "Mulching" AND "Predictive Maps" OR "Carbon Mapping".

Guidance provided for the use of Boolean operators:

- Use AND between the main search terms to ensure that all terms are present in the results.
- Use OR between synonymous terms to increase the comprehensiveness of your search.
- Use NOT to exclude irrelevant terms.

Guidelines for applying search filters:

- Publication date: Limit the search to articles published in the last 5 years (2019-2024) to get more recent results.
- Language: Limit your search to articles in Portuguese or English.
- Type of publication: Peer-reviewed scientific articles.

Sample query:

- ("Convolutional neural networks" OR "Deep learning") AND ("Soil analysis" OR "Soil carbon") AND ("Predictive mapping" OR "Carbon sequestration")
- "Soil management" OR ("Crop rotation" OR "Mulch") AND "Predictive maps" OR "Carbon mapping" NOT "Literature review"

Tips:

- Use double quotation marks (" ") to search for exact phrases.
- Use asterisk (*) as a wildcard to find word variations.
- Use Google Scholar's search filters to refine your results.
- Explore the related articles and citations of the articles found to broaden the search.

We applied the following search query in the Google Scholar tool, ("Convolutional neural networks" OR "Deep learning") AND ("Soil analysis" OR "Soil carbon") AND ("Predictive mapping" OR "Carbon sequestration").

The Search returned 1,580 results, using the Scite tool integrated with google Scholar, it was possible to identify which articles received statements of support, and those that received contrasting statements, in this way 5 (five) articles were chosen from each, totaling the 10 (ten) articles selected to compose the initial portfolio of articles, as shown in Figure 1.

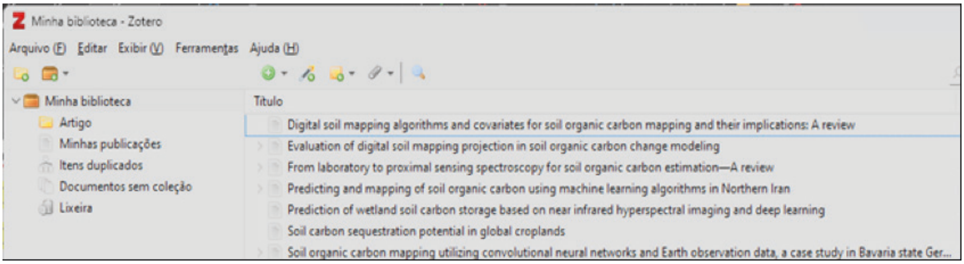

Figure 1 – Files selected and imported into Zotero.

Source: Authors, 2024.

Activity 2- Database Consultation, after reading the 10 articles, we can have an overview of the area and field of study (Santos and Campos, 2023, p.14), in this way the criteria for creating the new query of the final research were elaborated, to compose the final study database. The following filters were also defined: Article and Review Articles, open access, written in English, in the period between 2015 and 2023).

The following Query was created and applied in the web databases of Science and Scopus, "TS=("Generative Neural Networks" OR "Deep Learning" OR "Convolutional Neural Networks" OR "Artificial Intelligence" OR "Machine Learning") AND TS=("Soil Carbon Sequestration" OR "Agriculture" OR "Soil Organic Carbon" OR "Climate Change" OR "Sustainable Agricultural Practices" OR "Environmental Modelling" OR "Remote Sensing" OR "Hyperspectral" OR "Multispectral" OR "Radar") AND PY=(2015-2023)".

Applying the query, the search returned the following results from the WOS and Scopus databases, respectively: 1,975 articles found As shown in Figure 2, the data frame was downloaded in 4 files in the format "plain text and full record". The Scopus base returned 19,292 after application of the filters, as shown in Figure 3. The data frame in 2 files were downloaded in CSV format.

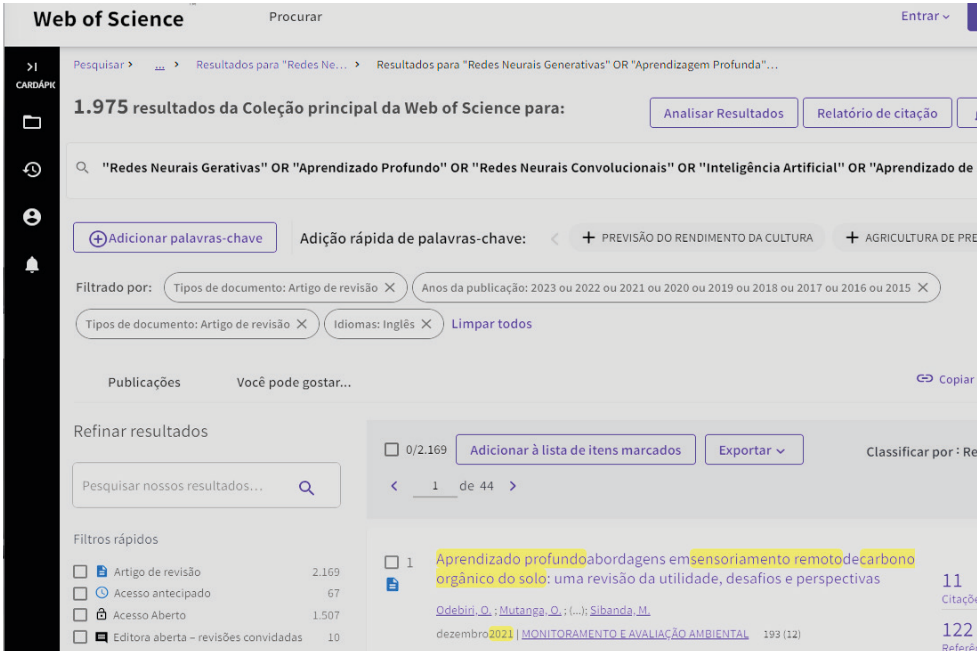

Figure 2 – Search result after applying the filters - WOS.

Source: Authors, 2024.

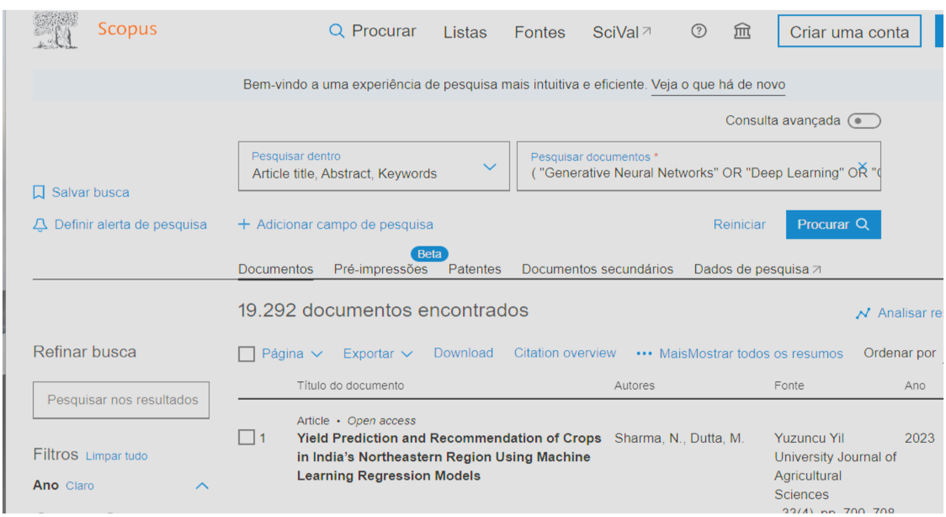

Figure 3 – Screenshot of the research carried out in the Scopus database.

Source: Authors, 2024.

The files have been saved in a specific folder targeted for PC search.

Activities 3 (Document Management), 4 (Standardization of Document Selection) and 5 (Composition of the Article Portfolio) were automated and incorporated into activity 6 in phase 2.

Phase 2 - Analysis

Activity 6 - Pre-treatment and Data Processing: in this activity, the tool R, RStúdio and its libraries – Bibliometrix and Biblioshyne, were used to perform the pre-treatment of the metadata obtained from the web of Science and Scopus. Figure 4 shows the R script applied to load the files into the console, transform the files to the accepted extension (Bibitex), merge the files, create a unified data-frame, and preprocess the data, deleting the duplicate files. Usage information can be obtained from the following link < https://bibliometrix.org/biblioshiny/biblioshiny1.html>.

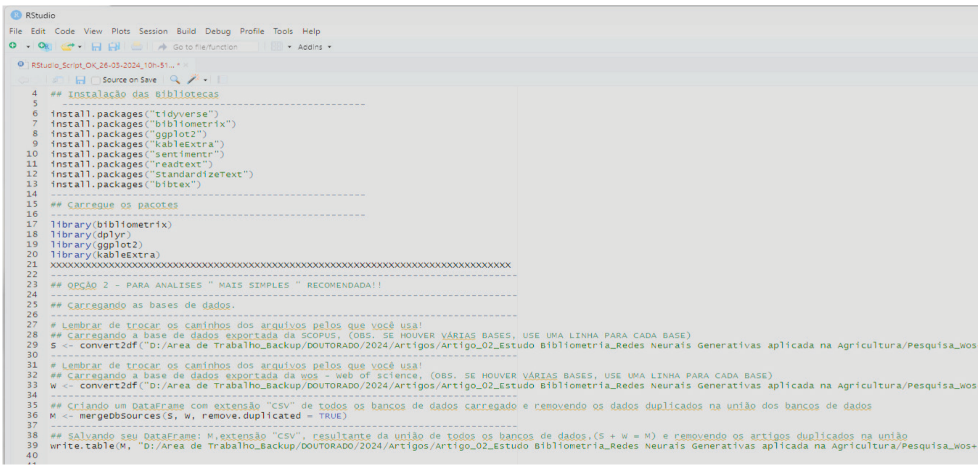

Figure 4 – Script R.

Source: Authors, 2024.

Data processing: After pre-processing using R Script, it is necessary to check the generated Unified Data Frame, filtering by DOI and excluding the rows without record, duplicate DOI and invalid records. This process is carried out by the author opening the file by performing the operations mentioned above. As a result of this post-processing, articles with duplicate DOI, articles without DOI and articles with less than 10 citations were excluded, this filter was applied to ensure a file size that can be uploaded to Biblioshyne. Screenshot of the Excel screen in figure 5.

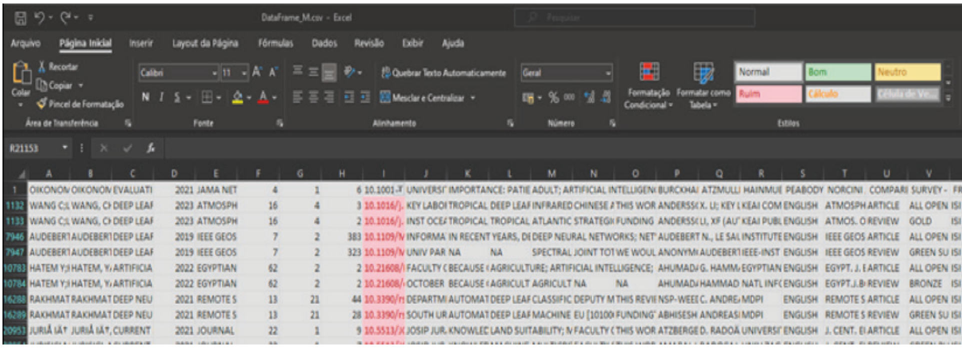

Figure 5 – Print of the opened CSV file.

Source: Authors, 2024.

Phase 3 - Synthesis

Activity 7– Organization of the literature: This activity was performed automatically using RStudio and the Biblioshyne and Bibliotrix libraries. The Data Frame was loaded into the tool, as shown in figures 6 and 7.

Figure 6 – Biblioshyne Library interface.

Source: Authors, 2024.

Figure 7 presents the summary of the data imported into the R software in the Bibliotrix / Biblioshyne interface, this initial report is presented to the user before the start of the analyses (Palma, Venancio, et al., 2022, p19), it has the purpose of informing the quality of the information contained in the import file.

Completeness of bibliographic metadata - **21118** documents from **Isi**				
Metadata	**Description**	**Missing Counts**	**Missing %**	**Status**
DT	Document Type	0	0.00	Excellent
SO	Journal	0	0.00	Excellent
LA	Language	0	0.00	Excellent
PY	Publication Year	0	0.00	Excellent
TI	Title	0	0.00	Excellent
TC	Total Citation	0	0.00	Excellent
AB	Abstract	2	0.01	Good
AU	Author	5	0.02	Good
DI	DOI	4	0.02	Good
C1	Affiliation	19	0.09	Good
CR	Cited References	62	0.29	Good
RP	Corresponding Author	778	3.68	Good
DE	Keywords	1821	8.62	Good
ID	Keywords Plus	3923	18.58	Acceptable
WC	Science Categories	21118	100.00	Completely missing

Figure 7 – Data imported into Biblioshyne.

Source: Authors, 2024.

Reading of the articles: in order to confirm the adherence of the articles to the theme, the consistency between the title, abstract and keywords was verified through the tool's interface, the first 50 articles were checked, all of which presented data correlated to the theme. Figure 8 presents the data contained in the imported file, in this interface it is possible to verify if the pre-processing of the data was carried out correctly, in addition to allowing filters for analysis, access to links to download the files in PDF format and Reading the main information of each article.

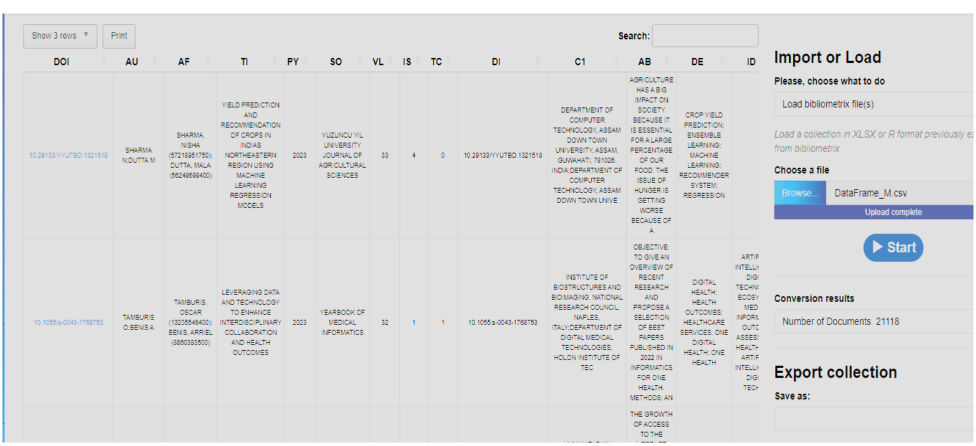

Figure 8 – Presentation of the imported data.

Source: Authors, 2024.

Analysis of the content obtained: Figure 9 presents an overview of the data, it allows us to obtain the most relevant data, allowing an initial analysis. Highlight the scientific productivity in a given period, the field studied, the published documents, co-authorships, the international collaboration, the average annual publication, among other information, providing a prior knowledge of the research carried out. In this activity, only the review articles were selected, 7,204 out of the total of 21,118 in the database.

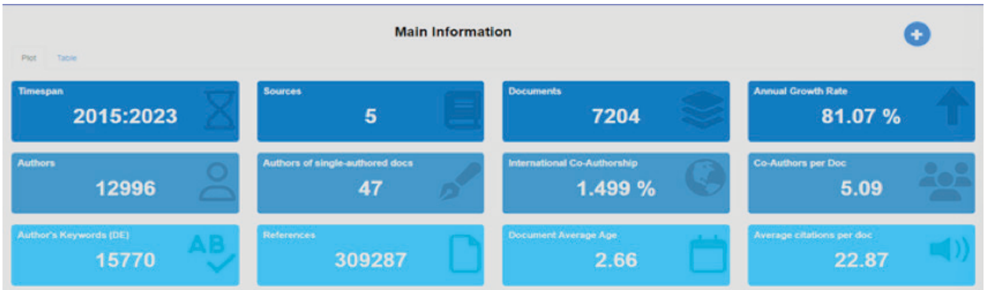

Figure 9 – Key information.

Source: Authors, 2024.

Figure 10 shows the graph showing an ascending line, indicating a significant increase in the number of articles published over the years. Starting with relatively low values at the beginning of the period, the line has a smooth curve initially, suggesting steady and moderate growth. However, in more recent years, the curve has become steeper, which points to an exponential growth in scientific production. This pattern suggests that there has been a substantial increase in interest and research in the area in question, reflected by the increasing number of publications. The chart could be an indicator of technological advancements, increased funding, broader collaborations, or an increase in the importance of the field of study.

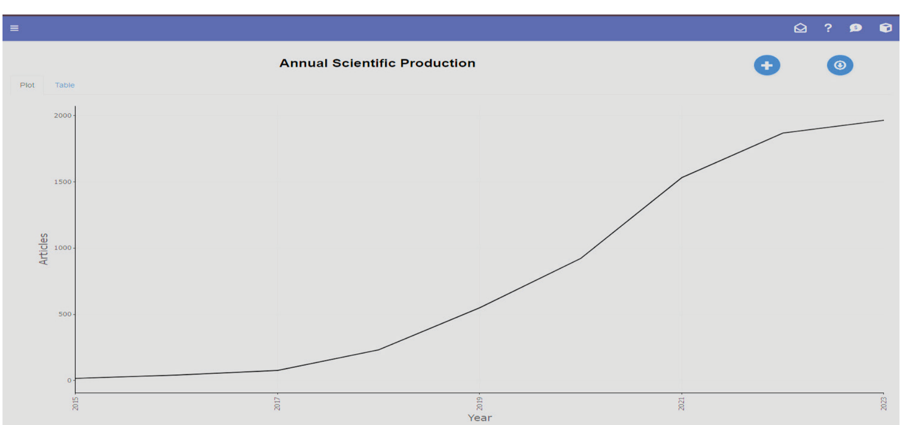

Figure 10 – Annual Scientific Production.

Source: Authors, 2024.

Figure 11 presents an analysis where we observe that “Machine Learning” is a central keyword for both authors and indexers, which reinforces its importance in the field studied and its coherence with the increase in publications previously identified. The thick links between the keywords and the sources suggest a large number of articles related to these terms, which indicates an area of intensive focus for the research community.

The chart also shows a diversity of indexed topics related to machine learning, including forecasting and deep learning, and how these topics connect with various sources, indicating that the subject is addressed from multiple perspectives and published in a variety of scientific journals. In addition, the presence of keywords related to “Agriculture” confirms that the agricultural sector is among the areas that presents significant possibilities for machine learning, which is consistent with the growth of the field indicated by the increase in annual scientific output.

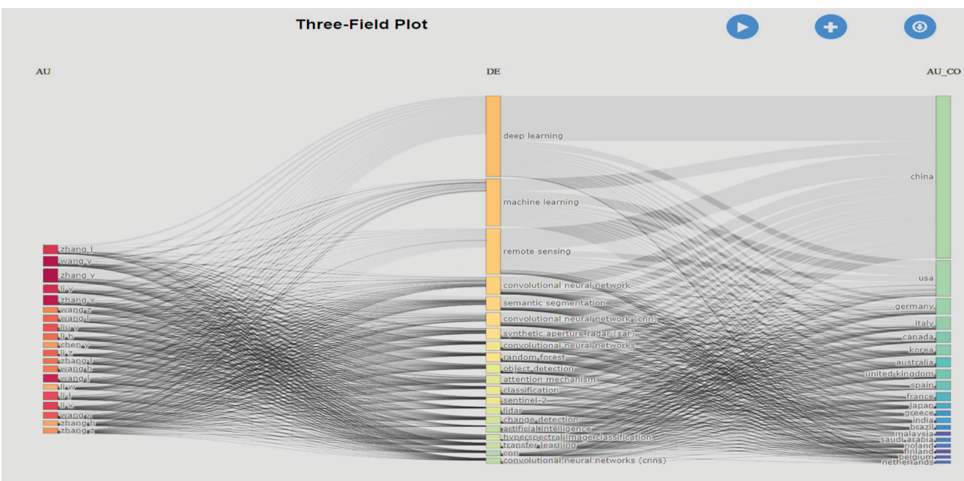

Figure 11 – Graph of three fields, author, keyword, and country.

Source: Authors, 2024.

Figure 12 presents the data analyzed based on Bradford’s Law, which is a principle that suggests that a small nucleus of journals in the field of study will be cited more than others. The chart typically divides into three zones: the core of frequently cited journals (the central zone marked on the chart), a medium set, and a large number of journals with few citations.

The vertical axis shows the number of articles and the horizontal axis, on a logarithmic scale, represents the rank of sources. The point at which the curve becomes flatter indicates the transition from the central core of journals to less cited sources. The core sources, highlighted in the chart, reveal that there are a relatively small number of sources where most documents are published and cited, aligning with Bradford’s Law.

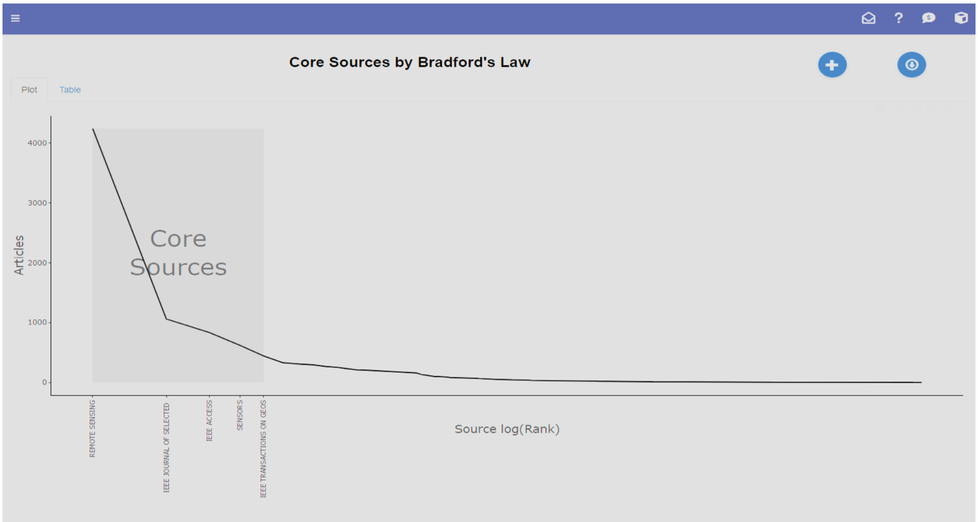

Figure 12 – Bradford’s Law.

Source: Authors, 2024.

Figure 13, the “Most Relevant Authors” graph, highlights the authors with the highest number of published documents in a specific field of research. The circles, whose sizes vary proportionally to the number of documents each author has contributed, clearly indicate that some authors have a significantly higher output than others.

The most productive author, represented by the largest circle at the top of the chart, has an exceptionally high publication count, approaching 600 documents. This suggests a dominant influence in the field of research. Other authors, although with smaller numbers, also show a substantial contribution, with several dozen publications each.

These results are consistent with previous analyses, reinforcing the idea that some researchers are extremely active and possibly thought leaders in their field. This could be due to involvement in extensive collaborative research or a focus on high-demand areas within the field. Author productivity can be driven by a variety of factors, including affiliation with institutions with substantial resources, leadership in collaborative research projects, or an active role in academic communities that value frequent publications.

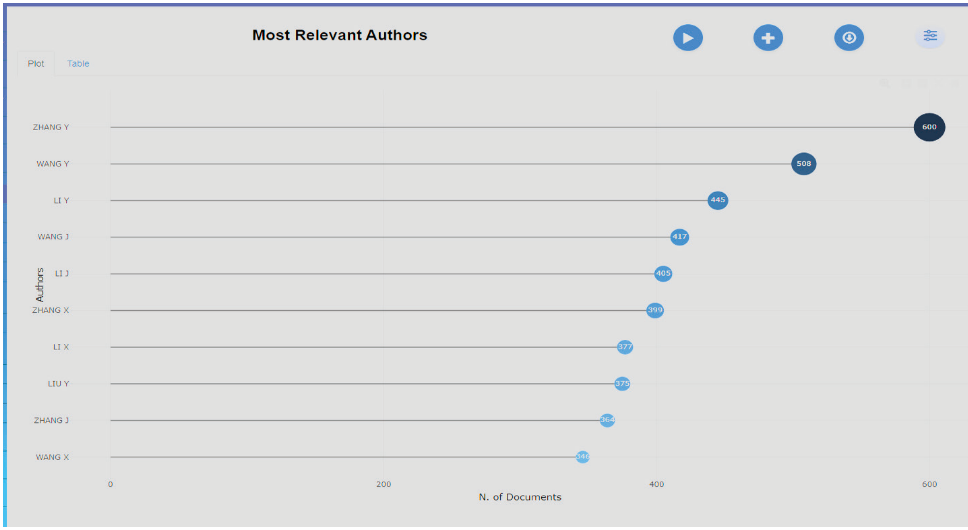

Figure 13 – Most relevant authors.

Source: Authors, 2024.

Figure 14 shows the graph related to the productivity of authors according to Lotka's Law, a law that describes the frequency of publication of authors in certain scientific disciplines. The principle is that the number of authors making a large number of contributions is relatively small, and that many authors publish only once. Lotka's law is often represented in a hyperbolic curve.

The graph presented has a sharp decline from left to right, with most authors clustered on the far left, indicating that they have a small number of publications. There is a rapid drop in the amount of authors as the number of written documents increases. This pattern is typical in the distribution of author productivity, where many contribute few articles and only a few write many.

The most productive author, ZANG Y together with WANG Y, identified in the previous graph as having approximately 600 and 508 documents and the 8 authors in sequence, are the ones that stand out in the overall trend. This type of analysis is useful for identifying opinion leaders and key contributors in a field of study.

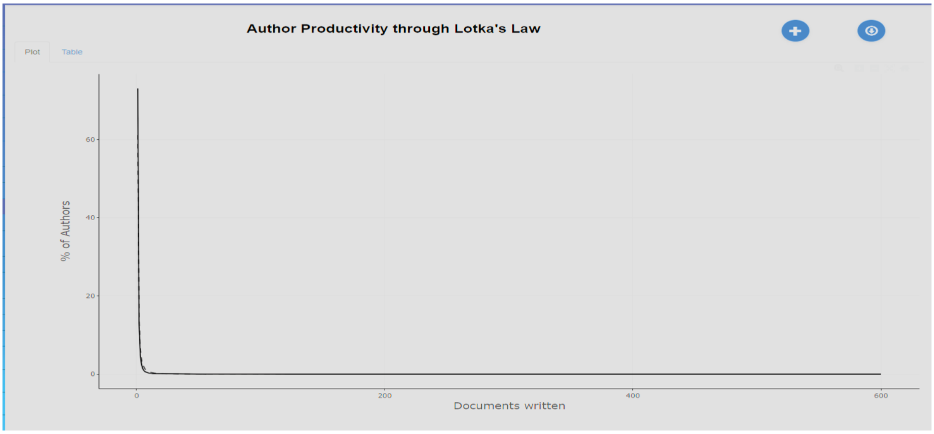

Figure 14 – Lotka's Law of Author Productivity.

Source: Authors, 2024.

Phase 4 - Write the Article

Activity 8 - The act of writing, in this activity, the knowledge and guidelines provided for in the SSF method were applied, such as analyzing the articles again, checking if the data are aligned with the theme and area of study, writing the article in line with the submission rules of the chosen journal, aligning the language style, removing mention of authorship, performing grammatical review and defining the writing language (Ferenhof and Fernandes, 2016, p. 561).

RESULTS AND DISCUSSIONS

The research adopted a bibliometric approach aiming to evaluate the scientific literature on the use of artificial neural networks in agriculture, with a particular focus on soil carbon sequestration. AI tools were used in the initial phase to determine the context and delimit the study area, as well as for data analysis, such as R and RStudio, accompanied by the Bibliometrix and Biblioshiny libraries, enabling the pre-processing, processing and organizing a significant amount of metadata of the articles obtained from the Web of Science and Scopus databases.

In the processing and pre-treatment phase, the data were initially subjected to a pre-treatment that included conversion to formats compatible with RStudio and Microsoft Excel, unification of multiple files into a single DataFrame and the exclusion of duplicate entries. This process was essential to ensure the quality and accuracy of the subsequent analysis.

The organization and synthesis of the literature was automated, facilitating the analysis of consistency between the title, abstract and keywords of the articles. This step confirmed that the selected articles adhered to the topic of interest, allowing a synthesis focused on the most relevant contributions and the identification of trends.

The analysis of Trends and Scientific Productivity allowed us to observe an exponential growth in the amount of literature available on the subject over the years. It has been observed that machine learning techniques, particularly deep neural networks, are increasingly being applied to improve soil carbon management, a crucial aspect for climate change mitigation.

The distribution of Publications and Authors' Contributions, after application of the Bradford Law, indicated that a central nucleus of journals dominates publications in this area, suggesting that these journals are frequently cited and considered fundamental for the dissemination of new knowledge and techniques. In addition, Lotka's Law helped to identify that although many authors contribute to the field, only a small number of them make frequent contributions.

CONCLUSION

Therefore, the results of this bibliometric study reveal a 1800% increase in publications on Generative Adversarial Networks (GANs) applied to agriculture in the period from 2015 to 2023. This growth demonstrates the growing interest in GANs and their applicability in fields such as carbon dioxide optimization using orbital imagery. The findings reinforce the role of GANs as a key tool for advances in agriculture, indicating promising areas for future investigations, especially in improving the integration of remote sensing data into agricultural models. In addition, the adoption of the SSF method enriched with digital tools has demonstrated success in reducing biases and improving bibliographic analysis, highlighting the need to increasingly integrate technology to support researchers helping in data analysis in the academic environment.

In addition, the practical application in the form of the exercise presented, demonstrated advantages and disadvantages in relation to the traditional bibliometric method, among them are, respectively: Increased efficiency in the Literature Review, reduction in the possibility of biases, greater ease in the discovery of Knowledge Gaps, allows greater collaboration between researchers, obtaining a Robust Theoretical Base. Possibility of information failure due to outdated tools, potential costs when opting for paid tools, prior knowledge of the tools, risk of bias in the data, and information due to processing load.

In this way, the results observed are intrinsically related to the use of the tools used, at the same time that they help in the processing and accelerate the process in several phases, it was observed that they are likely to present results that do not match what was expected, due to several factors, such as inadequate script, inadequate prompts, lack of knowledge of the software by the researcher and technical knowledge in the IT area (Garcia, Magalhães, *et al.*, 2018, p.113), the lack of use of best practices when handling data in software and apps.

Although AI tools applied to the writing of Scientific Articles provide numerous advantages, such as improved automation and efficiency in literature review, they are not without limitations. The understanding of these aspects is crucial for the effective use of these tools in the process of writing bibliometric articles.

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