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Bibliometric analysis of beneficial cannabis research: Performance analysis and science mapping from 2012 to 2022 and focus on Morocco

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ABSTRACT

Beneficial cannabis use has sparked growing interest among researchers, leading to an increase in empirical studies exploring its phytochemistry and applications. However, understanding the overall research orientation remains limited. This study aims to bridge this gap by conducting a bibliometric analysis of 7841 documents published from 2012 to 2022. The analysis reveals an annual growth rate of 16.83 %, with a focus on medicine, pharmacology, toxicology, pharmaceutics, biochemistry, genetics, molecular biology, and neuroscience. Performance analysis highlights metrics of sources, countries, affiliations, and authors, while science mapping identifies keywords, thematic evolution, and citation/co-authorship patterns. Notably, Morocco, despite its limited initial contributions, has shown recent steady growth in cannabis research, with an annual growth rate of 14.31 % and a 51.72 % international collaborative rate. This study provides valuable insights into established fields and potential research directions in cannabis research, paving the way for a deeper understanding among the audience. With the changing legal status of cannabis, research is rapidly expanding, focusing on the plant's bioactive compounds, pharmacological properties, and therapeutic applications. The dominant subject areas are medicine, pharmacology, toxicology, pharmaceutics, biochemistry, genetics, molecular biology, and neuroscience, covering nearly 76 % of the studied papers. Despite limited initial contributions from African countries like Morocco due to legal restrictions, beneficial cannabis research is gaining interest. Future research should prioritize in-depth exploration of specific compounds, comparative studies of cannabis-based products, and rigorous clinical trials. Fostering international collaborations and bridging the gap between research and policymakers are crucial for harnessing the full potential of cannabis while mitigating potential risks. This study serves as a reference for researchers to identify current orientations, blind areas, and gaps in cannabis research, offering suggestions for future studies.

1. Introduction

The term "Cannabis" is usually related to three species of flowering plants: sativa, indica, and ruderalis, while "Marihuana" refers to the dried arial parts (leaves, stems, and inflorescences) of the mainly consummated strains sativa and indica [1]. The World Health Organization classifies all preparations derived from the plant cannabis, containing Δ-9-tetrahydrocannabinol (THC), as "cannabis" [2]. The plant was classified as an illicit drug due to the intoxicating effects of some of its components, which can induce relaxation, feelings of euphoria, altered perception and wellbeing [3,4], it was removed from the British pharmacopeia, and the National Formulary and Pharmacopoeia and prohibited by the USA federal legalization: the "Marihuana Tax Act" [5,6], and the single convention on narcotic drugs sanctioned by the United Nations in 1961 [7,8]. These heavy legal restrictions for an extended period, resulted in poor knowledge of the plant, its rich phytochemistry and its potential effects. Since the enactment of the 2014 Farm Bill, there has been a gradual easing of restrictions on its cultivation and production [9].

In 2020, around 284 million people aged 15–64 used drugs worldwide, marking an increase of 26 % over the previous decade. In this time, cannabis cultivation increased, and its usage rate amplified by

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23 %, as 209 million people, roughly 4 % of the global population use cannabis, marking it the world most widely used illicit drug [10].

This surge of use led to a peak of interest in cannabis research, as an increased number of empiric studies was published, studying its chemical composition, its undesired effects, and its chemical, and biological activities. Despite the large number of conducted research, exploring every aspect of the plant, systematic reviews, and meta-analysis about the beneficial cannabis are limited, while bibliometric analysis studies focusing on the general patterns of scientific research on beneficial cannabis and studying trending themes and major contributions are lacking. Therefore, this paper aims to present a bibliometric analysis to follow the overall research directions and map the overgrowing flow of studies, to summarize the major and trending themes, and identify key research areas in beneficial cannabis field.

Bibliometrics is a statistical quantitative research assessment of broad academic outputs, when the data is considered too large for manual review [11]. It aims to present the state of the intellectual structure, emerging trends, access the quality of studies, analyze key areas, and predict possible directions of a research topic, following a set of methods to study big datasets, combining linguistics, textual and statistical sciences to explore the impact of a field, a set of researchers, or of a particular paper [12,13].

A search for "cannabis AND bibliometric" on Web of Science (WOS) database yielded 20 documents, while Scopus returned 28. After manually filtering duplicates and irrelevant entries, nine documents focusing on cannabis research were identified and retained for further in-depth examination to report the current state of knowledge and existing bibliometric studies in this field. Table 1 summarize the main findings of the selected papers, providing an overview of their aims and limitations compared to our current work.

The scarcity of existing bibliometric analyses on cannabis does not adequately cover the current state of knowledge and suggests a gap in the field. To the author's knowledge, no comprehensive bibliometric study has been conducted in this area.

This paper presents a decade-long analysis of academic publications focused on beneficial cannabis. This search strategy encompasses a large volume of documents by using a wide range of relevant keywords and their synonyms.

Additionally, this study employs performance analysis and science mapping approaches to analyze the retrieved data, and goes beyond keywords and titles, by incorporating "Keywords Plus" and abstracts to establish thematic maps, identify trending topics, and generate keyword clouds. This comprehensive approach provides a detailed report of research direction over the past decade, highlighting emerging themes and under-explored areas.

The bibliometric analysis approach is adopted in this paper due to its ability to systematically assess the breadth and depth, and map the landscape of beneficial cannabis scientific research, treating great amount of data to identify present and emerging trends in research topics, methodologies, and findings by examining patterns in the metadata of scientific publication over the studied period. It allows for a systematic and reproductible review process, reducing bias compared to traditional narrative reviews, and enhancing the reliability and validity of the study.

In the context of beneficial cannabis research, bibliometrics provides a robust framework for evaluating the current state of cannabis research, as it allows for a broader evaluation compared to reviewing individual studies, by examining publication patterns, emerging themes and topics, influential entities, and collaborative networks. This approach guides researchers to seminal works and key contributors, fostering a more strategic and informed approach to advancing knowledge in this field, while revealing areas gaining traction and exposing those with limited research outputs. This allows future research to avoid over-investigated topics and address knowledge gaps, while encouraging new partnerships and collaborations, ultimately leading to a more comprehensive understanding of cannabis and its potential benefits.

Table 1
Comparison of available bibliometric studies on cannabis.

Document	Aims & overview	Limitations
Evolution of Marijuana Research at the Biopsychosocial Level: a General View (Sixto-Costoya et al.) [14]	The paper studies the evolution of marijuana research from 2001 to 2020, cross-referring Web of Science and PubMed' results, focusing on the chronological evolution of MeSH terms in three branches: "Anthropology, Education, Sociology and Social Phenomena", "Chemical and Drugs", and "Psychiatry and Psychology".	▪ The keywords or MeSH terms used are exclusively: "marijuana use," "marijuana abuse," and "medical marijuana", returning limited results. ▪ The study focused exclusively on the analysis of the chronological evolution of the terms in three selected branches. ▪ No bibliometric analysis was conducted.
Exploring the research evolution of Papaver somniferum and Cannabis sativa: A bibliometric comparative analysis (Diaz-Bárcena et al.) [15]	The paper presents a comprehensive bibliometric comparison of Papaver somniferum (opium poppy) and Cannabis sativa (cannabis) research as sources of pharmacologically significant secondary metabolites, focusing on productivity, publication distribution, subject categories, and keywords.	▪ For the cannabis part, the study used only the keyword "Cannabis sativa," which limits the scope of data retrieved from Scopus. ▪ The study is an evaluation comparing two fields of research: Cannabis sativa and Papaver somniferum.
A bibliometric analysis of the cannabis and cannabinoid research literature (Ng and Chang) [16]	The paper focuses on articles and reviews related to cannabis research in general (29 802 documents), examining intersections with mental health, chronic illness, and other substances.	▪ The keywords used are limited to: cannabi*, hashish, marijuana, and marihuana, returning general results. ▪ The methodology is limited by the search being restricted to the title of the published research, moreover, no manual screening was performed.
Cannabigerol: a bibliometric overview and review of research on an important phytocannabinoid (Anokwuru et al.) [17]	The paper highlights the chemistry, biosynthesis, pharmacology and safety of cannabigerol, while performing a bibliometric overview to visualize research trends and performances.	▪ The study is limited by the focus on a single cannabinoid.
The most 100 cited papers in addiction research on cannabis, heroin, cocaine and psychostimulants. A bibliometric cross-sectional analysis (Zurián et al.) [18]	The paper investigates the 100 highly cited documents on psychostimulants, including cannabis, using Web Of Science.	▪ The study focused only on the most cited documents on cannabis among other drugs in addiction research.
Global Trends in Cannabis and Cannabidiol Research from the Year	The paper analyses cannabis and CBD related documents from 1940–2019 in Web Of	▪ The reliance on Web of Science and a limited keyword set results in a

(*continued on next page*)

Table 1 (*continued*)

Document	Aims & overview	Limitations
1940–2019 (Liu et al.) [19]	Science, following the development of this topic through three aspects: chemistry, pharmacology, and molecular biology.	constrained data output. Moreover, the focus on cannabidiol excluded broader aspects of cannabis research.
Molecular neuroscience at its "high": bibliometric analysis of the most cited papers on endocannabinoid system, cannabis and cannabinoids (Yeung et al.) [20]	The paper used Web of Science to identify the 100 most cited manuscripts on cannabis, cannabinoid, and endocannabinoid system published between 1986 and 2016.	▪ The study focused only on the most cited documents on cannabis among other drugs in addiction research, and it can be considered outdated due to recent advancements in cannabis research.
A bibliometric analysis of Cannabis publications: Six decades of research and a gap on studies with the plant (Matielo et al.) [21]	The paper covers publications related to Cannabis, from 1960 to 2017, retrieved from Scopus using the keywords (Cannabis + Biochemical, Cannabis + Biology, Cannabis + Forensic genetics, Cannabis + Genetics, Cannabis + Molecular markers and Cannabis + traceability)	▪ The limited keywords constrain the scope of included documents to only those conducted at the intersection of cannabis and predefined topics: biochemical, biology, forensic genetics, genetics, molecular markers, and traceability.
Scientific production in cannabis and tobacco consumption by means of the Web of Science (Osca-Lluch et al. [22]	The paper studies 1008 documents obtained from Web of Science, related to drug abuse or substance use, indicating a surge of interest in the field.	▪ The analyzed documents are solely related to substance abuse. ▪ The study can be considered outdates due to the significant evolution in cannabis research in recent years.

This article includes a specific focus on cannabis research within Morocco as a case study to identify current research themes within the newly invigorated research landscape, and to illustrate the broader implications of recent legislative changes in some countries.

Morocco represents a unique exemplar due to its status as one of the world's major suppliers of cannabis [23]. Despite its significant role in production, research on the potential therapeutic applications of cannabis has historically lagged behind, due to the previously stringent legal measures surrounding cannabis cultivation and use in Morocco. These restrictions effectively stifled scientific exploration in the field and influenced the overall research landscape as researchers faced considerable limitations due to legal constraints and social barriers.

The recent legalization of medical and industrial cannabis use in Morocco marks a transformative era for cannabis research within the country [24]. This legal shift has ignited a surge of interest, opening new avenues for scientific inquiry, to explore the potential benefits of locally cultivated cannabis varieties, and their chemovars. However, their chemical and genetic print, along with their potential abilities remains largely unknown, therefore, this bibliometric analysis is essential to guide researchers toward trending themes and provide a roadmap of how actual knowledge in beneficial cannabis field was constructed, along with the most influential papers that can be a source of inspiration to future studies, providing a base of globally adopted methods and findings that can be implemented to explore the local chemovars.

2. Aims of the study

Given the growing focus on beneficial cannabis research, especially with its rapidly expanding use for various purposes, it is crucial to explore more facets of this field and study its diverse aspects to unleash its full potential while ensuring its responsible usage and establishing safety guidelines. Despite this surge of interest, there is a significant gap in bibliometric analyses that map the field's landscape.

This paper aims to address this by evaluating beneficial cannabis research between 2012 and 2022, as it quantifies research output and impact, and maps the intellectual and conceptual structure as it offers insights into the prevailing research themes while identifying emerging areas of interest and shifts of focus over the past decade. By analyzing publication volumes and citations, it assesses the productivity and impact of authors, journals, institutions, countries, and assesses collaborative networks by investigating their patterns to understand the dynamics of the research community and to identify key research hubs, fostering further collaboration and innovation.

This review aims to provide a general map of the current state of knowledge in beneficial cannabis field, highlighting over-researched and under-explored areas. It contributes to a more informed understanding, and guide future research towards potential directions where studies are lacking, to fill in the existing gaps and enrich the expertise piled in the domain.

3. Methodology and tools

3.1. Data acquisition

A personalized protocol was followed to collect, filter, treat and analyze the available data. This bibliometric study englobes the two main techniques, the Performance analysis technique aiming to present results concerning the total publications, contributing authors and theirs metrics, highly cited papers along with their total and average citations, Collaboration index, Influential journals, subject categories, etc, and the Science Mapping technique focusing more on the most influential papers, authors, affiliations, and countries, co-authorship analysis, collaboration analysis, trend topics, and keywords analysis.

To perform this study, a roadmap consisting of 6 steps was constructed and followed to define keywords, select a database, collect, and filter the obtained results.

Step 1: Selecting and defining the search terms, by combining keywords relevant to the targeted documents. The terms selected for the initial screening are: "cannabi*" (the * allows the database to retrieve any documents with the keyword any terms no matter what is the suffix, including cannabis, cannabinoid, etc), "hemp", "haschich", "hashich", "hashish", "marihuana", and "marijuana" in order to include any document related to cannabis research that may be using a synonym of the term. As this paper focuses on the bioactive molecules in cannabis and its chemical, biological, and therapeutic potential, the main keyword is combined with other filtering terms: "bioactif", "medicinal", "actif", "medical", "therapeutic", "effect*", "function", "*chemical", "biologi*", "anti*", "chemic* acti*", "biologi* acti*".

Step 2: Choosing the database. Scientific publications related to cannabis research were retrieved from the Scopus database (http://www.scopus.com) belonging to Elsevier. This database was chosen due to its large coverage compared to other online databases. A similar search was conducted on Web of Science, returning less documents, which were already included in the Scopus results, confirming that the latter is the right choice as a database for this bibliometric analysis.

Step 3: Determining the search fields or criteria. To filter any irrelevant papers, the main term (cannabis and its synonyms) is searched in the Title field, while the filtering keyword is combined using the connector "AND", and searched in the title, abstract and keywords.

Step 4: Collecting initial search results. Using the query: *TITLE ("cannabi*" OR "hemp" OR "haschich" OR "hashich" OR "hashish" OR*

"marihuana" OR "marijuana") AND TITLE-ABS-KEY ("bioactif" OR "medicinal" OR "actif" OR "medical" OR "therapeutic" OR "effect" OR "function" OR "*chemical" OR "biologi*" OR "anti*" OR "chemic* acti*" OR "biologi* acti*"),* a search was conducted on Scopus database, listing 34 527 documents.

Step 5: Performing a preliminary analysis. The data collected using the initial search results was studied to get a global idea on the cannabis research from the start. The results are presented in Section 3.1.

Step 6: Refining the search results. For the main bibliometric analysis, the initial search is filtered with further care, to exclude any irrelevant papers. The results obtained in the initial search represent more than 68.47 % of cannabis related research documents, and 42,88 % of them are open access. The following filtering process was used to exclude any irrelevant data:

- Only include open access articles and reviews,
- Only papers published in Journals are included, while those published in conference proceeding, book series, trade journals, or those still in press are not considered.
- No language limitations were applied, including papers in English, German, Chinese, Spanish, French, etc, as long as an English abstract and keywords were provided by the authors.
- All irrelevant subject areas are omitted, removing papers from: Business, Management and Accounting, Energy, Earth and Planetary Sciences, Economics, Econometrics and Finance, Mathematics, Arts and Humanities, Materials Science, Computer Science, Physics and Astronomy, Social Sciences, Decision Sciences, and Engineering.

The final query is: *"TITLE ("cannabi*" OR "hemp" OR "haschich" OR "hashich" OR "hashish" OR "marihuana" OR "marijuana") AND TITLE-ABS-KEY ("bioactif" OR "medicinal" OR "actif" OR "medical" OR "therapeutic" OR "effect*" OR "function" OR "*chemical" OR "biologi*" OR "anti*" OR "chemic* acti*" OR "biologi* acti*") AND pubyear > 2011 AND pubyear < 2023 AND (limit-to (srctype, "j")) AND (limit-to (OA, "all")) AND (limit-to (pubstage, "final")) AND (limit-to (doctype, "ar") OR limit-to (doctype, "re")) AND (exclude (subjarea, "DECI") OR exclude (subjarea, "SOCI") OR exclude (subjarea, "COMP") OR exclude (subjarea, "PHYS") OR exclude (subjarea, "ARTS") OR exclude (subjarea, "MATE") OR exclude (subjarea, "MATH") OR exclude (subjarea, "ECON") OR exclude (subjarea, "BUSI") OR exclude (subjarea, "ENER") OR exclude (subjarea, "EART"))"*

The data acquisition process (Fig. 1) was completed on the 30th December 2023, and the retreived data was downloaded the same day, to prevent any inconsistencies, as Scopus database is updated regularly.

3.2. Data treatment and metrics

Bibliometric analysis approach is adopted in this paper, as it manifests in two main procedures: performance analysis accounting for contributions of various research entities, and evaluating the impact of their activity, and science mapping focusing on the links between theses contributors [25].

Performance analysis is considered the hallmark of bibliometric studies, as it accounts for the activity of research constituents. It is a descriptive scrutiny conducted to examine the contributors of a given field research -authors, journals, institutions, or countries- and pinpoint the various leading constituents, to understand how a particular field has evolved through time by examining several metrics:

- Descriptive statistics employed to summarize the data's basic features, providing insights on the studied corpus: counts of papers, sources, authors, collaboration rates, etc.

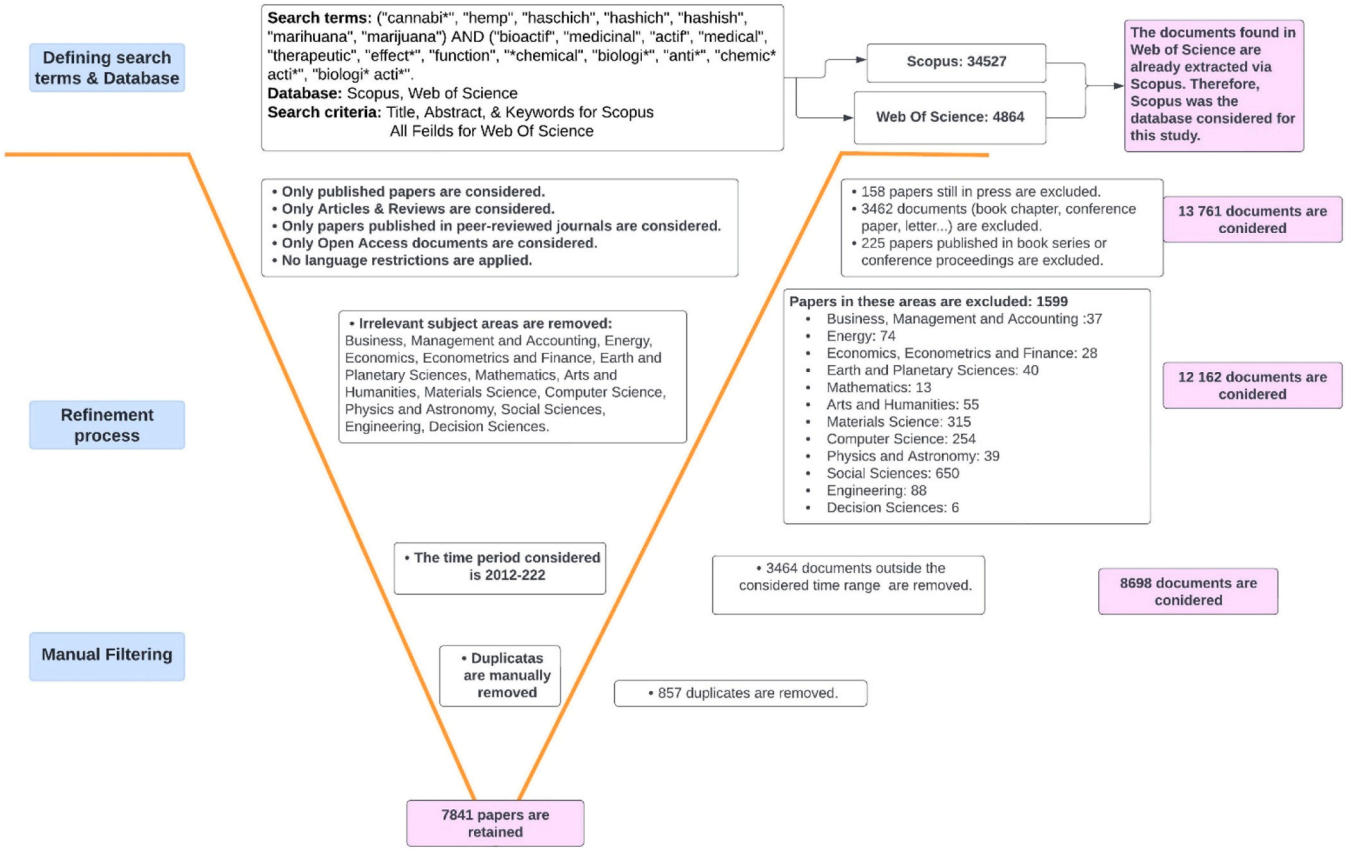

Fig. 1. Data acquisition process.

- Temporal analysis evaluating publications and citations counts through time as a proxy of productivity and impact, a core aspect that identifies the most productive and most influential entities. This helps pinpoint leading and most productive authors, journals, affiliations, and countries within the filed, and track their prominence over time. This also helps identify which papers or entities are considered most influential or pioneers in beneficial cannabis domain. Moreover, these metrics are combined to calculate mean citations per publication, and h-index. This index reflects both productivity and impact by measuring the number of publications (h) that have been cited at least h times, providing insights into trending subject areas and current theme interests.

  Science mapping is applied to monitor a scientific field and represent its conceptual and intellectual structure and its evolution. This method is applied through network analysis, thematic evolution, and keywords mapping.
- Network analysis techniques are used to understand collaborative patterns between authors, institutions, and countries, highlighting key contributors and their connections.
- Keywords mapping is applied by creating occurrences maps, and clustering co-occurrences to depict the main research themes and their evolution through the studied period. Clustering is also used to visualize the dynamic aspects of the field by examining the spread of research across various subject areas and reporting how certain topics gain or lose prominence. Furthermore, this approach can be used to track the appearances of methodology-related keywords and examine how research approaches have evolved, to identify any shifts from observational studies to in-vivo, in vitro, or clinical trials.

These chosen methods and tools are well-established in bibliometric research and are particularly suited for this study due to their ability to handle large datasets and provide comprehensive insights into the research landscape. The use of these robust statistical methods and tools ensures the validity and reliability of our findings, offering a clear and comprehensive overview of the research landscape in beneficial cannabis research.

3.3. Visualization tools

To present the obtained results, different graphics and visualization tools were used. The retained data is treated and filtered using Excel and Tableau Public spreadsheets, while performance analysis and science mapping were conducted using Biblioshiny tools, a set of packages in R programing language [26], that facilitate the in-depth analysis of data, and VosViewer software [27] used to create visual maps depicting the links between keywords, authors, and collaborative countries. Moreover, Flourish.Studio [28] and Lucid software [29] were used to visualize results and create figures.

These different tools are well-established within the field of bibliometric research and are particularly well-suited for handling and treating large datasets to create clear, interpretable visualizations.

4. Results

4.1. General landscape of cannabis research before 2012

This preliminary investigation aims to identify the overall cannabis research orientation in its early years up to 2012, in order to highlight the main factors influencing its evolution and shaping the interest of authors. Publications indexed in Scopus experienced a substantial surge over time, as depicted in Fig. 2. Up to 2000, a total of 4326 papers were published, indicating that within the last 22 years, the volume of cannabis related research surpassed 30 201 indexed papers, representing the great majority of works at a rate exceeding 87,47 % of the complete tally.

4.1.1. Main findings and their impact on research's orientation before 2012

Cannabis piqued interest in the past, with the earliest document indexed in Scopus being a correspondence authored by Ley, William in 1844 titled "*The medicinal properties of Indian hemp*" issued in The Lancet, followed by publication in 1845 by Donovan, M in The Dublin Journal of Medical Science, titled "*On the physical and medicinal qualities of Indian hemp (Cannabis Indica); with observations on the best mode of administration, and cases illustrative of its powers.*" A gap in cannabis-related literature persisted until 1980, when The Lancet published an article by Reynolds J. Russell; "*On the therapeutical uses and toxic effects of cannabis indica*", along with 3 letters by different authors, under the same title: "*Toxic effects of cannabis indica*". Another letter by an unknown author, "*Effects of an overdose of cannabis indica*" was published a year later by the same source, It wasn't until the end of 1912 that another cannabis-related paper emerged, titled "*Psychological aspects of drug action*" by Hollingrowth H.L in Psychological Bulletin, reviewing several studies on

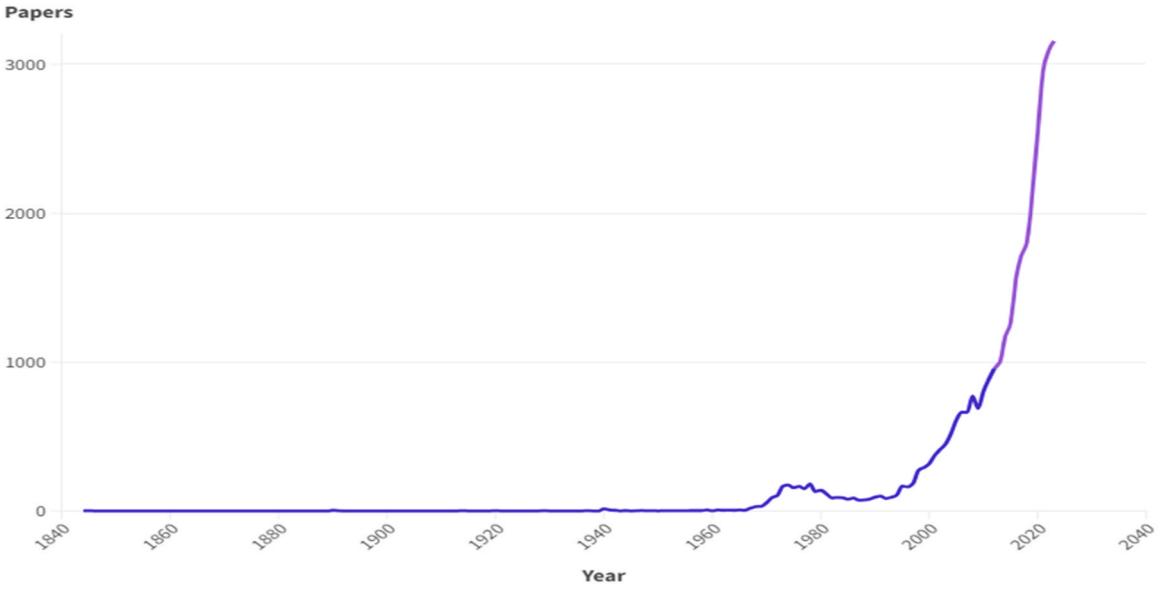

Fig. 2. Evolution of cannabis related publications over time.

anesthetics, including an essay by V. Robinson on experiments envolvin cannabis administration [30].

Aside from the first two indexed documents, the few research papers considered cannabis a drug, reporting its toxicity and the effects of its overdose. Up until 1940, research took a turn, as the few papers in Scopus focused mostly on the "fiber part" of the plant. However, 1940 marked a pivotal year, thanks to the work of Adams Roger who focused on isolating and determining the structure of cannabidiol and tetrahydrocannabinol, publishing several papers on the topic. The highly influential one is an article published in Journal of The American Chemical Society titled "*Structure of Cannabidiol, a Product Isolated from the Marihuana Extract of Minnesota Wild Hemp. I*" gaining 187 citations [31]. After these discoveries, the following years from 1940 to the late 50's marked an important interest in the pharmacology of individual cannabinoids, focusing on THC, CBD, and CBN [32]. Loewe's research (1946) was among the firsts to demonstrate THC's central excitant action by studying its ability to elicit catalepsy in mice, and corneal areflexia in rabbits [33]. These findings were revolutionary, as they established a link between cannabinoids structure and their activity, directing research towards exploring the psychotropic potential of cannabis

The initial surge in the quantity of papers indexed in Scopus occurred in 1967, with a sudden increase to 18 documents. By 2000, this number steadily increased surpassing 300, leading to a total of more than 4300 documents. Research during the late 1960s primarily focused on exploring the psychotropic properties and impacts of cannabis and specific cannabinoids on various biological systems, drawing comparisons with other recreational drugs, involving experiments on animals, along with the emergence of human studies.

By the early 1970s, the focus of research shifted towards pharmacokinetics, fueled by the significant interest in the Cytochrome P450 system (CYP) of drug-metabolizing enzymes, as its functions and significance were elucidated by Estabrook, Cooper, and Rosenthal in 1963, almost a decade following its initial identification in 1955 by Klingenberg [34]. These discoveries served as a base for future research by providing a more comprehensive understanding of drug metabolism. This era witnessed two other major discoveries by Howlett, A.C, namely the ability of cannabinoids to inhibit adenylate cyclase by interacting with G-proteins, and the discovery of the Endocannabinoid System ECS in 1988, achieved in partnership with Devane W.A at Saint Louis University, in a government-controlled study [35]. This discovery was affirmed through the cloning of CB1 receptor in 1990 in both rats (at the US national institutes of health) and humans (by Gérard et al., in Brussels), as well as the cloning of CB2 receptor in 1993 in Cambridge [32]. Subsequent research efforts directed towards gaining a better understanding the ECS and its role in regulating various physiological processes, ultimately leading to the recognition of ECS in humans.

In the 21st century, spanning from 2000 to 2012, publications count matching the query was constantly increasing, marking a significant growth factor of 180,3 % (rising from a total of 4326 documents in 2000, to 12126 in 2012). This surge can be attributed to the scientific discoveries made in the late 20th century, and the legislative changes in various countries to address the escalating interest in medical cannabis.

4.1.2. Most influential papers and authors in the field

The examination of the most influential papers, and prominent contributing authors within beneficial cannabis research was conducted on the preliminary set of retrieved data, without any time range restrictions, ensuring the inclusion of older, potentially foundational publications.

Table 2 presents a summary of the papers with the highest number of citations in the dataset, ranging from 2000 to over 4800.

The most referenced work by Devan et.al reported the identification and structural elucidation of anandamide (Arachidonylethanolamide), as an endogenous ligand for the cannabinoid receptor in the brain, demonstrating the presence of a naturally occurring cannabinoid receptor ligands within the brain, and its ability to modulate physiological responses [36]. This paper was cited more than 4800 times, revealing that research was oriented towards understanding the mechanisms by which cannabis interacts with the human body. Further emphasizing this orientation, the contributions of Matsuda and Munro focus on investigating the structure of cannabinoid receptors (both central and peripheral) and comprehending the endocannabinoid system to elucidate its potential as a target for therapeutic intervention [37, 38].

Table 2
Most cited papers in beneficial cannabis field up to 2022.

Document	Citations	Authors	Journal	Year
Isolation and structure of a brain constituent that binds to the cannabinoid receptor [36]	4830	Devane, W.A et al.	Science	1992
Structure of a cannabinoid receptor and functional expression of the cloned cDNA [37]	4339	Matsuda, L.A et al.	Nature	1990
Molecular characterization of a peripheral receptor for cannabinoids [38]	4289	Munro, S et al.	Nature	1993
Identification of an endogenous 2-monoglyceride, present in canine gut, that binds to cannabinoid receptors [39]	2419	Mechoulam, R et al.	Biochemical Pharmacology	1995
International Union of Pharmacology XXVII. Classification of cannabinoid receptors [40]	2395	Holett, A.C, et al.	Pharmacological Reviews	2002
Determination and characterization of a cannabinoid receptor in rat brain [35]	2098	Devane, W.A et al.	Molecular Pharmacology	1988

This analysis reports the significant breakthroughs, as the high number of citations prove the importance of these findings and indicates the research trajectory aimed at unraveling the intricacies of the endocannabinoid system and its function in human physiology, identifying cannabinoid receptors as promising targets for the development of cannabis-derived treatments.

The analysis of author productivity before 2012 reveals Makriyannis as the most prominent contributor, surpassing the second-highest contributor, Mechoulam, by a narrow margin (Fig. 3), and followed by Di Marzo, Huestis, and Mackie with more than 150 publication each. These high publication count suggests a concentrated research focus on cannabis, making them central figures in the field's development pre-2012. Moreover, the presence of multiple contributors with significant publication numbers indicates a collaborative research environment in cannabis research during this period.

4.2. Bibliometric analysis of retained documents

This study aims to focus on the last 10 years of academic research. Using the refined query (3.1 Data acquisition), before applying document type and Open access filters, Scopus database returns 20 201 documents, with an important growth factor of 223.12 % (from 956 papers published in 2012, to 3089 documents in 2022), indicating a

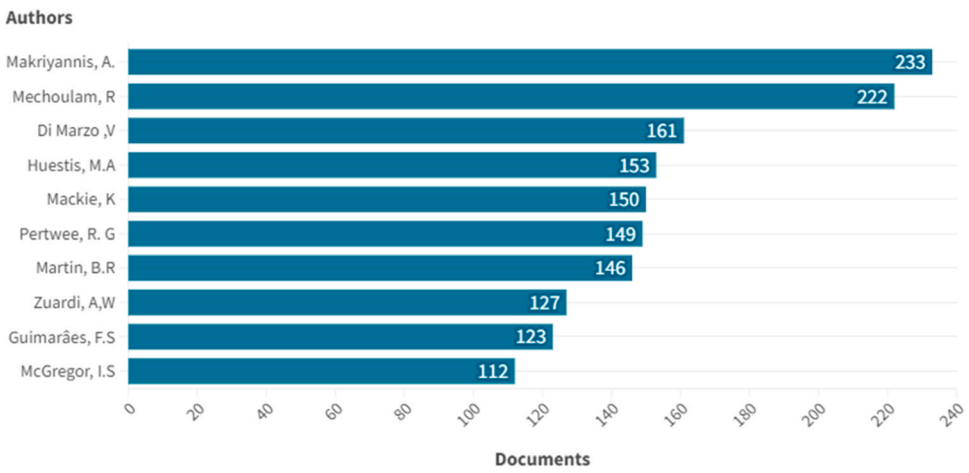

Fig. 3. Prominent contributors to cannabis research from 1844 to 2012.

substantial surge in interest, marking it a trending topic within the scientific community, and highlighting the increased awareness of its importance.

The majority of the returned papers are articles, accounting for 73.4 %, followed by reviews (13.4 %), while other types of papers accounted for the remaining 13.2 %, divided between conference papers, notes, book chapters, etc. (Fig. 4). Among the returned documents, 53.24 % are open access. Naturally, most scientific contributions are in English, representing 95.82 % of the total count, with 19357 documents, followed by German, Chinese, and Spanish papers, representing approximately 1 % each, while papers in other languages are rare. For this study, no language filters were applied.

4.2.1. *General overview of studied corpus*

Applying the final query, Scopus database returns 8698 documents from 974 different sources submitted by 16825 authors. These papers are downloaded and filtered with further care (Fig. 1) to remove duplicates or irrelevant entries.

7841 documents were retained for the study. Table 3 resumes the main information about the studied corpus.

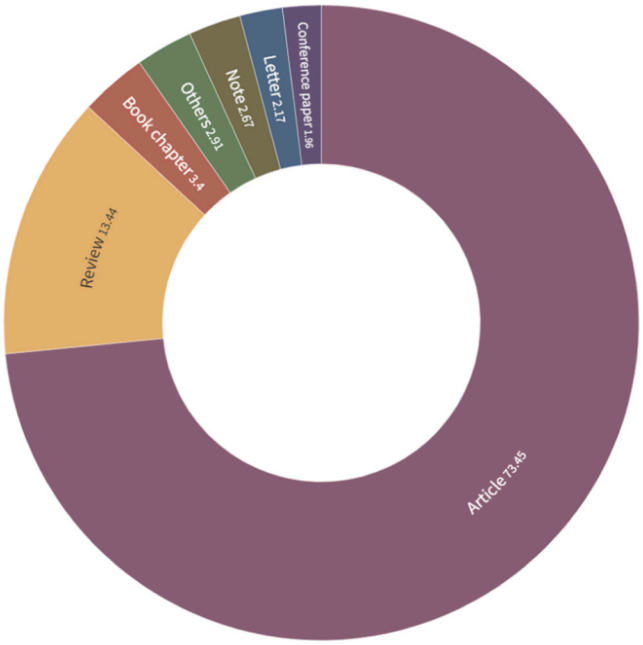

Fig. 4. Types of documents on cannabis research between 2012 and 2022.

Table 3
Main information about cannabis-related papers from 2012 to 2022.

Description	Results
Main information about data	
Timespan	2012:2022
Sources (journals, books, etc)	1807
Documents	7841
Annual growth rate %	16,83
h-index	172
Document average age	5,32
Average citations per doc	32,47
References	344071
Document contents	
Keywords plus (id)	27046
Author's keywords (de)	12498
Authors	
Authors	30593
Authors of single-authored docs	206
Authors collaboration	
Single-authored docs	226
Co-authors per doc	6,42
International co-authorships %	23,3
Document types	
Article	6512
Review	1329

4.2.2. *Scientific production per subject areas*

Scopus database categorizes documents or papers per subject areas, recognizing four wide areas: Physical sciences, Health sciences, Social Sciences and Life Sciences, these are divided into 27 subject areas and over 300 minor subject areas [41]. The filters applied in the query removed any irrelevant area of research, and the documents retained for this study covered 16 subject areas. Among the remaining subject areas, as shown in Fig. 5, presenting different areas based on publications count, medicine is the main one, taking more than 36 % (2893 papers) of the documents obtained over the studied period, representing the most important one, followed by Pharmacology, Toxicology, and pharmaceutics with a percentage of 18.75 % (1470 documents), while Biochemistry, Genetics and molecular biology took 11.03 % with 864 papers, and Neuroscience related papers represented 9,25 % with 725. The 24 % remaining was devised between other subject areas that each of them scored low percentages in this corpus, ranging from 4.53 % to 0.13 %.

The top nine subject areas covered 93,89 % of the studied corpus, therefore, their evolution over time is studied in more details (Fig. 6 & Table 4). The count of papers published in the selected fields rose drastically between 2012 and 2022, where Medicine and Pharmacology, Toxicology, and pharmaceutics held their leading positions over the

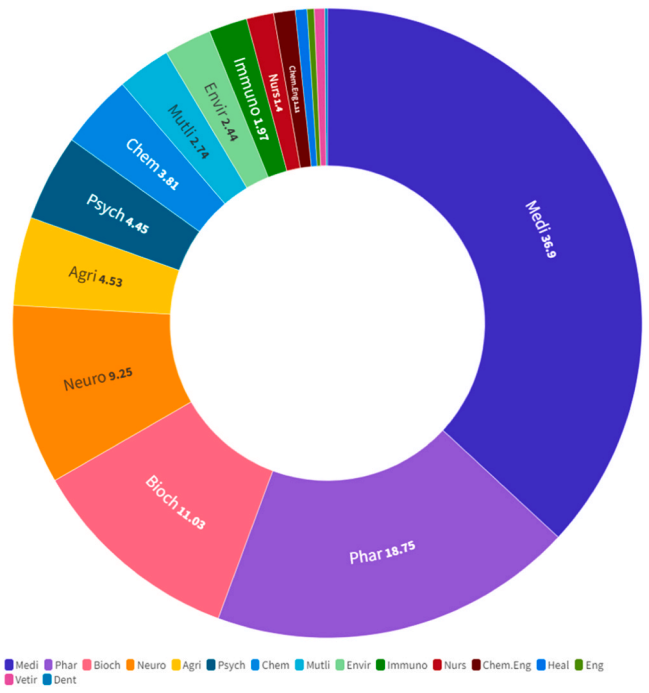

Fig. 5. Subject areas of Cannabis-related research.

years, with an incredible growth factor of 414,71 % for the first one and 222,06 % for the second. The greatest growth factor was observed in Agricultural and biological sciences, Chemistry, and Environmental Science, as they stood out with 595,83 %, 562,5 %, and 525,00 % respectively with an increasing count of documents between 2012 and 2022 ranging from 24 to 167 for Agricultural and biological sciences, 16–106 for chemistry, and 16–100 for environmental science.

The evolution of scientific output within these research areas through the studied period indicates that scientific research from 2012 to 2022 is oriented toward treating cannabis as a medical virtue, to study its therapeutic benefits and side effects, while displaying a growing focus on its chemical and ecological prospects. This shift suggests a forthcoming focus on a more comprehensive understanding of its chemical aspects to unleash its full potential while exploring its environmental implementations to better regulate its composition to ensure its applications in various fields within the legal frames.

4.2.3. *Evolution of scientific production and citations*

Over the last ten years, the total count of cannabis related papers indexed in Scopus Database increased intensely, form 316 papers in 2012–1497 in 2022, with an important annual growth factor of 373.73 %. These documents were cited more than 176000 times between 2012 and 2022. Simultaneously with publication's growth, citation count is rising each month. Fig. 7 shows the total documents per years and citations they received up until 2022. Logically, older documents dating back to 2012 scored more citations count comparing to new papers, surpassing 20 K citation at the end of 2022, proving their consistent contributions to the topic, while the most influential year in terms of citations count, in the studied corpus is 2016, with 522 documents that scored the higher citations count surpassing 23000.

For a better understanding, Fig. 8 illustrates the evolution of citation impact within the corpus. It examines two metrics: mean total citations per paper (Mean TCperART) and mean total citations per paper per year (Mean TCperYear). The analysis reveals that 2016 stands out as the most influential year in terms of mean citations per paper (6.32), followed by 2018 where documents received an average of 6.0 citations per year,

Table 4
Growth factor and publication count for the main areas from 2012 to 2022.

Subject areas	Doc count in 2012	Doc Count in 2022	Growth factor
Medi	170	875	414,71 %
Phar	136	438	222,06 %
Bioch	85	289	240,00 %
Neuro	83	144	73,49 %
Agri	24	167	595,14 %
Psych	21	75	257,14 %
Chem	16	106	562,50 %
Mutli	23	56	143,48 %
Envir	16	100	525,00 %

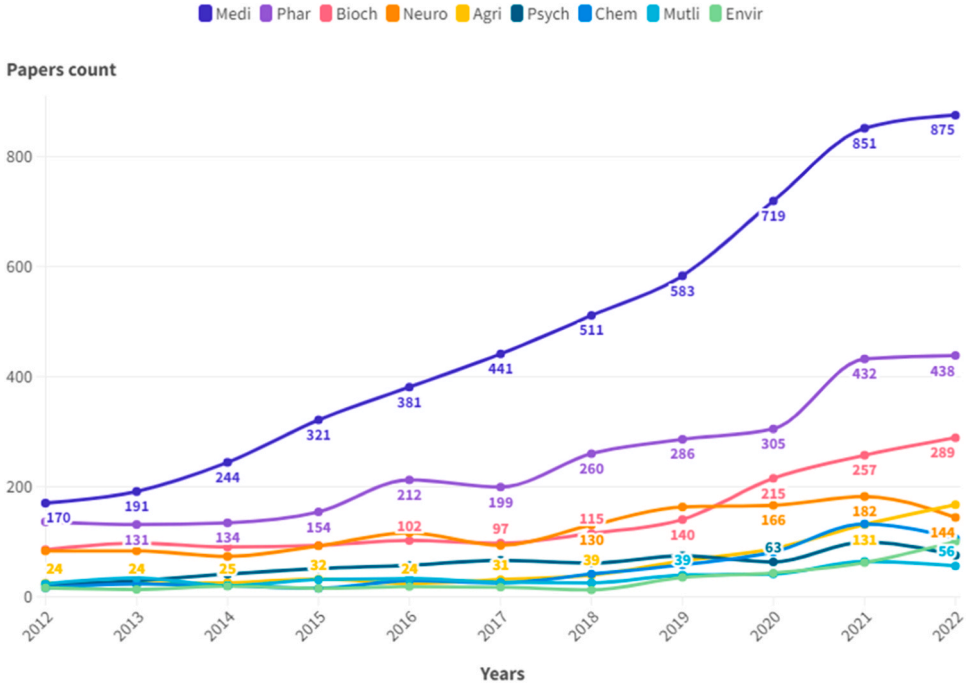

Fig. 6. Temporal evolution of scientific production per subject area.

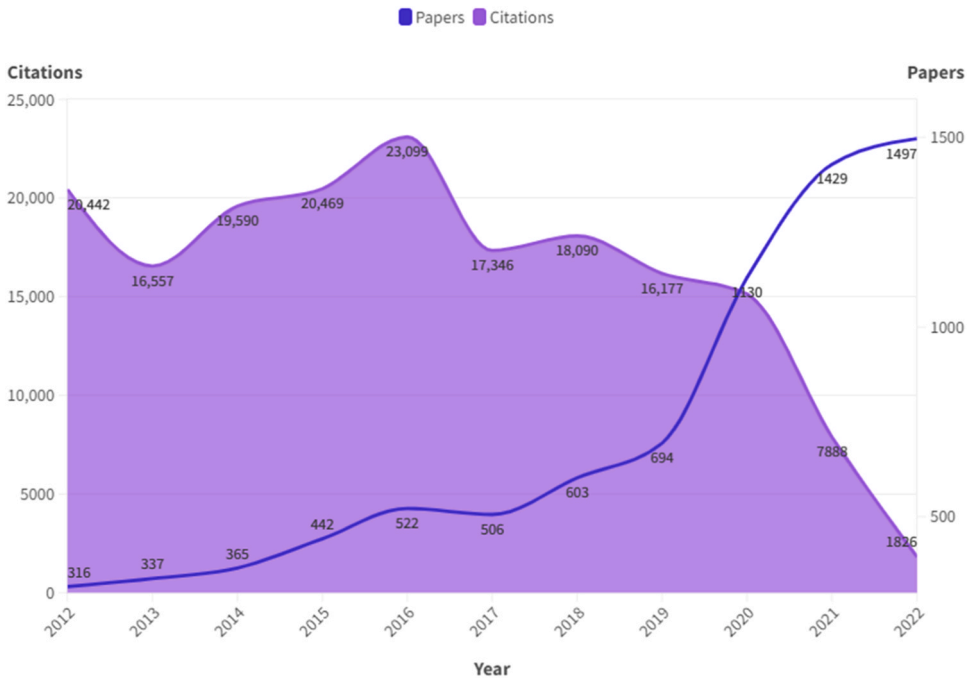

Fig. 7. Temporal analysis of scientific production and their citations count.

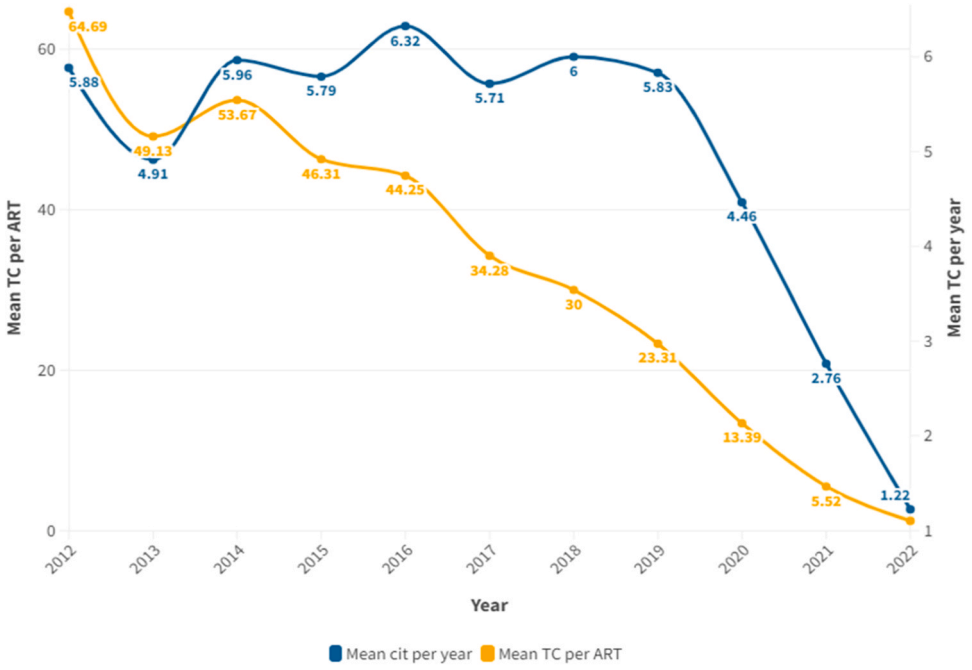

Fig. 8. Mean citations count per paper and per year for the studied corpus.

then 2014 with 5.963.

4.2.4. Influential sources and journals

The studied documents cover 1807 different sources or journals. Bradford's Law was applied to the studied corpus (Fig. 9), to identify the well-established journal, as it identifies the most productive and influential ones, grouping them in the Core zone. These sources were studied with further care, to report their academic metrics and influence, and their productivity over the studied period.(Fig. 10)

An analysis of publication sources reveals Drug and Alcohol Dependence as the most productive journal during the studied period, with 260 papers, and scoring over 10,700 citations. Interestingly, the ranking of journals shifts when classifying them by citations versus publication volume. The second most cited source is the British Journal of Pharmacology, accumulating more than 7400 citations. Notably, Cannabis and Cannabinoid Research, a relatively new journal established in 2016, ranks second in terms of publication volume (199 papers) despite its recent launch (Fig. 11). Rounding out the top three, PLOS ONE holds a consistent position in both metrics, publishing 175 papers and exceeding 6000 citations.

The dominance of the mentioned journals extends beyond publication volume and total citations (Fig. 10). These journals consistently

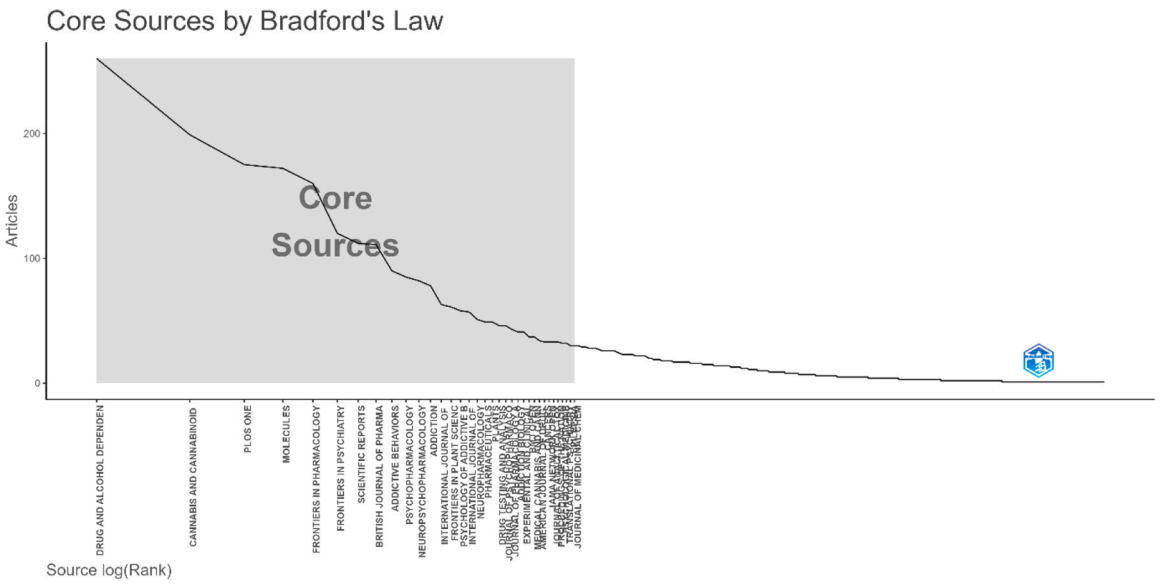

Fig. 9. Main Journals according to Bradford's Laws.

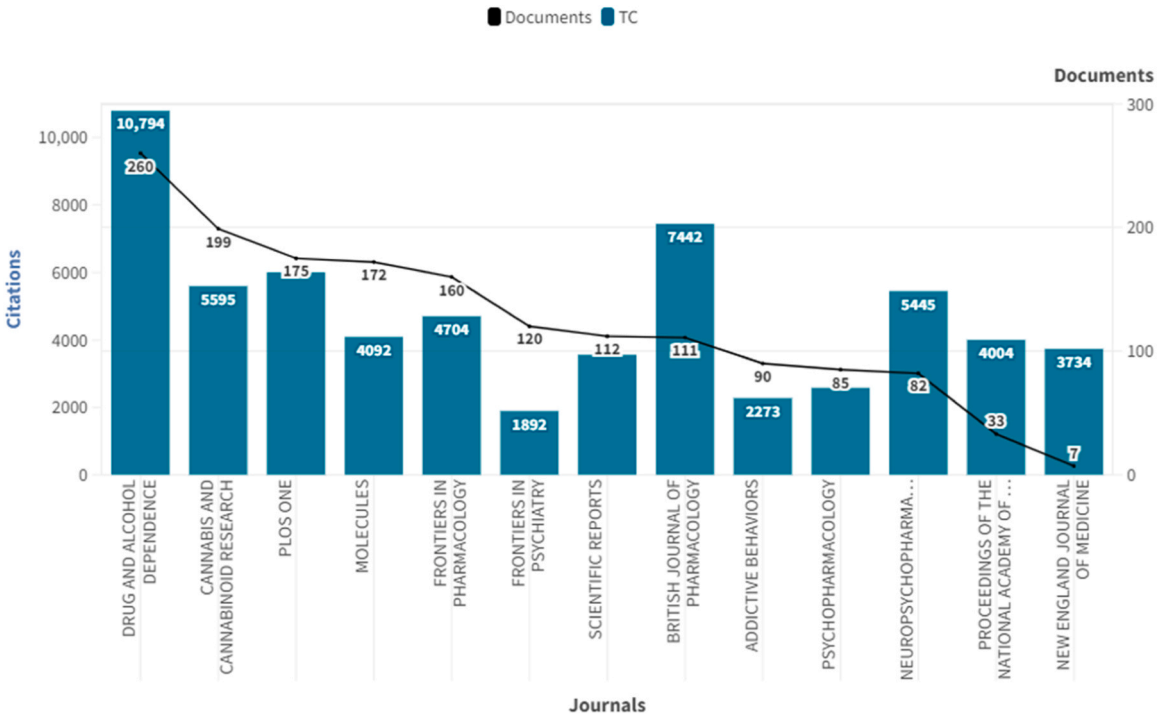

Fig. 10. Productivity and impact analysis of core zone sources.

rank highly across other key metrics, including mean total citations per paper (Mean TC per P), CiteScore 2022, h-index, g-index, and m-index. (Table 5).

It's worth noting the exceptional performance of Epilepsia journal in terms of Mean TC per P. Despite publishing only 31 documents, this journal boasts an impressive average citation count exceeding 3100, suggesting a high impact for each published paper.

4.2.5. *Worldwide production, performance analysis and collaborations*

4.2.5.1. Main productive countries in the studied corpus. During the studied period, the United States leads cannabis field of research, contributing a significant share of publications (2919 papers). Canada follows distantly in second place with 624 papers, while Italy and the United Kingdom hold the third and fourth positions with 391 and 361 documents, respectively. This dominance in publication volume translates to leadership in citations count as well- logically, due to the high number of publications. Fig. 12 further breaks down the scientific output of these major countries by publication type: Single Country Publications (SCP), representing research where all authors are affiliated with the country, giving insights on intra-country collaborations, and Multiple-Country Documents (MCP), accounting for papers involving authors from different countries, reflecting inter-country collaborations.

4.2.5.2. Performances of countries: h-index & citations count. To assess the influence of different countries in cannabis research, a performance

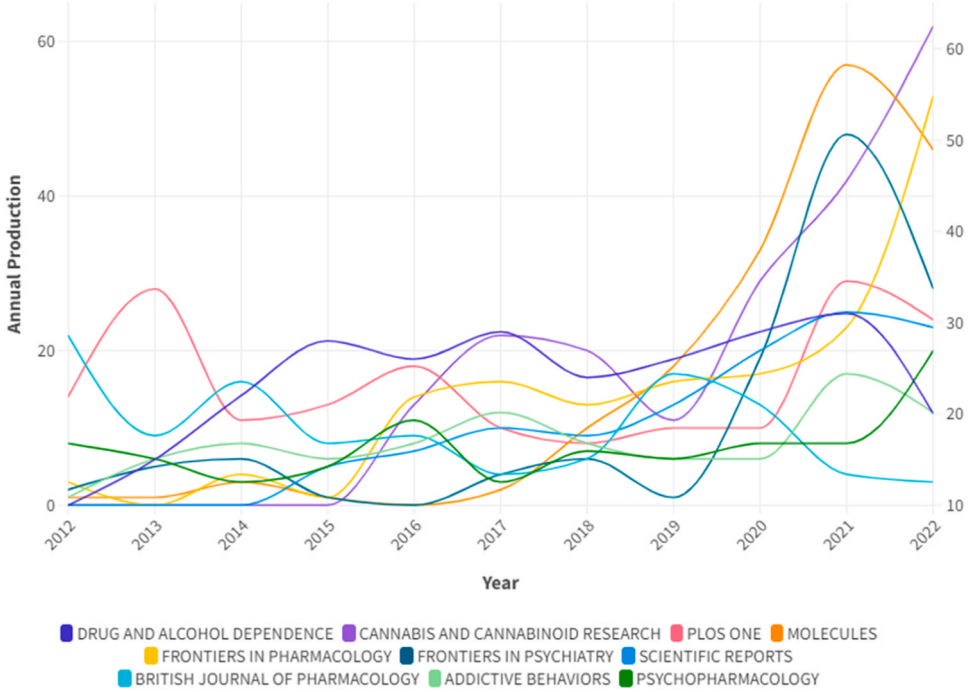

Fig. 11. Scientific production of main sources in the corpus.

Table 5
Metrics of most academically influential sources.

Source	Mean TC per P	Cite Score 2022	h_index	g_index	m_index
Drug & Alcohol Dependence	41,52	7.0	57	88	4,39
British Journal of Pharmacology	67,05	15.3	49	83	3,77
PLOS One	34,32	6.0	45	68	3,46
Neuropsychopharmacology	66,40	14.0	44	73	3,39
Cannabis And Cannabinoid Research	28,12	5.9	38	67	4,22
Frontiers In Pharmacology	29,40	6.3	38	61	2,92
Addiction	40,13	10.1	34	53	2,62
Scientific Reports	31,77	7.5	34	55	3,40
Molecules	23,79	6.7	32	54	2,46
Addictive Behaviors	25,26	7.4	29	44	2,23
Psychopharmacology	30,34	7.4	29	47	2,23
Epilepsia	101,63	10.6	26	30	2,36
Frontiers In Plant Science	44,18	7.1	25	51	2,50
International Journal Of Drug Policy	29,75	7.4	25	41	2,08
Frontiers In Psychiatry	15,77	5.4	22	39	1,69

analysis was conducted using citation counts and h-index (Fig. 13). The United States stands out as the clear leader, accumulating the highest total citations (103,165) and an impressive h-index of 146 between 2012 and 2022. This significant gap between the US and the second-ranked country, the United Kingdom (19,524 citations, h-index: 99), highlights the US's dominant position. Canada follows closely behind in third place with 16,235 citations and an h-index of 75, while Italy holds the fourth, with 12 477 citations and an h-index reaching74. Australia and Spain share the fifth rank in terms of h-index (69), with some difference in terms of citations count.

While the ranking order varies slightly for positions below seventh when considering citations versus h-index, or documents count, the top six countries (US, UK, Canada, Italy, Australia, and Spain) consistently hold their positions among the leaders in those metrics. This analysis confirms that these six countries are the most academically influential entities in beneficial cannabis research from 2012 to 2022.

4.2.5.3. Worldwide collaborations. A throughout analysis of collaboration patterns within the corpus reveals a global network of research alliances. This suggests that collaborations are not geographically restricted, with partnerships spanning across all five continents. For a better assessment of the strength of these collaborations, these documents were further studied to evaluate their frequency across different countries.

Fig. 14 depicts the collaborative landscape of beneficial cannabis research. It highlights alliances among the most prolific countries, categorizing them into seven distinct clusters (in different colors). These collaborations, represented by 535 links (representing internationally co-authored papers), involve countries -indicated by the nodes- contributing to at least 20 collaborative documents each, as a filter was applied to only retain those who meet the set threshold. Documents co-authored by 25 countries, or more were ignored in this study.

The size of the nodes in the graph indicates the number of publications a country has produced, while the distances between nodes reflect the strength of collaboration – smaller distances indicate more frequent collaborations.

The dominance of the US, UK, and Canada in cannabis research extends beyond individual contributions. As highlighted in Fig.+14, these countries lead international collaborations. The US stands as the most collaborative country, with 3752 collaborative papers involving 45

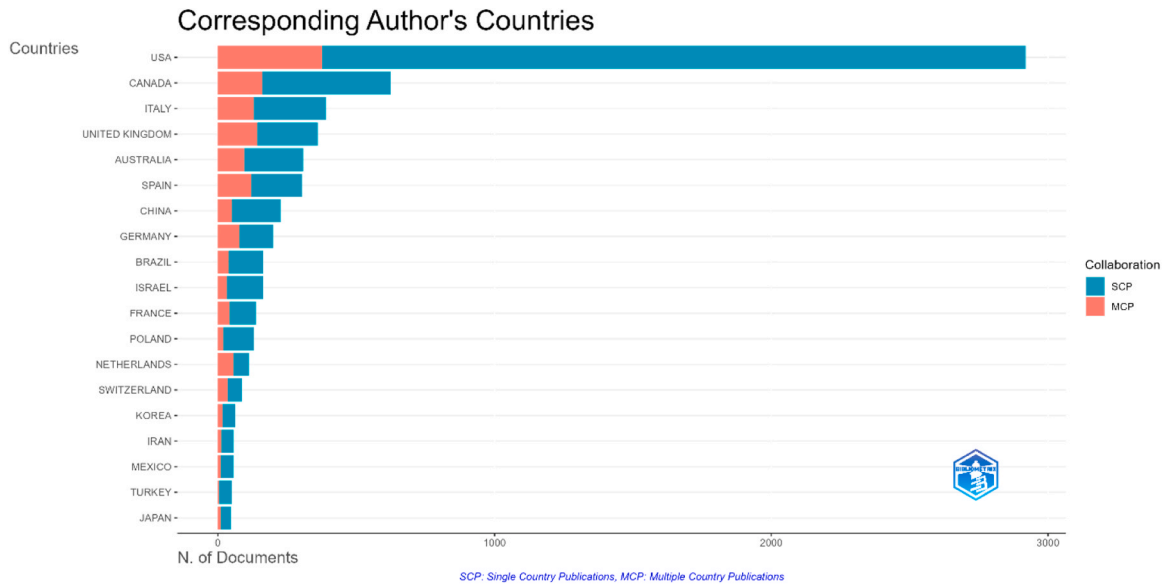

Fig. 12. Scientific production of the most relevant countries.

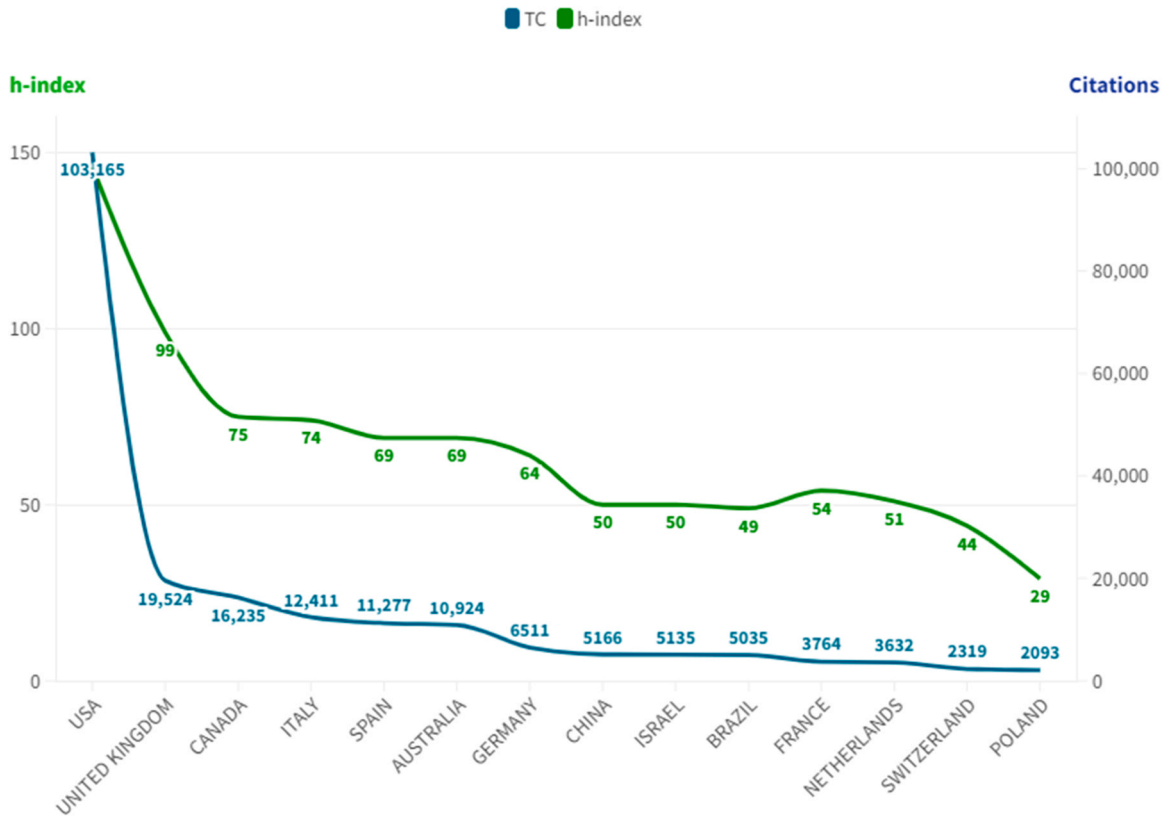

Fig. 13. Performances of countries (h-index and citations count) in the studied period of time.

partner countries. Notably, its strongest partnerships are made with Canada (225 co-authored documents) and the UK (184 co-authored documents). The UK follows closely behind, collaborating on 691 papers with 45 various countries, while Italy and Germany, each collaborating with 40 countries, come in next, with 568, and 423 links or collaborative country, respectively. Canada also demonstrates strong collaborative activity, partnering with 39 countries on 848 co-authored papers.

Due to large number of countries and collaborations between them, the graph can offer more information when consulted online using the VOSviewer control panel. To control its visualization, adjust clusters and select distinct countries, collaborations, or links to review their strength. For this, this graph can be reached online via this QR code: or the link http://tinyurl.com/yvrmwwt4.

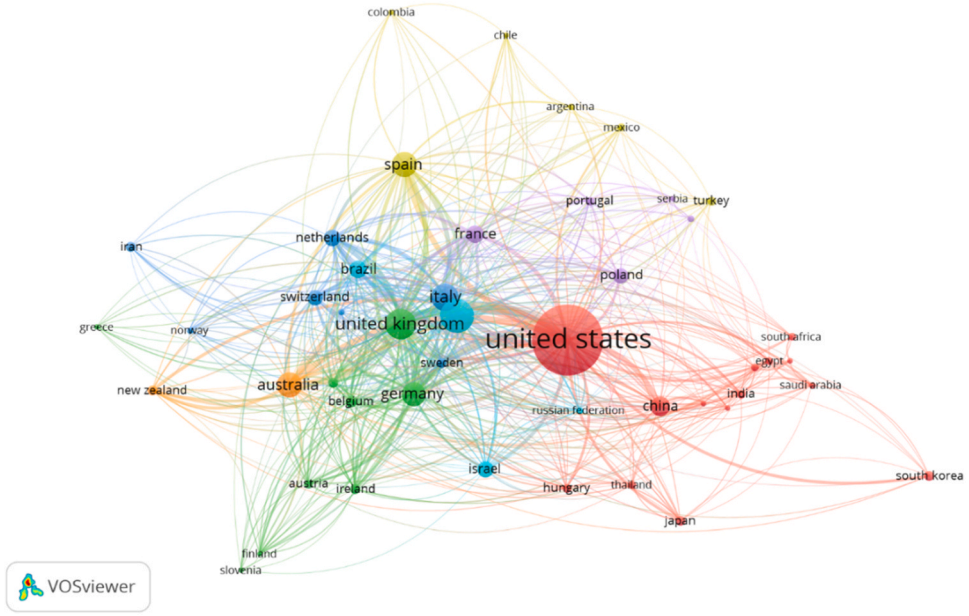

Fig. 14. Worldwide collaboration map in beneficial cannabis research.

4.2.6. Performance of institutions and affiliations

American institutions dominate the cannabis research landscape, with the University of California leading the pack with 686 publications (Fig. 15), followed by the University of Toronto (375), and University College London (336), highlighting the global reach of the field. Although Brazil is not among the top contributing countries, university of São Paulo is considered a major contributor to beneficial cannabis research, taking the fourth rank with 319 published papers.

Fig. 16 illustrates the collaborations map among leading institutions, with nodes representing institutions and links representing collaborative relationships. The size of the nodes correlates with the institution's research output, with the University of California being the largest due to its significant contribution. The map represent eight clusters, grouping institutions within the same collaborative network, affiliations within the same cluster likely share similar research interests or graphical proximity that facilitate conducting collaborative work. University of California has a betweenness centrality that surpasses 400 within the studied corpus, while the second in line; University of Toronto reached 231. This metric measures the institution's influence as a bridge between different groups within the network, proving these affiliations' crucial role in connecting research communities. The links in the collaboration map gives insights on the closeness centrality, a high centrality represented by a short distance between two nodes suggests that the institution is well-connected, as this metric measures how an affiliation can disseminate information within the network.

While University of California and University of Toronto hold their leading positions when ranked by production count, collaborations, betweenness, or closeness, the order changes for other affiliations according to the considered metric. Table 6 presents a classification according to PageRank; this algorithm assesses an institution's importance within the network based on the number and quality of incoming links. A high PageRank indicates that the affiliation is frequently cited or referenced by other influential institutions.

This network analysis reveals the complex interplay between institutions and the potential for knowledge sharing within the filed. It highlights both universities of California and Toronto as a dominant force in beneficial cannabis research in every key metric. These institutions are major contributors in terms or papers count, they conduct an important number of collaborative work, facilitate knowledge flow across the network clusters, and they are highly referenced, suggesting

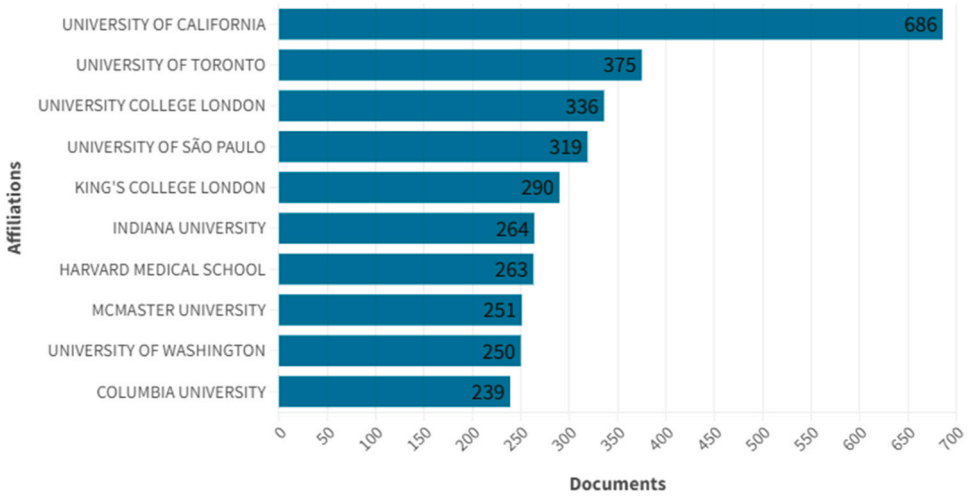

Fig. 15. Most contributing affiliations in the studied data.

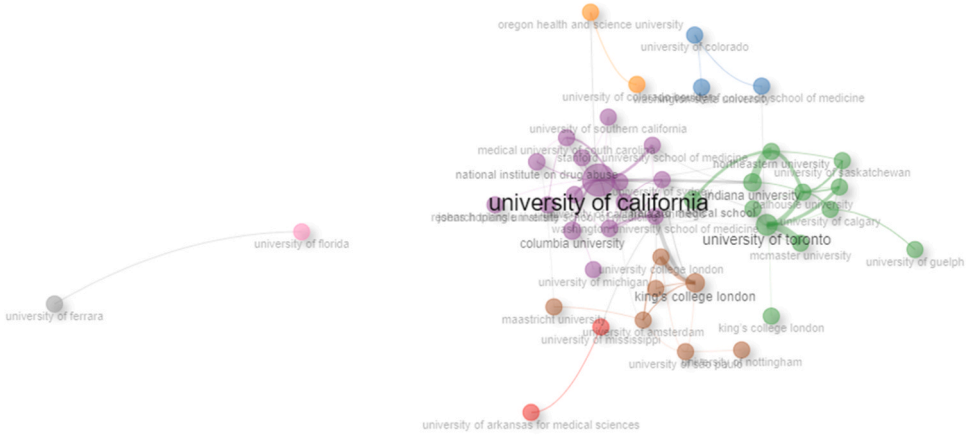

Fig. 16. Collaborations between the main leading affiliations in beneficial cannabis research.

Table 6
Collaboration metrics of leading institutions by PageRank.

Node	Betweenness	Closeness	PageRank
University of California	400.726	0.01515	0.0793
University of Toronto	231.480	0.01408	0.0711
King's college London	46.937	0.01176	0.0416
University of California San diego	59.329	0.01265	0.0391
Indiana university	82.964	0.01176	0.0341

their important impact in the field.

4.2.7. Contributing authors and their collaboration

The 7841 studied documents were written by 30593 authors, with an average of 4 authors per paper. Among these authors, 78 wrote or contributed to more than 20 papers each. The most relevant authors, when ranked by published papers are summarized in Table 7 along with their most influential or cited works in the studied corpus.

Huestis takes the lead as the most contributing author in beneficial cannabis research, with 70 papers in the studied data, while Mackie takes the second place, with 56 documents, followed closely by Freeman and McGregor with 54 papers each, while Makriyannis published 53. The collaboration network (Fig. 17) represents authors (nodes), with a minimum threshold of 3 collaborations between each of them (links). Mechoulam, Di marzo and Mackie are reported to be the most active in terms of collaborative works.

4.2.8. Thematic evolution and keywords analysis

An analysis of trending topics and the used keywords provides a better understanding of the conducted research. Biblioshiny tool was used to follow the thematic evolution, based on terms extracted from the titles, abstracts, and author keywords. Two thesaurus files were used, one to filter irrelevant words, and the second to replace or regroup similar ones in order to work with standardized keywords, 5 time slices were obtained, by setting 4 automatic cutting points, based on clusters evolution. Fig. 18 displays the thematic evolution of cannabis research throughout the studied period. An intentioned study through each time slice gives a better understanding of the trending topics; from 2012 to 2016, researchers were interested in identifying cannabinoids and understanding the endocannabinoid system, while from 2017 to 2019, the interest shifted towards the various activities of cannabis as the main themes were antioxidant activity, neuroinflammation, neuroprotection, anxiety disorder, epilepsy, etc we also find the terms cannabinoid receptors. 2020 was considered as the third time slice, due to the diversity

Table 7
Most contributing authors and their academic metrics.

Author	TP	TC	TP in topic	Most cited paper	h-index	Current affiliation	1st publication (1st author)
Huestis, M. A	541	26830	70	Synthetic cannabinoids: Epidemiology, pharmacodynamics, and clinical implications (2014; 489 citations)	81	Thomas Jefferson University, United states	1992
Mackie, K	339	42342	56	Cannabinoid 1 receptor promotes cardiac dysfunction, oxidative stress, inflammation, and fibrosis in diabetic cardiomyopathy (2012; 210 citations)	104	Indiana University Bloomington, United States	1984
Freeman, T. P	160	5616	54	The contribution of cannabis use to variation in the incidence of psychotic disorder across Europe (EU-GEI): a multicentre case-control study (2019; 485 citations)	39	University of Bath, United Kingdom	2009
Mcgregor, I.S	338	15925	54	Effects of Bioisosteric Fluorine in Synthetic Cannabinoid Designer Drugs JWH−018, AM−2201, UR−144, XLR−11, PB−22, 5F-PB−22, APICA, and STS−135 (2015; 157 citations)	69	Faculty of science, Sydney, Australia	1989
Makriyannis, A	558	26040	53	Crystal Structure of the Human Cannabinoid Receptor CB1 (2016; 381 citations)	81	Northeastern university, United States	1972
Vandrey, R	141	6232	49	A survey study to characterize use of Spice products (synthetic cannabinoids) (2012; 229 citations)	41	Johns Hopkins School of Medicine, United States	2005
Zuardi, A. W	250	13826	48	Inverted U-shaped dose-response curve of the anxiolytic effect of cannabidiol during public speaking in real life (2017; 193 citations)	61	University of Sao Paulo, Brazil	1981
Bhattacharyya, S	158	8402	42	Structural and Functional Imaging Studies in Chronic Cannabis Users: A Systematic Review of Adolescent and Adult Findings (2013; 291 citations)	49	King's College London, United Kingdom	2001
Curran, H. V	265	15278	39	Effects of cannabis use on human behavior, including cognition, motivation, and psychosis: A review (2016; 571 citations)	65	University College London, United Kingdom	1986

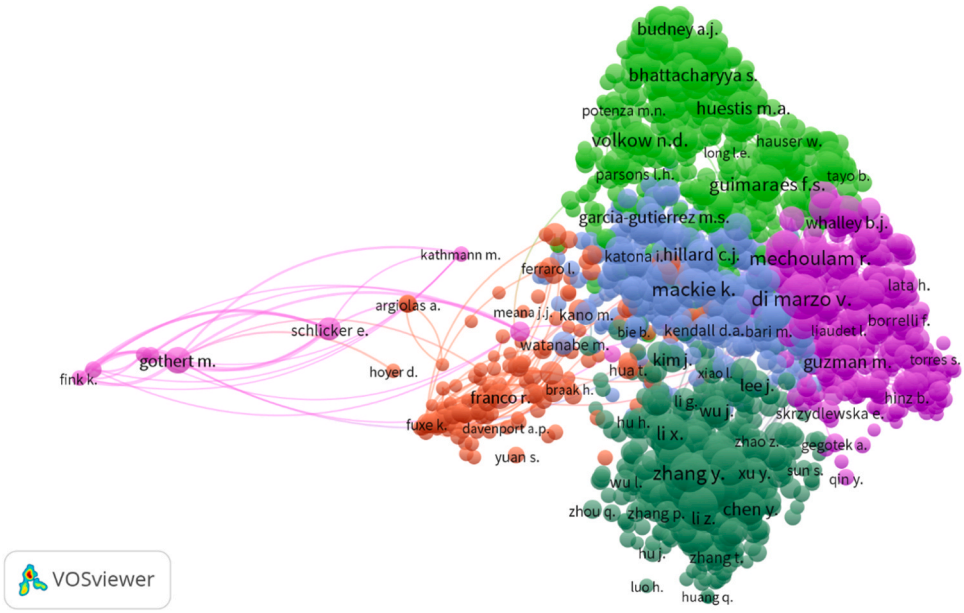

Fig. 17. Co-citation map of contributing authors.

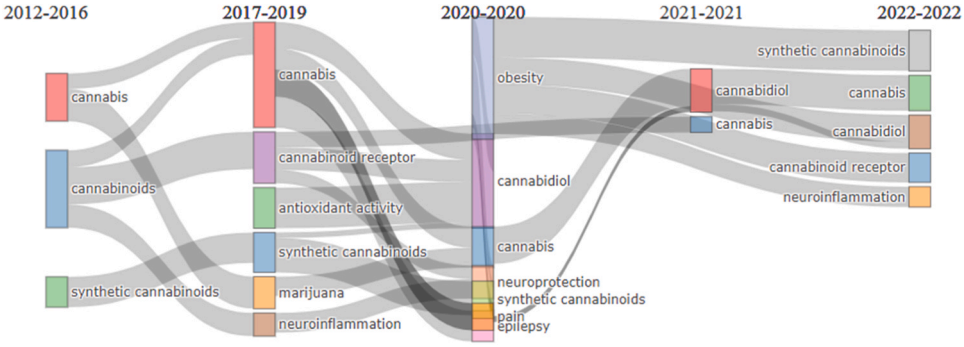

Fig. 18. Thematic evolution of cannabis research.

of studied themes, as we find mentions of obesity, seizures, neuroprotection, depressive symptoms, analgesic activity, and terpenes. The fourth period, 2021 was distinguished by research evolving around cannabidiol, anxiety disorder, and schizophrenia, while the last one focused on apoptosis, oxidative stress, Parkinson's disease, coronavirus disease 2019, chronic pain, Alzheimer's disease, inflammatory bowel disease, etc.

Besides defining main trending topics per year, a keyword analysis was performed, to identify main interest zones. Among all the studied documents, 27 046 keywords were extracted from titles, abstracts, and authors keywords. The minimum occurrence per word was set at 200, and the same thesaurus files were used to word with standardized terms. The most significant keywords, in terms of occurrence were extracted, 140 of them meeting the threshold, and were treated using Flourish tools, to create a words cloud (Fig. 19). The terms "cannabis", "cannabinoids", "cannabinoid receptor", and "cannabidiol" were naturally the most frequent ones, with occurrences surpassing 2000 times.

4.3. Focus on Morocco

Moroccan research on beneficial cannabis is rather humble, a total of 84 papers were found (until December 2023), scoring an h-index of 19, with 1201 total citations, and amid these papers, only 42 are open access. The oldest paper on cannabis dates back to 2001 when only one was published in Creativity Research Journal, by Bourassa et al. titled "Effects of marijuana use on divergent thinking" published in 2001, while in 2023, 25 papers were published and indexed in Scopus database. The most influential paper in terms of citation count is an article by Jaouad H, et al., intitled "Ethnobotanical survey of medicinal plants used for the treatment of diabetes, cardiac and renal diseases in the North Center region of Morocco (Fez- Boulemane)", published in 2001, in Journal of Ethnopharmacology, scoring 398 citations.

The period between 2012 and 2022, while witnessing a growing interest in cannabis research, still represents a relatively nascent field of study. To gain a broader perspective, the search was expanded to include all Morocco-based research on cannabis, regardless of publication type (ignoring Open Access filter). This yielded a modest corpus of 29 documents, indicating a substantial growth rate of 233 % from 2013 to 2022 (with no publications recorded in 2012). This translates to an annual growth rate of approximately 14.31 %. Furthermore, these documents garnered an average of 15.45 citations per paper, suggesting a gradual but consistent increase in research attention. The papers were published across 27 different journals, with a total of 161 authors contributing to the corpus.

The prevailing institutions in terms of research output are University Mohammed First, followed by Mohammed V University and Abdelmalik Essaâdi University.

4.3.1. International collaborations

Notably, a significant degree of international partnerships is evident,

Fig. 19. Most frequent keywords in cannabis research.

with a collaboration rate of 51.72 %. This average of conducted work with other countries is far more important than that of the main studied corpus (23,3 %), suggesting the Moroccan orientation toward international research. The most collaborations were mainly led with Spain, France, and the United Kingdom, while collaboration with Italy, USA, and Arabic or African countries are still modest (Fig. 20).

4.3.2. Science mapping and textual analysis

Science mapping approach was applied to the small collection of research papers to explore the Moroccan cannabis research landscape. Fig. 21 provides a representation of the connections between journals (left field), authors (middle field), and keywords (right field). The analysis exposes key areas of research emerging from the data. While "Cannabis sativa" and "cannabinoid" are logically prevalent among author, some researchers like Mansouri, Taaiifi, Elamrani, and others focus on the antioxidant properties of cannabis, publishing their work in food-science related journals. Another thematic cluster centers on anti-diarrheal, anti-secretory, and anti-ulcer properties, investigated by Bencheikh, Chda, El Abida, and Mahou. These authors published their studies in "*Evidence-Based Complementary and Alternative Medicine*" and "*Journal of Herbmed Pharmacology*." Abboussi's research explores acute toxicity, anxiety, and adolescence in the context of cannabis use, and their findings appear in "*International Journal of Developmental Neuroscience*," "*Neurotoxicity Research*," and "*Notulae Scientificae Biologicae*." Overall, this analysis highlights the diverse research interests within the Moroccan cannabis research community.

The analysis indicates a multifaceted approach to cannabis research in Morocco. While general interest in Cannabis sativa and cannabinoids is evident, specific research areas are emerging. Researchers are exploring the plant's potential as a source of antioxidants in food products, as a treatment for gastrointestinal issues, and as a substance with potential neurological impacts, particularly in adolescents.

For a better understanding of research interests, a textual analysis was conducted to assess the co-occurrence of the used keywords and

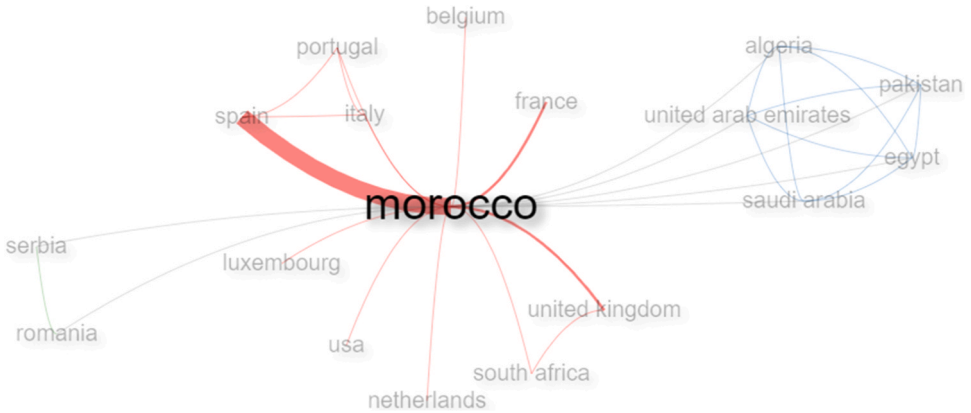

Fig. 20. Collaboration network of Morocco.

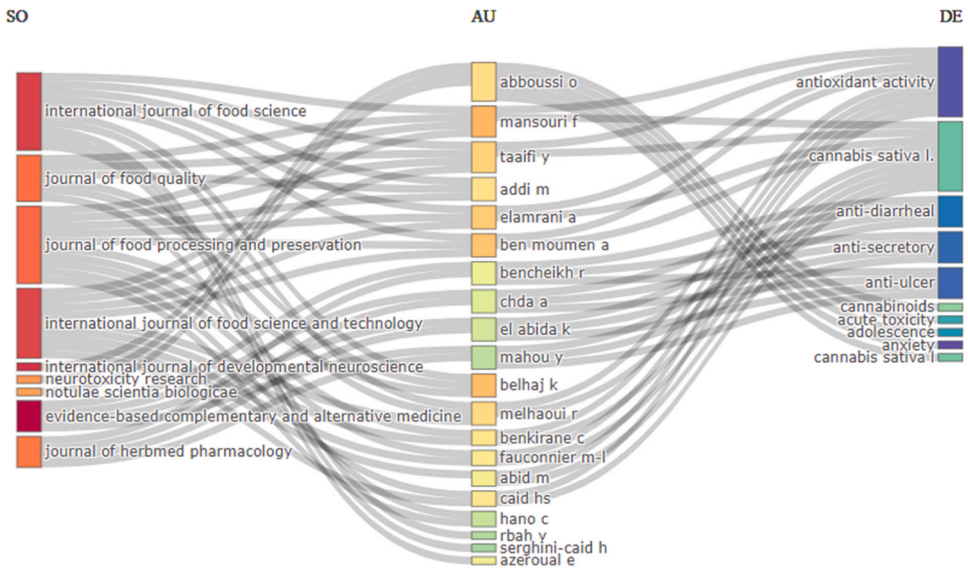

Fig. 21. Three-Field Plot, Focus on Morocco.

analyze the thematic evolution in order to define the major emerging niches in research. The map (Fig. 22) regroups 57 keywords in 4 different clusters represented in different colors. A threshold of 3 was set to further refine the analysis, and co-occurrence of these keywords was measured by the total links between them (522 in this corpus), while the size of nodes indicates its frequency.

Naturally, the map reflects the prominence of "cannabis" as a core keyword, interconnected with all clusters. The research landscape leans heavily towards preclinical studies, with frequent co-occurrences of terms such as "non-human," "rats," and "mouse." This foundational research is essential for understanding cannabis' basic properties and mechanisms of action before progressing to human trials.

An evident emphasis on the pharmacological aspects of cannabis is discernible through the clustering of keywords related to antioxidant, antimicrobial, and anti-inflammatory activities. This indicates a notable interest in exploring the plant's therapeutic potential. Conversely, the co-occurrence of "acute toxicity," "controlled study," and "risk factor" highlights a necessary focus on cannabis safety and potential adverse effects.

While preclinical research dominates the field, a growing interest in human studies is indicated by the co-occurrence of "human," "clinical article," and "case report." This shift towards clinical research is crucial for translating laboratory findings into real-world applications. Additionally, the connection between "schizophrenia," "non-human," and "cannabidiol" suggests a specific research focus on understanding the potential link between cannabis use and mental health disorders.

For further analysis, the interactive map was uploaded online and can be accessed via the link http://tinyurl.com/2a6gzmv9 or by scanning the QR code .

The thematic evolution map (Fig. 23) indicates a notable shift in the focus of Moroccan cannabis research. There is a clear transition from niches related to animal, and non-human studies toward a deeper exploration of cannabis' intrinsic properties. The emergence of the terms "antioxidant", and "bacteria" or "microorganisms" in signifies a growing interest in he plant's antimicrobial and antibacterial effects. Currently, the niche and motor themes are still related and focused on therapeutic sides of the plant, as it can be concluded from the keywords summarized in the focused cluster network of both the niche theme (b) and motor theme (c), suggesting a sustained effort to understand and harness cannabis' medicinal properties. In essence, the research community is broadening its perspective while maintaining a core focus on the plant's

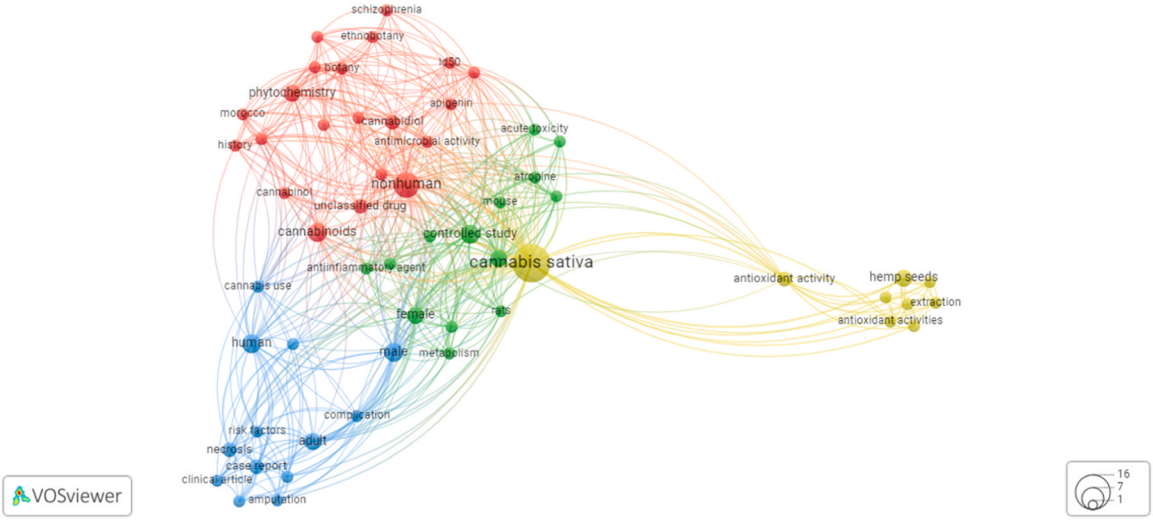

Fig. 22. Keyword map for cannabis research in Morocco.

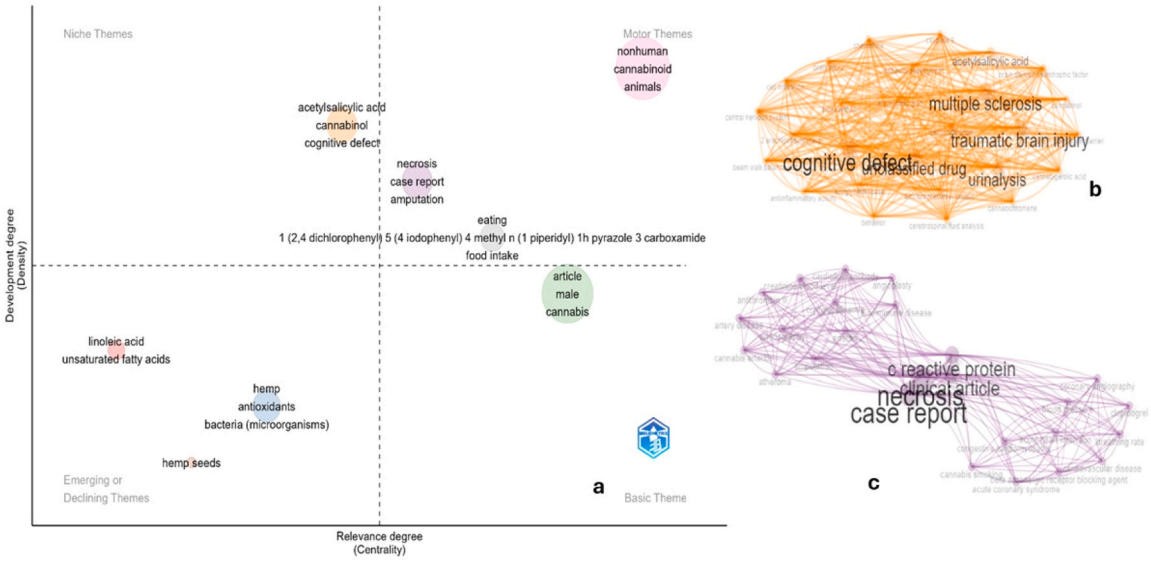

Fig. 23. Thematic evolution map of cannabis research in Morocco (a), with emphasis on cluster network of niche (b) and motor (c) themes.

therapeutic potential.

4.3.3. Interpretations and conclusions on Moroccan research landscape

The science mapping analysis (network analysis and textual mining) reveals a dynamic trajectory of Moroccan cannabis research. Studies transitioned from treating cannabis as a drug to exploring it as a beneficial virtue. Currently, the research landscape is expanding beyond its initial focus on animal studies to encompass a broader range of applications. While preclinical studies remain prevalent, a growing emphasis on human trials is evident. Researchers are investigating the plant's potential in various domains, including food science, gastroenterology, and neuroscience. There is a particular focus on understanding cannabis' intrinsic properties, particularly its antioxidant and antimicrobial potential. Simultaneously, the core focus on therapeutic applications persists, with researchers delving deeper into the plant's medicinal benefits.

This surge of interest is a result of the late pivotal changes in the legislative state of cannabis in Morocco, as its medical and industrial use has become legal in 2021, according to the Royal Decree N° 1–21–59 promulgating Law N° 13–21 [24]. This shift in the laws provided researchers with unprecedented opportunities to discover the promising potential of the nationally cultivated cannabis by exploring its diverse array of phytochemical compounds their potential therapeutic effects [42–44]. This multifaceted approach, coupled with a strong focus on safety and efficacy, and a strategic international outlook, as the country inclines toward international collaborations, underscores the significant potential of cannabis as an emerging subject of scientific inquiry, and highlights its gaining interest.

Given the country's role in cannabis production and exportation, the focus on unleashing its full capacity is not only driven by its potential beneficial effects, but also by the economic opportunities associated with the growing global market for cannabis-based products. Therefore, Morocco should stand poised to emerge as key player in the field of cannabis research and pave the way for the development of various products to address the increasing market demands.

5. Conclusion

This paper illuminates the dynamic trajectory of beneficial cannabis research, combining both sides of bibliometrics, performance analysis and science mapping, to treat a decade's worth of scientific outputs and provide an in-depth analysis of research orientations and trends.

Cannabis was initially perceived as a controlled substance, as the legal prohibition of its usage across the world slowed down research, leading to poor knowledge of the plant. With the late changes in its legal statue, the plant is undergoing a paradigm shift, being increasingly recognized for its potential benefits. The research landscape is expanding rapidly, as contributors are directing their efforts towards better understanding the plant's bioactive compounds, their interactions and working mechanism, with an emphasis on its pharmacological properties and therapeutic applications in general. Simultaneously with preclinical research remaining foundational, a clear trend towards human-based studies is evident, while focusing on measures for its safe usage, to avoid its undesired effects.

These directions are further confirmed by the general orientation of research, as dominant subject areas were medicine, Pharmacology, Toxicology, and pharmaceutics, Biochemistry, Genetics and molecular biology, and Neuroscience, covering nearly 76 % of the studied papers.

Despite the absence or rare contributions of African countries, namely Morocco as a consequence to the previous legal restrictions, beneficial cannabis research is gaining interest as this country is slowly, yet steadily emerging in its related-research, making modest contributions -in terms of papers count-, and inclining toward international collaborations to seek other alternatives to overcome the limited resources and face the legal prohibitions.

To maximize the potential of cannabis, future research should prioritize in-depth exploration of specific compounds, comparative studies of cannabis-based products, longitudinal research to assess long-term effects, and rigorous clinical trials. Moreover, fostering international collaborations is essential to accelerate progress and address global challenges related to cannabis. By adopting these recommendations, the cannabis research community can contribute significantly to improving human health and well-being.

On another side, concerted effort to bridge the gap between research and policies makers is crucial to harness the full potential of cannabis while mitigating potential risks.

This study can be used as a reference for beneficial cannabis researchers, to pinpoint the current orientation, and helps identify blind areas and gaps in research in this subject while providing new suggestions and unexplored aspects for future studies.

Limitations and consideration

It is essential to acknowledge the inherent limitations of bibliometric

analysis. The present study focused exclusively on Open Access papers, potentially limiting the scope of the research. Additionally, citation biases, such as self-citation and citation cascades, may have influenced the results. While this study did not impose language restrictions, relying on English keywords and abstracts may have excluded relevant non-English publications, potentially impacting citation counts given the predominance of English in scientific research.

Ethical considerations

The data and software used in this study are publicly available, as only Open Access papers were considered in this paper. No ethical standards or data privacy were violated while conducting this study.

Ethics approval and consent to participate

Not applicable

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CRediT authorship contribution statement

Hassan AMHAMDI: Supervision. **M'hamed Ahari:** Writing – review & editing, Validation, Resources, Funding acquisition. **Abdelmoneam TALHAOUI:** Validation. **Fatima-Zahrae LAABOUDI:** Writing – original draft, Methodology, Investigation, Funding acquisition. **Mohamed REJDALI:** Methodology, Formal analysis. **Amin SALHI:** Methodology, Data curation, Conceptualization. **Abedellah ELYOUSSFI:** Formal analysis, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article. All data generated or analysed during this study are included in this published article.

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Consent for publication

Not applicable

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