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THE RELATIONSHIP BETWEEN EX-SITU CONSERVATION AND SUSTAINABLE DEVELOPMENT: A BIBLIOMETRIC ANALYSIS

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Abstract: Research on the relationship between ex-situ conservation and sustainable development is fundamental because it will help the business world better understand how to utilise it from an ecological, economic, and social perspective. This study seeks to investigate the significance of the correlation between ex-situ conservation and sustainable development through a comprehensive analysis of existing literature utilising the Scopus database. This study systematically searched for the keywords "ex-situ conservation" and "sustainable development" throughout academic publications published in journals from 2000 to 2023. Furthermore, a comprehensive bibliometric analysis and citation mapping process was conducted, considering all pertinent factors. VOSviewer is a tool utilised for doing collaborative analysis of keyword writing, collaborative analysis of citation networks, and generating bibliometric maps to represent the scientific mapping of results and findings visually. Bibliometric analysis is a technique employed to assess the performance of a journal. This study utilises bibliometric analysis to uncover contributions, deficiencies, and limitations in four areas: sustainable development, ex-situ conservation, biodiversity, and climate change. The novelty of this work is crucial to highlight, as it explores a previously unexplored issue with a creative methodology.

Keywords: Ex-situ conservation, sustainable development, bibliometric.

Introduction

Conserving natural resources is crucial for the sustainable protection, management, and use of these resources, particularly in the face of issues such as overexploitation and environmental deterioration. Natural resource conservation endeavours to reduce environmental harm, rehabilitate deteriorated ecosystems, and preserve biodiversity by implementing prudent administration, creating protected conservation zones, and enhancing public awareness (Susilawati *et al*., 2020; Mondal & Palit, 2022). Natural resource conservation is crucial for sustainable development as it ensures the sustainable management of natural resources and promotes long-term prosperity for humans and ecosystems (Marpaung *et al*., 2023).

Conservation efforts can be performed through both in situ conservation, which occurs in the species' natural environment and ex situ conservation, which arises outside its natural habitat. The conservation of ex-situ ecosystems, which involves maintaining and restoring species or ecosystems in environments other than their original home is crucial for achieving sustainability. Amidst a period characterised by human actions leading to a substantial reduction in biodiversity and environmental degradation, the significance of eco-conservation has escalated in preserving the equilibrium of the global ecosystem (Mestanza-Ramon *et al*., 2020). Sustainable development is a notion that addresses the ongoing requirements of

humanity. This ensures that future generations can effectively use renewable energy sources without compromising their ability to meet their energy needs (Tomislav, 2018).

Sustainable development is a comprehensive strategy that encompasses the pursuit of economic, social, and environmental goals to satisfy the immediate needs of humanity without compromising the next generation's capacity to meet their demands. Furthermore, the expansion of the economy and unsustainable consumption patterns have exerted strain on the environment and natural resources while also exacerbating social inequalities (Schandl *et al*., 2016). Sustainable development recognises the significance of achieving equilibrium among economic, social, and environmental variables when making decisions while promoting innovation and change towards enhanced system sustainability (Bengtsson *et al*., 2018). In order to achieve a more equitable and environmentally conscious future for both humanity and the planet, it is necessary to prioritise the continuous growth of ecological, welfare, social, and economic justice. This requires sustainable efforts and endeavours (Halkos & Gkampoura, 2021).

The conservation of Situ oak is essential for promoting sustainable development in various aspects. Ex-situ conservation plays a crucial role in safeguarding the diversity of significant life forms in the global ecosystem by preserving and restoring endangered species that are extinct or at risk in a controlled setting (Braverman, 2014). The significance of biodiversity lies in its direct contributions to human well-being, including providing energy, sustenance, pharmaceuticals, and raw materials, as well as preserving and functioning vital ecosystems such as water and air cycles (Gebre & Gebremedhin, 2019).

Conservation efforts also contribute to the social dimensions of sustainable development by enhancing public consciousness regarding the significance of safeguarding the environment and biodiversity (Pharawati *et al*., 2022). Education and community engagement initiatives focused on ex-situ conservation can enhance our comprehension of the impact of human activities on ecosystems and strategies for maintaining ecological equilibrium (Sunkar *et al*., 2020). Ex-situ conservation can have a positive economic impact on local populations through the development of ecotourism and research initiatives focused on local resources (Rhama & Kusumasari, 2022). Ex-situ conservation might generate novel economic prospects by fostering sustainable ecotourism development, which entails active participation of local communities in environmental conservation endeavours (Braverman, 2014).

However, only a limited number of studies have utilised bibliometric methodologies to visually represent and chart different areas of sustainability-related knowledge, focusing on integrating sustainability across many jurisdictions and its contribution to ex-situ conservation. In their study titled "A Bibliometric Review of Research on Higher Education for Sustainable Development 1998-2018", Hallinger and Chatpinyakop (2019) examine the relationship between sustainable development and the allocation of ex-situ conservation responsibilities. The researchers explore how development sustainability impacts ecological, social, and economic aspects. Theoretical inquiry into the correlation between ex-situ conservation and sustainable development is a research domain that seeks to ascertain the factors of diversity, biodiversity, and global sustainability (Roberts *et al*., 2021).

Research on the correlation between ex-situ conservation and development sustainability is crucial as it will enhance the corporate community's comprehension of capitalising on ecological, economic, and social dimensions (Watanabe & Sumikawa, 2023). The contribution of development towards ex-situ conservation is substantial, considering the awareness and elements that influence the sustainability of development progress and organisational value. Examination: The objective of the present study was to systematically analyse all published works about the preservation and advancement of connection sites. The Scopus database was used

to conduct a literature review, which resulted in the discovery of sustainable publications published in credible and well-indexed journals (Manjarrez-Bringas *et al*., 2018).

The primary objective of this research is to visually represent network analysis and correlation citation mapping of various types of analysis (co-authors, co-occurrences, citations, bibliometric coupling, and co-citations) and units of study (authors, organisations, countries, documents, sources, cited references, sources quoted, and authors cited). This is derived from the network's ability to provide clear and comprehensive explanations. The software VOSviewer allows for exploring several versions of each relationship and the findings and comments sections offer thorough explanations of the results (Cao *et al.,* 2017).

The Scopus database, known for its comprehensive coverage of prestigious journals, conferences, book chapters, and other sources was chosen to curate this article to offer access to pertinent and top-notch publications on the research subject. The intention was to conduct a comprehensive bibliometric study of the scientific information obtained from the Scopus database, focusing on keywords associated with sustainable development and environmental protection (Casprini *et al*., 2020). This study employs bibliometric analysis to address the following research inquiries to inspire readers to take action:

RQ1: Which subfield focuses on ex-situ conservation and sustainable development as its main study area?

RQ2: Who is the preeminent author?

RQ3: Subject: What has been researched?

Methodology

Two analytical methods are used, namely descriptive analysis and bibliometric analysis, with the help of VOSviewer software.

Carrying out descriptive analysis is an essential step in interpreting the analysis results obtained from the literature search process carried out through the database and scientific search engine Scopus, which covers the period from 2000 to 2023 (Figure 1). This activity aims to understand in more depth the relationship between ex-situ conservation and sustainable development based on studies carried out and documented in scientific literature during that period.

Bibliometric analysis with VOSviewer allows visualisation of the relationships between scientific publications, authors, institutions, and key concepts related to ex-situ conservation and sustainable development in interactive maps. This method helps identify collaboration patterns, research trends, and dominant or emerging research areas. Thus, this research not only provides a comprehensive overview of the current status of research in the field of ex-situ conservation and its relationship to sustainable development but also shows potential new research avenues that can be used as a reference for researchers and policymakers in formulating effective strategies for conservation and sustainable development.

Bibliometric analysis is used to analyse and comprehend scientific articles using quantitative data (Xi *et al*., 2021). The concept relies on the notion that analysing patterns and trends in the literature can yield crucial insights into the current condition of a specific area, including its progress, research directions, and key contributors (Donthu *et al.,* 2021). The graphical representation of bibliographic information involves mapping keywords, nations, and authors. This is achieved by integrating bibliographies and doing co-citation analysis using specialised software. This approach aims to identify and characterise commonalities across different sources (Kern, 2019).

In order to carry out a bibliometric study, it is necessary to gather publications such as books, papers, and patents. The data should be evaluated and comprehended through diverse quantitative indicators (Rossberg, 2017). Commonly employed acts in this particular scenario include:

Citation count: This indicator quantifies the frequency with which a paper is referenced in other scholarly publications. The purpose of this study conducted by Lin *et al*. (2019) was to identify the most renowned individuals and institutions and the most often cited publications within a specific field.

Co-citation analysis: This statistic assesses the ease of comparing citation patterns among numerous articles. Lyu (2020) defines the term as categorising collections of academic publications with similar study subjects and themes.

Co-authorship analysis: This analysis quantifies the number of works that various individuals have collaboratively authored. This tool is utilised to ascertain the authors and organisations that engage in the highest frequency of collaboration on a specific subject (Schick, 2017).

Network analysis: This analysis involves evaluating the connections and interactions between various publications, authors, and institutions. He employed a method of identifying crucial players and examining issues on the pitch (Schick, 2017).

The objective of bibliometric analysis is to offer a quantitative and unbiased perspective on the current situation of a particular area. It can identify important patterns, investigate inquiries, and suggest possible paths for future research. Bibliometric analysis is a valuable tool for examining and comprehending different scientific publications and evaluating the performance of journals (Donthu *et al.,* 2021).

Bibliometric analysis is employed to identify significant research topics, trends, and patterns within a specific discipline. This can offer insights about the prevailing fields of study and topics of research inquiry. Bibliometric analysis is employed to ascertain the most prolific authors, institutions, and journals on a specific topic. This passage elucidates the concept of influential individuals in a certain domain and prominent research organisations (Wamba *et al.,* 2021).

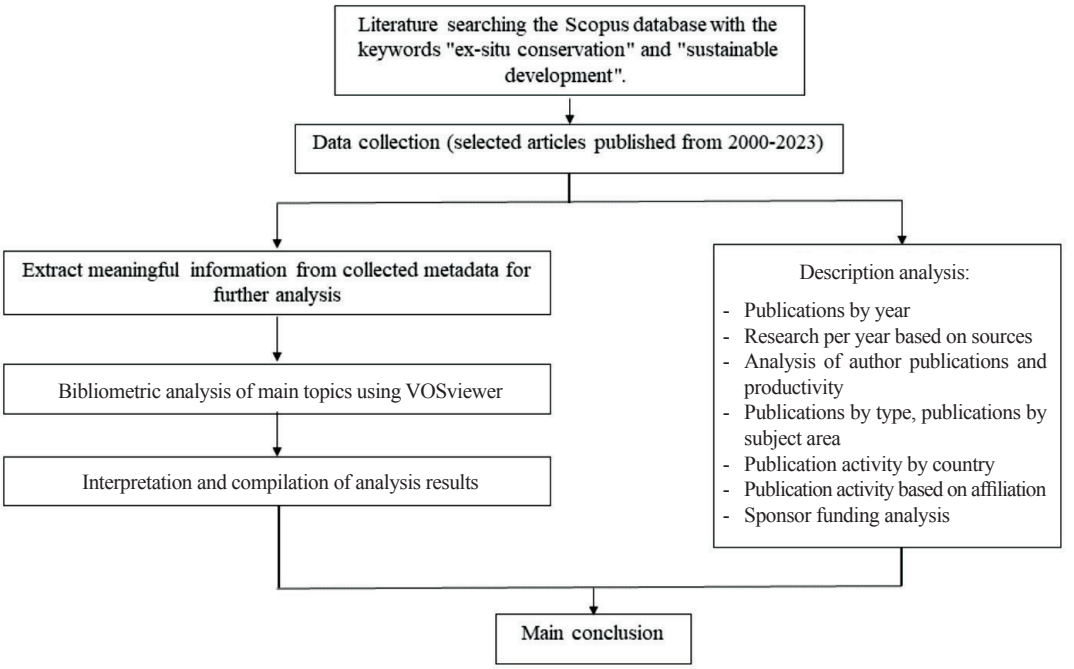

Figure 1: Flow diagram of the data collection process to data analysis

Data Collection

Bibliometric analysis is typically considered a quantitative research method because it involves gathering bibliographic information and relying on robust, trustworthy data such as indexed articles. Bibliometric analysis can specifically advance research topics related to ex-situ conservation and sustainable development. This study utilises bibliometric analysis, which relies on the Scopus citation database. To obtain bibliometric information, it is crucial to employ the most effective search engine (Allam *et al.,* 2022). Furthermore, the S corpus provides scholars with diverse bibliometric data regarding the authors or works they are investigating. Bibliometric analysis utilises various publishing trends to do quantitative analysis. According to Thompson and Walker (2015), bibliometric issues encompass a range of analytical and descriptive methodologies.

Data Analysis

A frequent procedure in bibliometric analysis involves gathering publication data, including books, articles, and patents, followed by applying diverse quantitative metrics to analyse and interpret this data (Thompson & Walker, 2015). The bibliometric analysis for this investigation was conducted in the subsequent sequence:

(1) The domain name www.scopus.com was established utilising the intended keywords "ex-situ conservation", "development", and "sustainable" in order to identify pertinent terms for the abstract, title, or keywords.

(2) Analysis of articles published between 2000 and 2023 revealed that Scopus publications encompass "ex-situ conservation" and "development sustainability". A total of 238 records obtained from Scopus were subsequently exported to the "text file normal", which includes comprehensive notes and cited references.

(3) To address research inquiries, reveal discoveries, and visually assess interpretations and conclusions, the exported data was refined and analysed using VOSviewer, a text mining application developed by Van Eck and Waltman (2010).

(4) According to a comprehensive analysis, there are 238 between 2000 and 2023. Sustainability was considered a relatively novel concept with indications of ex-situ conservation due to development; 2000 was selected as the promotional year.

Results and Discussion

Bibliometric analysis enables one to ascertain the references and authors who have had the greatest impact and are most frequently cited (Liu *et al.*, 2022). Bibliometric indicators such as the frequency of keyword occurrences in articles and co-citation analyses utilising frequently cited pairings of papers, provide insights into the organisation and flux of scientific inquiry. Hence, it is suggested that both analyses be presented in this section utilising identical elements (Zupic & Cater, 2015).

Publications by Year

Table 1 summarises groups/problems, the number of publications, and the countries conducting research. This summary is crucial for decision-makers to obtain information on existing needs quickly.

Since 2000, environmental scholars have developed a greater interest in sustainable development. The number of publications about the sustainability of development in forestry and environment has exhibited a substantial upward trend from 2000 to 2023, as depicted in Figure 2. As a foundation for our endeavours, trends in the number of studies indicate the expansion of scientific interest in this field.

Citations by Year and Most Cited Documents

The quantity of citations might indicate the significance of a text within a specific academic

Table 1: Summary of publication recapitulation

Group/Problem	Number of Publications	Country	Subject Research
The contribution of ex-situ conservation to sustainable agricultural production.	176	China, India, Italy, United Kingdom, United States	Agricultural and Biological Sciences
Impact of ex-situ conservation on the restoration and preservation of biodiversity.	98	China, India, Indonesia, Italy, United Kingdom	Environmental Science
Evaluation of the influence of ex-situ conservation on genetic diversity and its potential to support sustainable development.	33	India, China, Italy, United Kingdom, Norway	Biochemistry, Genetics and Molecular Biology
Analysis of the influence of ex-situ conservation on climate change and the sustainability of planetary ecosystems.	23	Indonesia, South Africa, United Kingdom, Benin, Botswana	Earth and Planetary Sciences
Developing technology that supports ex-situ conservation to achieve sustainable development.	17	India, Canada, China, United States	Engineering

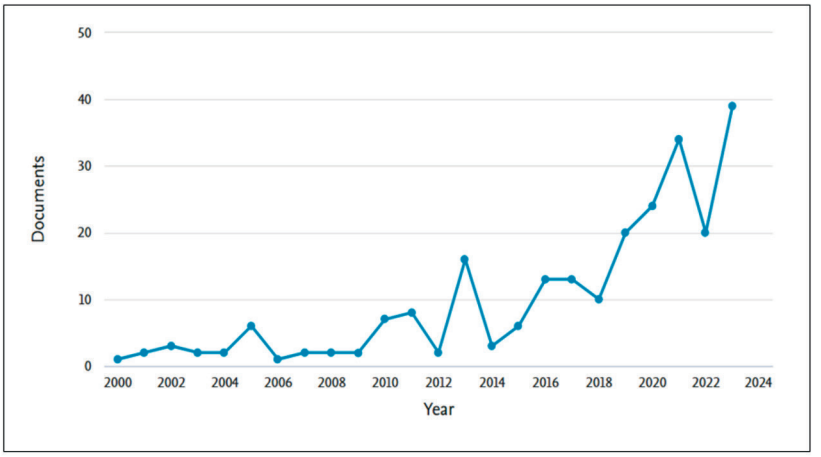

Figure 2: Publications by year

discipline (Baier-Fuentes *et al.,* 2019). According to Figure 3, the most productive journals in terms of publications are Acta Horticulturae, IOP Conference Series Earth and Environmental Science, Biodiversity Science, Genetic Resources and Crop Evolution, and Diversity. This graph also displays the years in which publications received higher citation rates and identifies the most commonly referenced papers for each year.

Analysis of Author Publications and Productivity

The significance of network analysis is reinforced by the disparity between the number of articles authored by a single individual and the number of articles with several authors. Krigas, N. and Maloupa, E. are the most prolific authors, having each written eight articles. In addition, Grigoriadou, K. achieved the second-

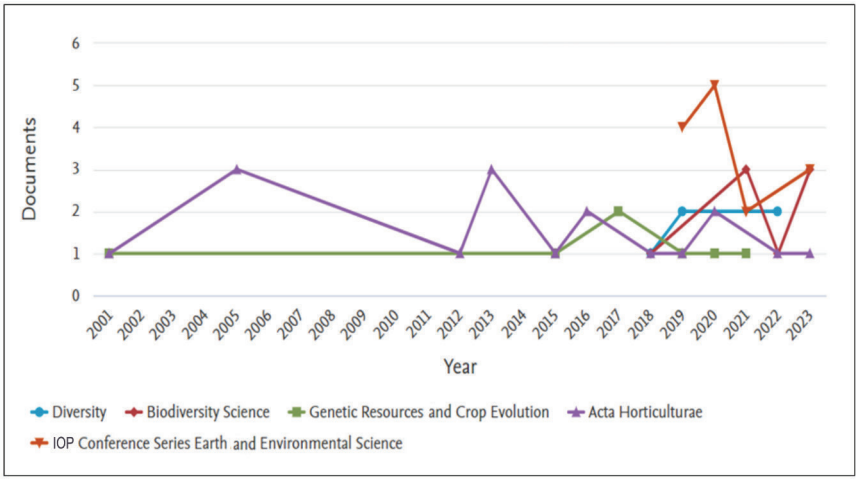

Figure 3: Research per year by source

highest level of productivity as an author, having written six publications. Ren, H., Sarropoulou, V., and Tsoktouridis, G. emerged as the top three prolific authors, each publishing five publications. The following four authors, Bebeli, P.J., Dey, A., Liao, J., and Maxted, N. have each written four publications on eco-conservation and sustainable development, making them very productive authors. Figure 4 displays the number of writers across all examined items, totalling 964.

Publication Type and Subject Area

Upon analysing publishing activity, we identified ten distinct categories of publications, 238 articles, and seven publications categorised by subject area. These findings support the importance of studying the management of knowledge sets. The diverse forms of publications include notes (0.4%), conference reviews (0.4%), Editorial (0.8%), book (1.3%), book chapters (14.3%), conference papers (1.7%), reviews (16.4%), and articles (51.7%).

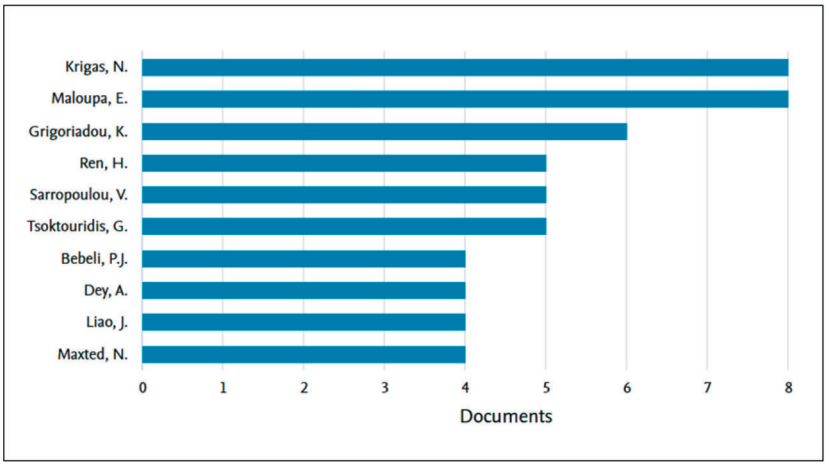

Figure 4: Publications by author

The materials examined exhibited a range of topics and formats, with scientific journal articles significantly prevailing (Figure 5).

The data presented in Figure 6 reveals the prevalence of various fields of study in published articles. The percentages indicate that chemistry accounts for 1.4% of the articles, energy for 1.6%, immunology and microbiology for 1.9%, social sciences for 4.0%, medicine for 3.9%, engineering for 3.9%, earth and planetary sciences for 5.3%, biochemistry, genetics, and molecular biology for 7.7%, environmental science for 22.5%, and agricultural and biological sciences for 40.6%. Figure 5 demonstrates the significance of environmental science and forestry concerning ex-situ conservation and sustainable development.

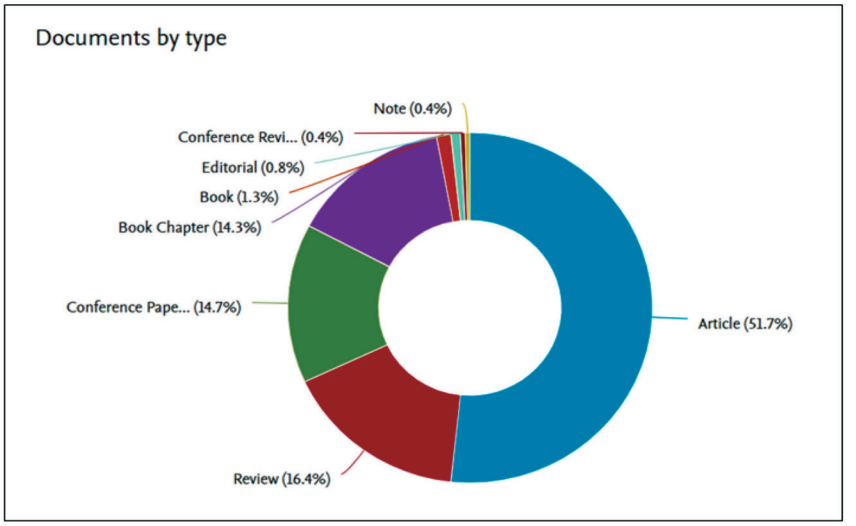

Figure 5: Publications based on type

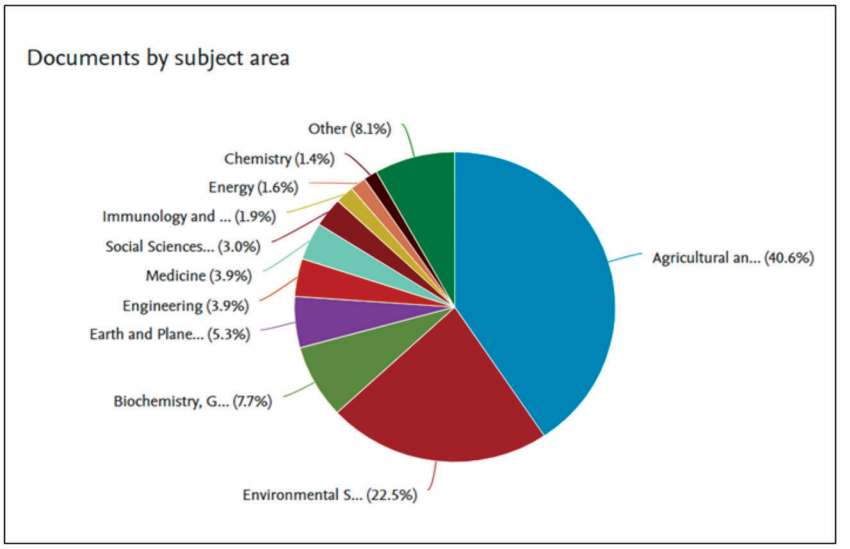

Figure 6: Publications by subject area

Publishing Activities by Country

The current topic of conversation revolves around the distinctive progress in sustainability and the recent efforts in oak conservation. The inclusion of our first-author affiliate data set is warranted due to the extensive research undertaken on this topic across 85 nations. Every nation generates a distinct quantity of publications. Figure 7 displays the top ten countries with a minimum of 50 articles. India is the most producing country in the world. The top ten countries consist predominantly of developed and emerging nations, which is an important point to emphasise. India, China, Italy, the United Kingdom, Indonesia, the United States, Germany, Greece, Australia, and Brazil are included in this group. According to this report, India is among the countries with the highest level of publication of impactful research on development and has shown significant improvements in sustainability. Additional significant clusters identified are China, Italy, and the United Kingdom.

Analysis of Publication Activity Based on Affiliate

Figure 8 demonstrates that the affiliates with the highest productivity have made the most notable contributions to sustainability and eco-conservation. The Chinese Academy of Sciences,

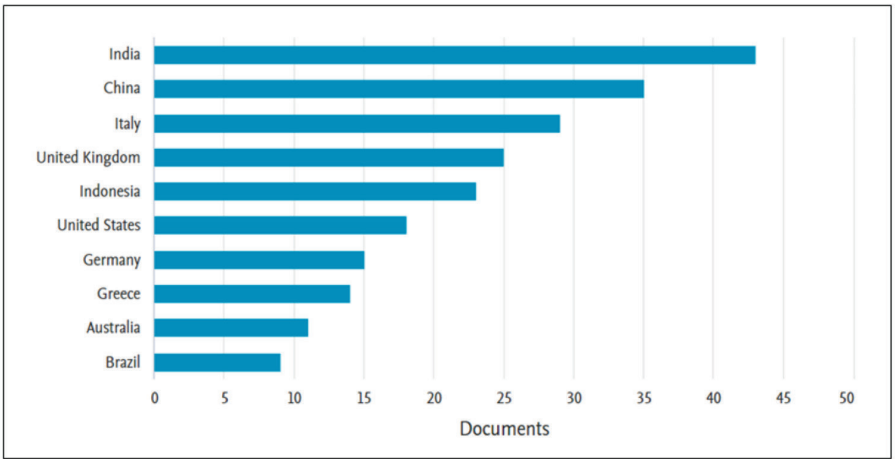

Figure 7: Publication activity by country

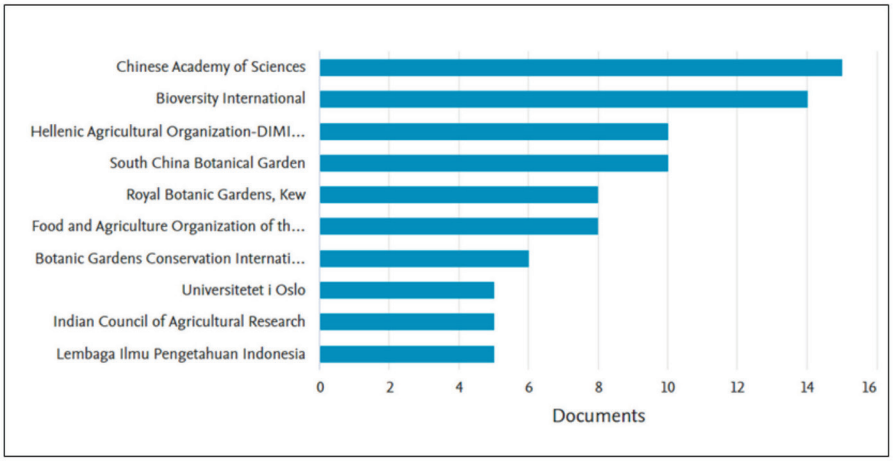

Figure 8: Most prolific affiliate publications on the development of sustainable

a highly respected institution in development analysis has the highest number of publications, with a total of 15 works. Meanwhile, Bioversity International is renowned for its 14 influential works in conservation. This was followed by the Hellenic Agricultural Organization-DIMITRA, South China Botanical Garden, Royal Botanic Gardens, Kew, Food and Agriculture Organization of the United Nations, Botanic Gardens Conservation International, Universitetet i Oslo, Indian Council of Agricultural Research, and *Lembaga Ilmu Pengetahuan Indonesia.*

Sponsor Funding Analysis

The ten funding sources whose publications have had the greatest impact on ex-situ conservation and sustainable development are enumerated in Figure 9. Funding sponsorship is dominated by the National Natural Science Foundation of China, as evidenced by its support for six publications. The European Commission and the Conselho Nacional de Desenvolvimento Científico e Tecnológico rank second, each having a maximum of five publications. The subsequent seven publications are supported by critical research funding.

Bibliometric Analysis of Main Topics Covered by Data Set

This section will analyse the crucial subjects inside our dataset. An analysis has been conducted on the author's most frequently utilised keywords. A comprehensive analysis of 238 publications and major topics about ex-situ conservation and sustainable development challenges is undertaken, providing detailed insights. The study employed keyword co-occurrence analysis to assess the connections between important regional issues (Sedighi, 2016). The data in Table 2 demonstrates the correlation between sustainability and the field of study of ex-situ conservation and development. This analyses the frequency of keywords across the entire network. The terms "sustainable development", "biodiversity", "conservation", and "climate change" are well understood and analysed manually. We exclusively considered words on the list a minimum of five times.

The keyword "sustainable development" is the most significant association, as it is the most often searched term and is strongly associated with "biodiversity" and "conservation", as demonstrated in the keyword co-occurrence network map see Table 2. The network diagram in Figure 10 illustrates the simultaneous occurrences of keywords.

The visualisation network identifies sustainable development, biodiversity, conservation, ex-situ conservation, forestry, climate change, and ex-situ and species conservation as key concepts (Figure 11). The visualising network reveals that the three most notable phrases are carbon emissions,

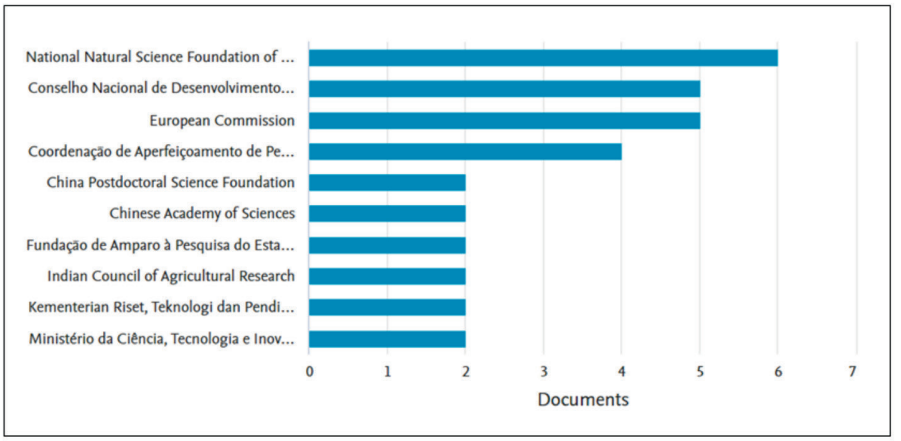

Figure 9: Funding sponsor writing regarding conservation in the forestry and environment sector

Table 2: Top 20 co-occurrences of keywords

No.	Keywords	Occurrences	Total Link Strength
1	Sustainable development	48	243
2	Biodiversity	44	229
3	Conservation	61	214
4	Climate change	15	118
5	Environmental protection	15	117
6	Endangered species	14	101
7	Forestry	14	96
8	Conservation of natural resources	11	95
9	Ex-situ	18	89
10	Species conservation	15	82
11	Genetic variation	8	81
12	In-situ conservation	15	78
13	Ex-situ conservation	24	77
14	Human	8	77
15	Plants	8	77
16	Conservation management	13	71
17	Sustainability	12	68
18	Non-human	18	66
19	Biotechnology	7	63
20	Planning	11	58

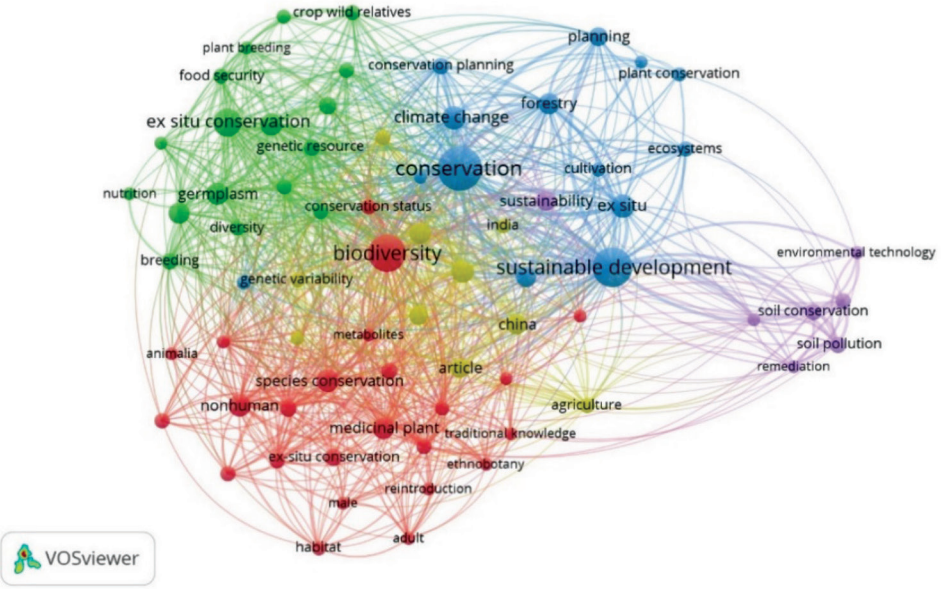

Figure 10: Representation network from the appearance of keywords together

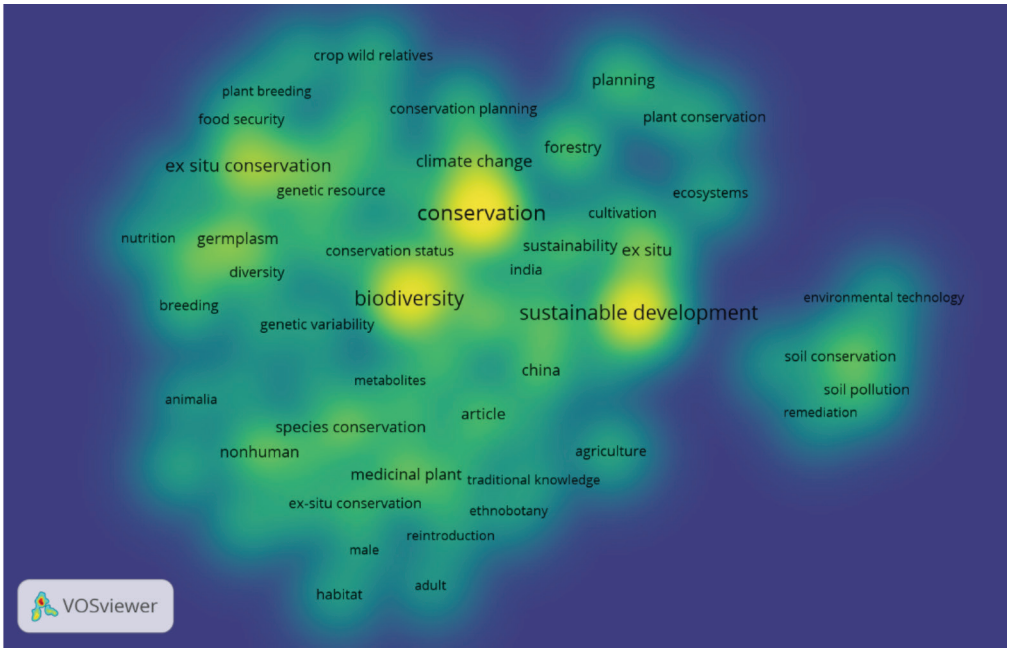

Figure 11: Cluster visualisation of the appearance of keywords together

climate change, and emissions trading. The study examined the dominant criteria such as influential authors, productive countries, referenced documents, sources, authors, and effective institutions, using a combined type analysis and changes in units of study. Groups are most prevalent in the field regarding items linked to the most common terms utilised.

In summary, several study opportunities exist in sustainable site conservation and development. These possibilities will continue to evolve as the interplay between ecology, social dynamics, and economic developments in the business sector unfolds (Ren & Blackmore, 2013). The corporate world can utilise good practices to achieve improved development and sustainability. Organisations should establish strategic partnerships with universities and institutes to exchange knowledge and expertise and obtain new opportunities for oak conservation, sustainable development, and innovation (Hache & Palle, 2019).

Benefits of Research Results

These results can help decision-makers formulate strategies integrating ex-situ conservation with sustainable development and support sustainable policies and practices. In addition, the study offers guidance for institutions and companies in monitoring conservation and sustainable development trends, enriching the literature with visual interpretation and analysis of contributions from different authors, scientific fields, and countries.

Conclusions

The primary objective of this study is to find scholarly research that can aid decision-makers in assessing the potential of sustainable development to enhance ex-situ conservation. This is accomplished through the analysis and visualisation of the correlation between the keywords "ex-situ conservation" and "sustainable development" in reputable journals such as the Journal of Acta Horticulturae, IOP

Conference Series Earth and Environmental Science, Biodiversity Science, Genetic Resources and Crop Evolution, and Diversity. This report assesses the global research advancements in developing ex-situ conservation and sustainable development between 2000 and 2023. The evaluation is based on 238 papers analysed in this study. Extensive research has been conducted on ex-situ conservation and sustainable development during the past five years. Notably, there has been a large increase in the volume of publications since 2018. Based on shared term network analysis, according to Scopus categories, the main study areas may be categorised into agriculture, forestry, environment, biology, and energy. As time passes, this journal's focus on chronology progresses alongside the advancement of research on ex-situ conservation and sustainable development.

One example of research titled "Comprehensiveness of conservation of useful wild plants: An operational indicator for biodiversity and sustainable development targets", cited 79 times, can provide a valuable contribution to decision-making regarding conservation and sustainable development, especially in improving conservation exit. Some ways this research can be used as an example in decision-making are Conservation Indicators and the Influence of Sustainable Development.

The Chinese Academy of Sciences is the leading institution in article contributions in this discipline. The bibliometric analysis findings demonstrate the contributions and deficiencies in this research, with India emerging as the most influential country. The research topics are categorised into four groups: Sustainable development, ex-situ conservation, biodiversity, and climate change. The paper's originality is noteworthy as it distinctively explores previously unexplored issues. Furthermore, for the first instance of timeline dynamics, the authors, co-authors, scientific areas, universities, and countries with the highest number of citations are presented using visual representation. It is important to clarify that bibliometric analysis has been created with the influence of PRISMA. A META analysis was not feasible due to the limited data availability, with only 238 available. This can be regarded as a constraint on learning. An analysis of the contribution of ex-situ conservation to sustainable development is being conducted through a study designed for illustrative purposes. This analysis is based on conclusions from a literature review conducted on many databases. This document aims to serve as a comprehensive guide for decision-makers responsible for monitoring emerging trends in conservation. It aims to enable these individuals to effectively identify and capitalise on opportunities that benefit institutions and enterprises because bibliometric analysis has been deliberately chosen.

Bibliometric analysis can be used to evaluate the performance of a journal, provided that it is relevant to research limitations. Bibliometric analysis can be used to assess the validity of a journal, although it is important to acknowledge the various limitations associated with this approach. An inherent limitation of bibliometric analysis is its dependence on quantitative metrics such as citation counts, disregarding the research's quality. Therefore, relying just on bibliometric analysis may not comprehensively assess a journal's trustworthiness. Furthermore, bibliometric analysis depends upon the number of citations a paper obtains, which can differ based on the journal's reputation, topic matter, and the duration since it was published. Bibliometric analysis can be employed to evaluate the efficacy of a specific journal, but it is crucial to consider the limitations.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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